OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

Industrial Development Report 2005

Capability building for catching-up

Historical, empirical and policy dimensions

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Industrial Development Report 2005

Capability building for catching-up

Historical, empirical and policy dimensions

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna, 2005

ID/424

UNIDO Publication

Sales No.: E.05.II.B.25

ISBN 92-1-106432-5

Contents

Figures

Tables

Boxes

Foreword

In my foreword to last year's Industrial Development Report 2004 I announced that this Report would address the issue of capability building metrics with a view to assist in the definition of policies and help bridge the gap between highly quantifiable macroeconomic targets and microeconomic ones which still remain highly notional and qualitative.

By placing the issue in historical, empirical and policy perspective, this Report brings home a number of insights of great importance relating to the conceptualisation, design and implementation of capability-building policies.

Developing countries enjoy the potential advantage of being able to draw on knowledge that has already been developed in the more advanced countries. But they confront a paradox, largely neglected in conventional policy prescriptions: to leverage knowledge you need to possess knowledge. It is not surprising that, throughout history, only a few countries have managed to free themselves from this paradox and acquire the ability to catch-up – which they did along different paths, including reliance on foreign direct investment, fostering infant industries while securing access to technology through arm's-length transactions and migratory flows. Within this diversity, the rapid rise of their domestic knowledge systems has been a common feature.

The importance of this fact is highlighted by the finding that almost 60 per cent of the difference in income between Sub-Saharan African countries and the advanced industrial countries can be attributed to gaps in the stock of knowledge.

In seeking to overcome this disadvantage, one crucial fact to be kept in mind is that the target is a moving one. Because advanced-country technologies are increasingly science-based, rights protecting their ownership stronger, and technical standards more stringent, the minimum threshold capabilities required to take advantage of the latecomer status keep rising, slowly but steadily. This imposes growing demands on developing countries' domestic knowledge subsystems and their interactions with the domestic business innovation and policy/governance subsystems. The required policies are largely outside the scope of the WTO agreements.

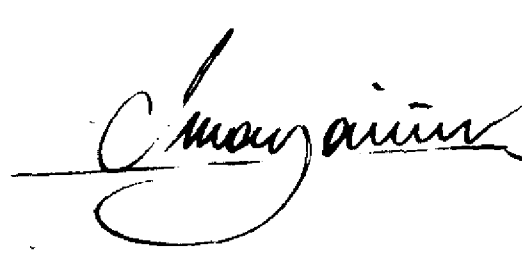
Policymakers facing this challenge find themselves in a quandary, because they largely lack the metrics, heuristics and needs-assessment methodologies required to design and implement competence-building policies. This is because conventional policy prescriptions have focused instead on tinkering with market-based incentives and macroeconomic framework conditions. For all their importance, these have become increasingly insufficient to meet the challenges of development.

Accurately identifying resource-allocation needs for competence building, particularly in the field of science and technology, takes more than conventional benchmarking exercises, relevant as these are. Fundamentally, it involves pinpointing the specific requirements posed to the developing economy, opened to international trade, capital and technology flows, that attempts to develop the technical, entrepreneurial and management skills, as well as the institutions and policies that can ensure a concurrent development in the domestic supply and demand of innovative resources.

This Report provides a framework for operational policy analysis and a guide for the assessment of capability-building needs to help overcome limitations in the current understanding of economic development. The Report tests this approach by reference to technical standards and food safety systems. Metrics and needs assessments are developed in both respects to help bridge gaps in knowledge that affect the innovative development of developing countries.

This approach is part of our efforts aimed at strengthening the role of the United Nations system in the economic development domain by contributing to redress the undersupply of specific public goods in the fields of environment, knowledge and market efficiency.

Finally, I would like to leave on record how proud and rewarded I feel by the feedback on the efforts that went into this revitalized series of UNIDO's flagship publication.



CARLOS MAGARIÑOS
Director-General
UNIDO

Acknowledgements

This Report has been prepared under the overall guidance of Carlos Magariños, Director-General of UNIDO and the direction of Francisco C. Sercovich. The in-house team included Muge Dolun and Helmut Forstner.

Knut Blind, Nick Crafts, Jan Fagerberg, Steffan Jacobsson, Roberto Mazzoleni, David Mowery, Gabriel Sánchez, Morris Teubal and Caroline Wagner were principal consultants. They provided valuable comments and feedback. Their contributions are indicated in the respective chapters. Roberto Mazzoleni collaborated in the drafting of Part I of the Special Topic Section.

Additional inputs were provided by: Rodrigo Arocena, Gerardo Gargiulo, Martin Srholec, Smita Srinivas, Judith Sutz, Christian Viand, Jebamalai Vinanchiarachi and Mario Wittner.

Many of the above-mentioned participated in consultations for this Report, including a workshop in Vienna.

This Report benefited greatly from the University of Columbia Catch-up Project, led by Richard R. Nelson.

Special thanks are due to Peter Evans, Erik Iversen and Dani Rodrik for their reactions on or contributions to specific aspects of the Report.

Thanks are also due to Sam Hobohm and Paul Makin, who collaborated with proof-reading.

Eduardo Crawley was in charge of style editing.

Michelle-Anne Yap provided clerical and secretarial support.

This Report is dedicated to the memory of Sanjaya Lall, dear colleague and friend, whose untimely death on June 18, 2005 deprived the international development community from one of its most lucid members.

Explanatory notes

Designation of least developed countries (LDCs) follows the United Nations definitions, which is based on three criteria: low income (less than $900 estimated GDP per capita, three year average), weak human resources (a composite index based on health, nutrition and education indicators) and high economic vulnerability (a composite index based on indicators of instability of agricultural production and exports, inadequate diversification and economic smallness).

The description and classifications of countries and territories used, and the arrangements of the material, do not imply the expression of any opinion whatsoever on the part of the Secretariat concerning the legal status of any country, territory, city or area, or of its authorities, concerning the delimitation of its frontiers or boundaries, or regarding its economic system or degree of development.

The following symbols are used in tables:
Two dots (..) indicate that the data are not available or not separately reported.
na is not applicable.

Totals may not add precisely because of rounding.

Abbreviations

3G	third generation
3G3P	3G Patent Platform Partnership
3GPP	Third Generation Partnership Project
A*STAR	Agency for Science, Technology and Research
ALOP	acceptable level of protection
APSTCH	*Asociación de Productores de Salmón y Trucha de Chile AG*
ARIB	Association of Radio Industries and Businesses, Japan
ARPANET	Advanced Research Projects Agency Network
BBN	Bolt, Beranek and Newman
BRC	British Retail Consortium
BSE	bovine spongiform encephalopathy
BTU	Basic Transmission Unit
CAD	computer aided design
CEO	chief executive officer
CEPD	Council for Economic Planning and Development
CIAA	Confederation of Food and Drink Industries of the European Union
CID	Centre for International Development
CIM	contract intensive money
CIS	Commonwealth of Independent States
C-MOS	Complementary Metal-Oxide Semiconductor
COPAL	*Coordinadora de Industria de la Alimentación*
CORFO	Chilean Economic Development Agency
CPI	Corruption Perceptions Index
CRADA	cooperative R&D agreements
CSIR	Council for Scientific and Industrial Research
CSNET	Computer Science Network
CTA	*Centro Técnico de Aeronautica*
CURL	Consortium of University Research Libraries
DARPA	Defense Advanced Research Projects Agency
DGBAS	Directorate General of the Budget, Accounting and Statistics
DOD	Department of Defense, US
DPI	Database of Political Institutions
DRAM	dynamic random access memory
EC	European Commission
ECAM	*École Central des Arts et Manufactures*
EIEC	Executive index of political competitiveness
EMI	electromagnetic interference
EPO	European Patent Office
ERA	Engineering Research Association
ERL	Energy and Resources Laboratories
ERSO	Electronics Research and Services Organisation
ETNO	European Telecommunications Network Operators' Association
ETRI	Electronics and Telecommunications Research Institute
ETSI	European Telecommunications Standards Institute
EU	European Union
EUREPGAP	Euro-Retailer Produce Working Group Good Agricultural Practices
EUROMET	European Collaboration in Measurement Standards
FAO	Food and Agriculture Organisation
FDA	Food and Drug Administration
FDI	foreign direct investment
FRAND	fair, reasonable and non-discriminatory
FRC	*Fondo de Recursos Concursables*
G-8	Group of Eight leading economists
GAO	General Accounting Office
GAP	Good Agricultural Practices
GATT	General Agreement on Tariffs and Trade
GDP	gross domestic product
GEM	Global Entrepreneurship Monitor
GERD	Gross domestic expenditure on research and development
GFSI	Global Food Safety Initiative
GGDC	Groningen Growth and Development Centre
GM	genetically modified
GMO	genetically modified organisms
GMP	Good Manufacturing Practices
GNP	gross national product
GPL	General Public License
GSM	Global System for Mobile Communications
HACCP	Hazard Analysis and Critical Control Points
HDI	Human Development Index
IAF	International Accreditation Forum
IAS	Argentine Institute for the Steel Industry
IC	integrated-circuit
ICT	information and communications technology
IDA	Industrial Development Agency
IDB	Industrial Development Board
IEC	International Electrotechnical Commission
IFCO	International Fruit Container Organisation

IFOP	*Instituto de Fomento Pesquero*
IFPRI	International Food Policy Research Institute
IFS	International Food Standard
III	Korean Institute for Information Industry
IIT	India Institute of Technology
ILA	Interim License Agreement
ILAC	International Laboratory Accreditation
IMP	Interface Messaging Processor
INAL	*Instituto Nacional De Alimentos*
INIA	*Instituto Nacional de Investigación Agropecuaria*
INTA	National Institute of Agricultural Technology
INTI	*Instituto Nacional de Tecnología Industrial*
IPPC	International Plant Protection Convention
IPR	intellectual property right
IPTO	Information Processing Techniques Office
IPTS	Institute for Prospective Technological Studies
IRAM	Instituto Argentino de Normalización y Certificación
IRMM	*Institute for Reference Materials and Measures*
IS	innovation systems
ISIC	International Standards Industrial Classification
ISO	International Standardisation Organisation
ISO/TMB	International Standardisation Organisation Technical Management board
IT	Information technology
ITA	industrial-cum-technological advance
ITP	Innovation and Technology Policy
ITRI	Industrial Technology Research Institute
ITU	International Telecommunication Union
JAPIA	Japan Auto Parts Association
JITAP	Joint Integrated Technical Assistance Programme
JLA	Joint License Agreement
JPO	Japan Patent Office
KAIST	Korean Advanced Institute of Science and Technology
KIET	Korea Institute for Electronics Technology
KIMM	Korea Institute of Machinery and Materials
KPN	*Koninklijke PTT Nederland*
KRISS	Korean Research Institute on Standards and Science
KSA	Korean Standards Association
LA	Licensing Administrator
LDC	least developed country
LIEC	legislative index of political competitiveness
LIUP	Local Industries Upgrading Programme
M&T	measurement and testing
MCR	Maximum Cumulative Royalty
MENA	Middle East and North Africa
LAC	Latin American and Caribbean countries
MIC	Market Intelligence Center
MICIT	Ministry of Science and Technology
MIT	Massachusetts Institute of Technology
MITI	*Ministry of International Trade and Industry*
MNC	multinational corporation
MOEA	Ministry of Economic Affairs
MSTI	Main Science and Technology Indicators
MVA	*manufacturing value added*
NBER	National Bureau of Economic Research
NBS	National Bureau of Standards
NIC	newly industrialised countries
NMI	national measurement institutions
NSB	National Science Board
NSC	National Science Council
NSF	National Science Foundation
OBM	original brand manufacturing
ODI	Overseas Development Institute
ODM	original design manufacturing
OECD	Organisation for Economic Co-operation and Development
OEM	original equipment manufacturing
OIE	*Office International des Epizooties*
OLS	ordinary least squares
OS	open source
OSS	open source system
PC	*personal computers*
PCR	polymerase chain reaction
PFI	Integrated Fruit Production
PPP	purchasing power parity
PSD	private sector development
PSTN	public switched telephone network
R&D	research and development
RICYT	*Red Iberoamericana de Indicadores de Ciencia y Tecnología*
RMV	Reference Market Value
ROHS	Reduction of Hazardous Wastes Initiative
RTD	research and technological development
S&T	science and technology
SAC	Satellite Applications Centre
SAG	*Servicio Agrícola y Ganaderó*
SCA	standards and conformity assessment
SCONUL	Society of College, National and University Libraries
SDO	*standard development organisations*
SEMATECH	Semiconductor Manufacturing Technology
SENASA	*Servicio Nacional de Sanidad y Calidad Agroalimentaria*
SERNAPESCA	National Fisheries Service
SIS	sectoral innovation system
SLA	Standard License Agreement
SMEs	small- and medium-sized enterprises
SMS	short message services
SPS	Sanitary and Phytosanitary Measures
SRR	Standard Royalty Rate
SSA	Sub-Saharan Africa
STDF	Standards and Trade Development Facility
STR	standards and technical regulations
TCP/IP	Transmission Control Protocol/Internet Protocol
TFP	total factor productivity
TFT-LCD	Thin Film Transistor Liquid Crystal Display
TIA	*Telecommunications Industry Association*
TNC	transnational corporation
TPG	Technological Public Goods

TRIPS	Trade-Related Intellectual Property Rights
TSMC	Taiwan Semiconductor Manufacturing Corporation
TTA	Telecommunications Technology Association
TTC	Telecom Training Centre
UAE	United Arab Emirates
UIPA	UMTS Intellectual Property Association
UK	United Kingdom
UL	Underwriters Laboratory
UMC	United Microelectronics Corporation
UMTS	Universal Mobile Telecommunications System
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNIDO	United Nations Industrial Development Organisation
UNSD	Statistical Division of the United Nations Secretariat
US	United States
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USTPTO	United States Patent and Trademark Office
UTRA	UMTS Terrestrial Radio Access
VLSI	very large scale integration
VTFS	Vocational Training Fund Statute
WBTBTS	World Bank Technical Barriers to Trade Survey
WEEE	Waste Electrical and Electronic Equipment
WEF	World Economic Forum
WHO	World Health Organisation
WIPO	World Intellectual Property Organisation
WTO	World Trade Organisation
WWI	World War I
WWII	World War II

Executive Summary

Section I

Special Topic: Capability building for catching-up

Much of the recent debate on economic development policy for low- and middle-income economies has operated in a vacuum of evidence about the factors that weigh most decisively in their ability to catch-up with the more developed economies. It is widely accepted that the new international trade rules significantly constrain the degrees of freedom available to developing-country policymakers in their quest for successful economic catch-up. However, the efforts to bridge that gap have overwhelmingly emphasised market-based incentives or macroeconomic framework conditions. Tinkering with policy on this plane has often happened at the expense of a broader perspective and policy design incorporating genuine needs assessment for domestic capability building and private sector development.

This year's Industrial Development Report focuses on a number of structural issues that have passed largely unnoticed and where substantial degrees of freedom remain for domestic policymaking vis-à-vis the international trade rules. Its key concern is the building and co-evolution of domestic institutions that promote innovative economic and social development. Its approach is based on the understanding that, in a world increasingly driven by innovation, the framework conditions indispensable to economic catch-up are being transformed, and this calls for updated responses. The transformation that business needs in order to rely on innovation as a competitive weapon cannot be delivered solely by market-based incentives or the supply of generic public goods such as macroeconomic stability, the rule of law, and functioning financial markets. The specific policies required to build capabilities within the knowledge, business and policymaking/governance subsystems largely fall below the radar of WTO agreements.

Catching-up is never a case of straightforward adoption or imitation of industrial technologies or institutions from advanced countries. This, as strongly suggested by the evidence compiled over more than a hundred years on the institutional and policy strategies associated with successful economic catch-up and development, reflects the considerable sectoral, geographical and cultural diversity in play. Since knowledge is hard to move around, as much of it is people-embodied and context-specific, domestic capabilities are crucial to the adaptation of industrial technologies, policies and institutions to a different economic environment. The trend towards increasing codification of knowledge does not lessen the need to build domestic capabilities to access and use it.

Past catching-up experiences – assessed in the first five chapters – reflect the variety of institutional mechanisms available to support the accumulation of technological capabilities. Some countries have relied extensively on multinational corporations, others on protecting domestic infant industries while securing access to technology through licensing, and still others on the immigration of skilled personnel to foster the dissemination of technological knowledge. But beyond this variety, the successful catching-up experiences of the past display some commonalities. One common feature is a rapid increase in the level of education and an emphasis on higher education in science and engineering. Another is the creation of public institutions to conduct industrial research and provide services to industrial firms. Last, but not least, important benefits were drawn from relatively unfettered access to S&T knowledge through the participation in international networks of scientific and engineering competence, and often from weak, if any, enforcement of IPRs on existing technology.

Taking stock of the above, the Report provides a framework for operational policy analysis and a guide for the assessment of capability building needs to help overcome evident limitations in the current understanding of economic development. Thus, the Second Part of the Special Topic focuses on the interactions between the knowledge, business innovation and policymaking subsystems, and addresses the policy capabilities needed to match the demand and supply of innovative resources – one of the most intractable problems still plaguing policymaking in the developing world. Two specific areas, standards and food safety, are explored to highlight these interactions and test the suggested policy analysis framework.

The pivotal role of technological capabilities and domestic learning systems

Technological capabilities are crucial to national economic performance – all the more so due to the introduction of stronger IPRs, regulatory harmonisation and standardisation, and the worldwide spread of emerging science-based industrial technologies. In the Doha Round era developing countries' prospects for catching-up with more advanced countries in productivity and income hinge increasingly on their ability to rapidly build up competences. This places domestic knowledge systems at the core of industrial development strategies. This is not new, but has acquired far greater importance in recent times.

Owing to the cumulative nature of learning, differences in the rate of accumulation of technological capabilities have an inherent tendency to translate into gaps in economic prosperity across countries. Narrowing these gaps has required sustained catch-up efforts of various kinds. Pivotal among these efforts has been the swift accumulation of technological capabilities. Contrary to views once popular among economists, domestic knowledge generation has been a requisite of catching-up. Tapping into the global pool of knowledge and building domestic knowledge systems go hand in hand.

Collective learning, both within single organisations and at more aggregated levels, is a vital feature of domestic competence building. Indeed, the effectiveness with which a firm is able to participate in and benefit from the generation of technologies is largely given by factors that lie outside the scope of the individual enterprise. The institutional environment within which a firm operates determines its incentives and opportunities and thus affects the scope of the capabilities it needs to master. The intervening factors include incentives to innovation, conditions of access to various kinds of inputs (including finance, skills and knowledge) and to relevant markets and regulatory requirements. Behind many of these factors lie the capabilities of a multiplicity of organisations, including input suppliers, educational and training institutions, research organisations, financial institutions, regulatory agencies and specialised service providers. Clearly then, both the quality of firms' technological capabilities and the scope for acquiring new capabilities can only be properly understood by considering the context within which both are shaped. The process of competence building is hence not only cumulative at an individual level but also systemic in character.

Effective public policies must aim not just at creating a functional S&T infrastructure adapted to the specific needs of the productive sector, but also at enabling the emergence of domestic demand for technological capabilities. In the private sector of the economy such demand depends on how far business firms internalise innovative activities as a key ingredient of their competitive performance. This critical pre-condition entails addressing the interplay and complementation between the incentives framework and the services of the S&T infrastructure, on the one hand and, on the other, the impact of various kinds of externalities (technological, informational, coordination) on companies' ability to conduct the risky business of exploring new production areas and new markets.

Critical factors for catching-up: assessing the evidence

The idea that social capabilities lie at the heart of economic development processes is not new. Until recently, however, attempts to rigorously assess the critical factors affecting catching-up potential – a precondition for effective policy design in developing countries – were handicapped by insufficient data and lack of relevant metrics.

The Report shows that this gap can be narrowed by applying factor analysis to recently collected data, by discerning broad dynamic trends for a cross-section of countries and identifying factors that affect growth.

Overall, the variables considered depict various facets of technological capability, institutions, policies and geography, which are broadly aligned with various theories of growth and convergence found in the economic literature. When common vectors underlying these variables are extracted from the data, five composite factors emerge. The first one is *knowledge,* by far the most important one, comprising variables highly correlated with the creation, diffusion and use of knowledge, such as R&D and innovation, scientific publications, ICT infrastructure, quality management and education. The second factor is *inward openness,* which comprises indicators of import trade and inward FDI. The third factor, *financial system,* concerns overall aspects of market capitalisation, country risk and access to credit. Together with *governance* and the *political system,* as well as a range of control variables covering geography and history, these factors are used to probe the issue of catching-up empirically.

As expected, social capabilities – including knowledge, governance and financial structure – are found to be positively and significantly associated with development level. The stock of knowledge seems to be a major source of difference in income levels across regions in 2002. Most strikingly, almost 60 per cent of the difference in income level between Sub-Saharan African (SSA) countries and the industrialised countries can be attributed to the difference in the stock of knowledge. However, low current levels of social capabilities do not necessarily mean that low-income countries are doomed to stay poor.

In fact, initially low levels of development (measured either in terms of income or knowledge stock) can signal a larger *potential* for faster growth and catch-up. Whether this potential for catching-up is or not realised depends on the rapid accumulation of capabilities. Low-income countries can be expected to grow more than two percentage points faster than the rich ones, other conditions (such as knowledge and governance) being equal. However, these other conditions are often not equal: the developing countries' higher potential for technological catch-up may be more than offset, for instance, by the better quality of the financial system and faster growth of knowledge in the rich countries. Hence, the difference in GDP per capita between rich and poor countries may end up widening rather than narrowing. In other words, in addition to facing the challenge of coordinating capability building policies across a wide range of areas, developing countries must also keep adjusting their aim to a moving target, due to the rapid growth of capabilities within rich countries.

Although the initial gap in income suggests a greater growth potential for the least developed countries, in the model used in the Report this is actually more than offset by the other factors taken into account. The result is a growth rate 2.1 percentage points lower than that of the successful industrialising countries of East Asia. The three factors cited – the financial system; governance; and the knowledge gap, a good proxy for overall social capabilities – account for approximately 80 per cent of the income growth differential between the two regions.

Empirical evidence presented in this Report suggests that countries wishing to strengthen their competitive position and to catch-up need to invest steadily in the generation of knowledge. This is a clear priority for development, but it is not sufficient. Well-developed knowledge capabilities need to be supported by an enabling environment such as a well-working financial system and governance capabilities. The historical and descriptive evidence presented in Chapters 3 and 4 provide further insights into the role of domestic capability building in catching-up.

Catching-up and falling behind: accounting for success and failure over time

What determines success or failure in the bid to catch-up? This question has intrigued policymakers, academics and industrialists for more than a century. At the extremes, the long-run trend since the Industrial Revolution seems to be towards divergence, not convergence, in productivity and income. But, in accordance with the empirical evidence provided above, what history shows is that in the few countries that have managed to catch-up with, even overtake, the leaders at different points in time, the key driving forces were technology and the environment that fosters it.

Data on per capita income across countries and regions since 1820 shows a long-run tendency towards divergence in the global economy. Not only have high-income countries grown faster on average than those with low income, but the distribution has also widened, so the gaps between the richest and poorest have grown. While the period between 1820 and 1950 was one of divergence in economic performance between the leading advanced countries, the decades that followed were characterised by 'club convergence' in income and GDP per capita among the industrialised economies, and further divergence between them and the lower-income economies. In particular, this tendency seems to have gained momentum after 1980.

Probably the most striking feature of the long-run evidence is the great variation in performance between countries with comparable initial levels of productivity and income. That said, the data helps to distinguish clearly between four groups of countries:

- countries that, having started with high level of initial income, are still *moving ahead* with high growth rates,
- high-income countries that have started to *lose momentum*,
- countries that, having started with low levels of income, enjoy high growth rates and are in the process of *catching-up*, and
- countries that are *falling further behind*.

Productivity catch-up requires higher-than-average growth for a sufficiently long time. How long this period must be depends on the size of the initial gap with respect to the target level. However, the aim of catching-up efforts cannot be expressed solely as that of achieving higher-than-average levels of GDP per capita. In order to better account for patterns of convergence and divergence, it is necessary to undertake a historical assessment of institutional developments that have influenced the accumulation of technological and social capabilities in catching-up countries.

Role of knowledge systems in catching-up experiences

The diversity of growth processes at the country level reflects differences in institutional patterns, interactions between the social actors and the pace at which social and technological capabilities have been accumulated. A privileged vantage point to assess the role of institutions in catching-up scenarios is that of focusing on the components of domestic knowledge systems such as higher education, technical and vocational training, research, technical associations, standards, metrology and technical regulatory bodies and institutions that support the interactions between training and research activities in the public sector and the formation of entrepreneurial and technological capabilities in emerging industries.

The institutional evolution of domestic knowledge systems in countries such as Germany, the US and Japan in the 19th century as well as in Taiwan Province of China and the Republic of Korea more recently illuminates the role of collective competence-building in economic catch-up. In all these cases significant institutional adaptation and innovation took place in response to particular local conditions. Amid the resulting diversity, however, important similarities are found, which provide useful lessons for contemporary policies. The success of the respective policies often relied on achieving a balance between rapid accumulation and enhancing the demand for technological skills and capabilities.

Since the 19th century catching-up experiences have often involved significant increases in enrolment in tertiary education – especially in science and engineering fields – as well as important adaptations to the needs of emerging industrial sectors. Not only was access to education greatly broadened, but also the scope of academic education, both by advances in natural science research and changes in attitude towards professional training. The international movement of students made another important contribution to the spread of S&T during the 19th and 20th century, coupled with movements of skilled industrial personnel. These changes coincided with the emergence of science-based industries – such as chemicals and electrical equipment – and of formal R&D laboratories in firms in these industries, both of which had an impact on the concept of the contribution expected from modern universities. Public policies and especially public funding often helped bring about greater closeness between industrial practice and academic education. The experiences from countries such as Japan and the US show that, while it is important to ensure continuity and pertinence, it is also necessary to strike a balance between supporting research that responds to the current needs of industry and making sure that part of the funding is allocated more flexibly to research with potential future returns.

Creating a domestic supply of scientists and engineers may not be sufficient to induce the emergence of private sector demand for their knowledge. Particularly during the early phase of industrial development, the creation of an effective technological infrastructure is likely to require a set of complementary policies and institutions to support private entrepreneurial efforts. A crucial determinant of an effective relationship between university and industry is the degree of responsiveness of educational curricula and activities to the emergence of new areas of industrial technology or specialised sectors. This often entails establishing effective networks between institutions of higher education, technical and vocational training, research units, technical associations and industry.

Competence building policies in Taiwan Province of China and the Republic of Korea provide useful examples of the design of institutions and investment in capabilities for which there is little initial demand. Imbalances in the national supply and demand of skilled personnel in these economies were remedied through private-sector development and policies that struck a balance between catering to current needs and anticipating the future needs of industry. Particular attention went to the efforts of public research labs in transferring and disseminating technology – such as ITRI in Taiwan Province of China and KIET in Republic of Korea.

The scope of the contributions of universities and public research institutes to capability building in a sector must evolve in tune with the nature of the technological activities carried out by national firms, their access to other sources of technological knowledge, and the structural characteristics of the evolving industry. Skill formation in the private industrial sector has been a critical component of the technological capability building efforts in virtually all catching-up countries. Public policy has often helped to shape these efforts, both by means of legislation on accreditation and certification and by encouraging skill formation through the use of levies and incentives. Another institutional set-up for which a wealth of experience exists is the establishment of industry research organisations such as the Engineering Research Associations in the UK and Japan, which were important means of raising technological capabilities across the board in a given industry by facilitating the exchange of technical information and the creation of opportunities for risk and cost sharing between participants. Entrepreneurship development policies, including incubator programs and venture capital support can also, given appropriate framework conditions, greatly assist in encouraging innovative activity.

The role played by standards, quality and metrology institutions in the formation of innovation systems is a much under-studied aspect of technological infrastructure. Chapter 4 closes with a review of the role of such infrastructure in the recent catch-up experiences in Taiwan Province of China and the Republic of Korea, which suggests that the capabilities embedded in these institutions can also promote industrial deepening and technological catch-up.

Accessing and mastering knowledge

Unequal access to codified information has been at the centre of public debates on the so-called knowledge divide. These debates have coincided with an explosive growth in the stock of codified S&T knowledge. The amount of new information stored on various forms of media doubled between 1999 and 2002, implying a 30 per cent yearly growth rate. Information flows through electronic channels have also increased at breathtaking speed, a phenomenon fuelled partly by the growth in the number of Internet users and the amount of information stored on the web. What is the potential significance of this trend for developing countries' strategies and prospects?

Specific features of these trends create challenges and opportunities for developing countries, whose development prospects are at least partly defined by their ability to adopt and adapt technologies (physical and social) originated elsewhere, that is, their ability to learn to apply S&T knowledge to the implementation of locally innovative economic activities. This in turn depends on the systematic nurturing of indigenous technological capabilities and the development of a domestic technology infrastructure, which can foster greater access to the available sources of codified knowledge.

Developing countries face two kinds of challenges in this respect. The first one arises from barriers to access that often accompany the codification of knowledge, imposed by the sources of that knowledge. Among these, pricing is pivotal. The second challenge is posed by the limitations on the use of codified knowledge, even when access is granted. Access to codified knowledge may be opened, but IPR enforcement may substantially restrict its use.

From a developing country's standpoint, the impact of the TRIPS agreement results from a balance between two forces: the marginal impact on domestic learning and innovative activities from increased access to patent disclosures, and the consequences of the creation or strengthening of IPRs on inward technology transfer. With respect to the former, the effect can be expected to be more significant for patenting activities by resident firms or individuals than by foreign holders. As to the latter, stronger IPRs protection might curb activities of reverse engineering and imitation of foreign products, but it might also support technology transfer activities structured around licensing agreements.

The capabilities required to take advantage of codified knowledge depend on the intended uses of the knowledge to be acquired. These may range widely, from merely transmitting it to third parties to reproducing it in an experimental setting. There are also differences across sectors regarding how pervasively codified knowledge is available as a carrier of commercially useful technology, and how complex are the capabilities required by the potential users of available knowledge.

Questions arise as to why dissemination is difficult, why advances in scientific knowledge do not lead immediately to new technological applications, and why the effectiveness of both processes varies significantly across sectors. Two fundamental explanations have been put forth. The first one is that the output of scientific research is not information that can be used at trivially low costs in the production and implementation of new technology. Scientific activity relies on a complex enabling infrastructure. Second, the mastery of tacit knowledge affects the efficacy of technology dissemination processes across firms or countries. (e.g. standards and technical regulations, generic drugs and semiconductors)

The capabilities required for exploiting various forms of codified knowledge reside only partly within any given firm. A distinctive feature of an innovation system is the presence of multiple, interacting actors and institutions, whereby firms' capabilities are enhanced by access to those of other actors in the system. The extent to which developing country firms can access and use available sources of codified knowledge depends on the diversity of the collective skills and capabilities they can rely upon in order to introduce locally innovative technologies. A remarkable mismatch is to be noted, however, between the increasing recognition of the need for domestic knowledge systems and a quite generalised recent decline in the allocation of resources to capability building in most of the developing world. This trend runs contrary to that found in the experience of the successful catching-up countries highlighted above.

Policy, knowledge and business innovation

In modern societies development and economic welfare rest on the permanent creation and destruction of knowledge. Rapid acquisition of new knowledge is fundamental to successful economic performance. Seizing opportunities for catching-up depends on the systematic mastery of knowledge and skills. This mastery does not develop more than minimally unless societies invest in acquiring it.

Competence building has yet to be given the centre-stage position it warrants both in the formulation of development policies and in the conceptual framework underlying these policies. This is because, first, theoretical considerations provide a very limited guide for policy and, second, there is a dearth of appropriate tools, metrics, heuristics and needs-assessment methodologies.

Although few would dispute that economic restructuring and productivity growth are increasingly driven by innovation, conventional policy approaches still do not adequately deal with this reality, particularly with the need to match the demand and supply of innovative resources. While the price system understates the demand for innovation because markets tend to under-reward innovation, system weaknesses often block the supply skills and expertise as well as their application to innovative activity.

A major inadequacy of conventional policy approaches to development stems from the insufficient attention paid to the dynamic correspondence between competence building policies and *private sector development. Policymaking to foster* economic transformation from this perspective still awaits formulation both in terms of a general framework and of specific guidelines.

The capability approach provides a privileged vantage point to address these issues. In articulating such an approach for the emergence and growth of innovation systems (IS) in developing economies, key phases of transformation need to be identified.

As poor countries get richer, sectoral production and employment become less concentrated and more diversified. This pattern lasts until fairly late in the development process. Then, incentives to specialise take over as the major force. Beyond a few specialised, export-oriented activities, a similar pattern can be expected in the allocation of resources to technological effort where technological learning tends first to spread across a broad range of activities, to become increasingly specialised and differentiated as the economy attains higher levels of development. Once business enterprises, along with complementary agents, have acquired broad-spectrum innovative competences, can they afford to seek more specialised innovative capability development tracks.

Information externalities, asymmetries and complementarities call for non-market interventions to overcome hurdles in the process of innovative development. These hurdles give rise to various kinds of mismatches in the pace of advance of capability building in the domestic knowledge, the business innovation and the policy/governance subsystems. Only when these subsystems advance in step does a potential for catching-up emerge. This potential normally develops along sectoral lines, in the context of conducive overall framework conditions, including those relevant to economy-wide innovative capability development.

Three phases can be discerned in IS growth. They consist in: first, establishing threshold conditions for the emergence of IS; second, promoting innovation-based growth; and third, prompting the growth of differentiated and specialised functions to generate systemic innovative responses to emerging opportunities. As we move across these phases, strategic priorities shift from stimulating generic innovative skills in the business sector to generating a critical mass of innovative SMEs, to the emergence of a venture capital/private equity industry market. Similarly, the private sector's share of total R&D increases, whereas the emphasis of the support infrastructure shifts from basic vocational training, information diffusion, metrology and standards to fostering specialised infrastructures and frontier technologies.

The experience of Ireland and the successful Asian catching-up countries highlight the fact that, although the respective strategies may differ in their degree of reliance on FDI and ways of mastering technology and skills, catching-up is highly unlikely to take place in the absence of openness to international trade, investment and technology flows. Developing-country policymakers must operate under severe limitations that did not exist back in the 1970 and 1980s, particularly those relating to stronger IPRs and the prohibition of export subsidies. These constraints do pose very stringent *demands on the ability to assimilate technology and to* export. However, the loss of policy autonomy ought not be exaggerated.

The crucial constraint on the pursuit of catching-up policies today resides in the national capability to articulate the co-evolution of the domestic knowledge, business innovation and policy/governance subsystems so as to move IS forward.

The emergence of this capability depends essentially on indispensable domestic factors such as social consensus and framework conditions. These conditions are not confined to the generic public goods of the conventional discourse (macroeconomic stability, rule of law, good governance) but also comprise stimuli to technological capability formation and innovative development.

Standards, technical change and catching-up

Technical standards help focus the direction of technological search efforts by limiting product diversity and speeding up selection. This entails the need for policy to watch the balance between gains in innovative efficiency and reductions in the necessary degree of diversity of innovative endeavours.

The ensuing challenges for policy are not trivial. For instance, a new technology may have a lower potential for improvement than an old one it intends to replace, or the costs of shifting to a new, more promising technology, may be perceived as higher that those of continuing with the old one. As policymakers are rarely able to anticipate technological change and time their decisions optimally, they are normally left with the responsibility of creating appropriate framework conditions for standardisation, letting private committees manage the standard-setting process.

The nature of the incentives provided by standards and IPRs differs sharply. The former are largely market-driven devices for collective processes of innovation convergence, which promotes selection, while the latter are aimed at rewarding individual inventions, thus fostering diversity. Since they influence the trade-offs between the public and private dimensions of knowledge differently, a potential for conflict ensues. Such is the case when applying standards requires the use of proprietary technologies with high patent and standards intensities.

While potentially moving towards the coordination of technologies, standardisation has also been taking a more pivotal role in the knowledge-creation process. The influence of IPR pooling is heightened by the increasing intensity of patenting in particular areas such as mobile telecommunications and semi-conductors. The ensuing effects on the use of IPRs and standards, combined with trends such as market integration across borders, convergence of technologies and the increasing pace of technological change have put them on a collision course.

IPRs and standards may be designed to complement one another, thus fostering the creation and diffusion of knowledge; or IPRs may be used to block standards; or the conflicts may be mitigated by efficient licensing mechanisms such as equitable patent-pool schemes allowing IPRs to be factored into standards without infringing property rights. This is an emerging intermediate scenario.

The key conclusion coming out of this analysis is that only firms that possess technological assets to trade will be placed in a position to exert influence on the outcome.

From the perspective of countries attempting to catch-up, actual disadvantages in this field may be offset, at least partially, by paying particular attention to the early integration between R&D and standardisation activities at the project, program and institutional levels. A window of opportunity in this respect arises when building up new research and standardisation capabilities, in contrast with the often broken-up systems in industrialised countries, which are just beginning to address the problem.

The extent to which developing country domestic firms can influence the specification of international standards will depend largely on the quality of their own patent portfolios.

As technological pace-setters, advanced countries exert great influence on developing-country standardisation processes. Yet, involvement by developing-country experts in international standard-setting activities contributes to enrich their tacit knowledge – in addition to the access to codified knowledge that the standards themselves entail. However, these experts cannot be expected to exert much influence over them. While accounting for the overwhelming majority of ISO members, for instance, developing countries account for just three out of the 12 members of the Technical Management board and are responsible for barely five per cent of its Technical Subcommittees, which set policies, actions and standards. In contrast, the US, Germany, the UK, France and Japan hold among them 65 per cent. The remaining 30 per cent is held by other developed nations. Nevertheless, active involvement in international standardisation processes may contribute to developing countries' awareness about developed-country preferences. Since standards are shaped not just according to technological requirements, but also to market needs and users' preferences, this may ultimately have a knock-on effect on the final specification of international standards and on the competitiveness of developing-country firms.

From a developing, potential catching-up country standpoint, the information and the practices and routines entailed by standards (particularly those relating to quality management) are an input for improved competitiveness, credibility and reputation. As is only to be expected for the case of a standard-follower country, this occurs pretty much across the board, rather than just in frontier technology areas. Because of the very recent and rapid diffusion of public technical standards in developing countries, governments have a key role in helping set up the necessary standards and conformity assessment infrastructure as part of the threshold framework conditions for private-sector development. An efficient infrastructure of this kind, still largely absent in most of the developing world, is indispensable to offset the competitive disadvantages suffered by manufacturing firms from latecomer countries.

Standards are also important for developing countries embarking upon high-technology sectors whose products and services are becoming rapidly diffused globally. Adoption of standards in this case may entail important trade-offs requiring careful monitoring of technological trends.

Because of the different role of standards in advanced and developing economies, the policy implications also differ greatly. While in the former public policy issues are largely about stimulating the private sector to better handle the production and distribution of knowledge by means of the necessary institutional innovations, in the latter they are essentially about investing in capability building and in creating the incentives and institutions for the development of a responsive standards and conformity-assessment infrastructure to help enhance firms' quality management and international competitiveness. Only in very few cases are potential catching-up countries beginning to play a role in standard-setting in emerging technology fields. This experience may show the way for the countries that follow and for that reasons it calls for close monitoring.

Building Capabilities for Food Safety

Forty per cent of world trade in agricultural products (US$583 billion in 2002) comes from developing regions (WTO, 2003). While the international debate has largely focused on the controversy over agricultural subsidies in trade negotiations, much less attention has been paid to the capability building needs of developing countries in the face of ever more stringent requirements to the trade in agricultural products. As the volume of international trade in agricultural products originating from developing countries suggests, much is at stake, even after discounting the effect of trade distortions created by subsidies.

The ability to compete in agricultural and food products is increasingly about meeting safety, quality, and environmental requirements (above and beyond price and basic conditions). In the last decade, changes in how the risks involved in the food chain are perceived by the public and approached by the scientific and policymaking community have resulted in increasingly stringent standards and regulations. Not only is there greater scrutiny of production and processing techniques, but there are also stricter traceability and labelling requisites across the food supply chain. While most SPS measures, such as those relating to human health and safety, are embodied in technical regulations, there is also a discernible upward trend in the development of private standards, as retailers in developed economies, motivated by commercial strategies of mitigation and differentiation, impose conditions along the supply chain.

While many in the developing countries perceive the increasing requirements as a potential and significant barrier to trade, the ability to raise capabilities in this field also presents a major opportunity for upgrading and catching-up with other high-value food-exporting developing countries. Unfortunately, while costs are immediate and easy to account for, the benefits from compliance tend to be much more difficult to ascertain. Since SPS compliance is also a 'moving target', the three subsystems of the IS – the knowledge, the business innovation and the policy/governance subsystems – need to co-evolve to keep up with changing demands.

In order to continue to trade, developing countries need to enhance private firms' ability to comply with these requirements as well as strengthen the institutional infrastructure, that helps demonstrate compliance. SPS-related risks are often not limited to one stage of production or processing. Dealing with such complex challenges in a dynamic context requires more than adopting good practices and new technologies – it involves raising domestic capacity to interact with the international system, enhancing the knowledge base, building legitimacy and trust in the domestic institutions and guiding the direction of search, experimentation and market-building for a growing business innovation system.

Since the requirements of a well-functioning SPS system are relatively complex, it would not be realistic to expect that all the actors and sub-sectors in developing economies (and especially the least developed ones) to evolve concurrently in a smooth fashion and to achieve sufficient capabilities to undertake a decisive approach to food safety in a short period of time. In fact, even in semi-industrialised economies with developing IS, growth of capabilities in the food safety area are uneven.

As a result, interventions are required not only at the final product-testing level but also upstream of the supply chain for effective quality and food safety control. This involves:

- Building policymaking capabilities, including the updating of legislation to enable food safety control agencies to respond to current challenges that go beyond basic control of hygiene and supporting participation in international standard setting and planning activities. Critically, the way in which risk management is handled by food safety institutions and reflected in relevant legislation can drastically enhance or diminish the potential for technological and entrepreneurial innovation in the private sector.
- Reinforcing the technological capabilities within the institutions of the domestic knowledge subsystem, particularly those of the food standards and quality control agencies, through investments to upgrade their testing and measurement, risk analysis and certification capacity, R&D efforts, ICT resources, training and organisational changes for enhanced performance.
- Setting and fine-tuning public-private cooperation for the effective functioning of the food safety system. This is largely due to the need to adapt the technologies to local conditions, so catching-up in this area requires indigenous capabilities to co-evolve within the firms as well as within the technological support infrastructure to help absorb and adapt necessary technologies to the local needs.
- Helping to build capabilities in the private sector to deal with increasingly stringent standards and to gain competitive advantages. The business innovation subsystem is a critical but often the weakest component of an emerging developing-country IS. An emerging IS assumes a threshold level of technical competence such as those required to introduce new production methods to comply with SPS measures and other requirements involving technological choices, in addition to financial resources and legal/technical knowledge about how to access low-cost technologies and transfer them. Support to the business sector should promote experimentation and new market formation by enabling investments in HACCP, GAP and GMP, information systems for traceability and labelling, and uptake of environmental technologies.

A UNIDO-sponsored needs assessment exercise conducted in cooperation with SENASA (Servicio Nacional de Sanidad y Calidad Agroalimentaria) in Argentina reveals cost estimates of the upgrading needs of the Agency based on reactive and proactive strategies. The investments in the case of the reactive scenario would require US$53.4 million over five years whereas the proactive scenario would require US$ 133.6 million. These figures represent increases of 32 per cent and 80 per cent, respectively, on the current budget of US$33.5 million. While some one-off investments are required initially to upgrade existing capacity, recurrent expenditures are also required to ensure that dynamic capabilities are built to manage emerging needs. Such resource mobilisation is a necessary but not a sufficient condition to build a legitimate and trusted institution, which requires significant policy/governance capabilities as well as effective links with the business innovation subsystem.

Comparing the assessed needs of a single country with the US$65 to 75 million spent worldwide by bilateral and multilateral agencies in recent years to build trade-related capacities, it is clear that there is a strong rationale for significantly extending and improving the delivery of international technical assistance for specific supply-side constraints and conformity with requirements.

Section II
A Review of World Industry

The review focuses on salient features of global industrial performance during 1990-2002. Quantitative assessments are obtained by the use of six industrial indicators. The narrative addresses industrial performance in three dimensions: activity, industry and technology.

Levels of industrial activity are measured and discussed under two aspects and with reference to the pivotal development indicator of per capita income. The first aspect is domestic and involves the potential of 'manufacturing income' of each economy. The second is international and introduces the perspective of comparative advantage in industry, which is associated with the potential of 'manufacturing trade'.

Structural characteristics are used to assess economies in the other two dimensions. The industry dimension is represented by the weight of industrial production and trade in the entire economy, which provides an indicator of 'industrial advance'. The technology dimension is assessed via the weight of medium- or high-technology branches in industry, which provides an indicator of 'technological advance'. The rationale behind emphasizing this view of structural traits is the key role of industry-*cum*-technology for economic growth.

Activity levels

Between 1990 and 2002 developing economies increased their share in world production from less than 16 per cent to more than 23 per cent. While this is a formidable rise of industry in the developing world as a whole, its result still falls short of the 'Lima target' of a quarter of global output. Changes in the other two broad country groups were also significant: transition economies saw their share halved over the twelve years, and that of the industrialised economies – still the lion's share – shrank nearly five percentage points to less than three-quarters of world industrial production.

The performance of individual regions and countries within the above broad categories varied widely – particularly so between the geographic regions of developing countries. East and Southeast Asia, already the leading region in 1990, doubled its share in world production by 2002, reaching a percentage three times larger than that of the runner-up region, Latin America. Unlike all other regions, with the exception only of Sub-Saharan Africa, Latin America even experienced a slight decline of its share. In addition, there was a faint sign of improvement visible for the LDCs, whose share in world industry remains, however, still minuscule.

When industrial production is related to the number of people who benefit from it, directly or indirectly, the global picture is one of glaring unevenness. Differences are overwhelming in comparisons between individual countries. The same is true for the gap between the industrially richest and poorest parts of the world, a gap which, moreover, has been significantly widening rather than narrowing. A comprehensive assessment of global industrial unevenness, however, produces a picture that is less dark and in which significant improvements can be traced. In this context, the special position of China in today's world development can be seen in the light of its impact on reducing industrial unevenness.

In comparisons between individual countries or geographic regions, industrial production per capita is the natural indicator of the level of domestic activity and, more broadly, of the level of industrial development at large. Here too, differences between country groups and regions are striking. Industrial activity in the industrialised economies is at a level ten times higher than that of transition economies and sixteen times that of developing economies. Among the developing regions, too, gaps in activity are wide, with a ratio of about nine between the highest and the lowest regional averages. The highest level of per capita output throughout the period is that of Latin America. By 2002, East and Southeast Asia had attained the second place with activity not far below that of the leading region. The Middle East and North Africa hold a middle position, whereas South Asia and Sub-Saharan Africa rank at the low end.

Comparisons between countries reveal an almost unimaginably broad range of activity. The ratio between the level of the leading economy (Switzerland) and the trailing economies is of the order of one thousand. And for only a handful of developing economies, the so-called Asian Tigers, GDP per capita is higher than Switzerland's industrial output per capita. While the size of gaps is certainly exacerbated by the standard method of international comparison chosen here, their qualitative nature remains unchanged when measurement changes.

The same holds for the salient features of the core ranking of countries by industrial output per capita. All the industrialised economies are found in the highest quarter of this ranking. So are three of the four Asian Tigers, and Malaysia.

In this connection, the outstanding performance of Singapore is underscored by its being the only developing economy among the top ten in terms of domestic-activity level. The second quarter of the ranking contains a number of large developing countries, among them China, which attained a position close to the middle (the median) of the global distribution by activity levels. In the lowest quarter all the LDCs are clustered with activity levels below a sixth of the average of all developing economies.

When economies are compared with respect to the international level of industrial activity, Singapore moves to the top of the world ranking. Apart from individual cases such as that of the star-performing Asian Tiger economy, the international ranking is quite similar to that produced by the domestic assessment. With respect to both, the evidence is that of high levels of industrial activity being the prerogative of the industrialised economies – with the most impressive exceptions to this rule constituted by a handful of Asian economies.

Structural traits

Four out of the six indicators used in this review reflect structural properties of an economy. Two of them measure the relative importance of industry within the entire economy. Their combination gives rise to an indicator of 'industrial advance', a tool for assessing the position of an economy in the industry dimension. The other two capture, in analogous fashion, technology within industry as well as 'technological advance' and allow for country assessment in the technology dimension. The interaction of industrial and technological advance yields a new indicator, the 'industrial-*cum*-technological-advance' (ITA) index.

The joint criteria of industry-*cum*-technology lead to assessments of country groups and of individual countries that parallel those based on activity levels. In particular, within the developing world structural differences between regions are immense. In an assessment by the ITA index, East and Southeast Asia clearly leads among the developing regions, whereas differences among other regions are modest. For the latter as a whole, the average ITA value remains below a third of the level of industrialised economies, despite a remarkable increase of developing economies ITA over the 1990s. By contrast, a sample of LDCs average an ITA value of only about half the level of developing economies (excluding East and Southeast Asia).

It is, again, the inter-country comparison that bears out the full variation of structural differences in the industry and the technology dimensions. For the roughly one hundred countries assessed in the review the index of 'industrial-cum-technological advance' ranges from a maximum of slightly over 0.5 to a minimum of virtually zero. Once more Singapore takes the lead, ahead of industrialised economies, and three other Asian economies are among the top ten in the world. Overall, there has been 'industry-cum-technology advance' between 1990 and 2002, as the number of economies in the upper half of the ITA range increased from 22 at the beginning to 28 at the end of the period. In this increase, economies from East and Southeast Asia (among them China) are prominent. By and large, the North-South divide observed for activity levels is reproduced with respect to structural characteristics. Industrialised economies still dominate the upper half of the ITA range while Asian star-performers are moving in rapidly. In the ITA interval between 0.25 and 0.125 – that is, half of the upper half – economies from all groups and regions are found, including large countries like Turkey, Indonesia and the 'giant' India. On the other hand, all the LDCs (except Bangladesh) covered in the review are clustered around the low end.

Of the two constituents of the notion of 'industrial-*cum*-technological advance', the industry dimension plays the conventional part, both conceptually and with regard to measurement. This is reflected in the ranking of countries by 'industrial advance'. Nevertheless, this 'conventional' assessment produces some surprise results. Thus, among the top ten economies in the ranking, eight are East or Southeast Asian countries, while most industrialised economies are found in lower ranges. And for half of these surprise-countries, which include China, the unexpectedly high ranks are the result of a spectacular increase in the 'industrial advance' indicator over the 1990s. Another astonishing fact is the highly mixed composition of the lower half of the country distribution by industrial advance, which includes even four industrialised economies.

The 'modern' component of the ITA index – that of 'technological advance' – produces a considerably wider range and a different ranking of economies. While Singapore is again the leader, the top ten economies are equally spread between industrialised and (mostly Asian) developing countries. The highest quarter of the technological-advance ranking 'belongs' to a large extent to the industrialised economies. However, about a third of the economies in these high ranks are of developing countries. At the low end of the 'technological-advance' ranking there are countries from all developing regions, except East and Southeast Asia. All the LDCs in the sample are found there, though with some variation in the values of the corresponding indicator.

Finally, taking up the time-honoured analysis of structural change, the association between the central structural measure – that of 'industrial-cum-technological advance' – on the one side and the income level on the other is examined. The results lend plausibility to the notion that 'industrial-cum-technological advance', as indicated by the ITA index, starts from a low level at low incomes, reaches high rates of progress over a fairly wide middle range of income and levels off at the highest income levels – which bodes well with the evolution of IS depicted in Chapter 6.

Section I

Part 1

A historical, emprical and conceptual perspective

CHAPTER 1

The pivotal role of technological capabilities and domestic knowledge systems

Technological capabilities have become crucial to national economic performance – all the more so due to the introduction of stronger intellectual property rights (IPRs), regulatory harmonisation and standardisation, and the spread of emerging science-based industrial technologies worldwide. In the Doha Round era the developing countries' prospects for catching-up with more advanced countries in productivity and income hinge increasingly on their ability to build up competences rapidly. This places domestic knowledge systems at the core of industrial development strategies. Although not entirely new, this feature has acquired far greater importance in recent times.

Insights in this regard have been emerging at least since the early 1960s. Alexander Gerschenkron (1962) noted that late-comer countries could achieve rapid economic growth by exploiting technological knowledge accumulated by firms in advanced economies through painstaking trial-and-error learning. However, the complexities of inward technology absorption and the requisite institutional underpinnings remained neglected, indeed unseen, for several decades, largely because the prevailing view among economists focusing on growth was that catching-up would follow as a matter of course by virtue of capital flows towards the countries where capital was relatively scarcer. Over time, these perceptions about the ineluctability of catching-up have been steadily undermined by empirical evidence showing patterns of persistent divergence in per capita income across countries, and by the realisation that convergence is not at all unconditional.

Catch-up consists of much more than imitation of the industrial technologies, prescriptions and institutions in leading economies.

The process of economic catch-up consists of much more than imitation of the industrial technologies, prescriptions and institutions in leading economies (Nelson, 2003a). Inward flows and 'imitation' of industrial technologies coming from these economies involve a good deal of adaptation to a different economic environment, often resulting in the development of entirely new technologies in the 'late-comer' economy (for example, the 'Toyota production system'). Policy and institutional adaptations are also part of the catching-up process. Both the United States (US) and Germany used tariffs to protect domestic producers during a good deal of their economic catch-up with Britain, a nation that adhered to free trade during much of the 19th and early 20th centuries. Likewise, German economic catch-up drew heavily on the development of a homegrown institution, the large industrial banks that financed and invested in many leading firms, notably in the chemical industry. A similar mix of institutional, economic and policy imitation and innovation has been observed in the economic catch-up processes of the Republic of Korea and Taiwan Province of China.

Homegrown knowledge systems matter

In the past, sustained economic growth at country level has coincided with the development of domestic innovation systems (IS). This is not accidental. Some features of these systems differ across countries, but others are quite similar. In particular, advanced economies' IS are characterised by a complex web of relations between economic actors involved in the production, transmission and absorption of technological knowledge. Although firms are key actors in these webs, the effectiveness of the system rests also upon contributions by other institutions, such as public and private universities and research laboratories; technology extension and diffusion agencies; vocational and professional training institutions; and agencies for quality, metrology, standards and conformity.

The limited technological capabilities of developing economies match weaknesses in the variety of their IS institutions and, particularly, in the intensity of the interactions between these institutions and between them and private firms. These weaknesses cannot be dismissed on the strength of the oft-heard notion that in their quest for growth most of those economies do not require local actors to create new technological knowledge. This notion presumes that technology absorption does not require innovative capabilities. But technology is not a body of knowledge that can be used off the shelf: learning about existing technologies and their use in a competitive environment are inherently challenging tasks.

> ***Existing local knowledge and competences largely determine how effectively an organisation can master inflows of technological knowledge.***

Tacit knowledge is a crucial (people embodied) element of technological capability. Along with it, codified information, with its significant public properties, has an important bearing on social learning and economic development. These properties call for a nuanced view of the complex processes through which knowledge (both fundamental and applied) is created, imitated, and transferred (Nelson, 2003a), a view that has largely eluded economists till now.[1]

The learning process required for mastering a technology entails not only access to codified information, but also an adequate capacity for learning and the possibility to fine-tune performance on the basis of experience. This is because much technological knowledge is unarticulated and tacit, and can be transmitted only at a cost through imitation and apprenticeship (Polanyi, 1958; Nelson, 1992; Langlois, 2000). The 'blueprint' characterisation of technology fails to comprehend the knowledge-intensive nature of the technology transfer and adaptation processes.[2] Often enough, adoption of technology requires adaptation to local conditions, such as distinctive qualities of physical inputs, skill availability, and scale. This is why existing local knowledge and competences largely determine how effectively an organisation can master inflows of technological knowledge (see box 1.1 and Chapter 5).

Box 1.1 Information and knowledge: limits to and uses of codification

How far can tacit knowledge be codified and what accounts for the degree of codification? What difference, if any, do advances in ICTs make in this regard? Following the seminal contribution by Nelson and Winter (1982) (who in turn drew on the works of J. Schumpeter, M. Polanyi and H. Simon), a debate has ensued about this. This debate is crucial for the understanding of what it takes to disseminate knowledge across organisations and countries.

According to one strand, too much is being made of tacit knowledge: the more tacit knowledge is codified into easily transmissible, cheaply accessible messages, the better (see David and Foray, 1994; Cowan and Foray, 2000). Much more knowledge would be articulable and codifiable, and actually codified (but kept undisclosed), than meets the eye. The actual degree of codification depends on reward systems relating to, and the costs and benefits of, articulating tacit knowledge and turning it into transmissible formats. The availability of cheap computational power entices the conceptualisation of problems in abstract forms (Arora and Gambardella, 1994). Codification permits to test theories and conduct experiments much more rapidly and effectively. Examples are such high impact breakthroughs as the rational design of molecules and the polymerase chain reaction (PCR). Progress in ICTs, by abruptly reducing the costs of codification, makes a real difference in increasing the availability of codified knowledge. At the same time, the costs of moving knowledge around decreases as firms increasingly use generic knowledge bases and produce information usable in different contexts.

The second strand, while agreeing that the concept of tacit knowledge needs a critical overhaul, contests that tacit and codified knowledge are substitutable inputs; that know-how can be reducible to low-cost generic know-what (i.e. knowledge becoming information), except to a very limited extent, and that the boundaries between tacit and codified knowledge are determined by the respective costs and benefits (e.g. Nightingale, 2003). According to this view knowledge is a *capacity* (as opposed to information, which is a *state*) that cannot be reduced to know-how, while only part of the know-how can be reduced to articulated know-what. Consequently, knowledge codification does not make learning and transfer any easier. Tacit knowledge acquisition is key to the development of domestic knowledge systems, which in turn are central to a capability development-based catching-up strategy. The diffusion of new generic technologies will always continue to rely extensively on tacit knowledge, for instance, in terms of the complementary assets and complex contracting skills required by innovative start ups and small and medium-sized enterprises (SMEs) with respect to alliances, mergers, acquisitions and original equipment manufacturer (OEM) arrangements (see Teece, 1986). In addition, most of the knowledge required by venture capital and private equity companies is tacit, as is most of the knowledge associated with 'social technologies' (see Nelson, 2003b). In short most of the complex management and strategy-related functions at the firm and policy levels crucially involve experienced-based tacit knowledge.

Both approaches contain useful, complementary insights for public policy. The first one draws the attention towards properties of knowledge such as its public and non-rival dimensions, its generic attributes and the generation of externalities, while the second focuses on the excludable dimensions of knowledge, its context-specificity and its localised nature (both in geographic and technical sense). From a developmental perspective, however, knowledge should not be looked at purely either as an *object* or as a *process*. Both qualities are highly complementary and interacting.

Does it help developing countries to have access to a rapidly expanding supply of S&T information? It certainly does, since it may help to foster technology dissemination (see Chapter 7). Does a greater, and presumably affordable, supply of S&T information reduce the need to invest in developing the competence to make use of such information? Certainly not; on the contrary, it actually increases that need. Greater accessibility is not to be confused with greater usability (see Chapter 5). No matter how extensive and valuable the available S&T information may be, it will be of little use in the absence of the capabilities to process it and act on it. Even if codified knowledge itself is made free or nearly free, disseminating its use entails a costly activity of overcoming asymmetries in the ability of economic agents to contextualise it for specific applications. Reducing such asymmetries is one of the key missions of the technological infrastructure.

Note: Conventionally, the following distinctions are made: *Data:* unstructured observations or facts; *Information:* data placed within a meaningful context. *Knowledge:* meaningfully organised information (messages) through experience or inference. Knowledge can be viewed both as a *thing* to be stored and manipulated and as a *process* of knowing and acting. Organisations need to manage knowledge both as object *and* process. Knowledge ranges from general to specific. The former, often publicly available, is independent of particular events. The latter is context specific. Because of its lower context-specificity, general knowledge can be more easily and meaningfully codified and exchanged. Tacit knowledge is subconsciously understood and applied, difficult to articulate, developed from direct experience and action, and usually shared through interactive exchanges and shared experience. Codified knowledge can be more easily documented, transferred or shared.

The growing impact of knowledge systems

Advances in information and communication technologies (ICTs) over the last few decades have had a profound impact on the way in which information is disseminated and accessed. There has been a geometric growth of the amount of codified information and a sharp reduction in the cost of accessing it. As this trend has also embraced science and technology (S&T) knowledge, it has momentous implications for developing countries, in terms both of access to knowledge and of their ability to be part of and increasingly global process of knowledge creation and dissemination.

The roots of this process can be traced quite far back. Access to and generation of knowledge have played a crucial role in economic growth since at least the 18th century (Mokyr, 2003). Two things helped make it a central driving force. First, the belief that nature is understandable and can be controlled for the purpose of improving living conditions. Second, the ethos of open disclosure of knowledge that permeated the Enlightenment movement and the nascent scientific community of the 17th and 18th centuries. These conditions promoted a positive feedback between the acquisition and dissemination of knowledge about techniques (know-how) and knowledge about why techniques work (know-why). This feedback arose from interactions between individuals and fostered the emergence of institutions supporting these interactions and individual efforts. Positive feedback in the acquisition and dissemination of knowledge spurred improvements in production systems in those countries where institutional developments provided a relatively free and widespread circulation of knowledge and incentives for individuals and firms to undertake the risky activity of innovating.

This insight from history helps discern the pattern behind more recent developments. Thus, we see that the pace and direction of innovative activities reflect:

- perceptions of the demand for new products and processes;
- the efficacy of the means whereby firms can appropriate a sufficient share of the returns from their investment in innovative activity; and
- the opportunities for innovating which result from the current state of S&T knowledge.

In particular, the renewal of opportunities for innovating is encouraged by the commitment of resources to the 'production' of knowledge that is made widely accessible to the public at relatively low cost (Nelson, 1990; Machlup, 1962).[3] This body of public knowledge is a crucial input to the generation of proprietary knowledge by means of business research and development (R&D) and other firm-specific innovative activities (see Chapter 6).

As the influence of knowledge-intensive activities on economic growth increases, the conditions of access to codified knowledge for the production of goods and services become more important. Users of knowledge must not only have access to codified forms of knowledge but also the ability to make use of it. That ability is constrained by what users already know and are capable of doing.

Throughout modern history sustained economic growth and catching-up have been underpinned by a country's ability to produce and disseminate S&T knowledge.

Collective learning, both by single organisations and at more aggregated levels, is a key feature of domestic competence-building processes.[4] Indeed, the effectiveness with which a firm is able to participate in and benefit from the generation of technologies is largely given by factors that lie outside the scope of the individual enterprise. The institutional environment within which a firm operates determines its incentives and opportunities and thus the scope of the capabilities it needs to master. The intervening factors include incentives to innovation, conditions of access to various kinds of inputs (including finance, skills and knowledge) and to relevant markets and regulatory constraints. Behind many of these factors lie the capabilities of a multiplicity of organisations, including input suppliers, educational and training institutions, research organisations, financial institutions, regulatory agencies and specialised service providers. Clearly then, both the quality of firms' technological capabilities and scope for acquiring new capabilities can only be properly understood by considering the context within which both are shaped. The process of competence-building is hence not only cumulative at an individual level but also systemic in character.

Throughout modern history sustained economic growth and catching-up have been underpinned by a country's ability to produce and disseminate S&T knowledge. Access to knowledge has been important, as have been the institutional conditions enabling the continuing production of knowledge and its embodiment in capabilities. To a significant extent, these things are shaped at the national level. Accordingly, they play a key role in determining a country's ability to share in the bounty of sustained technological progress. Also, owing to the cumulative nature of learning, differences in the rate of accumulation of technological capabilities have an inherent tendency to translate into gaps in economic prosperity across countries. Narrowing these gaps has required sustained catch-up efforts of various kinds. Pivotal among these efforts has been the rapid accumulation of technological capabilities. Contrary to views once popular among economists, domestic knowledge generation has been necessary for catching-up. Tapping into the global pool of knowledge and building domestic knowledge systems go hand in hand.[5]

Catch-up: many paths, some key common features

Countries can succeed in narrowing the gap in economic conditions with more advanced countries in a variety of ways. National experiences have, of course, varied, as a result of the interplay among a number of factors, such as the sectorally specific knowledge they had to acquire, the matching requisite capabilities and the features influencing sectoral patterns of diversification of the national economy (geography, resource endowments, culture). They have also reflected the variety of institutional mechanisms available to support the accumulation of technological capabilities: some countries have relied more extensively on multinational corporations (MNCs), while others have relied upon protecting domestic infant industries while securing access to technology through licensing, and still others benefited from the immigration of skilled personnel to foster the dissemination of technological knowledge (see Chapters 4 and 6, and annex 6.2).

But beyond this variety, one can identify commonalities across the successful catching-up experiences of the past. One common feature is a rapid increase in the level of education and the development of higher science and engineering educational institutions. Another is the creation of public institutions to conduct industrial research and provide services to industrial firms. Last, but not least, important benefits were drawn from relatively unfettered access to S&T knowledge through the participation in international networks of scientific and engineering competence and often thanks to weak, if any, enforcement of IPRs on existing technology.

Public policies have played a fundamental role in these processes and remain today at least as central to national economic development prospects as they have been in the past, particularly with regard to competence-building, including investment in education, training and research institutions, and in agencies dedicated to extension, metrology, standards, and certification services. In other words, there is a need for policies aimed at the creation of an infrastructure for S&T with differing emphases according to level of development (see Chapter 6). Critically, effective public policies must also aim at enabling the emergence of domestic demand for technological capabilities. In the private sector of the economy such demand will depend on how far business firms internalise innovative activities as a key ingredient of their competitive performance. This critical pre-condition entails addressing the interplay and complementation between the incentives framework and the services of the S&T infrastructure, on the one hand, and on the other, the impact of various kinds of externalities (technological, informational, coordination) on companies' ability to conduct the risky business of exploring new production areas and new markets.

The economic environment of the 21st century has shifted in ways that demand more far-reaching institutional innovations on the part of those who wish to catch-up.

Economic catch-up has always involved some adaptation of leader nations' policies and institutions to a different set of circumstances, along with other forms of institutional, policy or technological innovation. The economic environment of the 21st century has shifted in ways that demand more far-reaching institutional innovations on the part of those who wish to catch-up. Contemporary conditions make the inception and growth of effective domestic knowledge systems an even more pressing priority for economic development and beg for renewed efforts to articulate the rationale for national investments in competence-building. The scope and context of the required public policies differ from those that prevailed in earlier times.

A much-noted aspect of the global trade regime overseen by the World Trade Organisation (WTO), the strengthening of international IPRs incorporated in the Trade-Related Intellectual Property Rights (TRIPS) agreement, limits the scope for 'reverse engineering' and other forms of imitation of advanced-nation industrial technologies by those seeking to catch-up (Nelson, 2003). A possible remedy for this may be investing more heavily in institutions and policies that can support the creation of new technologies. Similarly, the thrust towards trade liberalisation limits the ability of latecomers to resort to the industrial protection that historically played a role in economic catch-up in the US, Germany, Japan, Republic of Korea and Taiwan Province of China. Similarly, the growing adoption of standards and sanitary, phytosanitary and environmental regulations related to international trade, while offsetting information asymmetries, also increases the need for sophisticated domestic technological capabilities in developing countries both to leverage access to technical information and to avoid being excluded from actual or potential export markets (see Chapters 7 and 8).

Seeing through a blind spot in economic thinking

Much of the debate of the recent past over economic development policy for low- and middle-income economies has operated in an evidentiary vacuum. The emphasis on economic liberalisation and market-opening strategies of the 1990s replaced the focus of conventional policy prescriptions during the 1970s and 1980s on investment-led growth.[6] Yet, neither strategy has enjoyed great success and neither strategy, in and of itself, seems to dovetail well with the evidence compiled during the past hundred-plus years on the institutional and policy strategies associated with successful economic catch-up and development. For example, the remarkable economic transformation of the Republic of Korea and Taiwan Province of China since 1960 incorporates some elements of both frameworks, but adheres fully to neither, while including other important policies and institutions. Nor does the experience in economic catch-up of Germany and the US in the late 19th century relate closely to the prescriptions of either view.

One area in which historical evidence seems to disagree most sharply with prevailing wisdom concerns the contribution of systematic investments in institutions and activities related to the creation, transfer, application, and dissemination of knowledge to economic development. The design and role of a knowledge-based infrastructure for economic catch-up has received remarkably little attention in recent studies on economic development.[7]

Most people intuitively accept the idea that knowledge and economic development are intimately related, and hence that access to knowledge should be regarded as a vital factor. However, this is not the way different levels of development used to be explained by economists. From the birth of the so-called classical political economy two centuries ago, what economists have focused on when trying to explain differences in income or productivity is accumulated capital per worker. Similarly, differences in economic growth have been seen as reflecting different rates of capital accumulation. This perspective is probably an offshoot of the important role played by 'mechanisation' as a mean for productivity growth during the (first) Industrial Revolution, the period during which the frame of reference for much of economic reasoning was formulated.

Economists have largely done without a nuanced view of the complex processes through which knowledge (both fundamental and applied) is created, imitated, and transferred.

Closer to our own age Robert Solow adopted this perspective in his so-called neoclassical growth theory (Solow, 1956, 1957). His analysis made it clear, however, that this could not be the whole story. When students of economic growth started applying this perspective to long-run growth processes in the US and elsewhere, they found that capital accumulation, or factor accumulation more generally, could only explain a relatively small share of actual growth (Abramovitz, 1956; Solow, 1957; Fagerberg, 1994). This finding has since been repeated many times for different data sets.[8] It also provided the impetus over the following decades to the development of: (1) the so-called growth accounting, concerned with the measurement of the contribution of additional factors to economic growth; and (2) theoretical models where technological change is shaped by economic forces rather than being treated as an exogenous variable (the 'new growth theory').

While not intended for such a purpose, Solow's growth model became the basis for theoretical predictions about cross-country economic performance. The theory predicted that, under otherwise similar circumstances, investment in poor countries (that is, those with little capital) would be more profitable than in the richer ones, and so the former would enjoy higher investment and faster economic growth than the latter. This conclusion rested largely on two assumptions: that technological change is exogenous, and that all countries had access to the same body of technological knowledge. As a consequence of this logic, a narrowing of the development gap (so-called 'beta-convergence') was to be expected (see annex 2.1 and Chapter 3). The prediction that global capitalist dynamics would be accompanied by a convergence in income and productivity between initially poor and rich countries was not borne out of the facts (Lucas, 2002). Indeed, rarely has a prediction been so completely falsified by the evidence as this one.

Awaking to the role of institutions and environment

Admittedly, Solow's theory was based on standard neoclassical assumptions on how markets and agents perform, which might not be wholly applicable to developing countries. Hence, one possible explanation for the failure of many countries to catch-up could be that markets did not work properly, agents did not receive the right incentives, governments interfered too much in the economy, etc. – in short, that 'the rules of the game' were not adhered to. In the terminology used by Douglas North (1981), such rules are customarily called institutions. However, in common parlance as well as in some scholarly work, the concept of institutions is also used in a broader sense, to include not only rules and norms, but also organisations and other types of collaborative activities. In fact, in the sizeable empirical literature that has emerged on the subject, both definitions are used, and this can create some confusion.

As regards the role of institutions for growth and development, it has been argued that institutions in the narrow sense of the term (rules, norms) should be assumed to be relatively stable over time (Glaeser et al., 2004). However, many indicators of 'institutions' suggested in the recent scholarly literature are far from stable; indeed, they are rather volatile. Hence, it can be held that such indicators in most cases do not reflect 'institutions' in the above sense, but political choices, policies pursued by governments, etc. (Ibid.). If the analysis is restricted to indicators of institutions in the narrow sense (constitution, judicial checks and the like) and their relationship with levels and growth of gross domestic product (GDP), the correlations are in fact rather weak, in contrast to what holds for the more broadly defined 'institutional variables' (seen as reflecting political choices). Thus, institutions in the narrower sense are not good predictors of successful catch-up. Apparently of greater importance are the policies pursued. The available econometric evidence seems to confirm casual observation, ie that the political and legal systems of successful countries (and unsuccessful ones as well) can differ considerably. There is no 'one best way'. Policies amenable to catching-up, it seems, may originate in very different political and legal systems (from communist China to democratic Ireland, to take just one dissimilar pair).[9]

In recent years, many empirical studies have been conducted along similar lines by pushing the search for explanatory factors far back in time, such as what kind of systems (countries) the colonial settlers came from (Acemoglu, Johnson and Robinson, 2001), or by taking into account other exogenous variables that might have an impact on development (and policies), such as climate, exposure to diseases, geography (access to the sea, for instance), and ethnic diversity (Sachs et al., 2004; Masters and MacMillan, 2001; Bloom et al., 2003; Alesina et al., 2003). It is difficult to deny that historical or geographical factors may have an impact on long-run growth. However, it must be noted that in most cases there is conflicting evidence and interpretation about the impact of history, geography and nature on growth.[10] One reason for this may be that variables reflecting different causes are sometimes so strongly correlated that little can be asserted with certainty (except, perhaps, that there is a joint impact).[11] Another possibility, pointed out already by Moses Abramovitz (1994a), is that the problems arising from such conditions may spur the creation of new knowledge and new social arrangements, which may eventually eliminate the problems (and even make society better off in the long run). This leads us to the role of knowledge in growth.

From knowing what to knowing how

The first systematic attempts to conceptualise the relationship between knowledge and development did not come from mainstream economists but from economic historians (who looked at knowledge or technology in a different way). Rather than something that exists in the public domain and can be exploited by anybody everywhere free of charge, technological knowledge, whether created through learning or organised R&D, is in this tradition seen as deeply rooted in the specific capabilities of private firms and their networks or environments, and hence not easily transferable. Compared with the traditional neoclassical growth theory discussed earlier, these writers painted a much bleaker picture of the prospects for catch-up. According to this latter view, catch-up is not something that can be expected to occur only by market forces left to themselves, but something that requires a lot of effort and institution building on the part of the country determined to catch-up.

The stage for much of the subsequent research on the subject was set in the early 1960s (Gerschenkron, 1962).[12] Some countries are at the technological frontier, Gerschenkron pointed out, while others lag behind. Although the technological gap between a frontier country and a laggard represents 'a great promise' for the latter (a potential for high growth through imitating frontier technologies), there are also various problems that may prevent backward countries from reaping the potential benefits to their full extent. His favourite example was the German attempt to catch-up with Britain more than a century ago. When Britain industrialised, technology was relatively labour-intensive and small-scale. But in the course of time technology became much more capital- and scale-intensive, so when Germany entered the scene, the conditions for entry had changed considerably. Because of this, Gerschenkron argued, Germany had to develop new institutional instruments for overcoming these obstacles, above all in the financial sector; 'instruments for which there was little or no counterpart in an established industrial country'. He held these experiences to be valid also for other technologically lagging countries.

Catch-up is not something that can be expected to occur only by market forces left to themselves, but something that requires a lot of effort and institution building.

Arguing along similar lines, Abramovitz also placed emphasis on the potential for catch-up by latecomers. He defined it as follows: 'This is a potential that reflects these countries' greater opportunity to advance by borrowing and adapting the best practice technology and organisation of more productive economies' (Abramovitz, 1994b, p. 87). He suggested that differences in countries' abilities to exploit this potential might to some extent be explained with the help of two concepts: technological congruence and social capability.[13] The first concept refers to the degree to which characteristics of both leader and follower country are congruent in areas such as market size, factor supply, etc. As mentioned above, the technological system that emerged in the US towards the end of the 19th century was highly dependent on access to a large, homogenous market, something that hardly existed in Europe at the time, which may help to explain its slow spread there. The second concept points to the capabilities that developing countries have to develop in order to catch-up, especially the improvement of education (particularly technical) and the business infrastructure (including the financial system). Abramovitz explained the successful catch-up of Western Europe in relation to the US in the first half of the post-World War II (WWII) period as the result of both increasing technological congruence and improved social capabilities. As an example of the former he mentioned how European economic integration led to the creation of larger and more homogenous markets in Europe, facilitating the transfer of scale-intensive technologies initially developed for US conditions. Regarding the latter, he pointed to such factors as the general increases in educational levels and how effective the financial system had become in mobilising resources for change.

A pertinent concept in the applied literature on growth and development in this context is 'absorptive capacity'. It has been defined as 'the ability of a firm to recognise the value of new, external information, assimilate it and apply it to commercial ends' (Cohen and Levinthal, 1990, p. 128). As such, it is largely dependent on the firm's prior related knowledge, which in turn reflects its cumulative technological effort. However, the path-dependent nature of cumulative learning might make it difficult for a firm to acquire new knowledge created outside its own specialised field; it is therefore important for firms to retain a certain degree of diversity in their knowledge base through, among other things, nurturing linkages with holders of knowledge outside their own organisation (Ibid.).[14] As with social capability it is not obvious how to measure it, but the following three factors seem to be fundamental: (1) cumulative (formal and informal) R&D, (2) diversity of the knowledge base and (3) degree of openness and interaction across organisational boundaries. In this context, the concept can be expanded from a systemic perspective (see box 1.2).

Differences in countries' abilities to exploit the potential to catch-up might be explained with the help of two concepts: technological congruence and social capability.

Although the above focus was on firms, many of the same considerations apply at more aggregate levels, such as regions or countries, and the concept has won quite general acceptance. It should be noted, however, that the concept by definition collapses three different processes into one, namely (1) search, (2) assimilation (or absorption) of what is found and (3) its commercial application. Hence, it refers not only to 'absorption' in the received meaning of the term, but also on the ability to exploit and create knowledge more generally, recognising that the ability to assimilate existing knowledge and the ability to create new knowledge have so much in common that the distinction cannot be taken very far. This is particularly the case when the focus, rather than on formal R&D, is on innovative activities in a much broader, Schumpeterian sense, of particular relevance for developing countries.[15]

Current conditions call for developing countries to pay much greater attention to allocating resources to the development of their domestic knowledge systems.

The interplay between in-house or domestic knowledge creation and absorption of external knowledge can take place either across firms (through cooperation or arms-length transactions) or by firms tapping knowledge available in the domestic and international S&T system, either freely or at low access cost. Developing country firms engage in both, but the scope and indeed the need for the second form of interaction appears to have attracted less attention than it warrants. As noted earlier, this need arises from the hardening of conditions for access to proprietary knowledge and the increasingly science-based underpinnings of evolving technologies. Addressing the question of how entrepreneurship development and innovation in developing countries' private sector can best be fostered thus becomes central.

From a policy perspective, the dichotomy between the (public) dimension of codified information, on the one hand, and the (private) dimension of tacit knowledge as firm specific, path-dependent, localised and tacit, on the other, needs particular attention. It has been pointed out that, 'technology needs to be understood as a collection of many different kinds of goods. These goods can have the attributes of pub-

Box 1.2 'Absorptive capacity': new wine with an old label?

The recommendations of the United Nations (UN) Millennium Project (UNMP) and the Commission of Africa, as well as Britain's advocacy at the 2005 Group of Eight (G8) summit for massive increases in aid to Sub-Saharan Africa (SSA) have reinstated an old debate, this time in terms of a conflict between 'absorptive capacity' constraints and the need for 'scaling up' aid to end abject poverty. Concerns about macroeconomic, institutional and managerial constraints are being raised in relation to the effectiveness of aid.

The concept of 'absorptive capacity' used in this Report relates particularly to the ability to draw on external sources of knowledge to create wealth. As such, it can be applied as much at the firm as at more aggregated levels, where systemic features become pivotal. Although this concept is narrower than that normally used, 'absorptive capacity' in this sense is a key enabler of economic development and thus it also matters for aid effectiveness.

Aid effectiveness and its contribution to growth have been extensively studied for the past 40 years. Chenery and Strout (1966) made one of the first studies tying effectiveness to binding constraints such as 'absorptive capacity' (i.e., human capital), savings, and foreign exchange (also Millikan and Rostow, 1957; Rosenstein-Rodan, 1961; Adler, 1965; Guillaumont, 1971). The so-called three-gap approach to foreign transfers and GDP growth has largely focused on capacity constraints in financial and human capital terms. The debate on aid effectiveness entered a new phase with the publication of the *Assessing Aid* report by the World Bank in 1998. The report was based on Burnside and Dollar's analysis of the conditions of aid effectiveness, which found a positive impact of good economic policies on aid performance (1997, 2000).

One of the difficulties in appraising the issue lies in that 'absorptive capacity' is not a fixed factor. The elasticity of macroeconomic 'absorptive capacity' to aid – along with its impact on aid effectiveness – largely depends on how aid is allocated. To put it simply, that elasticity can be expected to raise, at least for some time, when aid is directly addressed to breaking the most egregious factors blocking productivity growth (such as lack of irrigation, low soil fertility, shortage of feeder roads and low nutrition) than when it is directed toward more generic aims. Nevertheless, 'absorptive capacity', in the sense used in this Report, needs to be addressed sooner rather than later in order to avoid even very well focused aid efforts falling into rapidly decreasing returns after not long.

For this reason, 'absorptive capacity' matters from the perspective of the financing gap through its influence on economic development. Many of the policies directed to raising it in the narrow sense directly relate to the sustainability of long term financing for development. Cumulative capabilities in the domestic knowledge systems and the interaction between agents in this system enable the private sector to take up a more substantive role in development strategy, and thus increase the effectiveness of overseas aid.

Sources: ODI (2005); Guillaumont and Chauvet (1999).

lic goods and private goods in varying proportions' (Nelson and Romer, 1996, p. 14).

The policy implications of this insight are momentous. As has been pointed out, current conditions call for developing countries to pay much greater attention to allocating resources to the development of their domestic knowledge systems. This implies growing demands on the management of the collective-action dimensions of technological knowledge, which will be the focus of the Second Part of this Special Topic section, starting in Chapter 6.[16]

Conclusions

Because local knowledge and competences largely determine how effectively inflows of technological knowledge can be mastered, catch-up consists of much more than the mere imitation of more advanced countries' industrial technologies, policies and institutions. A review of modern history shows that sustained economic growth and catching-up have been underpinned by countries' ability to produce and disseminate S&T knowledge. In addition, the economic environment of the 21st century has shifted in ways that demand even more far-reaching institutional innovations to catch-up than those of the past.

The above realization has taken long to come to fruition owing largely to the lack of a graded view of the multi-faceted processes through which knowledge is created, imitated, and transferred. In fact, the evidence strongly suggests that successful countries differ considerably in their political and legal arrangements. Beyond the working of market forces, catch-up requires substantial domestic capability-building efforts. Current conditions call for developing countries to pay much greater attention to the allocation of resources to the development of their domestic knowledge systems.

Notes

This chapter draws on background papers by Fagerberg and Srholec (2005) and Mowery (2005). However, the views expressed here are of UNIDO and do not necessarily reflect those of the authors.

1 For example, Mancur Olson argues that the Republic of Korea's case 'certainly supports the long-familiar assumption that the world's productive knowledge is, for the most part, available to poor countries, and even at a relatively modest cost' (Olson, 1996, p.8), without considering the particular institutional innovations and capability-building in the Republic of Korea that has allowed such technology transfer. The key distinction seems to be between a broad concept of 'knowledge' that has significant tacit elements as it can take many forms and may be created through research or learning but also acquired through education or training or simply by observing and trying to imitate – and 'codified knowledge' which refers to packages of knowledge that have been (or can be) converted into symbols for easy transmission, replication, and storage (Boisot, 1995 and Saviotti, 1998) (see box 1.1).

2 This oversight has been remedied to some extent in recent work. Word Bank (2002a) is one example but, unfortunately, it devotes little attention to the role of institutions in technological innovation and adoption outside of agriculture.

3 For a pioneering and critical orthodox approach to the concept and measurement of knowledge production please refer to Machlup (1962).

4 On collective learning, see Lundvall (1988).

5 In the second part of this Special Topic, we refer to the knowledge institutions as a 'subsystem' once we start looking at its interactions with other subsystems within an innovation system (IS).

6 See, for instance, Easterly (2003).

7 One exception is World Bank (1999). On the other hand, the extensive literature on 'national innovation systems' has focused primarily on innovation and economic performance in the industrial economies (Edquist, 2004).

8 Easterly and Levine (2001) provide a good overview of the more recent evidence on the subject.

9 However, successful catch-up may feed back to the political and legal system, as for instance the evidence from the Republic of Korea and Taiwan Province of China shows.

10 For instance, Glaeser et al. (2004) question the interpretation of the settler argument, suggesting that what the settlers brought with them was not so much their institutions as their human capital.

11 Alesina et al. (2003), for instance, conclude on this basis that, 'in the end one has to use theory and priors to interpret our correlations' (p. 183).

12 However, Thorstein Veblen (1915) is usually credited with initiating the approach. See Fagerberg and Godinho (2004) for details.

13 The term 'social capability' comes from Ohkawa and Rosovsky (1973).

14 In a similar vein, Nelson and Phelps (1966) present a model of economic growth where the rate of absorption of external technological knowledge depends on the level of human capital in the economy. Contrast this position with the one discussed earlier according to which all countries would have access to the same body of technological knowledge.

15 Zahra and George (2002), in a review of the literature, argue that the skills required for creating and managing knowledge differ from those related to its exploitation and that the two therefore deserve to be treated and measured separately. They term the latter 'transformative capacity'.

16 Even firm-specific routines have important attributes of 'publicness' (Nelson and Sampat, 2001).

CHAPTER 2

Critical factors for catching-up: assessing the evidence

Knowledge and capabilities are increasingly critical to catching-up, a trend that is further accentuated by advances in ICTs – that is the view we have been examining. Can this be tested empirically? Using factor analysis, we seek to discern broad dynamic trends for a cross-section of countries and identify vectors of underlining factors that affect growth.

As we have seen, the idea that social capabilities lie at the heart of economic development processes is not new. The pioneering work by Irma Adelman and Cynthia Morris during the 1960s, later continued by Jonathan Temple and Paul Johnson (1998), used factor analysis to identify and measure a wide set of economic, social and political indicators for a large group of developing countries. These authors show that the variation in the data could be reduced to four common factors, one of which was deemed especially significant. This factor, an amalgam of structural variables (share of agriculture, urbanisation, etc.), socio-economic characteristics (role of the middle class, social mobility, literacy, etc.) and the development of mass communications (measured through the spread of newspapers and radios in the population), is what Temple and Johnson use to gauge 'social capability'.[1]

Potential factors critical to catching-up and their indicators can be discerned within the conceptual framework laid out in the first chapter.[2] These variables – technological capabilities, institutions, geography – broadly align with various theories of growth and convergence presented in the economic literature.

The knowledge dimension

Technological capability can be largely captured by variables gauging the public and private activities aimed at absorbing, disseminating and creating technological knowledge. On the input side, R&D expenditures measure some – but by no means all – of the resources allocated to developing new products or processes. On the output side, the number of patents is one measure of inventive activity; while articles published in scientific and technical journals reflect the quality of a country's science base (on which, to some extent, innovation and invention depend).[3]

A well-developed ICT infrastructure is widely acknowledged as a critical factor for the ability to benefit from new technology. Three indicators of ICT dissemination in the economy are widely available: the numbers of personal computers, Internet users and fixed/mobile phone subscribers.

Another important aspect of the knowledge infrastructure is quality standards, for which the ISO 9000 certification seems to be a reasonably good and broadly available indicator. In fact, together with the more traditional measures of technological effort such as R&D expenditure and patents, ISO 9000 certifications provide quite a robust indicator of capabilities (see, however, Chapter 7 for some clarifications).

In addition, five indicators reflect different aspects of human capital. First, there are broad measures of human capital such as the *number of years in school*, the *teacher-pupil ratio in primary education* and *life expectancy at birth*. The teacher-pupil ratio is included to reflect the qualitative dimension of education, while life expectancy is a measure of the time horizon for individual investments in education. In addition, higher education as reflected in the *share of population that completed higher education* and the *rate of enrolment in tertiary education*, is also factored in.[4]

Other variables

Studies on absorptive capacity have noted that interaction across borders may serve as an important channel of technology transfer and spillovers from abroad. This issue is also very much emphasised in work inspired by the 'new growth theories' (see, for instance, Grossman and Helpman, 1991; Coe and Helpman, 1995). Four channels of technology transfer across country borders have been examined in the literature: migration, licensing, trade, and foreign direct investment (FDI) (for an overview see Cincera and van Pottelsberghe de la Potterie, 2001). However, due to lack of data only merchandise imports and stock of inward FDI, normalised by GDP, are used.

The crucial role of a country's financial system for mobilising resources for catching-up has been emphasised repeatedly. This aspect can be partially captured by the amount of credit to the private sector and by capitalisation of companies listed in domestic capital markets. These quantitative measures are complemented by the interest rate spread (lending rate minus deposit rate), which is included as a measure of the efficiency of the financial system.[5]

The importance of institutions, governance, and policies in giving economic agents incentives for creation and diffusion of knowledge is generally acknowledged. Although such factors often defy 'hard' measurement, especially in a cross-country comparison, some survey-based measures are considered here.[6] These include aspects such as human rights; functioning of the legal system; protection of property rights; extent of corruption and regulatory burden. These indicators taken from surveys are largely based on perceptions of the quality of institutions both in the broader sense of 'quality of governance' and in the narrower one of 'rules of the game'.[7] Variables relating to the checks and balances in the political system, such as indexes of political competitiveness, political rights and political constraints, were also factored in.[8]

History and geography

Finally, differences in geography, natural endowments and history have a discernible impact on development prospects. Although they are often difficult to change, increasing knowledge (for instance, learning to cope with diseases) may influence the scope of their social and economic effects. This also holds, to a large extent, for social characteristics that are the result of historical processes in the distant past, such as the roles of language, religion, or ethnic groupings. Because they are fixed factors, these serve as control variables.

The five main factors

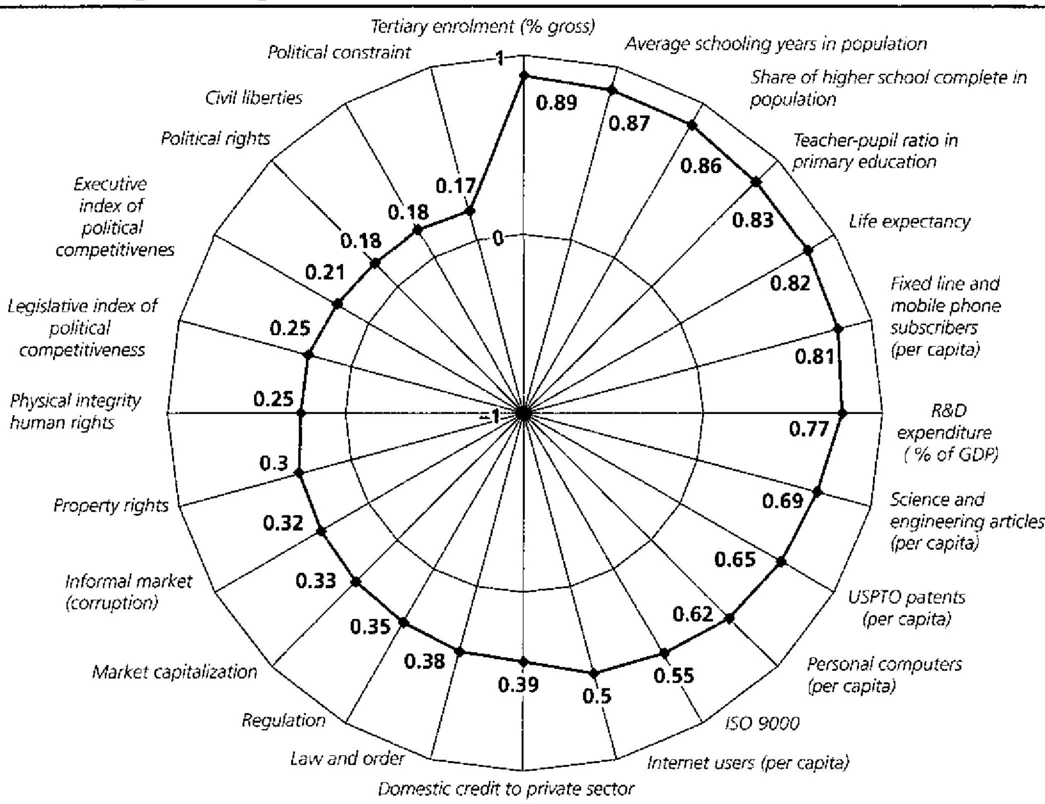
Altogether 29 indicators, along the several capability dimensions just reviewed, are taken into account (in addition to the fixed factors). This is a lot of information to learn from. It goes without saying that it would not be meaningful to take all these variables on board in, say, a regression analysis on economic growth, since many of them reflect slightly different aspects of the same reality and tend to be highly correlated. One of the key challenges in addressing the broad factors accounting for catching-up is how to combine this information into a smaller number of dimensions with a clear-cut economic interpretation.

Fortunately there is a well-developed branch of multivariate analysis, called 'factor analysis' (or principal components analysis), that is designed to detect underlying structures in large amounts of data.[9] It is based on the very simple idea that variables referring to the same dimension are likely to be correlated, so the complexity of a data set can be reduced to a small number of uncorrelated composite variables, each reflecting a specific dimension of the dataset's total variance.[10]

When factor analysis is carried out on these 29 variables, five principal factors (or vectors) result, which jointly explain 76.7 per cent of the total variance:

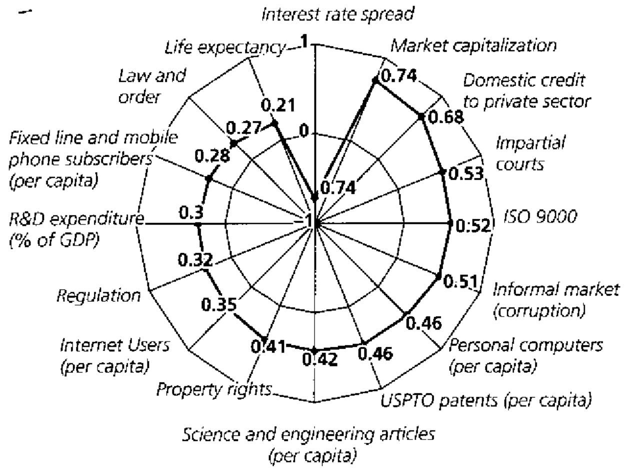
- The first factor correlates highly with the creation, use, and transmission of knowledge – R&D and innovation, scientific

Figure 2.1 Factor loadings: knowledge



Source: UNIDO calculations, see annex 2.1 for data sources.

Figure 2.2 Factor loadings: financial system



Source: UNIDO calculations, see annex 2.1 for data sources.

publications, ICT infrastructure, ISO 9000 certifications and education. Hence it is labelled **knowledge.**

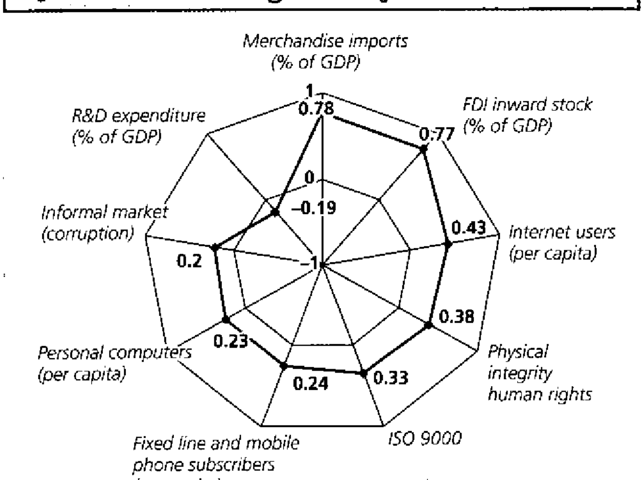
- The second factor is labelled **inward openness,** as it shows high correlation with imports and inward FDI.
- The third factor is labelled **financial system,** as it relates largely to the overall aspects of market capitalisation, country risk and access to credit.
- The remaining two factors, **governance** and the **political system,** are also mirrored in the results, but they are not entirely unrelated, as was to be expected.

The knowledge composite factor has significant correlation with 24 of the 29 variables (figure 2.1). Education, technological effort and infrastructure variables are most highly correlated with the knowledge factor. Other capabilities, particularly those related with the quality of institutions, also relate to this factor.[11]

The interpretation of the remaining factors becomes slightly broader when one considers all the significant loadings into each vector. For example, the inward openness factor is partly associated with aspects related to spread of telecommunications technology and adherence to international quality standards (ISO 9000) in addition to inward FDI stock and merchandise imports. For sure, these variables count as aspects of 'openness', albeit in a broader sense than if each variable is only allowed to factor into one composite.

The same goes partly for the financial system, which also takes on board aspects related to S&T, adherence to international quality standards and the working of the legal system (impartial courts and extent of corruption). Governance and political structure factors are inevitably closely linked to one another and also seem to relate to variables related to human capital, infrastructure and the investment environment. Hence, using significant loadings creates partly overlapping but not necessarily less meaningful factor definitions. For the sake of simplicity, the focus below will be on cases where each variable is allowed to factor into only one vector.

Figure 2.3 Factor loadings: inward openness

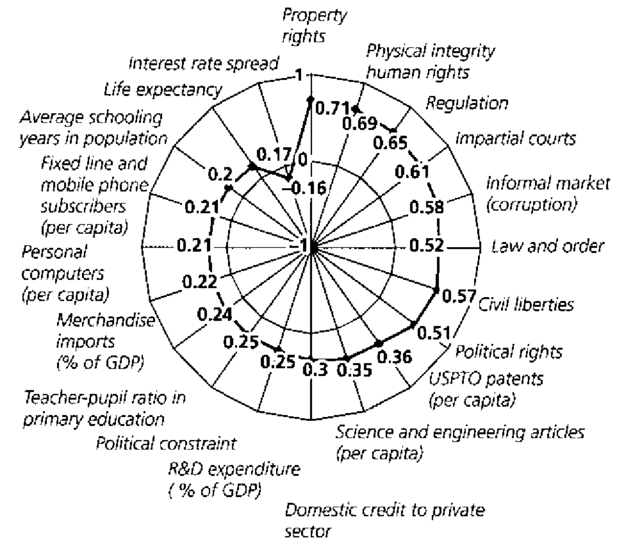


Source: UNIDO calculations, see annex 2.1 for data sources.

Capabilities and income levels

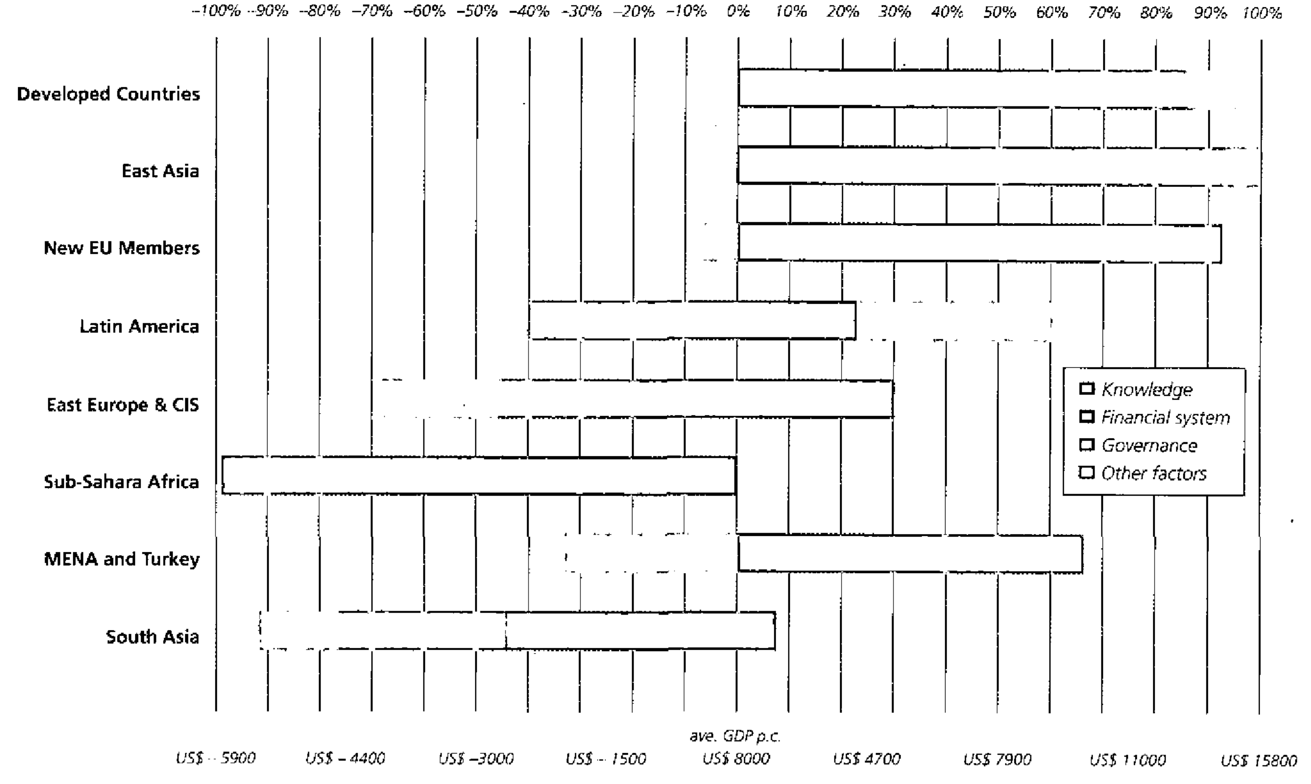
Having retained the key factors widely believed to be linked to the level of development and growth, the relationship between capabilities and current income levels can be tested by using multivariate analysis.[12] The regression analysis, though useful to summarise the descriptive evidence and test the sensitivity of changing some of the underlying assumptions, is *not* a test of causality. Arguably, the level of development may influence capability formation. That said, the results give substantial support to the idea that social capabilities – including knowledge, governance and financial structure – are positively and significantly associated with development level. This finding is invariant to changes in factor definitions, estimation techniques and inclusion of additional variables such as geography and history.

Figure 2.4 Factor loadings: governance



Source: UNIDO calculations, see annex 2.1 for data sources.

Figure 2.5 Deviation from average GDP per capita explained by factors (in % value and US$, 2000-2002)



Source: UNIDO calculations, see annex 2.1 for data sources.

How do these various factors contribute to each region's level of development, relative to the world average? As expected, the stock of knowledge seems to be a major source of difference in income levels across regions in 2002[13] (figure 2.5). In particular, the industrialised countries; the successful industrialising countries (Hong Kong SAR, Taiwan Province of China, Republic of Korea and Singapore) and the new members of the European Union (EU) seem to benefit significantly from their high levels of knowledge stock relative to other contributing factors. For instance, the level of the knowledge stock in the industrialised countries would account for about half of the total difference between their GDP per capita and the overall sample average (a difference that, in dollar value amounts to approximately US$7 900 per capita). Similarly, the level of knowledge would be a key ingredient behind the ability of the new EU members to raise their levels of income to the current level. On the other hand, SSA and South Asia suffer sharply from the lack of knowledge systems and weak governing capabilities. Most strikingly, almost 60 per cent of the differences in income level between SSA countries and the industrialised countries can be attributed to the difference in the stock of knowledge.

Regression analysis results give substantial support to the idea that social capabilities - including knowledge, governance and financial structure - are positively and significantly associated with development level.

For other developing regions, most visibly Latin America, Eastern Europe and the Commonwealth of Independent States (CIS), deficits in complementary social capabilities such as the financial system and governance hinder their ability to take full advantage of their relative good position in terms of stock of knowledge, making them fall behind in the level of development. In other words, the poor performance in these countries stem from a failure to develop a sufficient amount of complementary assets (financial system, governance) to exploit the potential given by their existing knowledge resources. In Eastern Europe and CIS more than 40 per cent of the difference in income can be attributed to the shortfalls in finance and governance.

Capabilities and economic growth

What matters most for long-term growth: the initial level or the change in capabilities? According to the knowledge-based approach, development implies an increase of the knowledge stock along several complementary dimensions.

Hence, levels of economic development and levels of knowledge development can be expected to bear a close correlation.[14]

Considering both the initial and final periods in the data, the correlation between knowledge stock and level of income stands around 75 per cent – which suggests that the initial level of income is a good proxy for the stock of knowledge (see figures 2.6 and 2.7). The main sources of deviation come from a group of small natural-resource rich countries (such as the United Arab Emirates, Oman and Botswana), all of which have higher levels of income than follow from their levels of knowledge, and from a group of former Soviet countries for which it is the other way around.

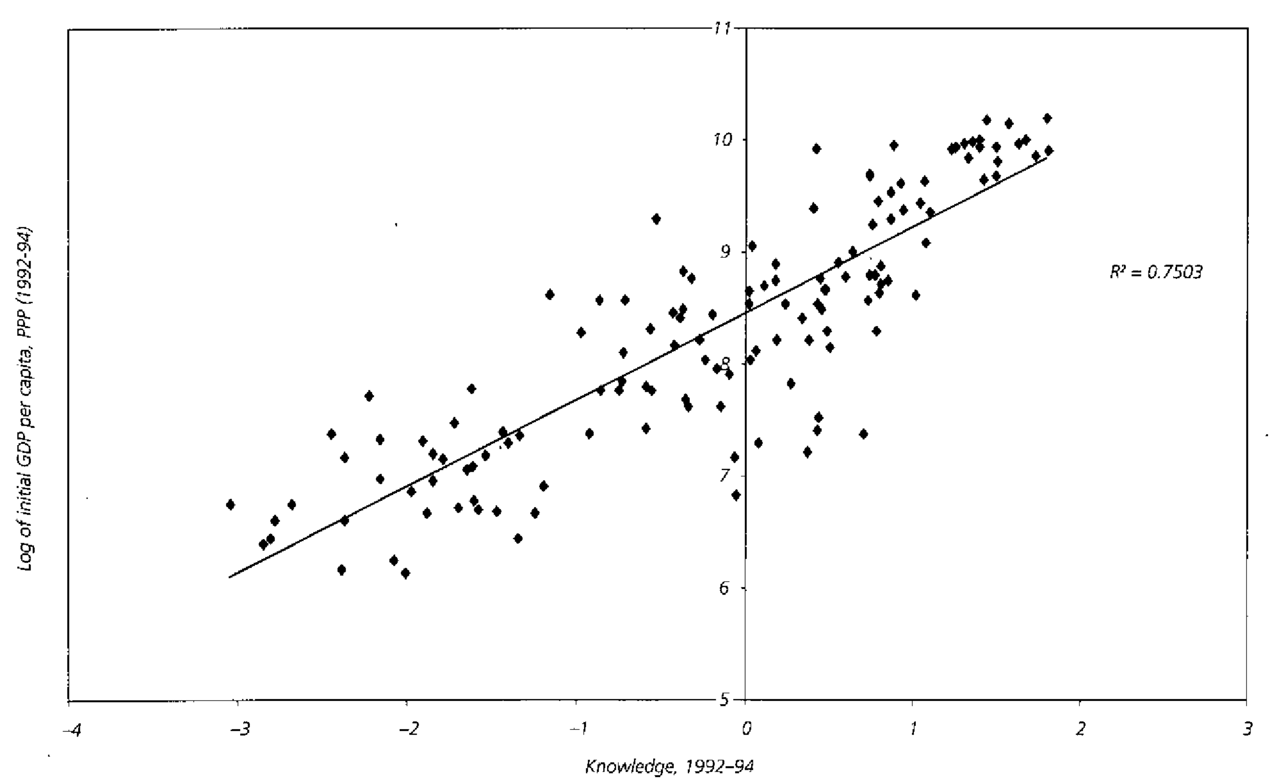
On the other hand, if the proposition that the less developed countries have a greater scope for higher growth is correct, economic growth should be positively correlated with a growing level of knowledge, but not necessarily with its initial level. In fact, since the latter may be seen as measuring the potential for catching-up in knowledge (just as GDP per capita), the correlation with economic growth may well be negative.[15]

The expectation that the correlation between initial income (or knowledge) and subsequent growth will be negative has previously been confirmed by many studies and also turns out to be the case here – albeit conditionally. Because of a larger scope for imitation, low-income countries should be expected to grow more than two percentage points faster than the rich ones, assuming that other factors are the same. Although the potential for catch-up is there, it requires a great effort by poorer economies to tap into it since the other conditions are not the same. In reality, the developing countries' higher potential for imitation is more than offset by the better financial system, better governance and faster growth of knowledge in the rich countries, so that in the end the difference in GDP per capita between rich and poor countries widens instead of narrowing.

Accumulation of knowledge coupled with increases in other capabilities, particularly in governance and finance, stand out as the most critical factors in taking advantage of the catching-up potential

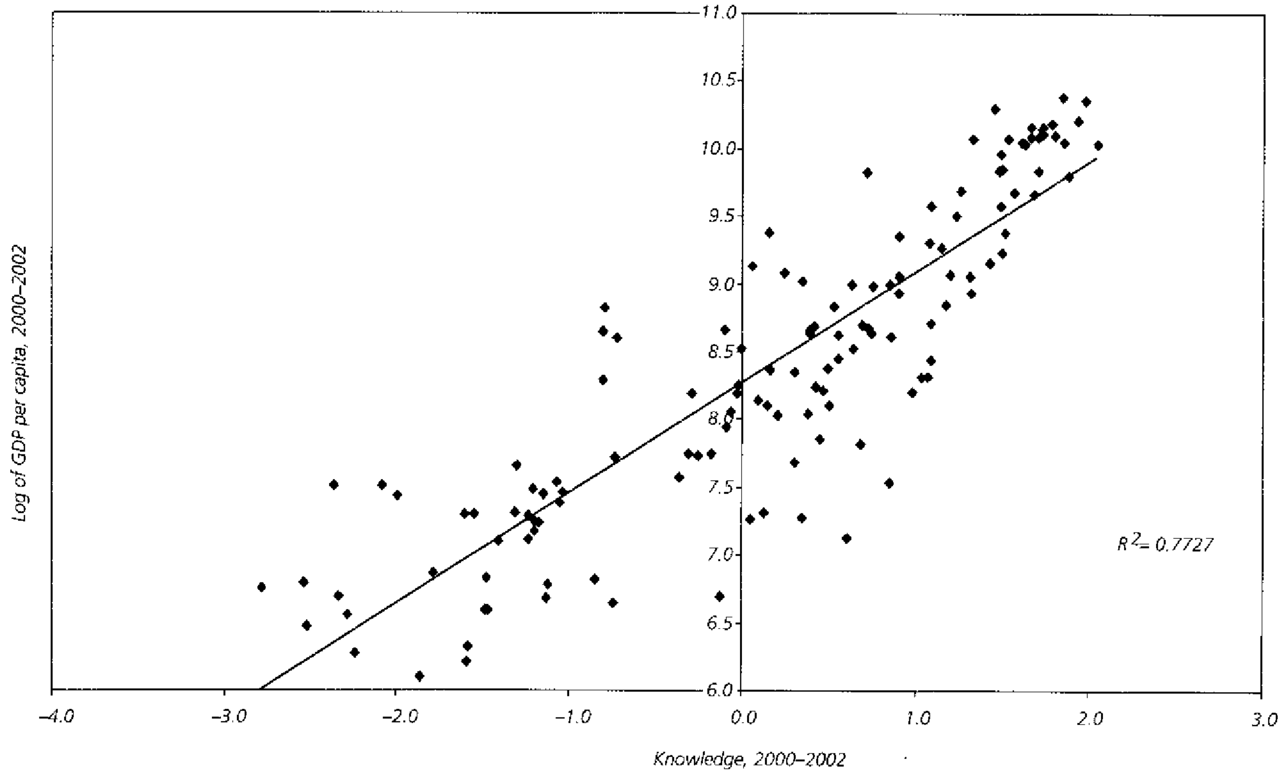
Accumulation of knowledge coupled with increases in other capabilities, particularly in governance and finance, stand out as the most critical factors in taking advantage of the catching-up potential (figures 2.8 and 2.9).[16] Furthermore, the model seems to capture quite accurately the qualitative features of growth across regions, and the estimated

Figure 2.6 **Initial level of GDP per capita, PPP vs. initial stock of knowledge (1992–1994)**



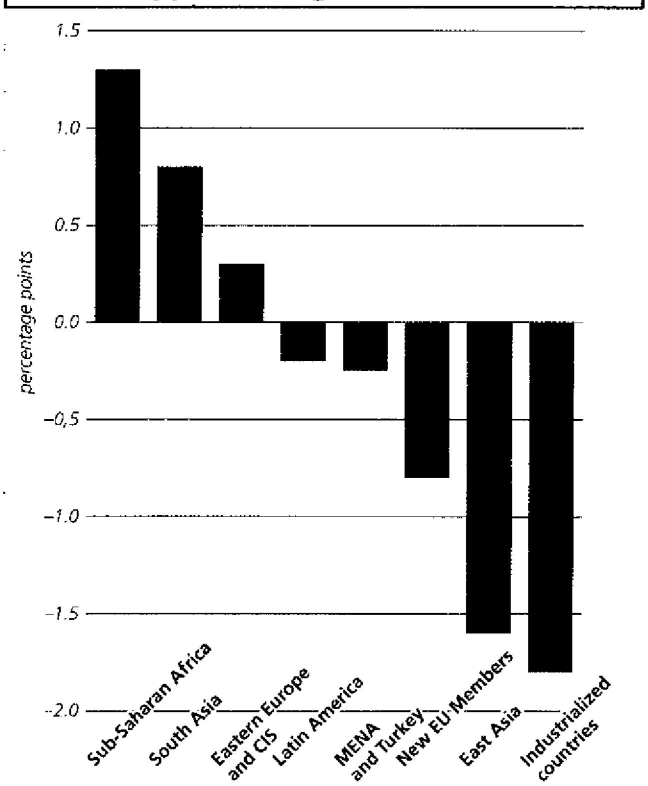
Source: UNIDO calculations, see annex 2.1 for data sources.

Figure 2.7 Knowledge and GDP per capita (2000–2002)



Source: UNIDO calculations, see annex 2.1 for data sources.

Figure 2.8 Contribution of initial GDP per capita to catching-up potential in regions (1992–2002)



Source: UNIDO calculations, see annex 2.1 for data sources.

growth rates are sufficiently close to the observed values (see table 2.1).

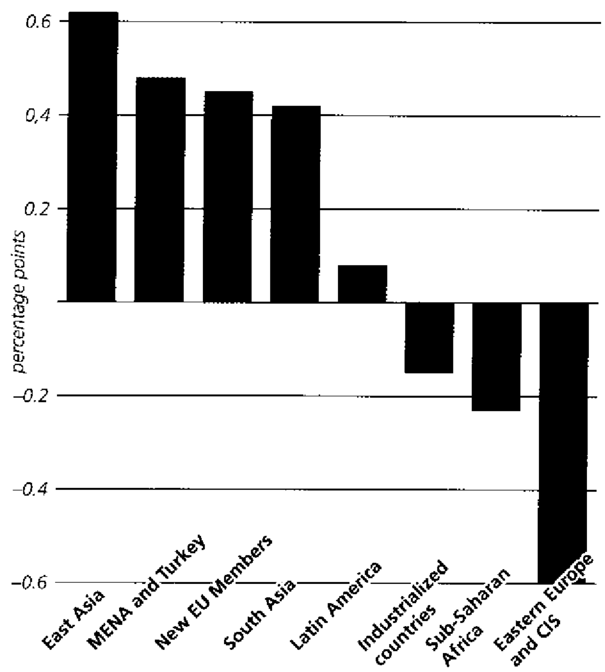
In the period 1992–2002 many countries, particularly in Asia, experienced rapid knowledge growth, as reflected in their GDP per capita growth rates (figure 2.10). When compared with other factors, growth in the knowledge base accounts for the largest portion of East Asian economies' GDP per capita growth. The former members of the Soviet bloc and the countries of SSA, both of which fell behind in knowledge and hence lagged in growth terms, record the least favourable performance. This said, as the knowledge factor is a composite of many variables, including different aspects such as R&D expenditure, education and technological infrastructure, and the results are aggregated by regions, the

Table 2.1 Estimated versus actual rate of growth: how much is explained by the model?

	Estimated growth	*Actual growth*
Industrialized countries	2.3	2.2
East Asia	3.3	3.3
New EU members	2.6	3.6
Eastern Europe & CIS	0.1	0.3
MENA and Turkey	1.6	1.1
LAC	0.8	0.8
South Asia	2.6	3.0
SSA	0.5	0.5

Source: UNIDO calculations, see Annex 2.1 for data sources.

Figure 2.9 **Contribution of change in knowledge to GDP per capita growth in regions (1992–2002)**



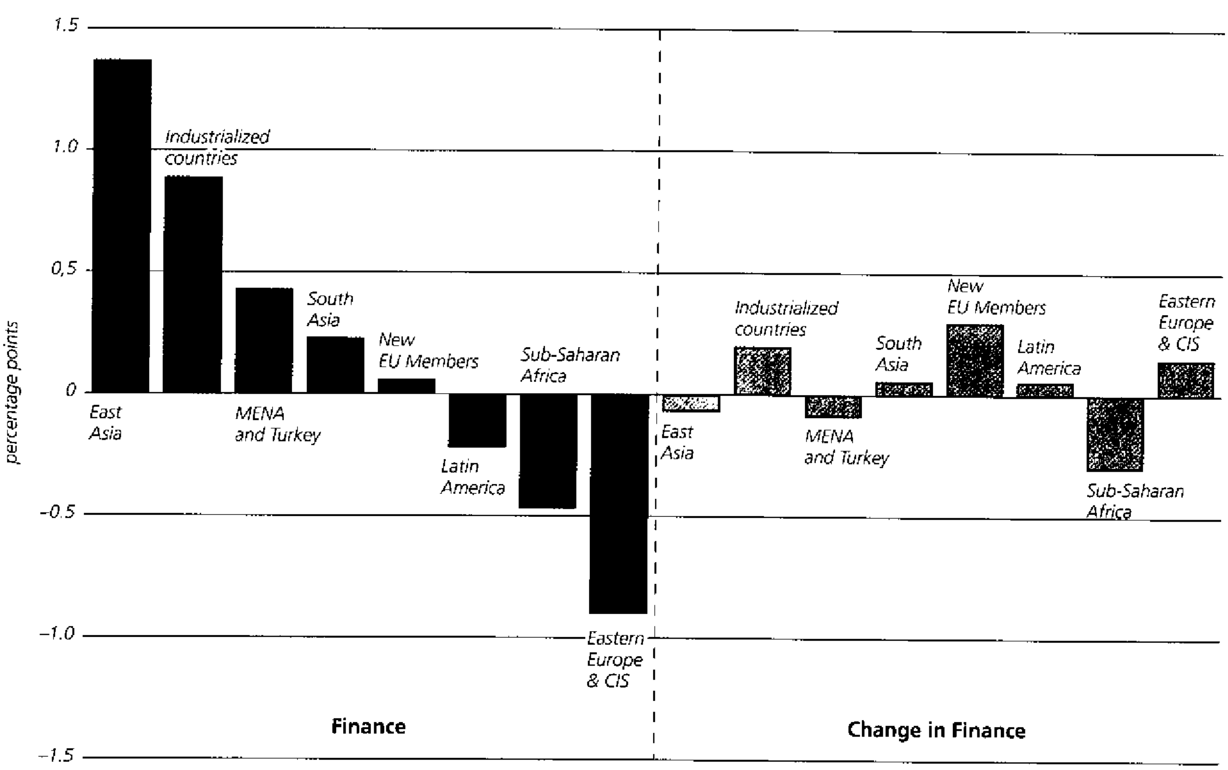
Source: UNIDO calculations, see annex 2.1 for data sources.

emphasis here should be placed on broad dynamics rather than particular estimates.

As highlighted above, the ability to tap into the catching-up potential also depends on other conditioning factors that contribute to an enabling environment. Particularly important in this regard are governing capacity and a well functioning financial system supporting a high level of learning activity in firms. Once again, a regional comparison of these factors highlights the relatively disadvantaged position of Latin America, SSA, and Eastern Europe and the CIS. In particular, the finance factor, which takes into account micro policies relating to access to finance and a measure for country risk, emerges as an important indicator of absorptive capacity and hence impact on growth (figure 2.10). Political institutions seem not to be a statistically significant factor, although this conclusion is somewhat affected by outliers in the sample with frequent occurrence of military conflicts or high proportion of gaps in hard data.[17] Similarly, changes in inward openness between 1992–2002 do not seem to impact significantly on the growth performance of regions in this period. This might be largely due to the fact that, other than in East Europe (including both the new EU members and the rest of Eastern Europe and CIS), there is relatively little change in this factor, which is composed of merchandise imports and inward FDI.

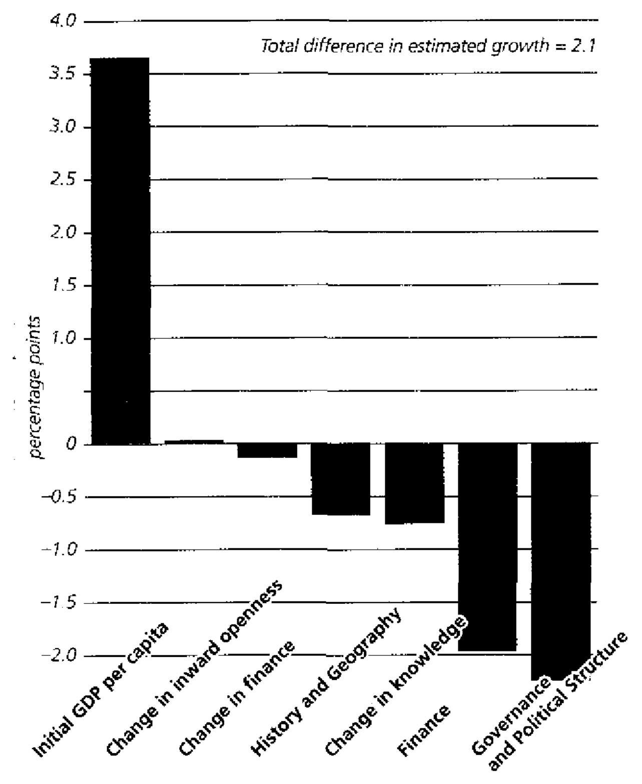
Although the initial gap in income indicates a greater potential for the least developed countries (LDCs) to catch-up, this is more than offset by the other factors taken into

Figure 2.10 **Contribution of finance and change in finance to GDP per capita growth (1992–2002)**



Source: UNIDO calculations, see annex 2.1 for data sources.

Figure 2.11 **Difference in potential growth explained by factors, LDCs vs. East Asia (1992–2002)**



Source: UNIDO calculations, see annex 2.1 for data sources.

account by the model, resulting in a full difference of 2.1 percentage points between them and the successful industrialising countries of East Asia. Three factors stand out here: the financial system, governance and the knowledge gap. These three factors, which can be considered a good proxy for overall social capabilities, account for approximately 80 per cent of the negative difference between the two regions (figure 2.11).

Summary and conclusions

This chapter has sought to improve the understanding of the critical factors affecting catching-up potential as a precondition for effective policy design in developing countries. Although the analysis is constrained by data availability, in due course both the quality and the coverage of relevant indicators will increase and provide new opportunities to assess the critical capabilities more precisely. The analysis shows that there is a particularly strong, significant, and robust statistical relationship between economic performance and rates of change of the knowledge level. Historical and descriptive evidence suggests that successful catching-up countries have given a high priority to the knowledge dimension of development. However, the global knowledge-based economy is a moving target. Past achievements do not suffice to stay high in the development hierarchy. A country wishing to retain its competitive position and, a fortiori, to catch-up, needs to invest continuously in the generation of knowledge capabilities. Although knowledge is a clear priority for development, it is not sufficient. Well-developed knowledge capabilities need to be supported by an enabling environment such as a well-working financial system and good governance. Hence, one of the challenges in development is to be able to coordinate these different aspects of development in an efficient way.

Annex 2.1:

Sources and methodology

Data for the analysis in this chapter was originally collected for all independent states (approximately 175 countries) and a large pool of indicators (approximately 100 indicators). The screening revealed that a group of (mostly least developed) countries suffers from a lot of missing data. Similarly data for a large number of relevant indicators are available only for a group of high and medium income countries or only for the most recent period (from the second half of the 1990s). A closer look, furthermore, revealed that some indicators suffer from high volatility (primarily in the developing world), methodological changes over the period or are merely variations of each other. These indicators were then skipped.

In order to strike a balance between the need to bring rich evidence for as many countries as possible and data availability and methodological coherence, 135 countries and 29 indicators on social capabilities (plus ten 'fixed factors') were selected. The indicators were used in the form of three-year averages (1992–1994 and 2000–2002) to limit influence of shocks and measurement errors occurring in specific years. To ensure comparability over time and across countries, all indicators were measured in real units (quantity), deflated (if applicable) with population or GDP and on an increasing scale – from low score (weak) to high score (strong). Where necessary, scales of the indicators were reversed to have all of them in an increasing order, e.g. teacher-pupil ratio instead of the opposite.

A brief overview of definitions, sources and time/country coverage of the indicators is given in table 2A.1 below. The main source of data is the World Bank (World Development Indicators 2004), which combines various sources of data for a large sample of countries. The database has been complemented by data from other organisations such as the United Nations Conference on Trade and Development (UNCTAD) (FDI Database), the Organisation for Economic Co-operation and Development (OECD) (Main Science and Technology Indicators (MSTI) and Patent Databases), the International Organisation for Standardisation (ISO), the Heritage Foundation, the Frazer Institute. National sources were only used for Taiwan Province of China and in a few cases for R&D data when necessary.

However, in spite of this short timeframe, there were some missing observations for certain indicators/countries, especially for the initial period. In general, a fully complete data set was available for one third of the countries only; another third was in the 90–99 per cent range, while the remaining had between 70–90 per cent of the data needed.[18] A few missing observations among the fixed factors (geography, etc.) have been filled in from other sources or estimated on the basis of regional averages. Full coverage of the indicators for social capabilities, however, is available for only one third of the countries and six indicators. In these cases, the impute procedure in Stata 8.2. was used to fill in the missing values (see the Stata 8.2. Manual for details). In each case the estimation was based on data for other indicators in the data set.

In many cases only a few observations had to be estimated. But in some cases larger amounts of data had to be estimated to keep the country or indicator in the analysis. The proportion of countries estimated for each indicator is given in the last column of the following table. Missing values were most frequent for stocks of human capital, market capitalisation of listed companies and some of the governance indicators. R&D expenditures were not available for most of the low-income countries. We assumed that a country with zero patents jointly with zero scientific articles has also zero R&D expenditures, which was the case for approximately 40 of the LDCs. The remaining missing R&D figures were estimated using the procedure described above.

Countries with a lot of missing data (between 15 and 30 per cent) include Turkmenistan, Uzbekistan, Lebanon, Kazakhstan, Saudi Arabia, Hong Kong SAR, China, Tajikistan, Azerbaijan, Macedonia, Burkina Faso, Georgia, Armenia, Cambodia, Kyrgyzstan, Laos, Mauritania, United Arab Emirates, Belarus, Ethiopia, and Viet Nam (these countries are marked with stars in table 2A.3). It should be stressed that considerable care was taken to check the estimated data against observed figures in countries with similar characteristics (level of development, region, history, etc.). In some cases the estimated data would exceed the maximum observed value of an indicator elsewhere. In such cases the data was truncated by replacing the estimated values by the maximum observed figure.

Finally, some indicators deserved special care due to their nature or methodology. It is customary, for instance, to suppress the 'home country advantage' of the US in the United States Patent and Trademark Office (USPTO) patent counts indicator, since the propensity of US residents to register inventions in their own national patent office is higher than that of non-residents. This home-base bias was adjusted downwards based on a comparison between the Japanese and the US patents registered at the European Patent Office (EPO), which represents a foreign institution for both US and Japanese inventors. The estimation method proposed by Archibugi and Coco (2004, p. 633) is:

$$\textit{Adjusted US patents at the USPTO} = (JAP_{USA} * USA_{EPO})/JAP_{EPO}$$

where JAP_{USA} represents patents granted to Japanese residents in the US, while USA_{EPO} and JAP_{EPO} capture patents granted to Japanese and American residents at the EPO.

The scale for some of the governance indicators was reversed in order to have the indicator in increasing order (with low value signalling weak governance and vice versa). Note that this change of scale does not alter any property of the data but simplifies the interpretation of loadings in the factor analysis.

Table 2A.1 **Indicators and definitions**

Indicator & definition	*Scaling*	*Source*	*Coverage over 1992–2002*	*% of countries estimated*
Gross domestic expenditure on R&D (GERD): GERD is total (public and private) intramural expenditure on research and experimental development (R&D) performed on the national territory. R&D comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge and the use of this stock of knowledge to devise new applications.	% of GDP	World Bank (World Development Indicators), OECD (MSTI Database), Red Ibero-americana de Indicadores de Ciencia y Tecnologia (RICYT) and national sources	Full	14
USPTO patents: Number of patents granted by the US Patent and Trademark Office (USPTO). A patent is assigned to a country according to the inventor's country of residence. When a patent was invented by several inventors from different countries, the respective contributions of each country are taken into account.	per capita	OECD Patent Database (based on the USPTO)	Full	..
Science & engineering articles: Scientific and technical journal articles refer to the number of scientific and engineering articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences. The articles are from a set of journals classified and covered by the Institute for Scientific Information's Science Citation and Social Sciences Citation Indexes. Article counts are based on fractional assignments, so as the patent counts.	per capita	World Bank (World Development Indicators) and the U.S. National Science Foundation (based on Institute for Scientific Information – Science Citation Index and Social Sciences Citation Index)	Full	1
Personal computers: Personal computers are self-contained computers designed to be used by a single individual.	per capita	World Bank (World Development Indicators; based on the ITU – World Telecommunication Indicators Database)	Full	9
Internet users: Internet users are people with access to the worldwide network.	per capita	World Bank (World Development Indicators; based on the ITU – World Telecommunication Indicators Database)	Full	1
Fixed line and mobile phone subscribers: Fixed lines are telephone mainlines connecting a customer's equipment to the public switched telephone network (PSTN). Mobile phone subscribers refer to users of portable telephones subscribing to an automatic public mobile telephone service using cellular technology that provides access to the PSTN. Subscription refers to the recurring fixed charge for subscribing to the PSTN.	per capita	World Bank (World Development Indicators; based on the International Telecommunication Union (ITU – World Telecommunication Indicators Database)	Full	..
ISO 9000 certifications: ISO 9000 is a family of standards approved by the International Standards Organisation (ISO) that define a quality management and quality assurance program. The ISO 9000 certification confirms that the enterprise follows procedures for ensuring quality defined by a collection of formal international standards, technical specifications and handbooks.	per capita	International Organisation for Standardisation (ISO)	Full	..
Tertiary school enrolment: Gross enrolment is the ratio of the number of tertiary students of all ages (gross) expressed as a percentage of the tertiary school-age population. Tertiary education, whether or not to an advanced research qualification, normally requires, as a minimum condition of admission, the successful completion of education at the secondary level.	% gross	World Bank (World Development Indicators), UNESCO and USAID (Global Education Database)	Full	1
Teacher-pupil ratio in primary education: Primary school pupil-teacher ratio is the number of primary school teachers (regardless of their teaching assignment) divided by the number of pupils enrolled in primary school.	ratio	World Bank (World Development Indicators), UNESCO and USAID (Global Education Database)	Full	5
Life expectancy at birth: Life expectancy at birth indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life.	years	World Bank (World Development Indicators)	Full	1
Average schooling years in population: The variable is constructed using each country's typical duration of years of schooling at each level, which is combined into a aggregate measure.	years	Barro and Lee (2000)	1990 and 2000	33
Higher school complete in population: Percentage of population who have successfully completed tertiary level of schooling. Each cycle of education has significant variation in duration across countries. The variable accounts of this variation by using information on the typical duration of tertiary level of schooling within countries.	%	Barro and Lee (2000)	1990 and 2000	33

Table 2A.1 Indicators and definitions (continued)

Indicator & definition	Scaling	Source	Coverage over 1992–2002	% of countries estimated
Merchandise imports: Merchandise imports show the c.i.f. value of goods received from the rest of the world. Goods simply being transported through a country (good in transit) or temporarily admitted (except for goods for inward processing) are not included in the international merchandise trade statistics.	% of GDP	World Bank (World Development Indicators)	Full	..
FDI inward stock: Foreign direct investment (FDI) is defined as an investment involving a long-term relationship and reflecting a lasting interest in and control by a resident entity in one economy (parent enterprise) of an enterprise resident in a different economy (affiliate enterprise). FDI stock is the value of the share of capital and reserves (including retained profits) in the affiliate enterprise attributable to the parent enterprise, plus the net indebtedness of affiliates to the parent enterprises. Inward direction denotes a non-resident direct investment in the reporting economy.	% of GDP	UNCTAD (FDI Database)	Full	..
Interest rate spread: Interest rate spread is the interest rate charged by banks on loans to prime customers minus the interest rate paid by commercial or similar banks for demand, time, or savings deposits.	%	World Bank (World Development Indicators)	Full	17
Market capitalisation of listed companies: Market capitalisation (also known as market value) is the share price times the number of shares outstanding. Listed domestic companies are the domestically incorporated companies listed on the country's stock exchanges at the end of the year.	% of GDP	World Bank (World Development Indicators)	Full	29
Domestic credit to private sector: Domestic credit to private sector refers to financial resources provided to the private sector, such as through loans, purchases of nonequity securities, and trade credits and other accounts receivable, that establish a claim for repayment. For some countries these claims include credit to public enterprises.	% of GDP	World Bank (World Development Indicators)	Full	2
Physical integrity human rights: The variable is an average score on a group of four rights known as the 'physical integrity rights': rights to freedom from extrajudicial killing, disappearance, torture, and political imprisonment. Extrajudicial killings are killings by government officials without due process of law. Disappearances are cases in which people have disappeared, political motivation appears likely, and the victims have not been found. Torture refers to the purposeful inflicting of extreme pain, whether mental or physical, by government officials or by private individuals at the instigation of government officials. Political imprisonment refers to the incarceration of people (including placing them under 'house arrest') by government officials due to political reasons.	index (0 to 2)	Cingranelli and Richards (2004); based on the Amnesty International and the US State Department Country Reports on Human Rights Practices	Full	1
Impartial courts: The variable refers to whether a trusted legal framework exists for private businesses to challenge the legality of government actions or regulation.	index (0 to 10)	Gwartney and Lawson (2004) – the Frazer Institute (based on the WEF Global Competitiveness Report; missing data filled from Kaufmann et. al 2003)	1995 and 2000–2002	20
Law and order: Rule of law and order is the degree to which the citizens of a country are willing to accept the established institutions, to make and implement laws and adjudicate disputes. High score indicates sound political institutions, a strong court system, and provision for an orderly succession of power. Low score reflects tradition of depending on physical force or illegal means to settle claims.	index (0 to 10)	Gwartney and Lawson (2004) – the Frazer Institute (based on Political Risk Component of the International Country Risk Guide (ICRG) by the PRS Group)	1995 and 2000–2002	23
Property rights: The factor scores the degree to which a country's laws protect private property rights and the degree to which its government enforces those laws. It also accounts for the possibility that private property will be expropriated. The scale of the indicator has been reversed into increasing order, while keeping its original range.	index (1 to 5)	Heritage Foundation – Index of Economic Freedom (based primarily on the Economist Intelligence Unit, Country Commerce and Country Reports)	From 1995 onwards	17
Regulation: The factor measures how easy or difficult it is to open and operate a business. The scale of the indicator has been reversed into increasing order, while keeping its original range.	index (1 to 5)	Heritage Foundation – Index of Economic Freedom (based primarily on the Economist Intelligence Unit, Country Commerce and Country Reports)	From 1995 onwards	17

Table 2A.1 Indicators and definitions (continued)

Indicator & definition	*Scaling*	*Source*	*Coverage over 1992–2002*	*% of countries estimated*
Corruption and informal market: The factor relies on Transparency International's Corruption Perceptions Index (CPI), which measures the perceptions of well-informed people with regard to the extent of corruption, defined as the misuse of public power for private benefit. The extent of corruption reflects the frequency of corrupt payments, the value of bribes paid and the resulting obstacle imposed on businesses. For countries that are not covered in the CPI, the informal market score is estimated using information on the extent of smuggling, piracy of intellectual property, informal labour, etc. The scale of the indicator has been reversed into increasing order, while keeping its original range.	index (1 to 5)	Heritage Foundation – Index of Economic Freedom (based primarily on the Transparency International, Corruption Perceptions Index)	From 1995 onwards	17
Index of democracy and autocracy: Institutionalised autocracies sharply restrict or suppress competitive political participation. Their chief executives are chosen in a regularised process of selection within the political elite, and once in office they exercise power with few institutional constraints. Institutionalised democracy is defined as one in which political participation is fully, competitive, executive recruitment is elective, and constraints on the chief executive are substantial. The variables ranges from autocracy to democracy in increasing order (Revised Combined Polity Score – POLITY2 variable)	index (–10 to 10)	Marshall and Jaggers (2002) – Polity IV Dataset	Full	1
Political constraint: The variable estimates the extent to which a change in the preferences of any one actor may lead to a change in government policy. It identifies the number of independent branches of government (executive, lower and upper legislative chambers) with veto power over policy change. The measure is then modified to take into account the extent of alignment across branches of government and to capture the extent of preference heterogeneity within each legislative branch (POLCONIII variable)	index (0 to 1)	Henisz (2002)	up to 2001	..
Legislative index of political competitiveness (LIEC): The variable reflects competitiveness of elections into legislative branches. Knowing the formal, constitutional rules governing countries is one way to characterise democracy; an important supplement is to know whether these rules are applied in practice. The indices of Electoral Competitiveness (LIEC & EIEC) address both of these issues. The highest score of the LIEC index goes to countries elections in which multiple parties compete in elections and the largest party receives less than 75 per cent of the vote. The lowest score goes to countries without legislature or with an unelected one. The score is supplemented by information on voting irregularities, whether candidate intimidation was serious enough to affect electoral outcomes, whether important parties boycott elections or the election results, etc.	index (1 to 7)	Beck, et. al (2001) – Database of Political Institutions (DPI)	up to 2000	1
Executive index of political competitiveness (EIEC): The variable reflects competitiveness for posts in executive branches of government. Besides the common features with the LIEC (see above), the EIEC takes into account a balance of power between legislature & executive, eg. the method of the electoral college appointing, whether the military has significant influence, whether the political system is presidential or parliamentary, etc.	index (1 to 7)	Beck, et. al (2001) – Database of Political Institutions (DPI)	up to 2000	1
Political rights: Freedom is the opportunity to act spontaneously in a variety of fields outside the control of the government and other centres of potential domination. Political rights enable people to participate freely in the political process, including through the right to vote, compete for public office, and elect representatives who have a decisive impact on and public policies are accountable to the electorate. Political rights can be affected by state actions, as well as by non-state actors, including terrorists and other armed groups. The standards are derived primarily from the Universal Declaration of Human Rights. The scale of the indicator has been reversed into increasing order, while keeping its original range.	index (1 to 7)	Freedom House – Index of Freedom in the World	Full	1

Table 2A.1 Indicators and definitions *(continued)*

Indicator & definition	*Scaling*	*Source*	*Coverage over 1992–2002*	*% of countries estimated*
Civil liberties: Civil liberties allow for the freedoms of expression and belief, associational and organisational rights, rule of law, and personal autonomy without interference from the state. Civil liberties can be affected by state actions, as well as by non-state actors, including terrorists and other armed groups. The standards are derived primarily from the Universal Declaration of Human Rights. The scale of the indicator has been reversed into increasing order, while keeping its original range.	index (1 to 7)	Freedom House – Index of Freedom in the World	Full	1
Longitude of country centroid: Longitude is measured from the Prime Meridian with positive values going east and negative values going west.	degrees	Gallup, Sachs and Mellinger (1999) – CID Geography Datasets (missing data filled from Easterly and Sewadeh 2002)	Fixed factors	..
Latitude of country centroid: Latitude is measured from the equator, with positive values going north and negative values going south.	degrees	Gallup, Sachs and Mellinger (1999) – CID Geography Datasets (missing data filled from Easterly and Sewadeh 2002)	Fixed factors	..
Log of land area: Country's total area, excluding area under inland water bodies, national claims to continental shelf, and exclusive economic zones. In most cases the definition of inland water bodies includes major rivers and lakes.	log of km²	World Bank (World Development Indicators)	Fixed factors	..
Log of mean elevation (above sea level)	log of meters	Gallup, Sachs and Mellinger (1999) – CID Geography Datasets	Fixed factors	3
Access to ocean-navigable river: The proportion of the population in 1994 within 100 km. of the ocean or ocean-navigable river, excluding coastline above the winter extent of sea ice and the rivers that flow to this coastline.	%	Gallup, Sachs and Mellinger (1999) – CID Geography Datasets	Fixed factors	3
Malaria ecology: Ecologically-based spatial index of the stability of malaria transmission based on the interaction of climate with the dominant properties of anapheline vectors of malaria that determine vectorial capacity.	index (0 to 100)	Kiszewksi, et. al (2004)	Fixed factors	1
Cultural fractionalisation: Fractionalisation measures the probability that two randomly selected people from a given country will not belong to the same cultural group. The variable combines measures of ethnic and language fractionalisation into a single indicator of cultural fractionalisation. The ethic diversity is complemented by distance in languages tree diagrams between the ethic groups. If ethic groups in a country speak structurally unrelated languages, the cultural fractionalisation will be the same as the ethic fractionalisation. The more similar are the languages, the more will the cultural measure be reduced below the ethic fractualisation index.	index (0 to 1)	Fearon (2003)	Fixed factors	1
Religious fractionalisation: Fractionalisation measures the probability that two randomly selected people from a given country will not belong to the same religious group.	index (0 to 1)	Fearon and Laitin (2003), missing data filled from Alesina, et al. (2003)	Fixed factors	..
Log of oil & gas deposits per capita: Oil & gas (hydrocarbon) deposits are the log of total BTUs (Basic Transmission Unit – a unit of energy equal to the work done by a power of 1000 watts operating for one hour) per person of proven crude oil and natural gas reserves in 1993.	logs	Gallup, Sachs and Mellinger (1999) – CID Geography Datasets (missing data filled from the CIA Fact Book)	Fixed factors	3

Methodology

Factor analysis

Factor analysis is used to reduce a complex set of variables into a small number of (principal) factors that account for a high proportion of variance. First a matrix of correlations is computed. Then a vector explaining as much variance in the matrix as possible is identified and extracted from the data. The procedure is repeated as long as the last factor identified explains more of the total variance than an original variable (more than the inverse value of the number of variables). In analytic terminology this means that eigenvalue of each extracted factor should be higher than unity. This simple rule ensures that we will end up with fewer principal factors than the original number of variables. Note that the eigenvalues are the variance of the new factors that are successively extracted. The sum of eigenvalues is equal to the original number of variables. The result of this iterative process is a set of new (latent) variables that are linear combinations of the underlying indicators.

The problem, of course, is how to interpret the retained factors. In doing so it is helpful to look at the correlations with the original set of variables (the so-called 'factor loadings'). These 'factor loadings' show the proportion of the total variance of an original variable that is accounted for by the new composite factor, e.g., a loading 0.60 of a variable indicates that 36 per cent of its variance is explained by the composite factor.

The first factor identified typically explains by far the largest proportion of the variance, with most of the variables highly loaded in it. However, such a general factor – with many high loadings – is difficult to interpret. Furthermore, it is an artefact of the method that the general factor is followed by a series of bipolar factors with mixed positive and negative loadings, the interpretation of which are even more difficult.

Therefore, in a second step of the factor analysis, the solution is rotated to maximise differences in loadings of the original variables across the extracted factors. A number of computational methods have been developed for factor analysis and rotation. Although results were computed with more sophisticated extraction methods and rotations (such as maximum likelihood factor analysis and (bi)quartimax rotation) since the solutions are broadly the same, the analysis provided in Chapter 2 was based on principal component analysis and normalised varimax rotation. After the rotation, only a limited number of variables load high on each factor, which simplifies the interpretation. Although the rotation changes factor loadings (meaning of the factors) and distribution of the accounted variance across the factors, it does not change the amount of total variance explained by the solution. This second step also provides us with the weights used to calculate the composite indicators (the 'factor score coefficients').

The composite indicators that follow from weighing together the original variables with the 'factor score coefficients' (so-called 'factor scores') are uncorrelated with each other, which is of course a highly desirable property in regression analysis. However, since each factor score is a linear combination of all the original variables (although only a few of them may have high weights), doubts may be expressed about the interpretation. To reduce such interpretation problems one possibility might be to only take into account those original variables that load highly when constructing a particular indicator (and disregard the other, less important variables).

For instance, one might choose to include only those original variables, for which the factor loadings are shown to be significantly different from zero at, say, a one per cent level of significance. In a sample of 270 observations, an absolute value of the correlation coefficient above 0.15 is significantly different from zero at one per cent level, which is the threshold used in the following. Alternatively one might allow each original variable to be included in only one of the composite indicators, which would of course be preferable from an interpretation point of view. However, one less desirable consequence of this may be that the property of uncorrelatedness may no longer apply.

In addition to these there are two data issues that need to be highlighted:

First, the indicators have to be standardised (deducting mean and dividing by standard deviation) before aggregating them into a composite. The indicators were standardised with the mean and standard deviation of the pooled data (from the initial and final period). This means that the change of a composite indicator over time will reflect both changes in each country's relative position (across countries) and changes in the absolute level of the underlying variables (over time).

Second, variables should be relatively evenly distributed, e.g., variables with a 'two sample split' (for example very high values for the developed countries and close to zero for the poorer ones) should be avoided. For the very same reason outliers need to be dealt with. Simply excluding outliers from the sample may not be the best solution, as important observations may be lost. A log-transformation of the data set was used to significantly reduce these problems. Some variables containing zeroes or negative scale had to be rescaled to positive values. To achieve this transformation the minimum observed value in the sample was added to all of the observations.

Table 2A.2 presents the factor loadings after rotation and the corresponding factor score coefficients that result from a factor analysis on pooled data for the initial and final period for the 135 countries (270 observations). Entries in bold represent significant correlation coefficients (absolute value above 0.15). The boxed areas show the variables associated with the various factors when only one link is allowed between a variable and a factor.

Table 2A.2 **Results of factors analysis**

Number of observations = 270 (factor analysis of 135 countries on pooled data for the initial and final period)	*Factor loadings*					*Factor score coefficients*				
	Knowl-edge	*Inward Openness*	*Financial system*	*Govern-ance*	*Political structure*	*Knowl-edge*	*Inward Openness*	*Financial system*	*Govern-ance*	*Political structure*
Research and development expenditure (% of GDP)	**0.77**	**−0.19**	**0.30**	**0.25**	0.14	**0.13**	**−0.16**	**0.00**	**−0.01**	−0.03
USPTO patents (per capita)	**0.65**	−0.01	**0.46**	**0.36**	**0.28**	**0.05**	−0.07	**0.08**	**0.01**	**0.00**
Science & engineering articles (per capita)	**0.69**	−0.06	**0.42**	**0.35**	0.15	**0.08**	−0.09	**0.06**	**0.02**	−0.04
Personal computers (per capita)	**0.62**	**0.23**	**0.46**	**0.21**	**0.39**	**0.04**	**0.07**	**0.10**	**−0.07**	**0.03**
Internet users (per capita)	**0.50**	**0.43**	**0.35**	−0.01	**0.47**	**0.04**	**0.20**	**0.09**	−0.16	**0.06**
Fixed line and mobile phone subscribers (per capita)	**0.81**	**0.24**	**0.28**	**0.21**	**0.30**	**0.13**	**0.09**	**−0.03**	**−0.05**	**−0.01**
ISO 9000 certifications (per capita)	**0.55**	**0.33**	**0.52**	0.14	**0.37**	**0.02**	**0.14**	**0.16**	−0.11	**0.02**
Tertiary school enrolment (% gross)	**0.89**	0.01	0.14	0.15	**0.26**	**0.19**	−0.04	−0.10	−0.05	**−0.01**
Teacher-pupil ratio in primary education	**0.83**	0.06	0.12	**0.24**	0.01	**0.19**	0.00	−0.11	**0.01**	−0.08
Life expectancy at birth	**0.82**	0.03	**0.21**	**0.17**	0.15	**0.16**	−0.02	**−0.05**	**−0.04**	−0.04
Average schooling years in population	**0.87**	0.11	0.09	**0.20**	**0.20**	**0.19**	0.03	−0.13	**−0.01**	**−0.03**
Share of higher school complete in population	**0.86**	0.00	0.05	0.12	**0.24**	**0.20**	−0.04	−0.14	−0.04	**−0.01**
Merchandise imports (% of GDP)	0.04	**0.78**	−0.06	**0.22**	−0.11	0.00	**0.46**	−0.11	**0.09**	−0.09
FDI inward stock (% of GDP)	−0.02	**0.77**	0.15	−0.02	0.25	−0.06	**0.43**	0.06	−0.08	0.02
Interest rate spread (lending rate minus deposit rate)	−0.09	0.05	**−0.72**	**−0.16**	−0.06	0.11	0.07	**−0.37**	**0.08**	0.02
Market capitalization of listed companies (% of GDP)	**0.33**	0.13	**0.74**	0.14	0.10	**−0.05**	0.03	**0.33**	−0.12	−0.04
Domestic credit to private sector (% of GDP)	**0.39**	0.06	**0.68**	**0.30**	**0.25**	**−0.05**	−0.02	**0.25**	**−0.04**	**0.00**
Physical integrity human rights	**0.25**	**0.38**	−0.07	**0.69**	0.12	**0.00**	**0.19**	−0.24	**0.31**	−0.04
Impartial courts	0.14	−0.01	**0.53**	**0.61**	0.03	−0.10	−0.05	**0.16**	**0.18**	−0.04
Law and order	**0.38**	0.06	**0.27**	**0.52**	0.00	**0.01**	0.00	**−0.01**	**0.16**	−0.06
Property rights	**0.30**	0.01	**0.41**	**0.71**	**0.22**	**−0.06**	−0.06	**0.03**	**0.23**	**0.00**
Regulation	**0.35**	0.01	**0.32**	**0.65**	0.11	**−0.02**	−0.05	**−0.01**	**0.22**	−0.03
Informal Market (corruption)	**0.32**	**0.20**	**0.51**	**0.58**	0.10	**−0.06**	**0.07**	**0.11**	**0.14**	−0.05
Index of democracy and autocracy	0.15	0.04	0.08	0.10	**0.90**	−0.05	−0.04	−0.03	−0.02	**0.24**
Political constraint	**0.17**	−0.06	0.10	**0.25**	**0.76**	**−0.05**	−0.10	−0.04	**0.06**	**0.20**
Legislative index of political competitiveness	**0.25**	0.08	0.12	−0.15	**0.79**	**0.00**	−0.01	0.03	−0.16	**0.21**
Executive index of political competitiveness	**0.21**	0.15	0.13	−0.07	**0.85**	**−0.03**	0.03	0.02	−0.12	**0.22**
Political rights	**0.18**	−0.01	0.06	**0.51**	**0.78**	**−0.07**	−0.08	−0.12	**0.19**	**0.19**
Civil liberties	**0.18**	0.06	0.08	**0.57**	**0.72**	**−0.08**	−0.04	−0.12	**0.22**	**0.17**
Explained % of total variance	26.8	6.6	12.9	13.2	17.2	..	..	..	..	..

Note: Extraction method: principal components; rotation: varimax normalized; the highest loadings for each factor are encapsulated within a frame; significant loadings (at 1% level) are in bold.

Table 2A.3 **Composites of social capabilities**

Countries	*Knowledge* 1992–1994	*Knowledge* 2000–2002	*Inward Openness* 1992–1994	*Inward Openness* 2000–2002	*Financial system* 1992–1994	*Financial system* 2000–2002	*Governance* 1992–1994	*Governance* 2000–2002	*Political structure* 1992–1994	*Political structure* 2000–2002
Developed Countries										
Australia	1.8	1.7	–0.3	–0.1	0.7	0.8	1.4	1.5	1.1	1.1
Austria	1.4	1.7	–0.2	0.4	0.8	0.9	1.3	1.3	1.1	1.1
Belgium	1.5	1.8	0.9	1.5	0.4	0.5	1.4	1.2	1.2	1.1
Canada	1.7	1.7	0.0	0.4	0.9	0.9	1.6	1.5	1.1	1.1
Denmark	1.7	1.9	–0.2	0.4	0.6	0.8	1.5	1.6	1.1	1.1
Finland	1.5	1.9	–0.5	0.2	0.9	0.9	1.4	1.5	1.1	1.1
France	1.3	1.5	–0.4	0.1	0.7	0.8	1.2	1.0	1.0	1.1
Germany	1.3	1.7	–0.5	0.1	0.6	0.8	1.6	1.3	1.0	1.1
Greece	1.1	1.6	–0.3	–0.1	0.0	0.7	0.8	0.5	1.0	1.0
Ireland	1.1	1.5	0.9	1.3	0.1	0.6	1.5	1.6	1.1	1.1
Israel	1.4	1.9	0.0	0.3	0.6	1.1	0.5	0.5	1.0	1.0
Italy	1.3	1.6	–0.8	–0.3	0.0	0.7	1.0	0.9	1.1	1.1
Japan	1.4	1.7	–2.3	–1.7	1.5	1.6	1.4	1.2	1.1	1.1
Netherlands	1.4	1.7	0.5	1.1	0.6	1.4	1.5	1.5	1.2	1.1
New Zealand	1.5	1.7	0.1	0.3	0.9	1.0	1.5	1.6	1.0	1.1
Norway	1.5	1.8	–0.3	–0.2	0.8	1.0	1.6	1.4	1.1	1.1
Portugal	0.8	1.3	0.2	0.5	0.4	1.3	1.1	0.9	1.1	1.1
Spain	1.0	1.5	–0.4	0.2	0.7	1.3	0.9	0.8	1.1	1.1
Sweden	1.8	2.1	–0.3	0.4	1.0	0.9	1.3	1.4	1.1	1.1
Switzerland	1.6	1.8	0.0	0.5	1.5	1.5	1.5	1.4	1.0	1.0
United Kingdom	1.4	1.6	–0.1	0.1	1.3	1.3	1.7	1.5	1.0	1.0
United States of America	1.8	2.0	–1.1	–0.7	2.0	2.2	1.6	1.4	1.1	1.1
East Asian Tigers										
Hong Kong SAR*	0.9	1.3	2.1	2.3	1.4	1.6	1.7	1.7	–0.1	0.3
Republic of Korea	1.0	1.5	–0.6	–0.1	1.6	1.3	0.6	0.7	0.8	0.9
Singapore	0.8	1.5	2.0	2.1	1.1	1.2	1.6	1.6	–0.1	–0.2
Taiwan Province of China	0.9	1.5	–0.1	0.3	0.8	1.1	1.3	1.0	–0.5	0.8
New EU members										
Czech Republic	0.9	1.2	0.3	1.1	0.6	0.8	1.0	0.8	0.3	1.0
Estonia	0.8	1.5	0.2	1.5	–0.5	0.4	1.1	1.1	–0.1	1.0
Hungary	1.1	1.5	0.2	1.2	0.2	0.6	1.2	0.8	0.3	1.1
Latvia	0.8	1.3	–0.1	0.7	–0.8	0.1	0.5	0.5	–0.2	1.0
Lithuania	0.8	1.3	0.0	0.7	–0.4	–0.2	0.7	0.3	–0.1	1.1
Poland	0.9	1.4	–0.6	0.2	0.8	0.2	0.7	0.6	0.1	1.0
Slovakia	0.7	1.1	0.1	1.0	0.5	0.6	1.1	0.3	0.2	1.0
Slovenia	1.1	1.7	0.4	0.6	–0.6	0.4	1.2	1.0	0.3	1.1
Middle East, North Africa and Turkey										
Iran	–0.3	0.4	–0.4	–1.0	0.0	0.0	–1.1	–2.0	–1.3	–0.3
Jordan	0.4	1.0	0.6	0.8	1.1	1.0	0.6	0.4	–1.2	–0.8
Kuwait	0.8	1.1	–0.8	–0.8	1.3	1.0	1.0	1.1	–1.9	–1.1
Lebanon*	0.5	1.1	0.1	0.1	0.4	1.2	–0.1	–0.4	–0.5	–0.2
Oman	–0.5	0.2	0.3	0.0	0.3	0.3	1.1	0.9	–2.7	–2.0
Saudi Arabia*	0.4	0.9	–0.1	–0.4	–0.1	1.3	0.5	0.4	–3.5	–3.2
Syria	–0.1	0.2	0.0	–0.3	0.2	0.3	–0.6	–0.7	–2.0	–1.8
Turkey	0.0	0.6	–0.6	0.0	–0.5	–0.2	–0.3	–0.2	0.6	0.7
United Arab Emirates*	0.4	0.7	0.2	–0.1	0.5	0.1	1.1	1.2	–2.0	–2.2
Algeria	–0.4	0.0	–0.7	–0.5	0.1	0.1	–0.3	–0.4	–1.6	–0.3
Egypt	–0.1	0.5	–1.6	–1.9	0.5	0.9	–0.9	–0.2	–0.6	–0.6
Mauritania*	–1.9	–1.0	0.1	0.5	0.4	–0.7	0.0	–0.3	–2.3	–0.5
Morocco	–0.2	0.1	–1.3	–1.1	0.7	0.6	0.7	0.4	–0.9	–0.8
Tunisia	–0.2	0.4	0.8	0.9	0.1	0.3	0.3	0.4	–1.2	–0.5
Yemen	–1.3	–0.7	0.9	–0.1	–0.2	–0.2	–0.8	–1.1	–1.0	–0.4
Latin America										
Argentina	0.8	1.1	–1.3	–0.8	0.1	–0.1	0.6	0.0	0.9	0.9
Bolivia	–0.1	0.3	–0.1	0.3	–0.4	0.1	–0.1	–0.5	0.8	1.0
Brazil	0.1	0.5	–1.4	–0.7	–0.1	–0.7	0.0	–0.3	0.6	0.7
Colombia	0.0	0.4	–0.7	–0.4	–0.3	–0.1	–1.2	–1.2	0.8	0.7
Costa Rica	0.5	0.8	0.3	0.7	–0.4	–0.1	0.4	0.5	1.0	1.0
Dominican Republic	–0.5	–0.1	0.4	0.7	–0.4	0.0	–0.1	–0.2	0.8	0.9
Ecuador	0.1	0.4	–0.2	0.3	–0.5	–0.2	–0.6	–0.8	0.7	0.9
El Salvador	–0.2	0.2	–0.3	0.4	–1.3	–1.0	0.3	0.4	0.8	0.9
Guatemala	–0.7	–0.3	–0.1	0.1	–0.4	–0.2	–0.4	–0.9	0.1	0.7
Haiti	–1.7	–1.5	–0.6	–0.2	–0.5	–0.3	–3.1	–2.3	–1.5	–0.1
Honduras	–0.8	–0.3	0.2	0.7	–0.2	0.2	–0.2	–0.7	0.8	0.8
Chile	0.6	0.9	0.1	0.4	0.4	0.5	0.9	1.2	0.1	1.1
Jamaica	–0.4	0.1	0.7	0.8	–0.2	0.0	0.2	0.2	0.8	0.7
Mexico	0.2	0.6	–0.5	0.2	0.4	–0.1	–0.1	–0.7	0.5	0.8
Nicaragua	–0.5	–0.3	0.5	0.9	–0.1	0.1	–0.8	–0.7	0.3	0.8
Panama	0.5	0.7	0.4	0.4	0.7	0.9	0.3	0.1	0.3	1.1
Paraguay	–0.4	0.3	–0.2	0.1	–0.2	–0.2	–0.1	–1.1	0.5	0.7
Peru	0.2	0.5	–1.0	–0.5	–1.4	–0.2	–0.9	–0.5	0.4	0.8

Table 2A.3 Composites of social capabilities (continued)

	Knowledge		*Inward Openness*		*Financial system*		*Governance*		*Political structure*	
Countries	*1992–1994*	*2000–2002*	*1992–1994*	*2000–2002*	*1992–1994*	*2000–2002*	*1992–1994*	*2000–2002*	*1992–1994*	*2000–2002*
Trinidad and Tobago	–0.3	0.4	0.4	0.9	0.2	0.2	0.4	0.8	1.0	0.9
Uruguay	0.6	0.9	–0.6	–0.5	–0.8	–0.2	0.6	0.6	0.8	1.1
Venezuela	0.5	0.6	–0.4	–0.4	–0.2	–0.5	–1.0	–1.0	0.8	0.2
East Europe & CIS										
Albania	–0.3	0.0	0.0	0.2	0.1	–0.2	0.0	–0.6	–0.3	0.7
Armenia*	0.5	0.7	–0.9	0.6	–1.0	–0.9	0.1	–0.3	–0.2	0.1
Azerbaijan*	0.3	0.5	–1.1	0.4	–0.7	–0.8	–0.7	–0.9	–1.2	–0.6
Belarus*	0.8	1.1	–1.2	0.7	–1.2	–1.0	–0.1	–1.2	–0.7	–0.6
Bulgaria	1.0	1.1	–0.1	0.7	–0.4	–0.1	–0.1	–0.2	0.1	1.0
Croatia	0.8	1.2	–0.2	0.6	–0.5	0.3	–0.1	–0.1	–0.2	0.7
Georgia*	0.7	0.8	–1.4	–0.1	–1.6	–1.2	–0.8	–1.0	–1.0	0.5
Kazakhstan*	0.5	0.6	–0.7	0.5	–1.0	–0.7	0.1	–0.5	–1.1	–0.9
Kyrgyzstan*	0.1	0.3	–0.9	0.5	–1.1	–1.4	0.1	–0.7	–0.8	–0.5
Macedonia, FYR*	0.5	0.7	–0.6	0.7	–0.7	–0.3	0.3	–0.8	0.1	0.7
Moldova	0.5	0.6	–0.1	1.0	–0.8	–0.3	0.0	–0.3	–0.9	0.7
Romania	0.5	0.9	–0.9	0.4	–0.6	–0.6	–0.3	–0.4	–0.1	1.0
Russia	0.8	1.2	–1.8	–0.4	–1.4	–0.5	0.0	–0.8	–0.5	0.2
Tajikistan*	0.0	–0.1	–0.2	0.8	–1.0	–1.1	–2.2	–1.1	–1.6	–0.5
Turkmenistan*	0.4	0.0	0.1	0.7	–1.3	–0.8	–0.5	–1.0	–1.8	–2.1
Ukraine	0.8	1.0	–0.9	0.4	–1.5	–0.8	–0.5	–0.6	–0.6	0.7
Uzbekistan*	0.4	0.0	–1.0	–0.3	–0.8	–0.9	–0.6	–1.5	–1.6	–1.7
South Asia										
Cambodia*	–2.3	–2.0	–0.4	0.7	–1.4	–0.9	–1.3	–0.4	–0.7	–0.5
China	–0.3	0.4	–0.2	0.1	1.8	1.4	–0.8	–0.7	–2.0	–1.8
Indonesia	–0.7	–0.1	–0.1	0.1	0.4	0.5	–1.1	–1.5	–1.5	0.0
Laos*	–2.1	–1.3	–0.2	0.3	–1.0	–1.0	0.0	–1.8	–1.8	–1.6
Malaysia	0.2	0.9	1.1	1.5	1.1	1.2	0.9	0.5	0.4	0.4
Papua New Guinea*	–1.6	–1.3	0.4	0.8	0.1	0.0	–0.2	–0.5	0.9	1.0
Philippines	0.1	0.5	0.0	0.5	0.3	0.7	–0.6	–1.0	0.4	0.9
Thailand	0.3	0.7	0.2	0.8	1.1	1.1	0.5	0.6	0.5	0.9
Viet Nam*	–1.8	–0.4	0.2	1.0	–0.6	0.5	–1.4	–1.6	–2.0	–1.5
Bangladesh	–1.6	–1.2	–1.4	–0.7	–0.1	0.1	–1.3	–1.7	0.1	0.7
India	–0.6	–0.2	–1.8	–1.1	0.1	1.1	–1.7	–1.1	0.7	0.9
Mongolia	0.0	0.1	0.2	0.9	–0.7	–0.5	0.7	0.1	–0.2	0.7
Nepal	–1.8	–1.2	–0.9	–0.6	1.2	0.5	–0.2	–1.5	0.2	0.7
Pakistan	–0.9	–1.0	–0.6	–0.4	0.1	0.2	–0.4	–1.1	0.1	–0.2
Sri Lanka	–0.6	–0.1	0.2	0.4	–0.1	0.2	–0.4	–0.1	0.5	0.7
Sub-Saharan Africa										
Angola*	–2.2	–2.1	0.5	0.8	–1.7	–1.7	–1.4	–2.0	–1.4	–0.7
Benin	–1.9	–1.5	0.2	0.1	–0.3	–0.5	0.2	–0.1	–0.3	0.6
Botswana	–0.8	–0.8	0.6	0.5	0.2	0.0	0.8	0.8	0.6	0.8
Burkina Faso*	–2.7	–1.8	–1.5	–1.4	–0.5	–0.3	0.0	–0.5	–1.4	–0.3
Cameroon	–1.4	–1.2	–2.1	–1.6	–0.5	–0.8	–0.8	–1.4	–1.4	–0.6
Congo, Dem. Rep*	–2.0	–1.6	–0.6	0.3	–1.5	–2.2	–2.8	–2.3	–1.6	–2.0
Congo, Rep.	–1.4	–1.1	–0.2	0.2	–0.5	–1.1	–1.1	–1.5	–0.6	–0.7
Cote d'Ivoire	–1.4	–1.2	–0.2	0.3	–0.1	–0.5	0.1	–0.9	–1.2	–0.1
Ethiopia*	–2.0	–2.5	–1.1	0.0	0.3	0.4	–0.7	–0.8	–1.6	–0.5
Gabon	–1.1	–0.8	–0.2	–1.6	–0.7	–0.8	0.3	0.2	–1.0	–0.2
Gambia	–2.1	–1.6	1.1	0.8	–0.6	–0.3	0.0	–0.3	0.6	–0.8
Ghana	–1.3	–1.1	0.2	0.8	–0.9	–0.6	0.3	–0.1	–1.8	0.5
Guinea	–2.4	–2.4	–0.6	–0.4	–0.8	–1.2	–0.1	–0.9	–1.9	–0.3
Chad*	–3.0	–2.8	–0.5	0.8	–0.9	–1.2	–1.1	–1.1	–1.8	–1.0
Kenya	–1.2	–0.8	0.0	–0.1	–0.4	–0.1	–0.5	–0.9	–1.0	0.2
Madagascar	–1.2	–1.5	–0.7	–0.4	–0.3	–0.6	–0.4	0.0	0.3	0.8
Malawi	–2.4	–2.2	0.2	0.3	–0.3	–1.0	–0.2	0.1	–1.6	0.5
Mali	–2.8	–2.3	–0.7	0.2	–0.4	–0.5	–0.5	0.0	–0.3	0.7
Mauritius	–0.4	0.1	0.4	0.5	0.5	0.5	0.9	0.7	1.0	0.9
Mozambique	–2.8	–2.5	0.2	0.5	–0.6	–0.3	–0.8	–0.8	–1.2	0.5
Namibia	–0.7	–0.7	0.9	0.8	0.0	0.2	0.8	0.8	0.9	0.8
Niger	–2.8	–2.3	–0.1	–0.1	–0.5	–1.2	–0.9	–0.8	–1.0	0.0
Nigeria	–1.7	–1.1	0.4	0.2	–0.5	–0.3	–0.4	–1.1	–1.7	–0.9
Senegal	–1.6	–1.2	–0.4	0.4	–0.2	–0.4	–1.2	–0.2	0.2	0.7
Sierra Leone	–2.3	–1.9	–1.6	–0.5	–1.3	–1.1	–2.0	–0.5	–1.6	–0.5
South Africa	0.1	0.2	–0.6	0.2	0.7	0.8	0.0	0.2	0.5	1.0
Sudan*	–1.8	–1.1	–1.3	–0.6	–1.2	–1.4	–1.6	–2.2	–1.5	–2.1
Swaziland	–1.0	–0.8	1.4	1.3	0.0	–0.3	0.6	0.4	–2.9	–1.7
Tanzania	–2.0	–1.6	–0.3	–0.2	–0.9	–0.8	–0.1	–0.1	–1.4	0.2
Togo	–1.5	–1.2	–0.1	0.7	–0.1	–0.5	–0.9	–1.2	–1.4	–0.4
Uganda	–1.6	–1.4	–0.9	0.1	–1.2	–0.8	–0.7	0.0	–0.9	–0.4
Zambia	–1.6	–1.5	0.1	0.7	–1.8	–0.9	0.0	–0.1	–0.3	0.3
Zimbabwe	–0.7	–0.7	–0.4	–0.1	0.3	–0.4	0.0	–1.3	–0.1	–0.4

Note: For definition of the variables see Table A.1. Countries with a high level of missing data (between 15% and 30%) and countries influenced by military conflicts are marked by stars.

Regressions for income and growth

Multivariate regression analysis was first carried out to determine the relationship between the five capabilities previously identified and GDP per capita. To test for the sensitivity of changing the definitions of the factors, two different weighting schemes were used; first when only one link is allowed between an indicator and a factor and second, when the broader version based on all significant correlations between indicators and factors was used.

To test for the robustness of the results with respect to the composition of the sample, the relationship with two different estimation techniques (OLS and a robust regression technique, iteratively re-weighted least squares which assigns a weight to each observation, with lower weights given to outliers) were estimated. As is customary in the literature, the table below also reports versions including, in addition to the capabilities mentioned above, a battery of indicators reflecting geography, nature and history.

Finally, since many of the variables included in the analysis were not significant following traditional statistical criteria, a stepwise backward-selection regression was undertaken in which the insignificant variables were gradually eliminated until the 'best model' was found. The aim of the stepwise procedure is to include only variables that contribute to the explanatory power of the model (above a chosen significance level). At each step the stepwise method also attempts to reintroduce already eliminated variables to control for a possibility that some of them might become significant later on. In the analysis reported here the threshold for removal was specified at 20 per cent significance and the level for reintroducing a variable was 15 per cent.

Table 2A.4 presents the results from the regression analysis on income levels. Beta-coefficients are reported; hence the role of a variable in the regression is reflected in the size of the estimated coefficient. Beta-coefficients can be calculated by running regression on variables that have been standardised on the same scale before the estimate (deducting mean and dividing by standard deviation). The only difference between a regression estimate on the original versus the standardised data is magnitude of the coefficients (all other statistics such as significance of factors and R^2 remains the same).

Secondly, a Hausman (or Durbin-Wu-Hausman) test for

Table 2A.4 Regression results – income levels

Construction method of the composite indicators	*One factor per variable*					*Significant loadings*				
Estimation method:	*Simple OLS*	*Iteratively reweighted-least sq.*	*Simple OLS*	*Iteratively reweighted-least sq.*	*Stepwise backward selection*	*Simple OLS*	*Iteratively reweighted-least sq.*	*Simple OLS*	*Iteratively reweighted-least sq.*	*Stepwise backward selection*
Constant	..	0.02	..	0.01	..	..	0.01	..	0.01	..
	..	(0.48)	..	(0.14)	..	..	(0.28)	..	(0.14)	..
Knowledge	0.61[3]	0.64[3]	0.60[3]	0.61[3]	0.57[3]	0.48[3]	0.51[3]	0.47[3]	0.48[3]	0.48[3]
	(12.11)	(13.16)	(8.75)	(8.28)	(11.46)	(11.37)	(11.74)	(9.05)	(7.89)	(11.32)
Inward Openness	–0.03	–0.03	–0.01	–0.02	..	0.01	0.01	0.03	0.02	..
	(0.91)	(0.84)	(0.21)	(0.54)	..	(0.14)	(0.18)	(0.55)	(0.38)	..
Financial system	0.14[3]	0.13[2]	0.13[2]	0.14[2]	0.16[3]	0.39[3]	0.37[3]	0.39[3]	0.39[3]	0.40[3]
	(2.81)	(2.58)	(2.58)	(2.48)	(3.52)	(6.80)	(6.46)	(6.72)	(6.37)	(8.07)
Governance	0.30[3]	0.31[3]	0.28[3]	0.29[3]	0.27[3]	0.21[3]	0.23[3]	0.19[3]	0.20[3]	0.20[3]
	(5.50)	(6.07)	(4.84)	(5.21)	(5.05)	(2.82)	(3.37)	(2.62)	(3.00)	(3.84)
Political structure	–0.03	–0.03	–0.04	–0.03	..	0.002	0.003	–0.01	–0.01	..
	(0.77)	(0.78)	(0.92)	(0.77)	..	(0.04)	(0.08)	(0.10)	(0.16)	..
Longitude of country	..	..	–0.05[1]	–0.04	–0.06[2]	..	..	–0.07[3]	–0.07[1]	–0.08[3]
centroid	..	..	(1.68)	(1.07)	(2.00)	..	..	(2.62)	(1.90)	(3.10)
Latitude of country	..	..	–0.04	–0.03	..	..	..	–0.04	–0.04	–0.05[1]
centroid	..	..	(1.16)	(0.64)	..	..	..	(1.54)	(0.98)	(1.66)
Log of land area	..	..	0.04	0.03	..	..	..	0.02	0.02	..
	..	..	(0.86)	(0.54)	..	..	..	(0.60)	(0.33)	..
Log of mean elevation	..	..	–0.06	–0.06	–0.07[2]	..	..	–0.06	–0.06	–0.07[2]
	..	..	(1.41)	(1.21)	(2.09)	..	..	(1.52)	(1.24)	(2.40)
Access to ocean	..	..	0.05	0.05	..	..	..	0.02	0.02	..
or navigable river	..	..	(0.76)	(0.93)	..	..	..	(0.31)	(0.36)	..
Malaria ecology	..	..	0.02	0.01	..	..	..	0.02	0.01	..
	..	..	(0.45)	(0.20)	..	..	..	(0.44)	(0.23)	..
Cultural	..	..	–0.04	–0.02	..	..	..	–0.04	–0.04	..
fractionalization	..	..	(0.81)	(0.54)	..	..	..	(0.90)	(0.89)	..
Religious	..	..	–0.001	–0.02	..	..	..	–0.02	–0.03	..
fractionalization	..	..	(0.01)	(0.49)	..	..	..	(0.48)	(0.84)	..
Log of oil & gas	..	..	0.08[1]	0.07	0.09[2]	..	..	0.09[2]	0.09[2]	0.08[2]
deposits per capita	..	..	(1.79)	(1.52)	(2.59)	..	..	(2.19)	(2.04)	(2.34)
F	138.92	157.97	60.96	56.21	123.45	152.52	158.01	63.79	62.43	111.64
R^2	0.85	..	0.87	..	0.86	0.86	..	0.88	..	0.88
Observations	135	135	135	135	135	135	135	135	135	135

Note: Depended variable is log of average level of GDP per capita over 2000–2002 (PPP, constant 1995 US$). Absolute value of robust t-statistics in brackets; [1], [2], [3] denote significance at the 10, 5 and 1 percent levels. Standardized variables used in the estimates (beta values reported).

Table 2A.5 Regression results – growth

Construction method of the composite indicators	One factor per variable					Significant loadings				
Estimation method:	*Simple OLS*	*Iteratively reweighted-least sq.*	*Simple OLS*	*Iteratively reweighted-least sq.*	*Stepwise backward selection*	*Simple OLS*	*Iteratively reweighted-least sq.*	*Simple OLS*	*Iteratively reweighted-least sq.*	*Stepwise backward selection*
Constant	..	−0.01	..	0.00	..	..	−0.01	..	−0.02	..
	..	(0.10)	..	(0.08)	..	..	(0.21)	..	(0.26)	..
Log of the initial	−0.47^{2}	−0.40^{2}	−0.43^{2}	−0.41^{2}	−0.57^{3}	−0.55^{3}	−0.46^{3}	−0.53^{2}	−0.51^{3}	0.70^{3}
GDP per capita	(2.45)	(2.37)	(2.00)	(2.22)	(3.84)	(2.76)	(2.85)	(2.37)	(2.80)	(4.60)
Knowledge	0.01	0.00	−0.26	−0.18	..	0.03	0.03	−0.15	−0.06	..
	(0.05)	(0.00)	(1.13)	(0.92)	..	(0.18)	(0.21)	(0.81)	(0.34)	..
Inward Openness	0.00	−0.05	0.03	−0.09	..	0.05	−0.05	0.08	−0.09	..
	(0.00)	(0.70)	(0.29)	(0.95)	..	(0.52)	(0.45)	(0.57)	(0.76)	..
Financial system	0.41^{3}	0.27^{2}	0.33^{1}	0.19	0.37^{3}	0.72^{3}	0.56^{3}	0.64^{3}	0.48^{3}	0.72^{3}
	(2.92)	(2.58)	(2.33)	(1.64)	(2.68)	(3.99)	(4.51)	(3.32)	(3.30)	(4.58)
Governance	0.39^{3}	0.41^{3}	0.47^{3}	0.48^{3}	0.43^{3}	0.10	0.24^{1}	0.18	0.36^{2}	0.28^{2}
	(3.30)	(3.34)	(3.30)	(3.51)	(3.69)	(0.65)	(1.67)	(1.07)	(2.26)	(2.20)
Political structure	0.13	0.14	0.19	0.20^{1}	0.13	0.11	0.09	0.09	0.09	..
	(1.16)	(1.58)	(1.50)	(1.80)	(1.53)	(0.96)	(0.86)	(0.65)	(0.71)	..
Δ knowledge	0.30^{3}	0.29^{3}	0.30^{3}	0.26^{3}	0.30^{3}	0.22^{2}	0.22^{3}	0.21^{2}	0.20^{2}	0.22^{3}
	(3.54)	(4.05)	(3.18)	(3.28)	(4.07)	(2.42)	(2.98)	(2.04)	(2.33)	(2.76)
Δ inward openness	0.10	0.12	0.13	0.13	0.12	0.10	0.13	0.14	0.15	0.14
	(1.18)	(1.48)	(1.41)	(1.36)	(1.47)	(1.11)	(1.56)	(1.42)	(1.52)	(1.60)
Δ financial system	0.25^{3}	0.26^{3}	0.21^{2}	0.22^{2}	0.24^{3}	0.34^{3}	0.37^{3}	0.31^{3}	0.33^{3}	0.34^{3}
	(2.69)	(3.11)	(2.21)	(2.48)	(2.62)	(4.03)	(5.14)	(3.37)	(4.09)	(4.31)
Δ governance	0.02	0.10	0.07	0.11	..	−0.08	0.06	−0.03	0.07	..
	(0.20)	(1.39)	(0.65)	(1.44)	..	(0.62)	(0.68)	(0.23)	(0.79)	..
Δ political structure	0.05	0.12	0.05	0.14^{1}	..	0.15	0.18^{1}	0.11	0.20^{2}	..
	(0.47)	(1.46)	(0.43)	(1.66)	..	(1.22)	(2.04)	(0.88)	(2.02)	..
Longitude of country	..	..	0.11	0.11	0.10	..	..	0.08	0.06	..
centroid	..	..	(1.55)	(1.47)	(1.48)	..	..	(1.09)	(0.81)	..
Latitude of country	..	..	0.10	0.03	..	..	..	0.08	0.00	..
centroid	..	..	(1.25)	(0.34)	..	..	..	(1.01)	(0.02)	..
Log of land area	..	..	0.01	−0.02	..	..	..	0.02	−0.01	..
	..	..	(0.10)	(0.18)	..	..	..	(0.15)	(0.13)	..
Log of mean elevation	..	..	0.10	0.02	..	..	..	0.08	0.01	..
	..	..	(0.93)	(0.24)	..	..	..	(0.82)	(0.09)	..
Access to ocean	..	..	0.04	0.11	..	..	..	0.06	0.12	..
or navigable river	..	..	(0.28)	(0.89)	..	..	..	(0.48)	(1.05)	..
Malaria ecology	..	..	−0.07	−0.09	..	..	..	−0.03	−0.06	..
	..	..	(0.66)	(0.81)	..	..	..	(0.26)	(0.53)	..
Cultural	..	..	−0.17^{1}	−0.07	−0.16^{1}	..	..	−0.17^{1}	−0.06	−0.17^{2}
fractionalization	..	..	(1.73)	(0.80)	(1.92)	..	..	(1.68)	(0.69)	(2.04)
Religious	..	..	0.06	0.04	..	..	..	0.03	0.00	..
fractionalization	..	..	(0.74)	(0.51)	..	..	..	(0.30)	(0.01)	..
Log of oil & gas	..	..	0.12	0.06	0.11	..	..	0.11	0.08	0.11
deposits per capita	..	..	(1.32)	(0.65)	(1.40)	..	..	(1.19)	(0.86)	(1.39)
F	9.11	6.65	4.84	3.95	9.64	9.08	7.80	4.66	4.49	9.61
R^2	0.36	..	0.41	..	0.39	0.36	..	0.40	..	0.38
Observations	135	135	135	135	135	135	135	135	135	135

Note: Depended variable is annual growth of GDP per capita over 1992–2002 (PPP, constant 1995 US$). Absolute value of robust t-statistics in brackets; ^{1}, ^{2}; ^{3} denote significance at the 10, 5 and 1 percent levels. Standardized variables used in the estimates (beta values reported).

endogeneity of the independent variables was carried out on the data to test for a possible endogeneity bias in the estimates, due to a possible feedback from the level of development (the dependent variable) on capabilities. The test is performed by first regressing each potentially endogenous explanatory variable on all exogenous variables, and then including residuals from these regressions in the original model. If some of the residuals come out as significant in the original model estimate, the endogeneity of the variable is accepted and the model is then estimated by, say, two-stages least squares regression in order to obtain consistent results (Wooldridge 2002, pp. 118–122). However, in the present case the test failed to provide evidence of endogeneity.

Table 2A.5 presents the results from the regression analysis on GDP per capita growth between 1992–2002. As before, estimates are reported using two different estimation techniques (OLS and iteratively reweighted least squares), two different ways to define the composite indicators (one factor per variable and significant loadings) and with (and without) a battery of other indicators reflecting exogenous factors related to geography, nature and history. In addition, results for a 'best model' in which insignificant variables were gradually eliminated using a stepwise backward-selection method, is also reported although the log of the initial GDP per capita was always included (to test for 'conditional convergence').

Table 2A.6 Regression results – growth (excluding countries with the most missing data and wars)

Construction method of the composite indicators	*One factor per variable*					
Estimation method:	*Simple OLS*	*Iteratively reweighted-least sq.*	*Simple OLS*	*Iteratively reweighted-least sq.*	*Stepwise backward selection*	*Iteratively reweighted-least sq.*
Constant	0.00	−0.05	0.00	−0.01	0.00	−0.05
	(0.69)	(0.66)	(0.41)	(0.12)	(0.53)	(0.69)
Log of the initial	−0.31	−0.24	−0.15	−0.18	−0.25[1]	−0.12
GDP per capita	(1.18)	(1.32)	(0.54)	(0.91)	(1.91)	(0.98)
Knowledge	0.02	0.08	−0.35	−0.06		
	(0.06)	(0.45)	(1.12)	(0.25)		
Inward Openness	0.04	−0.01	0.14	−0.02	0.13	0.01
	(0.49)	(0.19)	(1.13)	(0.21)	(1.40)	(0.09)
Financial system	0.37[2]	0.17	0.25	0.07	0.20	0.04
	(2.43)	(1.62)	(1.60)	(0.60)	(1.64)	(0.41)
Governance	0.34[3]	0.33[3]	0.38[2]	0.33[2]	0.34[3]	0.32[3]
	(2.72)	(2.75)	(2.63)	(2.39)	(2.92)	(2.65)
Democracy	0.24	0.19	0.34[1]	0.28[2]	0.34[2]	0.32[3]
	(1.30)	(1.66)	(1.71)	(2.11)	(2.29)	(2.94)
Δ knowledge	0.30[3]	0.33[3]	0.33[3]	0.30[3]	0.42[3]	0.36[3]
	(3.48)	(3.83)	(2.93	(3.05)	(3.99)	(4.20)
Δ inward openness	0.06	0.03	0.02	0.04		
	(0.57)	(0.30)	(0.20)	(0.41)		
Δ financial system	0.14[3]	0.12	0.09	0.07		
	(1.31)	(1.26)	(0.77)	(0.66)		
Δ governance	0.10	0.19[2]	0.15	0.20[2]	0.18	0.22[3]
	(0.91)	(2.49)	(1.26)	(2.52)	(1.43)	(3.01)
Δ democracy	0.23	0.24[2]	0.20	0.24[2]	0.20[1]	0.27[3]
	(1.44)	(2.45)	(1.20)	(2.28)	(1.71)	(3.02)
Longitude of country centroid	..	..	0.15[2]	0.13[1]	0.14[2]	0.15[2]
	..	..	(2.40)	(1.82)	(2.49)	(2.19)
Latitude of country centroid	..	..	0.11	0.05		
	..	..	(1.33)	(0.63)		
Log of land area	..	..	0.03	−0.07		
	..	..	(0.17)	(0.72)		
Log of mean elevation	..	..	0.17	0.07	0.13	0.03
	..	..	(1.18)	(0.75)	(1.42)	(0.41)
Access to ocean or navigable river	..	..	0.04	0.05		
	..	..	(0.28)	(0.36)		
Malaria ecology	..	..	−0.06	−0.04		
	..	..	(0.49)	(0.36)		
Cultural fractionalization	..	..	−0.12	0.02		
	..	..	(1.04)	(0.23)		
Religious fractionalization	..	..	0.09	0.03		
	..	..	(0.76)	(0.42)		
Log of oil & gas deposits per capita	..	..	0.15	0.09	0.13[1]	0.06
	..	..	(1.47)	(1.02)	(1.65)	(0.87)
F	6.88	5.06	4.05	2.80	7.14	5.46
R^2	0.32	..	0.39	..	0.36	..
Observations	110	110	110	110	110	110

Note: Depended variable is annual growth of GDP per capita over 1992–2002 (PPP, constant 1995 US$). Absolute value of robust t-statistics in brackets; [1], [2], [3] denote significance at the 10, 5 and 1 percent levels. Standardized variables used in the estimates (beta values reported).

To test for a possible endogeneity bias in the estimates, due to a possible feedback from economic growth (the dependent variable) on capability changes, the Hausman (or Durbin-Wu-Hausman) test for endogeneity was carried out but it failed to confirm the existence of such endogeneity problems.

Finally, table 2A.6 reports the result of the growth regressions when countries with high frequency of armed conflict and estimated data were excluded from the sample.

Formal tests of Convergence vs. Divergence

Table 2A.7 **The β-convergence hypothesis**

	1960s	1970s	1980s	1990s	1960–2000	Adjusted 1960–2000
Testing the convergence hypothesis:						
Constant	−1.21	−1.90	-3.29[2]	−2.77[1]	−0.31	−0.01[3]
	(0.64)	(1.97)	(2.19)	(1.89)	(0.26)	(3.04)
Log of the initial level	0.53[2]	0.50[2]	0.53[3]	0.48[3]	0.28[1]	0.55[3]
	(2.31)	(2.14)	(3.10)	(2.91)	(1.91)	(6.54)
R^2	0.04	0.04	0.06	0.05	0.02	0.92
F-stat	5.36	4.56	9.59	8.47	3.66	42.82
Number of countries	107	112	115	116	105	105
Estimate without outliers:						
Constant	−2.20	−2.87[1]	-5.96[3]	−2.03[2]	−2.04[2]	−0.01[3]
	(1.55)	(1.97)	(5.67)	(2.13)	(2.09)	(2.92)
Log of the initial level	0.64[3]	0.62[3]	0.81[3]	0.40[3]	0.48[3]	0.40[3]
	(3.68)	(3.59)	(0.12)	(3.75)	(2.96)	(9.27)
R^2	0.09	0.09	0.19	0.07	0.11	0.85
F-stat	13.55	12.90	44.98	14.08	15.68	85.99
Number of countries	94	96	103	102	95	101

Note: The last column gives results based on variables weighted by shares in world population in 1960. The dependent variable is the average annual growth rate of GDP per capita (constant 1996 US$) in % over the period; log of the initial year is natural logarithm of GDP per capita in the first year of the period; absolute value of robust t-statistics in brackets; DFITS statistics used to exclude outliers with a cut-off point at abs (DFITS)>2*sqrt(k/n); 1, 2, 3 denote significance at the 10, 5 and 1 percent levels.

Source: Penn World Table Version 6.1 (Heston, Summers and Aten 2002).

Table 2A.8 **The σ-convergence hypothesis**

	1960	1970	1980	1990	2000
Number of countries	96	96	96	96	96
Coefficient of variation (standard deviation/mean)					
All countries	0.948	0.959	0.952	1.017	1.057
The richest quartile in 1960	0.304	0.279	0.271	0.329	0.367
The poorest quartile in 1960	0.298	0.374	0.381	0.679	0.694
Max/min country	39	61	50	54	91
The richest to the poorest quartile in each period	11.3	13.8	16.0	20.0	24.1

Note: GDP per capita (constant 1996 US$).

Source: Penn World Table Version 6.1 (Heston, Summers and Aten 2002).

Notes

This chapter draws on a background paper by Fagerberg and Srholec (2005). However, the views expressed here are of UNIDO and do not necessarily reflect those of the authors.

1 Progress on various aspects of social capability has been considerably slowed down by measurability and data availability problems (such as country coverage and time span). Better indicators with broad coverage are needed to measure the role of capabilities in development more accurately. Although the supply of indicators has improved in recent years, partly as a result of an increasing concern for the importance of many 'non-economic' factors (those traditionally not taken into account by economists), coverage is still relatively limited, except perhaps for the last few years. This significantly constrains the analysis of the factors underlying catching-up. In particular, developing countries tend to suffer from inconsistent coverage, which can also be interpreted as lack of capabilities in monitoring key public policy concerns. Hence, there seems to be an important trade-off between determining broad dynamic trends for a large set of countries including many developing ones and the length of period under study. In view of these trade-offs, the analysis in this chapter was carried on 135 countries and 29 explanatory variables over the relatively short timeframe of 1992–2002.

2 Since the purpose of the analysis is to explore global dynamic trends in catching-up, some missing observations were estimated with the help of information on other, similar, variables or countries, rather than reducing the sample. However, it must be noted that this inevitably introduces an element of uncertainty. While the analysis can provide a sweeping view of differences in development and capabilities across different country groupings, it is difficult to claim that the cumulative nature of capabilities and their causal impact on income and growth can be accurately assessed. See annex 2.1 for details on how this was done.

3 In the following quantitative analysis, only patents granted in the US are used to assure consistency in terms of criteria for novelty, originality, etc. Both patent and article counts are very reliable sources of quantitative data. Note, however, that the propensity to patent or publish varies considerably across scientific fields and sectors or industries, and that many innovations are not registered by these means. Moreover, there can be an upward language/regional bias for English-speaking nations or countries with a close links to the US. No attempt was made to correct for these possible biases.

4 Indicators of enrolment in primary and secondary education measure flows, which may not have any impact on the labour force within the time span considered here and have upper boundaries ('saturation' levels) which imply that most developed countries will have values close to 100 per cent. Indicators with this property are not well suited to factor analysis, because they tend to cluster into a single dimension due to this property alone, regardless of the economic content.

5 Another indicator, suggested by Clague et al. (1999) but not included here due to lack of data for European countries, is 'contract-intensive money' (CIM) which reflects trust in a country's legal and financial system.

6 Data has been collected from expert panels and surveys provided by the Transparency International, Amnesty International, Freedom House, World Economic Forum (WEF), PRS Group, Economic Intelligence Unit, Polity IV Project, various U.S. based State Agencies and others (see the Annex 2.1 for details).

7 Note that here the composite governance indicators developed by the World Bank, which provide composite measures of voice and accountability, political stability, government effectiveness, regulatory quality, rule of law, control of corruption for a large sample of countries between 1996 and 2002, are not used since the sources for these indicators are by and large the same as those utilised here.

8 Sources of data include expert panels and surveys provided by Freedom House, Polity IV Project and Database of Political Institutions (DPI)

at the World Bank. For more details on definitions and coverage see table 2A.1.

[9] For a brief overview see Kline (1994). For more details see annex 2.1.

[10] This method has been widely used in the social sciences for a long time (Spearman, 1904; Hotelling, 1933) and was applied to the study of social development in the pioneering study by Adelman and Morris mentioned above.

[11] It can be noted that the knowledge factor presented here has a very high correlation with other measures of technological capability proposed elsewhere. For example, the correlation coefficient between the rankings resulting from the ArCo measure (Archibugi and Coco, 2004) and the United Nations Industrial Development Organisation (UNIDO) knowledge factor is 0.96. Similarly, the rank correlation coefficients between the World Economic Forum's Technology Index (WEF, 2004), the RAND Cooperation's Science and Technology Capacity Index (RAND, 2002) and the Human Development Index of the United Nations Development Programme (UNDP, 2003) on one hand, and the UNIDO knowledge factor, on the other, are 0.88, 0.94 and 0.91 respectively. So that the issue is no so much whether capability indicators are reliable enough, but discerning how do the capabilities come about and how do they relate to economic catch-up.

[12] The regression analysis was carried out on both definitions of factors (first when only one link is allowed between the variable and factor; and second when all significant correlations are used) to test for sensitivity. To test for the robustness of the results with respect to the composition of the sample, the relationship with two different estimation techniques (ordinary least squares (OLS)) and a robust regression technique, iteratively re-weighted least squares) were used. In addition, as is customary in the literature, a battery of indicators reflecting geography, nature and history, are included in some specifications of the model to test for the effect of initial geographical conditions. Finally, since many of the variables included in the analysis were not significant following traditional statistical criteria, a stepwise backward-selection regression is reported in which the insignificant variables were gradually eliminated until the 'best model' was found. For more details on the methodology and detailed results of the regressions please refer to annex 2.1.

[13] Since the aim of the analysis is to develop synthetic measures for levels and changes of capabilities and ascertain broad systematic trends, the discussion is kept at the aggregate regional level as opposed to a country level. As the factors assembled here are an agglomeration of various dimensions of capability, individual values for each country may yield ambiguous interpretations. See, however, table 2A.3 for a breakdown of factors for each country.

[14] This can be estimated by using a tool akin to the 'Barro-type' regression analysis (see Barro, 1991). In this model economic growth (the dependent variable) is regressed on the scope for catching-up in knowledge, measured by (the log of) GDP per capita of the country in question, and a number of other factors. These factors are assumed to be of importance for the ability to exploit the scope for catching-up (or convergence) and are hence often called 'conditional factors' in the literature. The growth-regressions including these factors are interpreted as tests of so-called 'conditional convergence'. In contrast to the (absolute) convergence (or divergence), which refers to observable empirical patterns directly between initial income and growth rate, 'conditional convergence' is not directly observable. The reason is that the potential for catch-up to which it refers may be masked by unfavourable 'conditional factors' such as governance or financial system. The first to introduce this technique appears to have been John Cornwall (1976), who was inspired by Schumpeter's emphasis on creation and dissemination of technology as the source of economic development. In contrast to many recent exercises in this area, Cornwall had a clear argument for the inclusion of GDP per capita as an explanatory variable; it represented the gap in technology between frontier and the latecomer countries. As such it represented a potential for high growth in the latter through successful imitation of superior technology developed elsewhere. This argument was subsequently refined by the so-called 'technology gap approach' to economic growth (Fagerberg, 1987, 1988; Verspagen, 1991). Such gaps, it was argued, are not only exploited (through imitation) but also created (through innovation).

[15] Other theoretical approaches might yield different predictions on this point. For instance, one version of the knowledge-based approach – that associated with 'new growth theory' (Romer, 1990; see Aghion and Howitt, 1998 for an overview) – points out that due to increasing returns on investments in knowledge, countries with higher levels of knowledge development may grow faster than those with less knowledge if the economy is essentially closed to external spillovers.

[16] While the regression results reported here (one variable per factor and step-backward selection model) refer to the specification of the model in which only initial GDP per capita was kept to test the convergence hypothesis, a different specification using the initial knowledge stock variable broadly gave similar results. For more details on the regression results please refer to annex 2.1.

[17] A sensitivity test was conducted excluding from the sample the countries with frequent occurrence of military conflicts and a high share of estimated data (see annex 2.1). This reduced the sample to 110 countries. Among the excluded countries there were many of the former socialist CIS member countries, Asian countries such as Cambodia, Laos and Viet Nam, some Middle Eastern countries such as Lebanon, Saudi Arabia and United Arab Emirates, and several countries severely plundered by wars (mostly in Africa). The results confirm the importance of growing knowledge and good governance for growth. However, in some specifications, the financial system (and its improvement) failed to be significant, while political structure was. Hence, it is possible that the finding that political structure is not significantly correlated with development depends on the inclusion of the above countries, some of which have been successful in catching-up recently despite their unfavourable political conditions.

[18] Only 11 countries, mostly former Soviet republics, had less than 80 per cent of the observations required.

CHAPTER 3

Catching-up and falling behind: accounting for success and failure over time

Why do some countries succeed in catching-up while others fall behind? This question has intrigued policymakers, academics and industrialists alike for more than a century.[1] At the extremes, the long-run trend since the Industrial Revolution seems to be towards divergence, not convergence, in productivity and income. But what history shows is that some countries have managed to catch-up, even overtake the leaders at different points in time, and when this has happened, technology and the environment that fosters it regularly turn up among the driving forces.

Catching-up in historical perspective

The divergence at the extremes has been dramatic: 250 years ago the difference in income or productivity per head between the richest and poorest country in the world was approximately 5:1; today this difference has increased to 400:1 (Landes, 1998). Other sources may give different numbers but the qualitative interpretation remains the same. However, the view at the top has changed over time, several times.

During most of the 19th century the United Kingdom (UK) was the leading capitalist country in the world, with a GDP per capita about 50 per cent above the advanced country average (table 3.1). This lead reflected, among other things, the process of economic, social and institutional change that had taken place in Britain already in the course of the Industrial Revolution (Von Tunzelmann, 1995). However, during the second half of the century, the US started to catch-up with the UK and eventually, during the early part of the 20th century, overcame it. It is clear, in retrospect, that US growth was based on the development of a new technological system, based not so much on new products as on new ways of organising production and distribution (Taylorism, Fordism, etc.). Significant productivity gains were obtained through the development of large-scale production and distribution systems well suited to the large, fast-growing and relatively homogenous American market (Chandler, 1990; Nelson and Wright, 1992).

Europe initially failed to take advantage of these innovations. One main difference between the US and Europe in the first half of this century was market size: the European markets were smaller and less homogenous. Hence, it is not obvious that US methods, if applied to European conditions in this period, would have yielded better results. This is what Abramovitz (1994a) called lack of 'technological congruence' (see Chapter 1). Two world wars and an intermediate period of protectionism and slow growth added to these problems (Abramovitz, 1994a). The US lead increased even further and peaked around 1950, when GDP per capita in the US was about twice the European level.

While the period between 1820 and 1950 was one of divergence in economic performance between the leading capitalist countries, the decades that followed were characterised by 'club convergence' in income and GDP per capita among the industrialised economies. The productivity gap between the US and other developed countries was halved – arguably as a result of imitation of superior US technology. For instance, European production and exports in industries such as cars, domestic electrical equipment, electronics and the like grew rapidly from the 1950s onwards. The gradual reduction of barriers to trade within Europe from the 1950s onwards has generally been regarded a key contributing factor to this process, as has the general rise in incomes and living standards (Abramovitz, 1994b; Maddison, 1982, 1991).

European countries were not alone, however, in exploiting the window of opportunity given by superior US technology. From the 1950s onwards Japan, and later other Asian economies, aggressively targeted the very same industries as those that had grown rapidly in Europe (Johnson, 1982; Wade, 1990). Initially this did not attract much attention among policymakers or industrialists. This changed when, during the 1970s and 1980s, it became evident that Japanese suppliers often outperformed their European and US competitors, and that this could not be explained solely by low wages. Closer attention revealed that the Japanese, like the Americans before them, had made important innovations in the organisation of production that led to both increased quality and higher productivity (Von Tunzelmann, 1995).

As Europe, Japan and other countries started to catch-up in many typical mass consumption goods, US industry leaped forward in another area: science-based industry. Before the First World War (WWI) – and arguably in the interwar period as well – Europe, and Germany in particular, had been at the forefront in this area. In fact, science-based industry, characterised by high R&D investments, highly-educated (and qualified) labour and close interaction between industry, research

Table 3.1 GDP per capita over 1820–2003 (thousands, in 1990 international Geary-Khamis dollars)

	1820	1870	1910	1950	1970	1980	1990	2003	Annual growth 1820–1950	Annual growth 1950–2003	Annual growth 1990–2003
Western Europe and Western offshoots:											
Western Europe											
Austria	1.2	1.9	3.5	3.7	9.7	13.8	16.9	20.8	0.9	3.4	1.6
Belgium	1.3	2.7	4.2	5.5	10.6	14.5	17.2	21.1	1.1	2.6	1.6
Denmark	1.3	2.0	3.9	6.9	12.7	15.2	18.5	22.8	1.3	2.3	1.6
Finland	0.8	1.1	2.1	4.3	9.6	12.9	16.9	20.5	1.3	3.1	1.5
France	1.2	1.9	3.5	5.3	11.7	15.1	18.1	21.3	1.1	2.7	1.3
Germany	1.1	1.9	3.5	4.3	11.9	15.4	18.6	21.0	1.1	3.1	0.9
Greece	0.7	0.9	1.6	1.9	6.2	9.0	10.0	13.5	0.8	3.8	2.3
Ireland*	0.9	1.8	2.7	3.5	6.2	8.5	11.8	24.6	0.9	3.7	5.8
Italy	1.1	1.5	2.6	3.5	9.7	13.1	16.3	19.1	0.9	3.3	1.2
Netherlands	1.8	2.8	4.0	6.0	11.9	14.7	17.3	21.4	0.9	2.5	1.6
Norway	1.1	1.4	2.5	5.5	10.0	15.1	18.5	25.9	1.2	3.0	2.6
Portugal	1.0	1.0	1.2	2.1	5.5	8.0	10.8	13.9	0.6	3.7	2.0
Spain	1.1	1.4	2.3	2.2	6.3	9.2	12.1	16.5	0.6	4.0	2.4
Sweden	1.2	1.7	3.1	6.7	12.7	14.9	17.7	21.6	1.3	2.3	1.5
Switzerland	1.3	2.2	4.3	9.1	16.9	18.8	21.5	22.2	1.5	1.7	0.2
United Kingdom	1.7	3.2	4.9	6.9	10.8	12.9	16.4	21.1	1.1	2.2	2.0
Overseas											
Australia	0.5	3.6	5.7	7.4	12.0	14.4	17.1	23.1	2.1	2.2	2.3
New Zealand	0.4	2.7	5.2	8.5	11.2	12.3	13.9	17.4	2.4	1.4	1.7
Canada	0.9	1.7	4.4	7.3	12.1	16.2	18.9	23.3	1.6	2.3	1.6
United States	1.3	2.4	5.3	9.6	15.0	18.6	23.2	29.2	1.6	2.2	1.8
Asia											
China	0.6	0.5	0.6	0.4	0.8	1.1	1.9	4.4	–0.2	4.6	6.7
India	0.5	0.5	0.7	0.6	0.9	0.9	1.3	2.2	0.1	2.4	4.1
Indonesia	0.6	0.7	0.9	0.8	1.2	1.9	2.5	3.5	0.2	2.8	2.6
Japan	0.7	0.7	1.3	1.9	9.7	13.4	18.8	21.7	0.8	4.8	1.1
Malaysia	..	..	0.9	1.6	2.1	3.7	5.1	8.5	..	3.3	4.0
Philippines	..	..	1.1	1.1	1.8	2.4	2.2	2.6	..	1.7	1.3
Singapore	..	..	1.3	2.2	4.4	9.1	14.4	21.7	..	4.5	3.2
Republic of Korea	..	..	0.9	0.8	2.0	4.1	8.7	15.8	..	6.0	4.7
Taiwan Province of China	..	..	0.7	0.9	3.0	5.9	9.9	17.3	..	5.8	4.4
Thailand	..	0.7	0.8	0.8	1.7	2.6	4.6	7.1	..	4.2	3.4
Vietnam	0.5	0.5	0.8	0.7	0.7	0.8	1.0	2.2	0.1	2.3	6.3
Latin America											
Argentina	..	1.3	3.8	5.0	7.3	8.2	6.4	7.5	..	0.8	1.2
Brazil	0.6	0.7	0.8	1.7	3.1	5.2	4.9	5.4	0.7	2.3	0.8
Chile	..	..	2.7	3.8	5.3	5.7	6.4	10.4	..	1.9	3.8
Colombia	..	..	1.2	2.2	3.1	4.3	4.8	5.3	..	1.7	0.8
Mexico	0.8	0.7	1.7	2.4	4.3	6.3	6.1	7.1	0.9	2.1	1.2
Peru	..	..	1.0	2.3	3.8	4.2	3.0	3.7	..	1.0	1.6
Venezuela	..	0.6	1.1	7.5	10.7	10.1	8.3	7.0	..	–0.1	–1.3
Africa											
Egypt	..	..	0.7	0.9	1.3	2.1	2.5	3.0	..	2.3	1.4
Ghana	..	..	0.7	1.1	1.4	1.2	1.1	1.4	..	0.5	1.9
Morocco	..	..	0.8	1.5	1.6	2.3	2.6	2.9	..	1.3	0.8
South Africa	..	..	1.6	2.5	4.0	4.4	4.0	4.4	..	1.1	0.7
Eastern Europe											
Czechoslovakia	0.8	1.2	2.1	3.5	6.5	8.0	8.5	9.6	1.1	2.0	0.9
Hungary	..	1.3	2.1	2.5	5.0	6.3	6.5	8.0	..	2.3	1.6
Yugoslavia	..	..	1.0	1.6	3.8	6.1	5.8	5.2	..	2.4	–0.8
Soviet Union	0.7	0.9	1.5	2.8	5.6	6.4	6.9	5.4	1.1	1.2	–1.9

	1820	1870	1910	1950	1970	1980	1990	2003
Western Europe and its offshoots:								
Mean	1.1	2.0	3.6	5.5	10.6	13.6	16.6	21.0
Coeff. of variation	0.32	0.37	0.36	0.42	0.28	0.22	0.20	0.18
All countries (data fully available over 1820–2003):								
Mean	1.0	1.5	2.7	4.3	8.5	10.9	13.2	16.6
Coeff. of variation	0.38	0.55	0.58	0.62	0.52	0.49	0.49	0.48
All countries (data available only over 1910–2003):								
Mean	..	..	2.2	3.6	6.7	8.7	10.4	13.3
Coeff. of variation	..	..	0.67	0.73	0.66	0.62	0.64	0.63

Source: Maddison (2001) for 1820–1990 and the Total Economy Database (GGDC, 2005) for 2003 data. The Geary-Khamis is an aggregation method to obtain prices and volumes in terms of purchasing power parities relative to a base country. Widely used to obtain internationally comparable output statistics, it estimates category 'international prices' (reflecting relative category values) and country PPPs (depicting relative country price levels) simultaneously from a system of linear equations. The Geary-Khamis PPPs give weights to countries according to their size measured in terms of gross national product (GNP). For example, in application of this method, the GDP of the United States counts for approximately 5 times as much in the determination of international prices as that of India and about 7.5 times as much as that of Brazil. The main advantage of the Geary-Khamis method is that it is additive, i.e., it generates results for each country that are consistent over different levels of aggregation. On the other hand, Geary-Khamis approach leads to an overstatement of the relative incomes of the world's poorest nations and is not as reliable for comparisons across time. It should be noted that absolute levels and differentials are quite sensitive to the choice of reporting method – for example in current dollar values the GDP per capita of India in 2003 is US$ 565 as opposed to US$ 1100 for China (World Development Indicators, 2004).

Note: * The data shown here for Ireland between 1820 and 1950 is included for illustrative purposes. They are not included in the averages as the UK figures already take account of the whole of Ireland for 1820–1920, and thereafter only the Northern Ireland province.

institutes and universities, was largely a German invention. However, in the beginning of this century the US business community. started to catch-up in this area (Nelson and Wright, 1992; Mowery and Rosenberg, 1993). Technical universities and business schools were founded, often in close interaction with industry. This drive towards a greater reliance on science and R&D was much strengthened during WWII and the Cold War due to massive public investment in this area. As a consequence, the leadership passed to the US.

During the 1970s and 1980s the Japanese, like the Americans before them, made important innovations in the organisation of production that led to both increased quality and higher productivity.

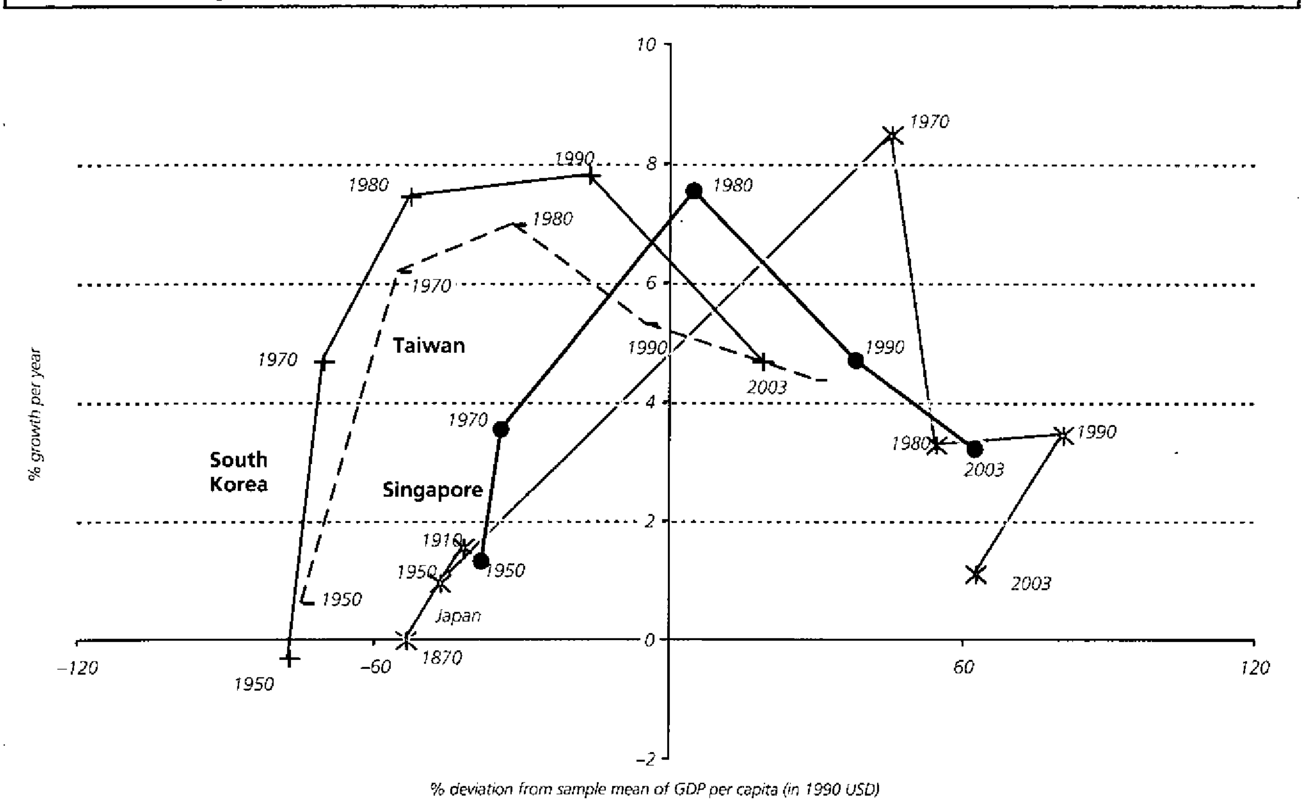
It was not long, however, before European countries and Japan started devoting more resources to higher education, science, and R&D. Following the Japanese example some of the Asian newly industrialised countries (NICs) began to invest massively in R&D from the 1970s onwards. These developments had a major impact on the structure of science-based industry worldwide (Fagerberg et al., 1999). Today the US has been replaced by Japan as the country that devotes the largest share of its income to R&D activities, and the club of high R&D performers has been enlarged with the arrival of a number of new members: Republic of Korea, Finland and Taiwan Province of China deserve particular mention. But most other countries, including the developing ones, have remained low R&D performers. They also continue to lag in other areas that impinge considerably on the creation and exploitation of knowledge in the contemporary world, such as the spread of ICTs.

Diversity in long-run performance

What is perhaps most striking about the long-run evidence is the great variation in performance between countries with comparable initial levels of productivity and income. Overall, roughly four groups of countries can be discerned in the long-term data on catching-up (figures 3.1–3.5).

1. Countries that began with below-average GDP per capita and experienced higher-than-average growth for a fairly long period of time, coming to enjoy a higher-than-average level of GDP per capita in 2003. These are Japan, Taiwan Province of China, Republic of Korea and Singapore in Asia, and European countries such as Ireland, Finland, Norway, Portugal, and Spain.
2. Countries whose recent growth performance suggests that they may be in the early phase of catching-up, since they

Figure 3.1 Catching-up experiences: East Asia



Source: Maddison, 2003 and GGDC, 2005.

are proceeding along paths similar to those of their predecessors. This group includes China, India, Indonesia and Thailand.

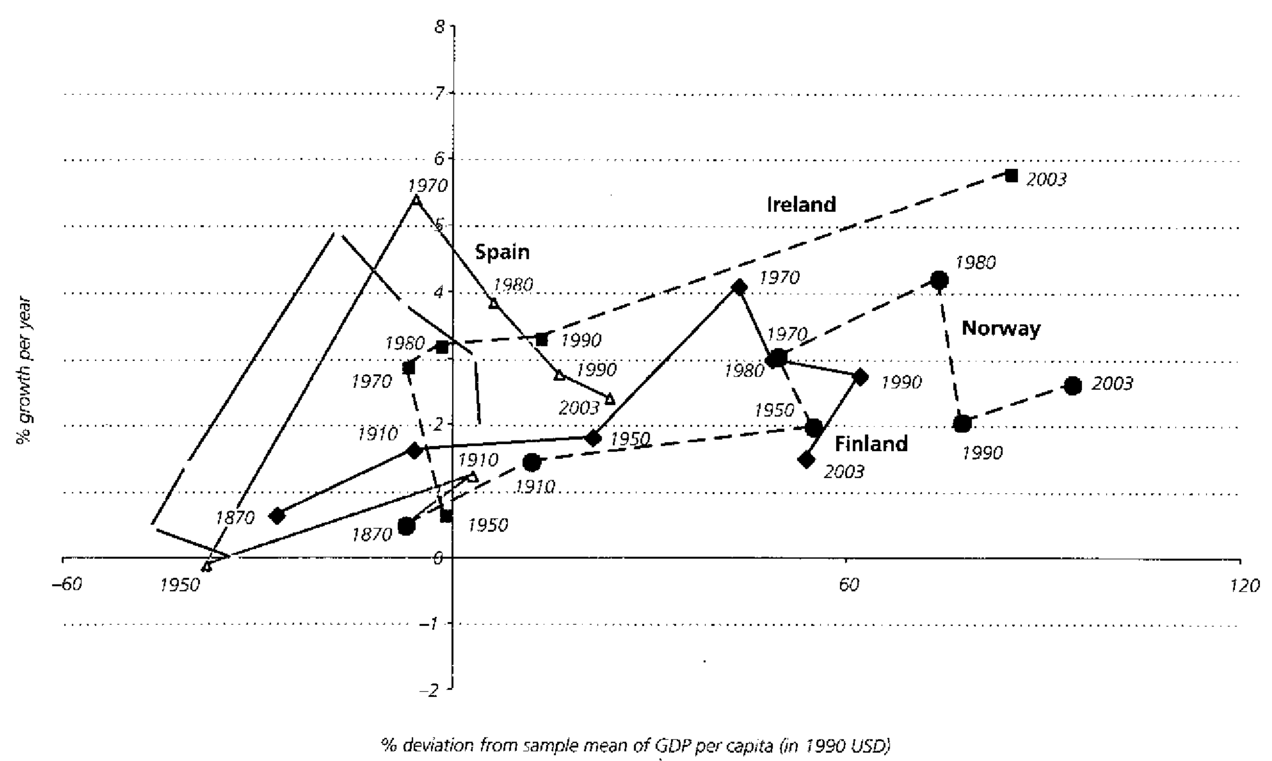
3. Countries like Argentina, Chile and Venezuela which, having started with higher-than-average levels of GDP per capita, fell below the average in the second half of the 20th century.[2]
4. Countries that started at a low level of income and fell further behind during this period, a pattern common to many SSA countries whose initial level of income and subsequent growth performance have resulted in a gap in GDP per capita that has grown ever wider.[3]

From a developing country's viewpoint, catching-up in terms of GDP per capita requires a period of higher-than-average growth for a sufficiently long time. How long this period must be for a country to catch-up depends on the size of the gap between its level of GDP per capita and the target level, however this may be defined. Among the catching-up countries, it can be noted that only modestly above-average growth rates have sufficed for countries that did not lag too far behind the sample average. This was the case for Nordic catching-up countries such as Finland and Norway, as well as for Portugal and Spain from 1870 to 1910. The East Asian catching-up experiences, on the other hand, are characterised by wider initial gaps and higher growth rates for longer periods. The same might be expected regarding the growth path of the countries that are in the process of catching-up today, such as China and India. That said, one should not infer that the target of catching-up efforts can be expressed solely as achieving higher-than-average levels of GDP per capita. Obviously, it is not possible for all countries to achieve such a goal.

> ***Catching-up in terms of GDP per capita requires a period of higher-than-average growth for a sufficiently long time. How long this period must be depends on the size of the gap between a country's level of GDP per capita and the target level.***

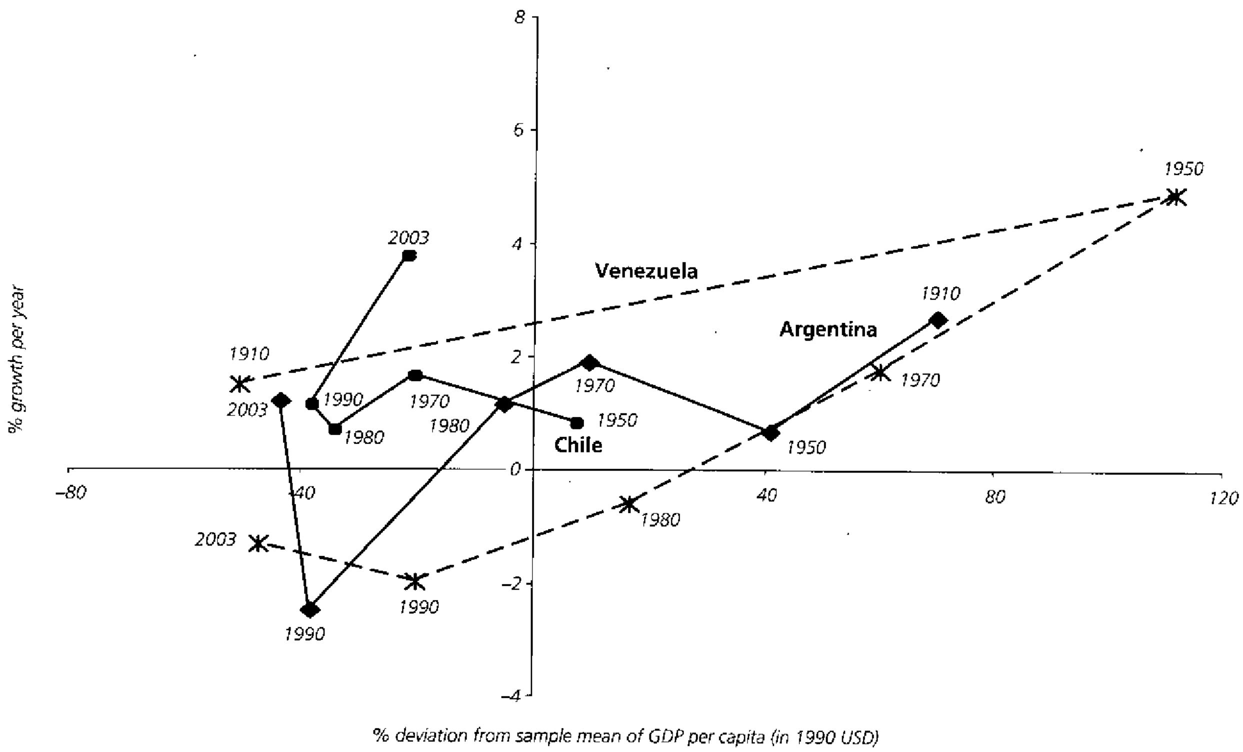
The broad categorisation of catching-up experiences outlined above can be visualised in more detail in figure 3.6, which shows the distribution of countries in a plot of annual average GDP per capita growth over the period 1960–2000 against the level of GDP per capita in 1960.[4] Dashed lines represent sample averages (of growth and level, respectively). As can be seen, four quadrants emerge. The countries in the top-left quadrant have high initial GDP per capita but grow

Figure 3.2 Catching-up experiences: Europe



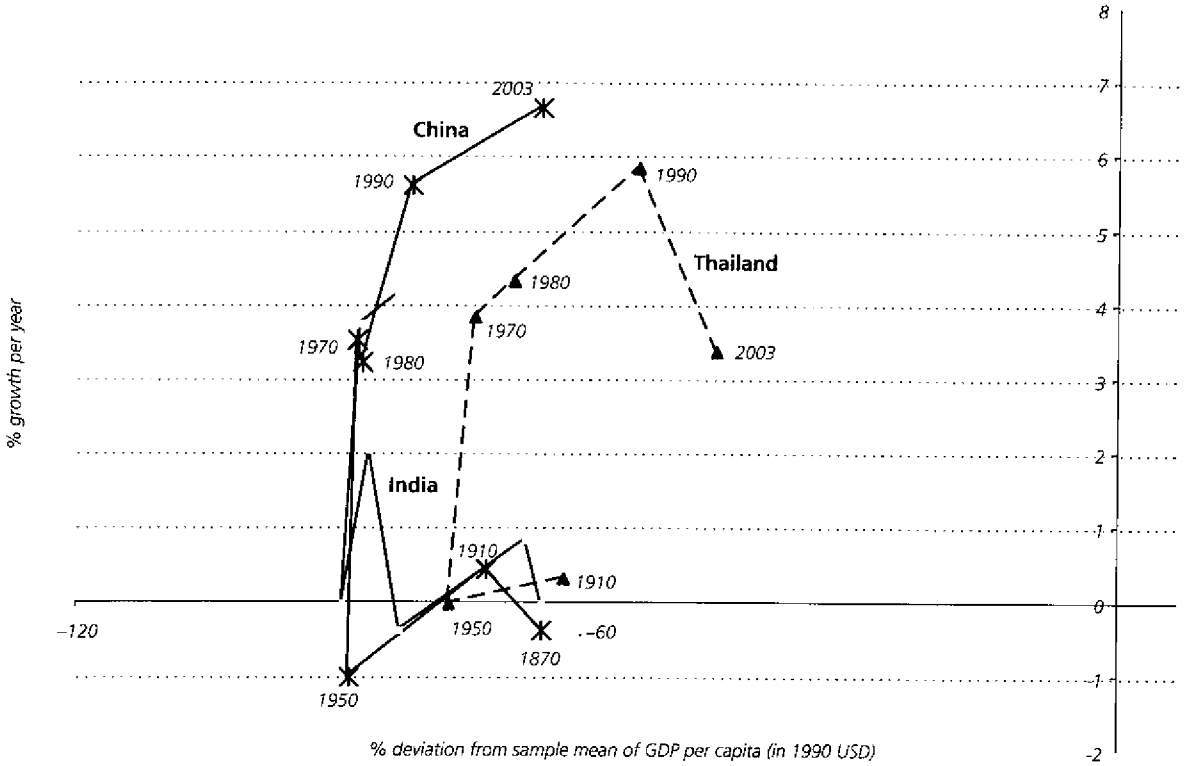
Source: Maddison, 2003 and GGDC, 2005.

Figure 3.3 **Catching-up and falling behind**



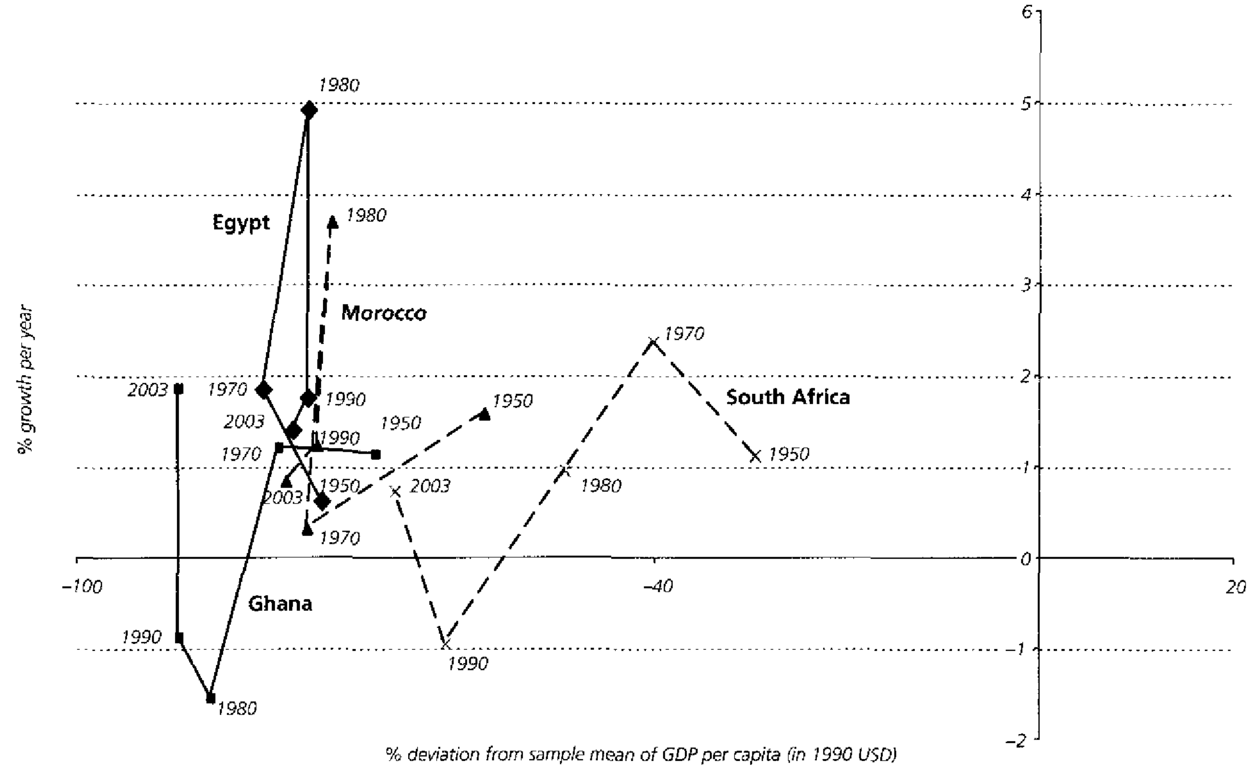
Source: Maddison, 2003 and GGDC, 2005.

Figure 3.4 **On the road to catching up?**



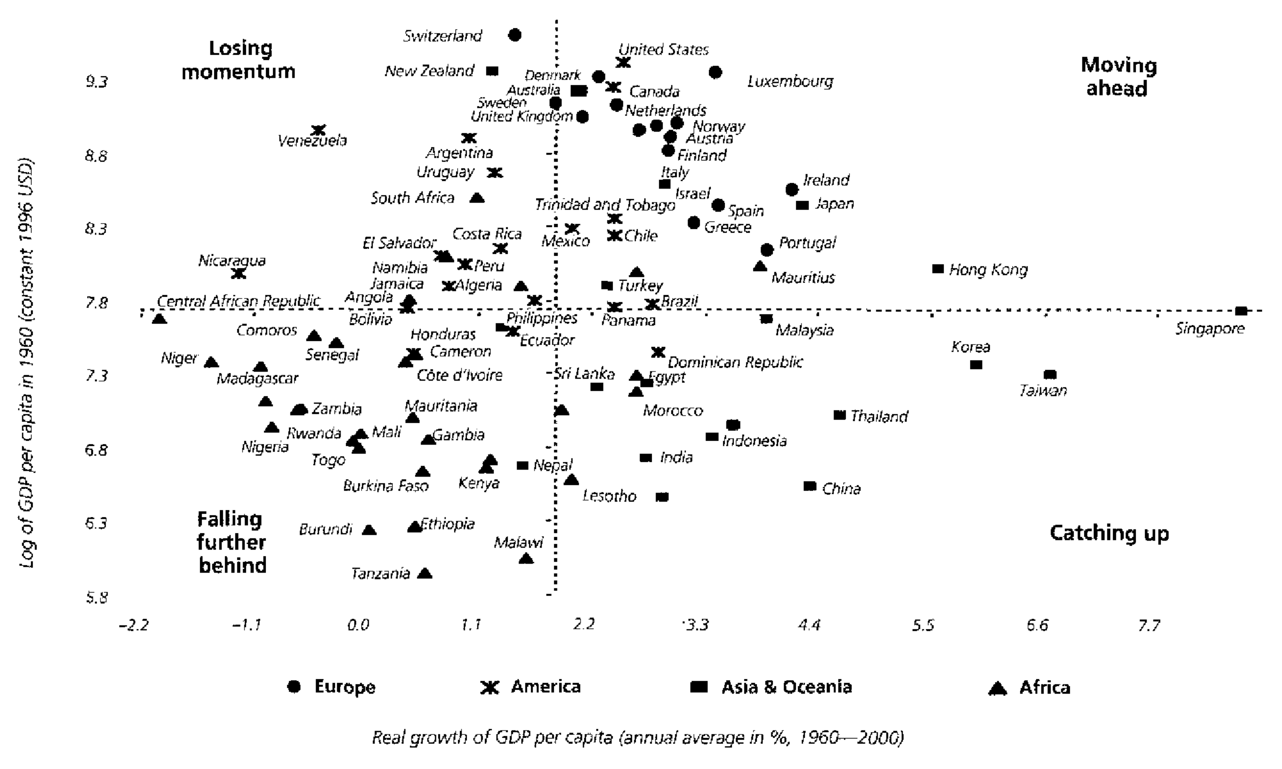
Source: Maddison, 2003 and GGDC, 2005.

Figure 3.5 **Stagnating or falling further behind**



Source: Maddison, 2003 and GGDC, 2005.

Figure 3.6 **Convergence vs. divergence in GDP per capita over 1960s–1990s**



Source: Penn World Table Version 6.1 (Heston, Summers and Aten, 2002).

relatively slowly; they may be said to 'lose momentum.' In contrast, the countries in the top-right quadrant continue to grow fast despite being relatively wealthy at the outset; these countries are 'moving ahead'. In the bottom-right quadrant there are countries that also grow at above-average rates but from a lower initial level – these are the countries that succeed in catching-up. Finally, the bottom-left quadrant is occupied by countries with the least fortunate outcome, initially poor countries that grow slowly and therefore 'fall behind'.

Quite clearly, there is much diversity in performance: all four quadrants are relatively well populated. But closer inspection reveals that there is a greater tendency for countries to cluster in the bottom-left and top-right quadrants – in the groups that are 'falling behind' or 'moving ahead' – than in the two other quadrants. This is consistent with a long-run tendency towards divergence in the global economy.

Formal tests of the tendency towards absolute convergence (or divergence) in income levels can be made by regressing the GDP per capita on its initial level and observing the sign of the correlation coefficient. A negative relationship would imply that rich countries tend to grow slower than the poorer ones, the so called β-convergence (Barro and Sala-i-Martin, 1992). However, a positive association is found for each decade as well as the period as a whole, indicating that high-income countries grow faster on average than those with low income. If the hypothesis that the distribution narrows through time is tested – the so-called σ-convergence – the results confirm, again, that for the sample as a whole the long-run tendency is towards divergence, and this tendency gains force after 1980.

But when the sample is divided into subgroups on the basis of the initial level of GDP per capita a more complex pattern emerges. For those in the richest quartile, there actually was a tendency towards convergence between 1960 and 1980, after which a trend towards divergence sets in. However, a similar tendency cannot be detected among the countries in the poorest quartile. For these countries the tendency points consistently towards divergence, albeit less so before the 1980s than afterwards (see tables 2A.7 and 2A.8 for details).

The long-term patterns of divergence and convergence in country-level GDP per capita invites further reflection on such patterns and their relation to the accumulation of technological capabilities at the country level.

Notes

This chapter draws on a background paper by Fagerberg and Srholec (2005) and inputs from Roberto Mazzoleni. However, the views expressed here are of UNIDO and do not necessarily reflect those of the authors.

1 Some of the earlier examples can be found in the debates in Germany and the US during the 19th century about what was needed to be able to catch-up with the UK, then the world leader (Chang, 2002).

2 Argentina and Venezuela experienced very large relative improvements in GDP per capita at different times – Venezuela in 1910–1950 and Argentina in 1820–1870 – but later experienced large fluctuations.

3 It may seem surprising that countries like South Africa and Chile, which are star performers in their respective regions, appear as having done rather poorly in terms of catching-up. However, it should be borne in mind that, in this analysis, what matters is performance *with respect to the sample average*, which is in turn influenced by the relative weights of the whole set of above-average versus below-average performers.

4 These data, which cover more than 90 countries at different levels of development, are drawn from The Penn World Table (Heston, Summers and Aten, 2002).

CHAPTER 4

Role of knowledge systems in catching-up experiences

The diversity of growth processes at country level undoubtedly reflects the existence of different institutional infrastructures, the interactions between various actors and the pace at which social and technological capabilities have been accumulated. This calls for a closer look at institutional evolution in different catching-up contexts, examining the role played by components of domestic knowledge systems such as higher education, technical and vocational training, research units, technical associations and other agencies of the technological infrastructure like standards and metrology bodies. Also meriting attention are the different institutional infrastructures to support effective interactions between training and research activities in the public sector and the formation of entrepreneurial and technological capabilities in emerging industries.

Introduction

The actual extent to which overall educational capital determines economic growth is still in debate.[1] However, cross-country data show a positive correlation between tertiary enrolment rates and measures of per capita income (Fagerberg and Godino, 2004). Furthermore, evidence on the centrality of scientific and engineering education to technological capability formation and on the latter's effects on economic growth is sufficiently strong to invite further qualitative investigation. Although investing in higher education in developing countries had been previously seen as a non-priority, this has changed in recent years.[2]

As clearly illustrated by the catching-up processes of the US and Germany in the 19th century and the more recent ones of Japan, the Republic of Korea and Taiwan Province of China, the international dissemination of educational and research models is subject to adaptation to local economic, social, and political conditions, not unlike production technologies. Amid the resulting diversity, however, there are important similarities which provide useful lessons for contemporary policies. Among these are significant increases in enrolment in tertiary education – especially in science and engineering fields – as well as important adaptations to the needs of emerging industrial sectors (see box 4.1).

In particular, significant growth of science and engineering education among catching-up countries has been quite visible: Taiwan Province of China and the Republic of Korea are eloquent examples. In fact when the share of science and engineering degrees in total degrees is compared with the country's level of development (as measured by GDP per capita) a cross-country pattern of catching-up potential similar to that highlighted in Chapter 3 emerges (figure 4.1). On the one hand, some countries are generating a lot of science and engineering talent and are on their way to technological catch-up (China is a good example); on the other hand, countries such as the Latin American ones in the sample are falling behind in terms of competences and economic performance. Among early and more recent catching-up countries there are cases in which this expansion has overtaken that of the US. For example, in 2000 Japan, with less than half the population of the US, graduated twice as many engineers, and China is graduating four times as many (National Science Foundation, 2004) (figure 4.2). That said, it is important to point that significant increases in enrolment do not always accompany improvements in the quality of competence-building efforts.[3] The effectiveness of expansion in science and engineering education depends on the institutional design and a whole host of complementary factors such as the interaction between industry and academia.

Early biases

During the 19th century catching-up experiences the scope of academic education was broadened both by advances in natural sciences research and changes in attitude towards professional training.[4] These changes coincided with the emergence of science-based industries – such as chemicals and electrical equipment – and of formal R&D laboratories in business firms in these industries, both of which had an impact on the concept of the role modern universities should play. These trends started to take hold first in German universities and later spread to the academic systems of other countries such as the US and Japan.

Training programs focused on engineering and industrial technology started to spring up in Europe at the end of 18th century. Notable examples are the École des Ponts et Chaussées (1775), the École de Mines (1783) and the École Polytechnique (1794), all in France. These institutions, though, were designed to train engineers for careers in public service, which limited their pertinence to industrial devel-

Box 4.1 Tertiary enrolment and catching-up in cross-century perspective

The prima facie case that increasing educational attainment has had an important role to play in the economic performance of successful catching-up countries has often been based on the observable association between economic performance and educational enrolment. Until the 19th century, the reform of higher education in continental Europe had failed to lead to sustained increases in enrolment. University education remained a rather exclusive option in Germany, where the accession of scientific disciplines to the academic curriculum was pioneered. Much of the growth in enrolment toward the end of the century occurred in the *Technische Hochschulen,* the polytechnic schools specialised in the teaching of engineering subjects. Even then the enrolment rates achieved by the last quarter of the 19th century was puny when compared to contemporary standards. By 1870, the German system of higher education served only less than one per cent of the relevant age group and yet constituted a model system for other countries to learn from. A different pattern can be seen in the US where the number of colleges increased rather sharply since the 18th century and so did enrolment (figure 4B.1). Already in 1870 the university enrolment rates in the US were between two and three times the rates in Germany or any other European country.

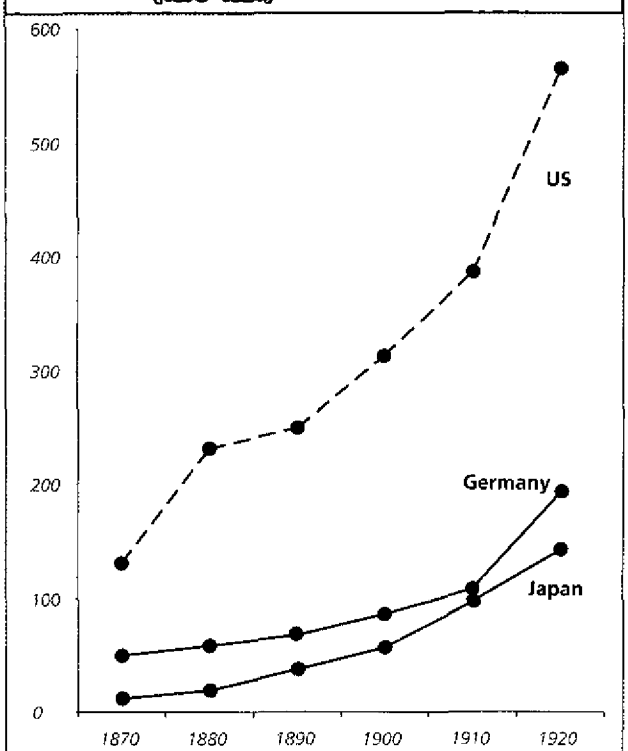
Japan was the first country where the inward transfer of S&T knowledge was an explicit target of government policy and institutional design. To this aim, a key instrument was the development of a system of higher education largely modelled after the institutions of the western economies, Germany, Britain and the US. The magnitude of the Japanese effort was impressive. Over the half-century between 1870 and 1920 student enrolment at Japanese higher education institutions grew by a factor of nearly 20, compared to a factor of about 11 in the US and six in Germany. As a result, Japanese student enrolment rates had substantially caught up with those of Western European countries by the 1920s.

The Republic of Korea and Taiwan Province of China are the most successful instances of economic catch-up during the second half of 20th century, a period when enrolment rates in secondary and tertiary education soared (figure 4B.2). At the end of the Japanese colonial period in 1945, both had only a minimal higher education infrastructure. The Republic of Korea's university student population was about 8 000 in 1945. At that time, 40 per cent of the labour force had no schooling and another 53 per cent had only primary education. The tertiary level educational infrastructure at the end of the Japanese occupation consisted of a handful of colleges established by religious missionaries during the late 19th century, and only one modern academic institution, Keijo Imperial University, established in Seoul by the Japanese government in 1924 to provide higher education for the Japanese expatriates. Korean students accounted for only between a quarter and a third of the total, and very small numbers of Koreans attended universities in Japan.

The Republic of Korea achieved universal education at the primary level within a decade and saw its university students' population grow by a factor of nearly 90 between 1950 and 2000. By 2000, Korean enrolment rates for tertiary education were comparable to those of the US, and significantly higher than the country's erstwhile coloniser, Japan. The growth of enrolment since 1945 owed a great deal to the financial aid provided by the US government. Between 1952 and 1963, 19 per cent of the US$100 million in aid for education provided by the US government was spent on higher education, with the bulk of the funds – approximately US$17 million – being used to upgrade the faculties at Seoul National University, as Keijo Imperial University was named after liberation from Japan.

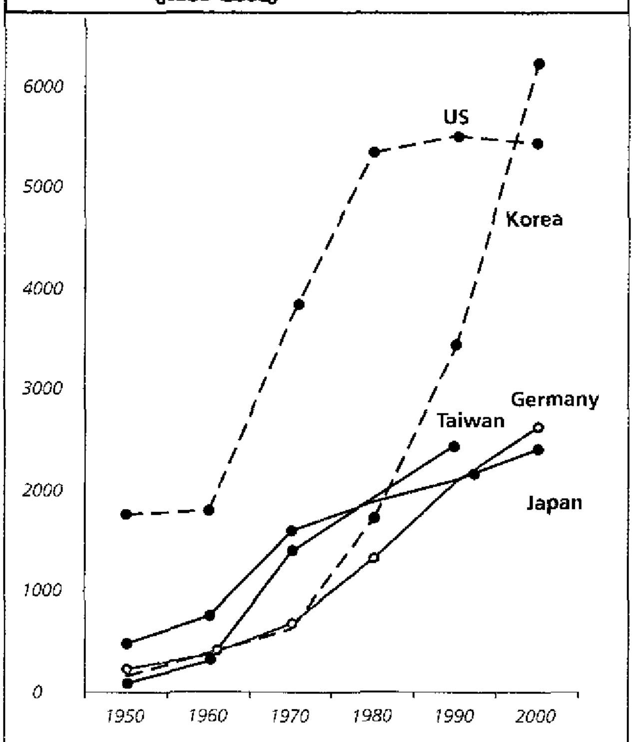
The experience of Taiwan Province of China shows a great deal of similarity with the Korean one. While the overall level of education of the Taiwanese was higher than that of Koreans, the number of universities was only seven in 1950, with about 1 000 faculty members and a student body of 6 600. Thirty-six years later, 22 000 faculty provided instruction to 440 000 students in 105 tertiary institutions. Such rapid growth was sustained by government's investment in education, which reached 5.83 per cent of GNP in 1985. By 2000, Taiwanese educational attainment levels had substantially caught up with those of the US.

Figure 4B.1 University students per 10 000 population (1870–1920)



Source: own elaboration, Mitchell 1995, 2003a, 2003b.

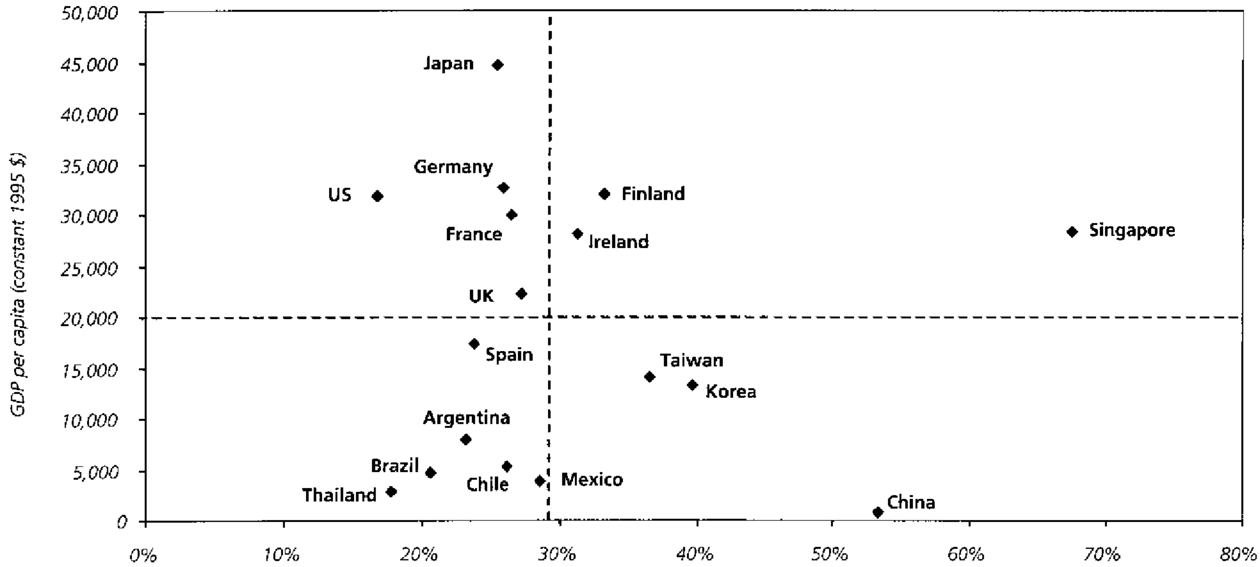
Figure 4B.2 University students per 10 000 population (1950–2000)



Source: own elaboration, Mitchell 1995, 2003a, 2003b, Korean Statistical Yearbook, Japan Statistical Yearbook, UNESCO Demographic Yearbook (various years).

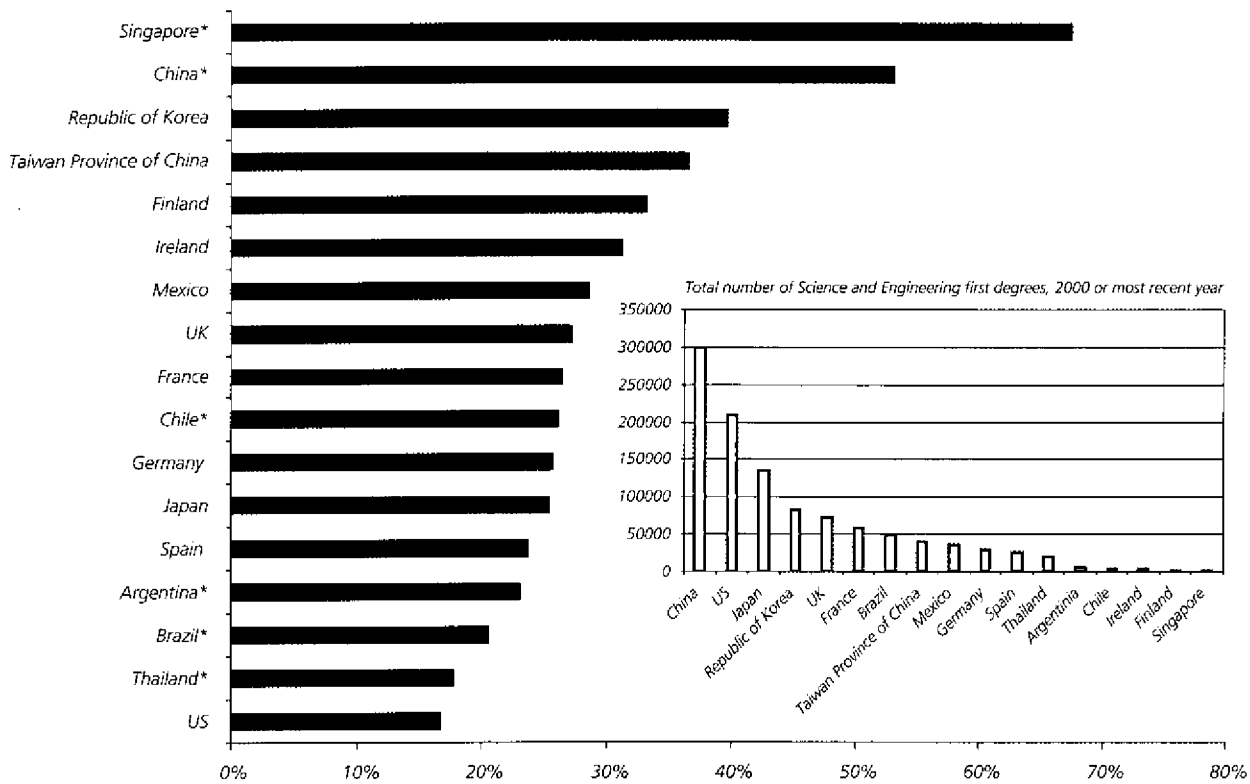
Sources: Lee, 1989; McGinn et al., 1980; Hsieh, 1989.

Figure 4.1 GDP per capita vs. share of natural science and engineering degrees in total first degrees (2000 or most recent year)



Source: NSF, 2004 and World Development Indicators, 2003.

Figure 4.2 Share of natural science and engineering degrees to all first degrees (2000 or most recent year)



Source: National Science Foundation, 2004. NS&E degrees include natural, agricultural, computer sciences, mathematic and engineering. First-degree programs in most countries are less than 5 years. However, for Germany, Italy, Portugal, Greece and Spain long degrees (more than 5 years) are taken into account. India is not represented in the figure due to the lack of reliable, updated, and internationally comparable information on science and engineering graduates.

* For these countries NS&E degrees include only Natural Sciences (physical, biological, earth, atmospheric and ocean sciences) and engineering, as there is no data available on mathematics/computer sciences and agricultural sciences. For China, the figure does not include mathematics/computer sciences but only natural sciences, agricultural sciences, and engineering. As a result, there is likely to be a downward bias for total number of NS&E degrees for these countries vis-à-vis countries such as US and Japan.

opment. The unmet need for high-skilled technical personnel led to the establishment in 1829, by a private industrialist, of the École Central des Arts et Manufactures (ECAM). However, the graduates of the school were predominantly employed in administrative and managerial duties in industry (Mazzoleni, 2003).

The tension between the emphasis on academic teaching covering math and natural sciences and the provision of practical training haunted many educational institutions in the first half of the 19th century. A good example is the 'academisation' of engineering in German universities and technical schools (Hochschulen) for most of the 19th century, which gave rise to a reform movement that emphasised laboratory research and training. This movement gained momentum after the 1890s. The same tension also created an increasing overlap between the focus of university teaching and research and that of the technical schools. Unlike France, where the specialised engineering schools had a higher status than universities in the resulting two-tier system, the German polytechnic schools had a vocational orientation through at least the first half of the century, and were considered of lower status than the universities.

The lack of opportunities for practical work and laboratory practice greatly reduced the effectiveness of the knowledge acquired by students for the development of enterprise-based technological capabilities, and this led to the estrangement of the industrial community from the evolution of the Hochschulen. As practical workshop experience was neither a requirement for admission to the Hochschulen, nor a component of their curricula, the graduates were shunned by industrialists who often preferred to recruit their technical workforce from among the alumni of the secondary-level trade schools. Overall, the Hochschulen graduates' predilection for abstract theorising and their disdain for practical considerations such as manufacturability of product designs and production costs diminished their appeal for industrialists until the end of 19th century.

The utilitarian higher-education model of the US

The prominence attained by the German polytechnic schools in international academic circles provided the inspiration for American engineering schools. Although inspired by the German model, the system of higher education in the US was characterised by an enormous adaptive capacity that ultimately gave it significant originality. The characteristics of professional education in the curricula and the formation of new institutes reflected the US penchant for the practical applications of science noted by Tocqueville (1876), and the dominance of a utilitarian conception of education.

Two features of the US higher education system are particularly noteworthy. First, the segregation of engineering from the universities that emerged in continental Europe was not replicated in the US. Second, the growth of the system was to a much larger extent the result of private initiative, so that institutional arrangements were much more varied than in Europe[5] (see box 4.1).

An important characteristic of engineering education in the US was its emphasis on shop culture and an orientation towards practical problem-solving and industrial practice.

The dissemination of engineering education in the US proceeded largely through the creation of new specialised institutes, such as Union College or the Massachusetts Institute of Technology (MIT). Older elite colleges which did not consider engineering a suitable discipline for their students' education, established sister institutions aimed at providing scientific and engineering training. Thus, the Lawrence Scientific School was established in 1847 as a branch of Harvard University thanks to a private endowment aimed at promoting the application of scientific education to engineering and mining and the invention and manufacture of machinery (though ultimately the school program emphasised the teaching of sciences, rather than engineering). Yale College followed in Harvard's footsteps with the creation of the Sheffield Scientific School in 1858, again thanks to a gift by a private entrepreneur. MIT provides another excellent example: Boston industrialists created it to support their production activities through research and education in the applied sciences and engineering. By 1985 there were 85 engineering schools active at college level. US universities have also distinguished themselves for the speed with which study programs are formed to support training and research in new fields of knowledge (Nelson and Rosenberg, 1994).

To a considerable extent, the engineering curricula in US colleges represented an adaptation of European models to local conditions, among which the differences in the standards of secondary education and the much greater emphasis given to practical work were of paramount importance.[6] As a result of these factors, the 'academisation' of engineering that characterised developments in Germany and France was hardly a problem in the US, in spite of the fact that many engineering schools drew inspiration from European institutions and very often adopted the same textbooks.

An important characteristic of engineering education in the US was its emphasis on shop culture and an orientation towards practical problem-solving and industrial practice. These were cultivated in part through the consulting relationships that members of the faculty established with industrial firms, often with the encouragement of administrators who thus hoped to attract industry funding for their colleges. Sponsored research activities at engineering colleges increased since the 1880s and by the early decades of the 20th century several of them had established departments of industrial research, research foundations and engineering experimental stations, whose activities consisted in carrying out research projects as a public service to local government agencies as well as local industry. The creation of the engineering experimental stations found inspiration in the institutions that had emerged in the US farming sector to carry out research and extension services with federal and state government funds. The public R&D infrastructure in US agriculture benefited from the establishment of the agricultural experimentation stations through which federal support to agricultural R&D was channelled since the late 1880s[7] (see box 4.2).

Reciprocal influence across countries in the design of scientific institutions continued to manifest itself through the 19th and 20th centuries, and not just among Western European countries and their colonies. Nineteenth century Japan is an outstanding example: the Japanese system had great influence on the academic systems that evolved since the mid-20th century in the Republic of Korea and Taiwan Province of China while they were under Japanese colonial rule.

Brain circulation and university research

The international movement of students was an important aspect of the spread of S&T during the 19th and 20th century catching-up experiences, complementary to the movements of skilled industrial personnel (Mazzoleni, 2003; Pollard, 1981). For example, a significant number of scientists working in the US chemical industry had been trained in Germany. Cross-border academic education in sciences did not only contribute to technological progress in countries and sectors lacking a strong domestic scientific base; the transfer of students and scholars also helped the development of national academic institutions. The trend towards recruiting foreign scientists for teaching and research positions was very visible in Japan in the early years of Meiji restoration, which began in 1868. The acquisition of knowledge and the creation of a higher education system were believed essential to catching-up with the advanced western economies. Foreign-trained Japanese students and educators, as well as the large number of foreign professors who were invited to Japan, played a significant role in laying the foundations of a system that within about 50 years achieved a standard comparable to those of most western European countries.

In Taiwan Province of China and the Republic of Korea the pattern of circulation of educated labour and academic personnel was different. The growth of the university system in these cases was so spectacular that it led to a temporary problem of unemployment among university graduates, as the increases in supply exceeded the economy's capacity to create adequate job opportunities. This was particularly true for large numbers of science and engineering students, who had to go abroad to pursue graduate studies or professional opportunities. About 20 per cent of Taiwanese students enroled in tertiary degree programs were studying abroad during the 1960s and 1970s. The percentage was even higher in the sciences, where a third of students migrated to foreign institutions (UNESCO, 1972). The government attempted to reverse this brain drain. Those who held foreign academic degrees – whose skills were often enriched by work experience abroad – were encouraged to play a dual role, contributing to the upgrading of technological capabilities in industrial firms and improving the quality and quantity of education, especially at graduate level.[8]

In spite of these efforts, research activities in universities remained underdeveloped. One of the most insightful scholars of Korean industrialisation noted in 1993 that the rapid growth of university enrolment in the Republic of Korea had significantly outstripped the growth in financial support for education and research in both the public and private universities, and that 'the student-professor ratio ha[d] retrogressed from 22.6 in 1966 to 35.8 in 1985, making all universities primarily undergraduate teaching-oriented rather than research-oriented' (Kim, 1993, p. 371). This highlights the failure to develop in the Republic of Korea's university system the type of strong complementarities between teaching and research that have proven to be effective for both activities in other national higher education systems, notably that of the US – and also highlights the critical role played in reversing the brain drain in both Taiwan Province of China and the Republic of Korea by the public research laboratories connected to the electronics and computer industry and the creation of science-based industrial parks. For example, more than half of the new firms based in Hsinchu Science-based Industrial Park has been established or supported by returning foreign-trained Taiwanese since 1980 (National Science Council, 1997).

Public funding of applied science in universities

The rise of applied science often depends on the universities' success at securing greater public funds for their institutes and labs. In Germany, for example, increases in public funding fed the accumulation of technological capabilities during the 1820–1870 period, as a result of a growing recognition that valuable research in natural sciences and medicine required adequate funding and as a response to the dependence of a growing number of doctoral students on lab research.

The contrast between Germany and Britain in university funding is especially striking.[9] British universities received far less public funding, supported less technical education, and were less closely linked with industrial research (especially in such industries as chemicals) than was true in Germany by the 1880s. British university enrolment increased between 1900 and 1913 by 20 per cent, far less than the 60 per cent increase in German university enrolment during the same

It is necessary to strike a balance between supporting research that responds to the current needs of industry and making sure that part of the funding is allocated more flexibly to research with potential future returns.

Box 4.2 **The US public agricultural research infrastructure**

Much of the remarkable productivity performance of US agriculture during the past century has been attributed to public investments in agricultural R&D and extension. By the end of the 19th century the US was investing more than US$60 million (in 1984 dollars) in agricultural research, an amount that by 1925 had grown sevenfold in constant-dollar terms. By the mid-1950s, private and public R&D investment in agriculture amounted to more than US$1.5 billion. During the earlier period, total factor productivity in US agriculture grew at an average annual rate of 1.55 per cent, enabling an increase in real agricultural output during this period of more than 550 per cent, while real inputs grew during this entire period by only 15 per cent. Publicly funded research and extension account for more than half of total factor productivity growth between 1950 and 1982, a higher fraction than that accounted for by privately funded R&D.

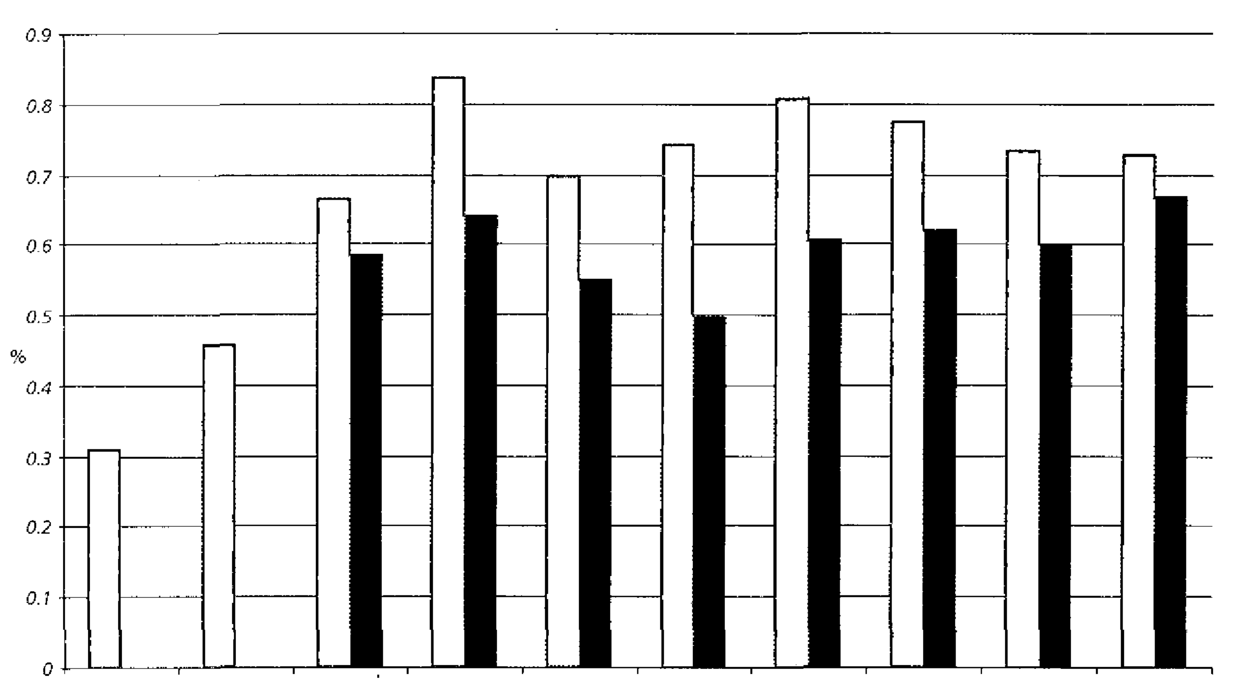
The Morrill Act of 1862 laid the foundations for the public agricultural R&D system in the US. The Act granted federal lands to each state for the establishment of colleges devoted to teaching agricultural and engineering subjects, thereby creating some of the first research and teaching institutions in these fields. The next major step occurred in 1887 with the passage of the Hatch Act, which was influenced by developments during the 1850s and 1860s in European agricultural research, aided by the development of agricultural chemistry in Germany and the UK. Much of the research activity in both nations was centred in 'experiment stations' that sought to apply new scientific advances to agricultural practice. The United States Department of Agriculture (USDA) had begun its own research program in the 1860s, focusing on analyses of soils and fertiliser and the development of standards to prevent the adulteration of agricultural inputs, but this program was modest in scope. The Hatch Act provided federal financial support for agricultural experiment stations in each state, with management responsibility for these institutions delegated to state governments. The research institutions created by the Hatch Act drew on both federal and state funds, and in some cases performed research under the terms of privately funded contracts.

The other major component of the US public agricultural R&D system was the agricultural 'extension' system, designed to support the adoption of agricultural practices and technologies. The Smith-Lever Act of 1914 expanded and 'nationalised' these activities and the resulting agricultural extension system incorporated state and federal funding and personnel, with considerable variety in organisational structure and linkages to academic agricultural research and teaching. Non-federal public funds played an important role in supporting key activities, such as the state agricultural experiment stations and agricultural extension. The share of state funds has risen significantly since the early 20th century, from approximately 46 per cent in 1905 to more than 70 per cent by 1985. A similar trend is apparent in the state share of funding for agricultural extension activities during 1915–1985 (figure 4B.3).

The balance between private and public R&D investment kept shifting. Until the end of the 19th century, private sources accounted for the majority of agricultural R&D investment. But in the aftermath of the Hatch Act and the Smith-Lever Act, public funding grew significantly. By 1915, public funding outstripped private R&D funding by almost 50 per cent, and public funding accounted for the majority of agricultural R&D investment until 1945. Private investment in agricultural R&D grew more rapidly during the post-1945 period than public investment, however, and by 1985, privately financed agricultural R&D exceeded public investment by nearly 40 per cent.

The prominent role of state funding within the US agricultural research system both reflects and reinforces the broad political support for public agricultural R&D investment. This funding structure also reinforces closer linkages between public research programs and local groups of users (farmers in various climate and crop regions) whose needs vary substantially from one state to another. A drawback is that the decentralised structure of the resulting publicly-financed R&D system, as well as its close links to important client groups, has weakened the public sector's performance in fundamental research and has made the system less responsive to new scientific opportunities.

Figure 4B.3 **Funding for U.S. agricultural R&D institutions (1895–1985)**



Source: Huffman and Evenson, 1993.

Sources: Huffman and Evenson, 1993.

period.[10] In Germany, lobbying by chemical industry organisations, the election to legislative bodies of leading figures from the chemicals industry,[11] and industry-academic collaboration for the support of applied research all played a role in prompting the expansion of public funding for academic research in chemistry, which culminated in the establishment of the Kaiser Wilhelm Institute for Chemistry in 1911.

The system whereby funds are allocated has been a key element in the design of public support programs for academic research. The Japanese experience suggests that increases in research funding that are not accompanied by greater emphasis on competitive allocation will have limited effects on the overall quality of the academic research enterprise. While it matters to ensure continuity and relevance, it is also necessary to strike a balance between supporting research that responds to the current needs of industry and making sure that part of the funding is allocated more flexibly to research with potential future returns (box 4.3). Furthermore, the experience of Korean universities discussed above highlights the importance of teaching-research complementarities and the role of public funding in promoting (or hampering) these linkages.

Role of public research and technology support institutes

The relationship between tertiary education in science and engineering and technological capability building is often mediated by public research institutions. These have benefited, on the input side, from the domestic scientific and engineering talent produced by the local universities and polytechnics. On the output side, they have provided assistance to indigenous firms in inward technology absorption and in performing domestic R&D and other kinds of technology-based business services.

Creating a domestic supply of scientists and engineers may not be sufficient to induce the emergence of private sector's demand for their knowledge. Particularly during the early phase of industrial development, the creation of an effective technology infrastructure is likely to require a set of complementary policies and institutions to support private entrepreneurial efforts. This was perceived to be an important policy tool in Japan, where instead of focusing on supporting research activities within universities, the government established a rather extensive system of public institutes and laboratories where various kinds of research activities related to industry and agriculture were carried out[12] (Bartholomew, 1989). Japanese government policy was influenced at least partly by the German system of universities, Hochschulen, and research institutes such as the Kaiser Wilhelm Gesellschaft laboratories, as well as the National Laboratory in Britain and the US National Bureau of Standards (which were perceived as having provided critical support to the country's industrial development). Private firms in these countries, particularly in sectors like chemicals and electrical equipment, had begun carrying out R&D activities in-house (Odagiri and Goto, 1993 and Uchida, 1980). The same was not true in Japan, where domestic firms in these industries relied upon the adoption of foreign technology and to a lesser extent on publicly funded research. In fact, public support for research aimed at industrial development increased as the access to foreign technology began to be restricted.

Technology support institutions in the Republic of Korea and Taiwan Province of China

Competence-building in the Taiwan Province of China and the Republic of Korea required policymakers to design institutions and invest in capabilities for which there was little initial demand. Imbalances in the national supply and demand of skilled personnel were remedied through private-sector development and policies that struck a balance between catering to current needs and anticipating future needs of industry. This was achieved to some extent by ensuring two-way information exchanges between research labs and universities and the private sector through personnel and technical knowledge flows.

Unlike their counterparts in industrialised nations, public R&D and technology support institutions were primarily

Box 4.3 R&D matching grant system in Costa Rica

In 2000, the government of Costa Rica introduced the Fondo de Recursos Concursables (FRC) – an R&D matching grant system to finance projects that contribute to innovation and technological change. The FRC is assigned approximately US$1.3 million yearly and is administered by the Ministry of Science and Technology (MICIT). By 2003 MICIT had financed 30 projects as part of the FRC, 25 of which were associated with agriculture and agro-manufacturing sectors, while the rest targeted industrial projects.

FRC is open to all SMEs and industry associations. In the first phase, these submit proposals for evaluation by MICIT according to their quality, clarity of objectives, justification of the technological need of the sector, the promised financial contribution, creativity and novelty of the proposal and the potential impact of the technology on the environment and economy. The selected projects receive a grant as a contribution share in line with their perceived externality. In a second phase, certified research institutes present their proposals for the projects selected in the first phase, and these proposals are selected according to the criteria of quality and price.

Costa Rica's R&D matching grant system responds to demands from the private sector, creating an environment of competition with the aim of both increasing the pertinence of projects to industrial development and reducing costs. The more applied the projects are, the less are the externalities that may be reaped, so the system is designed such that the government's contribution falls down as the benefits to the sector and economy at large decrease. Furthermore, the formal and periodic evaluation of presented and financed projects generate useful information both for the private sector and the policy makers. As technological, managerial and fund-raising capabilities of both the firms, industry associations and research centres increase, the system can also be expected to evolve and generate higher returns in terms of innovative activity and economic performance.

Source: Rodríguez-Clare, 2003.

engaged in technology development rather than in basic and applied research at the frontier of innovation. This was necessitated by the particular capability building needs of the industry as perceived by the government.

The efforts of public research labs in transferring and disseminating technology preceded the high-tech era. The institutional framework for capability building was established much earlier with the rise of agricultural support institutions and technology extension services with a mandate to demonstrate improved production and quality control methods and to provide management training courses. In the case of Taiwan Province of China, most of these institutions were put in place in the late 1950s and early 1960s, following the formulation of the first economic development plan in 1953.[13]

Numerous Taiwanese technology support institutions were established in the 1960s and early 1970s in order to facilitate the early phase of industrial development. The Metal Industries Development Centre, founded in 1963, was followed by similar technology development centres for chemicals, mining, energy, glass, textiles and food processing. State-run enterprises also set up research units, such as the Telecommunications Laboratories. In addition to these, the government sponsored the formation of a joint public-private consulting service to promote exports of machinery and whole production plants (Amsden, 1984 qtd. in Wade, 1990, p. 95). The National Science Council (NSC), established in the 1950s to oversee industrial technology development, monitored the creation of the Council for Economic Planning and Development (CEPD) and the Industrial Development Board (IDB). Furthermore, in order to collect, analyse and process information on S&T gathered domestically and abroad, as well as to serve as a contact point for all Taiwanese S&T institutions, the NSC established the S&T Information Centre in 1974.

The consolidation in 1973 of three existing public research laboratories (Union Industrial Research Laboratories, Mining Research and Service Organisation and Metal Industrial Research Institute) into the Industrial Technology Research Institute (ITRI) marked a watershed in Taiwanese competence-building policies. In subsequent years, ITRI played a key role in developing applied industrial technologies for key components and capital equipment; as an important source of technology training in process engineering, equipment engineering, product engineering, facilities and testing; and of management training in such areas as quality assurance, industrial engineering, production control and materials control.

These laboratories were soon complemented by a new one, the Electronics Industrial Research Centre (later renamed Electronics Research and Services Organisation, ERSO). ERSO was established to spearhead a national effort to develop indigenous capabilities in designing and manufacturing semiconductors. Through a license agreement with RCA, ERSO acquired its C-MOS technology in 1976 and established in 1977 a pilot production plant that could serve as a training facility. Later on, the technology was handed over to a spin-off firm, the United Microelectronics Corporation (UMC), whose ownership was turned over to private investors in stages. UMC's technical staff at birth included many engineers from ERSO.

ERSO promoted capability-building in the industry through both the transfer of technology to firms and the training of specialised engineering and scientific talent.[14] The same strategy was adopted through the 1980s and 1990s in order to develop a capability in component technologies for the electronics sectors. These included design and manufacturing of very large scale integration (VLSI) and dynamic random access memory (DRAM) chips, fabrication masks, CD-ROM, DVD-ROM, and Thin Film Transistor Liquid Crystal Display (TFT-LCD) display technology, among others. For virtually all these technologies, ERSO identified suitable foreign partners to acquire a license or enter a technology transfer agreement, and proceeded to establish a laboratory or pilot plant as a centre for technological learning and capability-building based on training and experimentation. In most cases, technologies and capabilities developed in this way were then spun off to newly formed enterprises.

In other cases, the technology would be licensed to the relevant firms or the firms would simply rely upon capabilities learned through their cooperation with ERSO to develop their own technology or enter licensing agreements with other firms. The interactions between firms were concentrated around ERSO headquarters and the neighbouring Hsinchu Science Park. The growth of chip design firms was facilitated by the Multi Project Chip undertaken by ITRI to provide universities with computer aided design (CAD) tools for chip design as well as chip foundry services. Nine universities participated in this initiative, training scores of specialists in chip design whose firms were then able to contract out to other firms in the cluster for manufacturing and other downstream activities.[15]

The electronics industry in Taiwan Province of China has until recently been very much fuelled by the creation of new entrepreneurial firms based on the technology transfer activities carried out by various divisions of ITRI, such as ERSO and the Computer and Communications Laboratory. Between 1979 and 1983, ITRI invested approximately US$18 million to further upgrade integrated-circuit (IC) technology and improve design technology through the introduction of computer simulation programs. At this stage, ITRI also developed logic simulation programs for mask design and developed capability to produce masks through transfer of technology from abroad. Later, between 1983 and 1988, process technology was improved and a Common Design Centre was initiated to disseminate application-specific IC technology to firms. In order to achieve widespread technology transfer of the basic design methodology and CAD tools to enterprises, the Common Design Centre offered training courses, CAD design software tools, design handbooks and conferences.

The model has been replicated by other government agencies, including the Institute for Information Industry (III), established in 1979 to support the development of domestic personal computer (PC) manufacturers, as well as laboratories and institutes aimed at other technology areas in Taiwan Province of China. In particular, the Market Intelligence Centre (MIC) was established by the III with the aim of assisting the government and industry in assessing and understanding the global business trends, while also allowing foreign companies and investors to understand the local IT business environment. Similarly, the Exhibition Centre for IT Promotion was established with the aim of educating the public particularly in rural areas on the growing applications of IT[16] (box 4.4).

In the early 1970s the Republic of Korea's government decided to make a big push for an indigenous technological capacity in electronics and informatics. The electronics industry was selected as one of the six industries to be promoted under the Heavy and Chemical Industry Plan of 1973. First, the government set out to create industry-oriented research institutes, both public and private, and to expand advanced training capacity in electronics. In addition it started to encourage technology transfer via licensing and consultants, rather than rely on FDI. In 1976 the Korea Institute for Electronics Technology (KIET) was established to plan and coordinate semiconductor R&D, provide technical assistance to firms, assist technology transfer from abroad and conduct market research. KIET indeed helped to pioneer the mastery of medium-scale semiconductor technology, but found that by about 1984 the *chaebols* had far superior production facilities and were rapidly expanding their in-house R&D capacity. So it changed its mandate (as well as its name, to Electronics and Telecommunications Research Institute) and sold most of its fabrication facilities to the private sector. It turned to initiating parallel basic research in semiconductors, computers,

The dissemination of environmental technologies through public research and extension services illustrates how public research institutions can help create new capabilities within the private sector.

Box 4.4 Federal R&D spending and creation of IT industries

Federal R&D spending in the US, much of which was defence-related, played an important role in the creation of an entire complex of 'new' post-war IT industries, including semiconductors, computers, and computer software. The origins of the Internet can be traced back to these efforts. Internet-related projects funded through the Department of Defense (DOD) include Paul Baran's early work on packet switching, the Advanced Research Projects Agency Network (ARPANET), and research on a variety of protocols, including the Transmission Control Protocol/Internet Protocol (TCP/IP). These public R&D investments in networking technology were preceded by 15 years of DOD investment in hardware and software technology that began with the earliest work on numerical computing. Federal R&D investments strengthened US universities' research capabilities in computer science, bankrolled the early deployment of the ARPANET, facilitated the formation of university spin-offs like BBN and Sun, and trained a large cohort of technical experts who aided in the development, adoption, and commercialisation of the Internet.

There is little data to estimate the total federal investment in Internet-related R&D. Even were such data available, the complex origins of the Internet's various components would make construction of such an estimate very difficult. Nevertheless, it is clear that federal investment in the academic computer science research and training infrastructure that contributed to the Internet's development was substantial. According to a recent report from the National Research Council's Computer Science and Telecommunications Board, federal investment in computer science research increased five-fold during the 1976–1995 period, from US$180 million in 1976 to US$960 million in 1995 in constant (1995) dollars. Federally funded basic research in computer science, roughly 70 per cent of which was performed in US universities, grew from US$65 million in 1976 to US$265 million in 1995.

Between 1956 and 1980 the cumulative National Science Foundation (NSF) funding for research in 'software and related areas' amounted to more than US$250 million, in 1987 dollars. Most of this funding went to US universities. Funding from the Defense Advanced Research Projects Agency's (DARPA) Information Processing Techniques Office (IPTO), which went to both universities and industry, averaged roughly US$70 million annually (1987 dollars) between 1964 and 1980, before growing sharply to more than US$160 million in 1984–1985. Between 1986 and 1995, the NSF spent roughly US$200 million to expand the NSFNET. The investments of NSF and DARPA in almost certainly constituted a majority of Internet-related R&D funding, especially in academia. These federal R&D expenditures were sizeable and importantly, contributed to both research and training of skilled engineers and scientists.

In addition to their size, the structure of these substantial federal R&D investments enhanced their effectiveness. DARPA's research agenda and managerial style gave researchers considerable autonomy and the agency spread its investments among a group of academic 'centres of excellence'. In its efforts to encourage exploration of a variety of technical approaches to research priorities, DARPA frequently funded similar projects in several different universities and private R&D laboratories. Moreover, the DOD's procurement policy complemented DARPA's broad-based approach to R&D funding. Contracts were often awarded to small firms such as Bolt, Beranek and Newman (BBN), which received the contract to build the first Interface Messaging Processor (IMP). This policy helped foster entry by new firms into the emerging Internet industry, supporting intense competition and rapid innovation.

The large scale of the US defence-related programs in computer science research and networking distinguished them from those in the UK and France; but the contrasts extend beyond the scale of these R&D programs. Unlike their counterparts in the Soviet Union or the UK, DOD program managers in information technologies, even before the establishment of DARPA, sought to establish a broad national research infrastructure in computer science that would be accessible to both civilian and defence-related firms and applications, and disseminated technical information to academic, industrial, and defence audiences. Classified R&D was important, but a great deal of US defence-related R&D consisted of long-term research that was conducted in universities, which by their nature are relatively open institutions.

Another factor in the success of federal R&D programs was their 'technology-neutral' character. US research programs avoided the early promotion of specific product architectures, technologies, or suppliers, in contrast to efforts in other industrial economies, such as the French 'Minitel' program, or celebrated post-war US technology policy failures, such as the supersonic transport or the fast-breeder nuclear reactor. The NSF, for example, focused on funding a variety of academic research projects, largely through grants to university-based computer scientists which formed a key component of the research and training infrastructure that supported the development and diffusion of the Internet. In addition to their research contributions, university computer science departments and Computer Science Networks (CSNET) formed the core of the early Internet.

Sources: National Research Council, 1999; Langlois and Mowery, 1996; Cerf, 2000; Nelson, 1984.

and telecommunications, more focused on technology frontiers rather than on commercialisation, which was now left to the *chaebols* (Wade, 1990).

The dissemination of environmental technologies through public research and extension services illustrates how public research institutions can help create new capabilities within the private sector to respond to the emerging competitive challenges while promoting sustainability. The Taiwanese government vested in IDB the authority for identifying cost-minimizing treatment technologies, lowering costs of abatement and reducing energy and water input intensities of production. Perceiving the opportunities for product differentiation and productivity gains, IDB invested in information gathering about the costs of alternatives and established with the Taiwan Environmental Protection Administration a joint program in pollution prevention and waste control. It also subsidised the purchase of pollution-control equipment by offering tax reduction, accelerated depreciation and access to subsidised credit for pollution control equipment purchase. ITRI was used to engage in state-of-the-art research on energy, water, materials and pollution intensity of sectors, including establishing performance benchmarks against international best practices. The Energy Research Organisation was established within ITRI in 1981, evolving into the Energy and Mining Research Service Organisation in 1983 and later the Energy and Resources Laboratories (ERL) in 1989. Since the early 1980s, ERL has played an important role in promoting clean production by benchmarking critical measures of resource use in important sectors, such as in wafer fabrication and cement production. Subsequently, IDB began providing technical assistance through private sector consulting firms and ITRI to help firms reach these standards and benchmarks (Angel and Rock, 2003) (box 4.5).

Technological infrastructure and industry

Interaction between universities and industrial firms

Since technologies cannot be taken 'off the shelf' and simply put into use by industrial firms, very little can be accomplished by way of assimilation of imported technologies without infrastructural investments in education, training, R&D, and other scientific and technological activities (Freeman, 2002, p. 156). On the other hand, the scope of the contributions of universities and public research institutes to capability building in a sector must evolve with the nature of the technological activities carried out by national firms, their access to other sources of technological knowledge, and the structural characteristics of the evolving industry (i.e. the presence of large corporations, or clusters of small- and medium-sized enterprises, etc.) (see further Chapter 6).

Policies aimed at creating demand for technological skills may be necessary if investment in advanced educational institutions is to be at all successful in assisting local firms with the accumulation of technological capabilities.

The role of universities and public research in technological catch-up is manifold and extends beyond the supply of domestic scientific and engineering talent. Universities and public research institutions contribute by providing assistance to indigenous private and public firms with the inward transfer of technology and other technology-based business serv-

Box 4.5 Emerging innovation system in satellite and geographic information in South Africa

Universities and publicly funded research institutes in South Africa have been making impressive strides in raising technological capabilities in geographic information and satellite technologies, forming in recent years the basis of a sectoral IS. In the southern African context, satellite-based information can make a powerful contribution to supporting sustainable development by developing and implementing products and services to address the needs of many users spread over a large area. Satellites currently in earth orbit provide monitoring information on the status of the earth's resources, environment, urbanisation and weather patterns. They are ideal for a wide range of applications to monitoring fires, marine phenomena, changing demographics, crop yields, land cover and droughts.

A good example of the emerging IS is the pioneering work done by the University of Stellenbosch by developing South Africa's first satellite, SUNSAT 1, launched into space in 1999. This micro satellite was designed, built, and tested by 22 Masters of Engineering students and the faculty at the Electronic Systems Laboratory in the Department of Electrical and Electronic Engineering. The development of SUNSAT 2, using new generation micro satellite technology, has been under way. This program combines both challenging research at the graduate level and train engineering students for an R&D career, while also requiring the adoption of systematic processes for product development from industry.

Simultaneously, the council for Scientific and Industrial Research (CSIR), the largest scientific and technological research, development and implementation organisation in Africa, and its stand-alone The Satellite Applications Centre (SAC) have been carrying out research and training to support the emerging satellite and remote sensing applications in the region. The Earth Observation unit at SAC offers training courses aimed at encouraging and supporting the growth and scope of indigenous remote-sensing techniques and capabilities in Africa.

Sources: CSIR, 2005; Schoonwinkel and Milne, 1997.

ices. A crucial determinant of an effective relationship between university and industry is the degree of responsiveness of educational curricula and activities to the emergence of new areas of industrial technology or specialised sectors.

Complementary policies aimed at creating demand for technological skills may be necessary if investment in advanced educational institutions is to be at all successful in assisting local firms with the accumulation of technological capabilities. As mentioned earlier, most instances of brain drain can be ascribed in part to the imbalance between the domestic supply of scientific and engineering talent and the demand for it by national firms.

It is well known from contemporary research on innovation systems that industrial sectors differ in their reliance on scientific and engineering knowledge and research results. There are also differences between sectors with respect to the mechanisms and channels for the transmission of knowledge and information across the university-industry interface.

The 19th century chemical and electrical equipment industries are often reputed to have been the first science-based industries, which makes it useful to review the role played by universities and *Hochschulen* in their development. University-based laboratory training in chemistry supported the acquisition of technological capabilities for chemical firms whose activities included the first forms of systematic R&D in an industrial setting. After undergoing reforms to increase the influence of lab-based training in the *Hochschulen*, by the 1870s Germany had nearly 30 university and technical university departments in organic chemistry, and seven major centres of organic chemistry research and teaching. Many of those who were technically trained in them moved into senior management positions within German industry, further strengthening the links between corporate strategy and industrial research (Murmann, 1998). Interaction with the chemical research conducted by the university system was among the main reasons for the rise to leadership of German firms in the production of synthetic dyes.

Broadly speaking, the growth of Germany's chemicals industry followed the development of strong research capabilities in German universities during the 19th century, and a similar pattern is apparent in the development of the German electrical equipment industry. The same cannot be said of either Japan or the US, however, where domestic universities' contributions to training of scientists and engineers outstripped their contributions to research throughout this period. In the case of Japan, university contributions to training remained more significant than academic research excellence through much of the post-1945 period, although university faculty were important technical consultants for many large Japanese industrial firms. Indeed, the weakness of scientific research in Japan's national universities reflected the legacy of the structure established in the late 19th century (see box 4.6).

On the other hand, the reliance of many US universities on state government funding, the modest scope of this funding, and the rapid expansion of their training activities all supported the growth of formal and informal linkages between industry and university research. US universities formed a focal point for the external technology monitoring activities of many US industrial research laboratories before 1940, and at least some of these university-industry linkages involved the development and commercialisation of new technologies and products. Linkages were often created through the use of industry-sponsored research contracts. One of the pioneers of this institutional adaptation was MIT. Although MIT did not have an engineering station, it adopted in 1920 a Technology Plan which established the framework for industry-sponsored research contracts for its faculty. Public institutions replicated this model through the creation of affiliated research foundations, circumventing restrictions on their contractual relations with specific firms.

Skill development

Skill formation in the private industrial sector has been a critical component of the technological capability-building efforts in virtually all catching-up countries. Public policy has often helped to shape these efforts, both by means of legislation on accreditation and certification and by active government policies to encourage skill formation through the use of levies and incentives.

The development of skill-building institutions in Germany during the late 19th century provides a good example on the role of public policy in this area. Germany has long been considered exemplary for its vocational system, which to this day attracts large numbers of youths and produces high-quality skills. However, the roots of the skill formation system in Germany goes back to the presence of an independent artisan sector which was formally and legally endowed with rights to regulate training and certify skills. Foundational legislation in 1897 created a framework for apprentice training under the control of an organised handicraft *(Handwerk)* sector, which was composed of self-employed master craftsmen who were distinguished in legal terms and social status both from industry and from the journeymen and apprentices they employed. This framework had important implications for the emerging labour unions and skill-intensive sectors such as machine industry, since it meant that the industry could rely on a relatively steady stream of certified skilled workers from the artisan sector. Later on, though, as the technological sophistication of industry increased and the skills provided by *Handwerk* proved increasingly insufficient, private machinery firms started internalising skill formation at company level and providing training as part of internal social programs. However, the legislation did not allow the firms to certify the skills their training conferred. The machine industry found it unacceptable that while they still had to contribute financial resources for public training, their needs were not being met and the training they dispensed was not recognised. As a result, large industrial firms started collaborating to demand the creation of a parallel system for promoting and certifying industrial training under the collective control of the Industry and Trade Chambers. An important turning point was the founding of the German Committee for Technical Education, jointly sponsored by Association of German Engineers and Association of German Machine-Building Firms. These efforts

Box 4.6 Role of public research institutions in sectoral IS – Japan vs. Brazil iron industry

The beginnings of the iron and steel industry in Japan vs. Brazil reflect the important fact that the institutional components of technology infrastructure differ across industrial sectors and across the phases of the life cycle of national industries. These differences reflect among other things the nature of the learning processes associated with acquiring capabilities.

In Japan, the Industrial Experiment Laboratory was putatively in charge of conducting some research and testing on iron and steel beginning around 1906. However, until 1915 its contributions in this area of industry were overshadowed by the activities of the state-owned steel firm Yawata Works, and later on by the research activities of the Iron and Steel Institute of Japan and of the Institute for Metals Research at Tohoku University. Production at Yawata Works represented the first foray by a Japanese company into the area of large-scale steel production. Yawata became a centre of technological learning and of technology diffusion, partly by providing technical assistance to other firms and partly through the migration to other companies of trained personnel. Indeed, the Iron and Steel Institute of Japan, established in 1915, became the industry's institutional venue for conducting cooperative research and broadly disseminating technological knowledge. The Institute's membership enjoyed extensive representation from both the academic and the industrial community, including not only iron and steel producers but also users. The Institute played an important role in the standardisation of iron and steel products, and the dissemination among domestic firms. The same form of partnership between institutions was also responsible for the establishment of the Institute for Metals Research, which started operating in 1916 with support from the government and Sumitomo Metals.

The iron and steel sector was in fact characterised by the importance of experience-based learning. Moreover, scale economies and the complexity of integrating vertically-related productive processes raise the financial requirements for entry. Under these conditions, a large public steel works was an essential component of the sectoral system of technological learning. While the industry benefited from the training of metallurgists and mining engineers at domestic universities, Yawata Works appears to have been a crucial element in the development of indigenous technological capabilities, by supporting their formation at the birth of a substantial number of private firms.

On the other hand, in Brazil the lack of policies to increase demand for skills in the private sector limited the impact of public training and research institutes in promoting sectoral development in its iron and steel industry. As early as the 1850s the owner of what was then the largest forge in Brazil, Jean Monlevade, had noted the importance of a model iron works as a centre for technological learning necessary for the creation of indigenous capabilities. However, financial support for such an investment failed to materialise. A couple of decades later, in 1876, the Escola de Minas, a school dedicated to mining and metallurgical engineering was established, modelled after the French Ecole des Mines. However, until the 1910s there was insignificant level of investment and enterprise formation in the industry and hence there was no demand for scientific and technological capabilities such as those provided by the Escola de Minas. Indeed, the school's survival was secured during the 1880s by the decision to provide training for civil engineers rather than persevering as a specialised school for mining engineering, a condition laid down by the provincial government of Minas Gerais in exchange for financial support.

Both members of the faculty and graduates of the Escola became involved with furnace design and plant management activities during the 1910s and 1920s, when a number of new iron and steel firms was formed, thanks in part to government financial support. But even the new plants were of limited scale by contemporary global standards. Since the 1930s, production experience and foreign technical assistance became the most relevant channels for technological learning. This was the case during the construction of the plant of the Companhia Siderurgica Belgo-Mineira in Monlevade, of the plant of the Companhia Siderurgica Nacional in Volta Redonda, and the plant of Usiminas in Ipatinga.

These examples show that creating a domestic supply of scientists and engineers may not be sufficient to induce the emergence of a private sector's demand for their knowledge. Particularly during the early phase of industrial development, the creation of an effective technology infrastructure is likely to require that a set of complementary policies and institutions be in place to support private entrepreneurial efforts.

Sources: Yonekura, 1994; Carvalho, 2002; Gomes, 1983; Mazzoleni, 2005; Paula, 1983; Dahlman, 1984.

culminated in a layered system of skill formation that gave Germany a distinct advantage in the development of technological capabilities in the machine industry (Thelen, 2004).

On the other hand, governments in Japan, the Republic of Korea and Taiwan Province of China deliberately pursued policies to encourage skill formation in industry. In Taiwan Province of China, government policies were largely motivated by the perception that private training left to its own means was inadequate. While available data about trends in public and private training is rather sparse, the last and most recent survey of in-firm training in Taiwan Province of China seems to have taken place in 1986 when the manufacturing census polled 56 047 firms. It found that only nine per cent of the sampled firms were engaged in formal training of any kind – roughly equal to the percentage of firms carrying out R&D (Tan and Batra, 1996). A smaller 1985 sample of data covering 5 619 firms from the Vocational Training Needs Survey conducted by the Directorate General of the Budget, Accounting and Statistics (DGBAS) shows that 21 per cent of the sampled firms had engaged in vocational training lasting more than one month. While the size and sector of the firms clearly affected their propensity to conduct training, training institutes provided 28 per cent of this training, another two per cent were trained abroad and approximately ten per cent of in-firm training of skilled labour was carried out through training programs contracted between factories and vocational schools (San, 1990). Large corporations such as Rexon and Acer made up most of in-firm formal training, but as SMEs account for up to 85–90 per cent of Taiwan Province of China's trade sector, the government has found it difficult to encourage in-firm training on a large scale.

As a response to low levels of in-firm training, many Asian countries experimented with skill levies to encourage skill formation, but without much success. Similar to the Taiwanese experiment with the Vocational Training Fund Statute (VTFS), which required all public and private enterprises with over 40 employees to contribute at least 1.5 per cent of their payroll to a vocational training fund and get reimbursed for providing training, the Republic of Korea's Special Law for Vocational Training was largely unsuccessful in promoting in-firm training as most companies preferred to pay the fine rather than provide the required six months of instruction. Singapore may have been one of the few successful exceptions in the use of training incentives to promote IT skills among firms.[17] The difficulties in encouraging in-firm training especially in the early stages of catching-up, compelled Taiwan Province of China to rely more on the public vocational education system as a source of technological capability building.

Entrepreneurship development

The promotion of entrepreneurship development is largely inspired in the Schumpeterian concept of entrepreneurial venture, that this author called 'the fundamental phenomenon of economic development', since it means creating new goods, investing in new methods of production, devising new business models and opening new markets (Schumpeter, 1942, p. 83). Entrepreneurial development policies aim to foster such venturing, both by supporting existing entrepreneurs and, perhaps more significantly in a development context, by fostering nascent entrepreneurs. University and public research lab spin-offs, incubator programs and other forms of clustering, managerial and entrepreneurial training and venture capital support are some of the tools of entrepreneurship development policy.

Although entrepreneurship development policies have been gaining growing recognition rather recently both in developed and developing countries, their impact on encouraging innovative activity is most clearly revealed by the catching-up experience of Taiwan Province of China.[18] More recently, entrepreneurial development in certain high-technology sectors through brain circulation of expatriates and emerging venture capital schemes in countries such as India and Costa Rica attest to the increasing significance of policies in this area.[19]

One of the most significant venues of entrepreneurship development policy in Taiwan Province of China was the close interaction between public research labs and start-ups. This interaction gave raise to some of Taiwan Province of China's most successful spin-offs. This was the case with Taiwan Semiconductor Manufacturing Corporation (TSMC), formed as a joint venture with Phillips for manufacturing VLSI chips, with Taiwan Mask Corporation, spun off from ERSO in 1989 as a specialised producer of fabrication masks, and with Vanguard International Semiconductor, a spin-off firm that established itself as the leading DRAM manufacturer. A considerable number of the start-up electronics firms that over time were formed in Taiwan Province of China featured ERSO-trained people as managers and CEOs. By 2000 more than 15 000 professionals had worked for ITRI, and 12 000 had gone on to hold positions in the high-tech sectors of the economy (Amsden and Chu, 2003). The establishment of the Hsinchu Science Park in 1980 and subsequent efforts at promoting entrepreneurship and high-tech start-ups in ten science parks across Taiwan Province of China has been a major policy tool in development of ventures. The pioneering Taiwanese experience has had a considerable demonstration effect across developing Asia and elsewhere.

Engineering Research Associations[20]

Engineering Research Associations (ERAs) are an institutional means of promoting collaborative R&D work between companies, either on their own initiative or in partnership with a public agency. They have been used to great effect by the Japanese in their technological catch-up efforts, particularly during the 1960s and 1970s. But the origin of ERAs dates back to previously existing research institutions, notably in Britain during the WWI. In 1917 the British government started to give financial aid to industries, which organised research and technical activities on a cooperative basis. The scheme was introduced with the aim of meeting the acute technological needs of British industry, the shortcomings of which had been revealed during the war. The government provided grants matching those of member companies in each of these research associations. Originally the intention was to discontinue the grants once a research association was established, but the policy was changed in 1945 to provide for permanent grants. The British research associations were successful in promoting certain industrial areas, particularly in enabling consortia of SMEs to match the scale and resources of large firms.

The engineering research associations in Japan drew on the British model, but embarked upon a dynamic development on their own. ERAs were used as a policy instrument in the aftermath of WWII in Japan, and enjoyed significant success, unlike many other experiments with research associations or their functional equivalents elsewhere. The initiative for establishing an ERA came in the earlier period from industry, to serve their basic needs, not from the government. Furthermore, as an adaptation of British research association model, none of the Japanese ERAs were intended to become permanent organisations. The average length of existence was 11.5 years for the ERAs established in the 1960s. The ERAs were established as non-profit making associations under a special regulation promulgated in 1961 and between then and 1983 a total of 71 ERAs were established.

Industry research associations are an important means of raising technological capabilities across the board in a given industry, as they facilitate the exchange of technical information.

Some of the earliest ERAs were created under the direct control of Japan Auto Parts Association (JAPIA) at a time when Japan did not manufacture passenger cars, so the companies involved with research associations were largely concerned with establishing practical results for testing components and improved production methods for buses and trucks. Furthermore, the ERAs played a very important educational role as the participating companies sent their engineers to the joint facilities for varying amounts of time.

Later on ERAs were seen by Ministry of International Trade and Industry (MITI) as a powerful policy instrument to support competitiveness in certain sectors such as information technologies. As opposed to other alternatives for channelling funds to support company-based industrial research – such as joint contracts, individual contracts for separate companies or even, to some extent, non-profit foundations – ERAs were perceived to be much more efficient in terms of resources required for their initiation and supervision. The length of the associations' lifespan seems to have shortened over time, and the MITI-supported laboratories often served more as a breeding ground for new technologies than as a means of addressing the immediate needs of industry.

Clearly, industry research associations are an important means of raising technological capabilities across the board in a given industry, as they facilitate the exchange of technical information. In addition to the opportunities for risk and cost sharing between participating units, the pooling of resources tends to speed up the research process and eliminate overlaps while ensuring that the research effort covers all aspects of product development.

Metrology, quality and standards institutions

A much under-studied aspect of technological infrastructure is the role played by standards, quality and metrology institutions in the formation of sectoral innovation systems. Although the proliferation of international standards and technical regulations is a relatively recent phenomenon, the current trends can be expected to increase the significance of capabilities embedded in these institutions and their role in promoting industrial deepening and technological catch-up (see further Chapters 7 and 8). Taiwan Province of China and the Republic of Korea provide valuable lessons in the role of standards and quality institutions in promoting industrial development, especially in certain sectors such as electronics.

The origins of the metrology, standards and quality control legislation and institutions in Taiwan Province of China and the Republic of Korea go back to the Japanese occupation. After their departure, the former Department of Administration in Taiwan Province of China combined the inspection institutions that were established during the Japanese occupation for fertilisers, plants, rice, canned food, and tea leaves into the Inspection Bureau under the jurisdiction of the Provincial Department of Agriculture and Forestry in 1945. In 1947, the National Bureau of Standards (NBS) was founded under the Ministry of Economic Affairs (MOEA), merging the National Weights and Measures Bureau and the Industrial Standards Committee originally established in the 1930s.

A good example of government's efforts to increase the quality of exported products through technical assistance and quality control is the export of bicycles to the US in the 1970s. In order to ensure that Taiwanese bicycle manufacturers could access US markets more easily and establish a reputation for high-quality exports, the government commissioned the Metal Industries Development Centre to design testing equipment for bicycle quality control and provided technical assistance to the firms to comply with the established standards. This was instrumental in improving the quality and marketability of bicycles and as a result by the end of 1970s Taiwan Province of China was exporting several million of them, having started with almost none at the beginning of the decade[21] (Dahlman and Sananikone, 1990).

As the phase of export promotion exerted more pressure on the standards and quality institutions, the system was redesigned in mid-1970s to concentrate more on each firm's quality control procedures rather than on inspecting each exported good for defects. Factories were classified into three categories based on inspection of their quality control procedures. Those scoring below the minimum were not given a license to export; those scoring the highest were allowed to export without inspection of their merchandise; only their quality control system was re-inspected yearly. In addition to having their systems inspected twice a year, those scoring in the middle had a one-in-thirty chance of having individual shipments inspected. The quality control systems of those in the third category were inspected three to four times a year and individual shipments faced a one-in-fifteen chance of being inspected.

The development of the IT and semiconductor industries heralded in a period of rapid expansion in needs for efficient standards and metrology institutions in Taiwan Province of China. For example, in order to aid the increasing sophistication of basic scientific research and establishment of more accurate measurement and standards within the industry, the National Science Council of Taiwan decided in 1974 to establish the Precision Instrument Development Centre to develop the professional skills in the manufacture of precision and testing instruments.

Since the production of silicon wafers required the observance of exceptionally high levels of technical standards, ERSO and ITRI together with the NBS established a number of centres and laboratories to answer the needs of private sector in these fields. In 1983 the Centre for Measurement Standards was formed as part of ITRI and four years later the National Measurement Laboratory was founded under contract to NBS. Subsequently, ITRI started to offer test and certification services to firms to see if a product met generally accepted specifications or safety requirements, particularly for exports.

As the sophistication of Taiwanese exports increased these specialised services from ITRI made an important contribution. For example, EU's Reduction of Hazardous Wastes Initiative (ROHS) and Waste Electrical and Electronic Equipment (WEEE) initiative affect both the MNCs and their suppliers who market electronic and electric equipment to the EU. Through the initiative of IDB and ITRI, the government has helped to improve conformity with these standards as well as providing the institutional framework to test and prove that those standards are being adhered to (Angel and Rock, 2003).

Today ITRI has a DVD Class-A Verification lab (one of eight in the world, and the only one in Asia outside Japan), an Aviation Quality Assurance and Inspection Lab, an Electromagnetic Testing Lab to meet safety standards set by the EU, Japan, New Zealand, Australia and the US, and an Office of Medical Devices Evaluation to help with review of certain medical supplies, as required by the Food and Drug Administration (FDA) of the US. Clearly these specialised and cost-effective services had significant impact on the development of the respective industries in Taiwan Province of China (ITRI, 2004).

Similarly, in the Republic of Korea the roots of the national standards, testing and quality institutions such as the Korean Agency for Technology and Standards go back to the early 20th century. With the onset of an era of rapid technological capability-building, the government invested in expanding the supply of these specific public goods by establishing the Korean Standards Institute (now Korean Standards Association (KSA)) in 1962 and the Korean Research Institute on Standards and Science (KRISS) in 1975. While KSA was mandated largely to provide quality management training and promote research in quality management, the KRISS became the central authority of the national standards system by providing national calibration services and disseminating national and international standards. Moreover, the Republic of Korea has been affiliated with numerous international standards and accreditation bodies such as ISO since the early 1960s. The development and promotion of technical standards in the electronic industry was an important contribution to the success of this sector: by affiliating with the International Electrotechnical Commission and ISO in 1963, Korean public standards bodies initiated the efforts to develop technological capabilities in this sector (see further Chapter 7).

Conclusion

The institutional evolution of domestic knowledge systems in countries such as Germany, US and Japan in the 19th century as well as in the Taiwan Province of China and the Republic of Korea more recently illuminates the role of collective competence-building in economic catch-up. In all these cases significant institutional adaptation and innovation due to differing local conditions took place. The success of the respective policies often relied on achieving a balance between rapid accumulation and enhancing the demand for technological skills and capabilities. This often resulted from establishing effective networks between institutions of higher education, technical and vocational training, research units, technical associations and industry. The next chapter will focus on the current challenges and opportunities facing developing countries in accessing and mastering knowledge, in order to highlight the increasing importance of competence-building policies for catching-up.

Notes

This chapter draws on background papers by Mazzoleni (2005), Mowery (2005) and Sercovich and Dolun (2005). However, the views expressed here are of UNIDO and do not necessarily reflect those of the authors.

1 Remaining questions about causal relationships between education, technological progress, and economic growth warrant further research. The hypotheses formulated in this respect include the growth impact of greater schooling (including at the tertiary level) on GDP growth, and, for example, the extent to which technological progress affects the demand for educated labour (see Pritchett, 2001).

2 See, for instance, World Bank (2002).

3 India is a case in point. Although it has several reputed and world-class institutions such as India Institute of Technology (IIT) and the Indian Institute of Science, it also has hundreds of recently established engineering colleges that do not meet quality standards. They offer outdated programs with inflexible structures and content. Quality assurance mechanisms are weak and programs in less than 15 per cent of institutions are accredited by the National Accreditation Board. Information technology (IT) is not significantly used for teaching. No more than six per cent of institutions have any noteworthy research activity. Most are essentially unconnected with industry (World Bank, 2005).

4 This occurred, in particular, through establishment of engineering programs, which were the province of vocational secondary schools until the end of 18th century.

5 In particular, the Morrill Act of 1862 was instrumental in promoting a utilitarian view of university education.

6 The differences in the approach to engineering typical of 19th century US and French professors can be illustrated comparing their scientific work on essentially identical topics (Kranakis, 1989). Abstract mathematical formulation of engineering problems and solutions were typical of the French scientific literature, much as tables of data evinced from extensive laboratory testing were the hallmark of US engineering work. Workshop and laboratory experience was considered an essential, if not dominant, component of the training of the engineers. Around 1900, the hours of laboratory and workshop experience included in the mechanical engineering program at Cornell exceeded hours of lecture by 25 per cent.

7 In spite of this, support for engineering research at the experimental stations remained rather small when compared to the support for agricultural research. Indeed, the employment levels and overall research budget of the US agricultural experiment stations dwarfed those of their counterparts in engineering. In 1936, the former had a research staff of 3 818 units and an overall budget of US$16.4 million. Engineering stations employed 960 researchers and spent US$1.3 million of research funds (Seely, 1993).

8 For example, the Korean Advanced Institute of Science and Technology (KAIST) – intended to be a research institution to assist the industrial community – was almost wholly staffed by faculty members with foreign doctoral degrees. Similarly in Taiwan Province of China the government tried during the 1980s to lure back its foreign-educated citizens by supporting graduate programs in science and engineering. A 1989 study of the National Taiwan University and the National Tsing Hua University revealed that 74 per cent and 84 per cent of their faculty, respectively, had received their degrees abroad (Hsieh, 1989). Likewise, the Academia Sinica, a public research institute, was in the late 1980s almost entirely staffed by Chinese Americans who had maintained their ties with academic activity in their native land.

9 See Murmann (1998, 2003a, 2003b).

10 Enrolment in Britain's 'redbrick' British universities (largely founded during the 19th century, (this group excludes the ancient English universities of Oxford and Cambridge) grew from roughly 6 400 to 9 000 during 1893–1911, but only 1 000 of those enrolled in these universities as of 1911 were engineering students, while 1 700 were pursuing degrees in the sciences. By contrast, the German technical universities alone enrolled 11 000 students in engineering and scientific degree programs by 1911. British government funding of higher education amounted to roughly £26 000 in 1899, while the Prussian government alone allocated the equivalent of £476 000 to support higher education. By 1911, the respective amounts stood at £123 000 and £700 000 (Haber, 1971, p. 45 and p. 51).

11 Murmann (2003a) highlights the important political role of the German chemicals industry in mobilising and maintaining political support for expanded public funding of research within German universities and elsewhere.

12 There were 15 non-academic laboratories in 1885. Another 15 were established before 1900. These laboratories included agricultural experiment stations, the Institute of Infectious Diseases, the Serological Institute, and in 1900 the Industrial Experiment Laboratory. Japan's

minister of education at the time, Mori Arinori, intended these efforts to serve purely utilitarian goals, having little regard for people whose pursuit of knowledge was not useful to action.

[13] It is arguable that the early success of Taiwan Province of China with rapid agricultural development relied on technology policies and heavy investment in infrastructure and irrigation during the 1950s rather than on government protection and distorted prices (Wade, 1990). The promotion of research in agricultural technology proved to be a success in such specialised areas as asparagus cultivation and the artificial breeding of grass carp, silver carp, and shrimp. Linear programming concepts were successfully applied to create a fixed computerised formula to increase production of hogs and other livestock. In the early 1970s, the Asian Vegetable R&D Centre and the Taiwan Plant Protection Centre helped to consolidate capabilities in agricultural technology. Furthermore, the productivity increases in agriculture allowed the industrial sector to develop more rapidly as the government heavily taxed the resulting surpluses in agriculture for use in industrialisation (Wade, 1990).

[14] Amsden and Chu (2003) report that by 2000 more than 15 000 professionals had worked for ITRI, and 12 000 had gone on to hold positions in the high-tech sectors of the economy in Taiwan Province of China (see section on entrepreneurial development policies below).

[15] A similar initiative was taken later on in the Republic of Korea.

[16] Today, however, the III works largely as an R&D centre for the information industry, having established six labs during the 1990s focused on advanced information system technologies, network and communications, multimedia technologies, embedded systems, and e-commerce.

[17] On Singapore's success with training incentives the World Bank's *The East Asian Miracle* noted, 'This success illustrates the importance of government's ability to foresee a major trend and coordinate complementary private investments. At the same time, businesses must stand ready to take advantage of the comprehensive support that the government provides' (World Bank, 1993, p. 202).

[18] The lack of business innovation development is not an issue that only affects developing countries. For example, according to the EU green paper on Entrepreneurship in Europe (COM 2003 27) and the Global Entrepreneurship Monitor, (2002) 93 per cent of the European entrepreneurs consider their business to be replication of existing business activity, hence having little innovative input. This is also related to the unevenness of development in different subsystems of an innovation system, which is taken up further in Chapter 6 of this Report.

[19] The impact of Intel's Venture Capital business based in Costa Rica in encouraging entrepreneurial experimentation and innovation provides an interesting example. To date Intel Capital has invested more than US$60 million in 20 companies in Latin America. Also, the Indian diaspora in the US features an immense entrepreneurial potential, already making strides back home. The Indian-American community boasts 1.68 million people, with an average per capita income of US$60 093. More than 87 per cent of them have completed high school and 62 per cent have some college education (over three times the average in the US). In 1998 4 092 Indian professors were teaching in US universities. In 1997 Indian students obtained 3.2 per cent of the total number of doctorates granted by US universities. Approximately 300 000 Indian-Americans work in Silicon Valley, accounting for more than 15 per cent of start-ups in the US and have an average annual income of around US$200 000. Although diaspora members' investment in India's software industry and business services still accounts for only three per cent of FDI, they are making a significant contribution in the form of knowledge linkages, helping Indian firms to absorb technical and managerial knowledge. Outsourcing to India often comes by initiative of employees of Indian origin (World Bank, 2005). 'With the help of its diaspora, China has won the race to be the world's factory. With the help of its diaspora, India could become the world's technology lab' (Huang and Khanna, 2003).

[20] This section draws heavily from Jon Sidgurdson (1986) 'Industry and State Partnership: The historical role of the engineering research associations in Japan'.

[21] After 1986 the government intensified industrial upgrading in the bicycle industry. The Taiwan Bicycle Industry R&D Centre received grants from IDB to undertake R&D and provide consulting services. In 1987, the Materials Research Lab of ITRI helped the firm Giant develop a carbon-fibre bicycle frame. By the 1990s Materials Research Lab had secured 17 patents pertaining to the bicycle derailleur (Amsden and Chu, 2003). Today, Taiwanese bike manufacturers are increasingly focusing on high-value products such as composite materials bikes and electric bikes. In fact, at a time when global bicycle market is contracting, Taiwan Province of China is exporting an increasing volume of electric bikes, to the tune of US$700 million in 2004 (Industry News, 12/02/2004).

CHAPTER 5 Accessing and mastering knowledge

The explosive growth in the stock of codified knowledge related to S&T is one of the most striking trends in history. This trend is of course part of a broader one toward increasing levels of production of information and its storage in a variety of formats, including paper, film, magnetic, and optical media. The amount of new information stored on any of these media doubled between 1999 and 2002, which implies a yearly growth rate of 30 per cent. Likewise, information flows through electronic channels have increased at breathtaking speed, a phenomenon fuelled partly by the growth in the number of Internet users and the amount of information stored on the web (Lyman and Varian, 2003). What is the potential significance of this trend for developing countries' strategies and prospects?

Unequal access to codified information has been at the center of public debates regarding the so-called knowledge divide. One way to bridge it is the systematic nurturing of indigenous technological capabilities and the development of a domestic technology infrastructure which can foster greater access to the available sources of codified knowledge. Specific features of these trends create challenges and opportunities for developing countries, whose development prospects are at least partly defined by their ability to adopt and adapt technologies (physical and social) originated elsewhere, that is, their ability to learn to apply S&T knowledge to the implementation of locally innovative economic activities.

Developing countries face two kinds of challenges in this respect. The first one arises from barriers to access that often accompany the codification of knowledge imposed by the sources of that knowledge. Among these, pricing is pivotal. The second challenge is posed by the limitations on the use of codified knowledge, even if access is granted. Codified statements can be used only to the extent that the recipient is able to decode them and to carry out the tasks called for by the specific use envisaged. Developing country technological capabilities largely determine the potential uses to which codified knowledge can be put.

Access to the knowledge itself

Some restrictions affect access to the codified knowledge itself. Proprietary databases are an evident instance. Another is the rising price of electronically accessible scientific literature. This has been linked to a very visible trend: the growth in the number of electronically accessible scientific journals has been coupled by growing concentration in the publishing industry, to the point where only five publishers came to account for 44 per cent of all articles in the scientific journals included in the databases of the Institute of Scientific Information (Morgan Stanley Equity Research, 2002). This concentration has been accompanied by significant growth in the price of access to scientific journals, estimated at somewhere between 400 and 650 per cent in the 1984–2002 period (id, p.11). Between 1998 and 2003 the average price of an academic journal increased by 58 per cent according to the UK's Consortium of University Research Libraries (2003).

Several initiatives have been taken in the developed countries to promote the notion of open access to scientific literature. Commitments to open access to the results of publicly funded research have been made by national as well as international organisations.

Concern over the growing cost of access to the scientific literature has recently led to various efforts to counter the trend. Although developing-country subscribers often benefit from differential pricing, it is noticeable that several initiatives have been taken in the developed countries to promote the notion of open access to scientific literature, realised through the creation of peer-reviewed open-access electronic journals available free of charge to readers, or self-archiving initiatives. Commitments to open access to the results of publicly funded research have been made by national as well as international organisations; among them are UNESCO (1999 Budapest Declaration) and the OECD Committee for Scientific and Technological Policy. The latter's 2004 'Declaration on Access to Research Data from Public Funding', however, notes that the commitment to openness is to be balanced by the desire to protect social, scientific, and economic interests. This concern leads us to the second form of restrictions on access.

Restrictions on the use of accessed knowledge

Access to codified knowledge may be opened, but IPR enforcement may substantially restrict its use. Thus, for example, open access to a patents database provides an individual or organisation with access to codified statements regarding a technology, but many important uses of the information disclosed in a patent are subject to the patent-holder's control. On the other hand, access to scientific publications may be restricted to subscribers of a journal or of a database, yet the use of the information is not constrained unless the underlying knowledge is also the subject of IPRs. Various national and international trends have increased the potential scope of IPR protection, both in terms of content and of the growing number of countries providing IPR protection to domestic and foreign applicants.

The growing economic significance of IPRs can be gleaned from a variety of indicators. Patenting has increased quite rapidly since the early 1990s in the advanced economies (US, Japan, EU).[1] The progressive implementation of the TRIPS agreement will expand the scope of patent protection available to inventors under national patent laws. These trends have become the matter of public debate in the context of patents on pharmaceuticals. Of course, the extension of patent systems has in principle the dual effect of enabling the disclosure of technological knowledge through the publication of patents and of reserving to the patent-holder exclusive control over the use of the knowledge disclosed.[2]

The creation of IPRs might curb activities of reverse engineering and imitation of foreign products, but it might also support technology transfer activities structured around licensing agreements.

From a developing country's standpoint, the impact of the TRIPS agreement results from a balance between, on the one hand, the marginal impact on domestic learning and innovative activities from increased access to patent disclosures and, on the other, the consequences on the extent of inward technology transfer resulting from the creation of IPRs. With respect to the former, the effect can be expected to be more significant with respect to patenting activities by resident firms or individuals than by foreign holders. As to the latter, the creation of IPRs might curb activities of reverse engineering and imitation of foreign products, but it might also support technology transfer activities structured around licensing agreements.

Economists and business analysts have long been discussing how effective IPRs are as a means of protecting the returns from R&D investment. Empirical investigations of this question in the advanced economies reveal important cross-sectoral differences. They also illustrate how business enterprises rely upon means other than patenting to protect their intellectual property, including secrecy. Thus, what is likely to determine the effects of the extension of the IPR regime on the innovative activities of developing-country firms is the extent to which the availability of IPRs will induce firms to avail themselves of the protection they offer.

Of potentially greater significance for development is the growing propensity of academic research institutions to patent the results of their R&D. Following the lead set by the Bayh-Dole Act of 1980 in the US, legislative measures encouraging or requiring recipients of public research funds to patent have spread among many OECD countries.[3] In the US, universities and other public research organisations receive now a significantly larger share of patents than was the case a quarter of a century ago. Thus, while commitments have been made to promote the principle of openness in the dissemination of the scientific publications resulting from publicly funded research, there has been increasing recourse to IPRs on the results of such research to enhance the yield of ensuing commercial innovations. Concern over the effects of the encroachment of IPRs on S&T knowledge that was once placed in the public domain has been expressed with increasing intensity, particularly in areas such as molecular biology or software, where the proliferation of patents has threatened to create significant difficulties for researchers.[4]

The key distinction between accessing codified knowledge and using it is the focus of table 5.1, where knowledge is regarded as private or public depending on conditions of access, and as proprietary or non-proprietary depending on conditions of actual use. Examples in the table highlight that within the trend toward the growing codification of S&T knowledge questions of access and use should be clearly distinguished. Admittedly, the conditions of use for many items of codified knowledge cannot be defined unambiguously for the whole universe. Thus, having access to an electronic version of a copyrighted scientific paper enables use of the knowledge revealed in the paper (provided that the knowledge disclosed is not IPR-protected), but not the reproduction and sale of the paper. Access to an open-source software program under the 'copyleft' system makes it possible to use the software, but it requires that modifications to the software be made available to anyone through a general public license (see Chapter 7, box 7.1).[5]

Both sets of conditions presented in the taxonomy relate to the concept of excludability that economists use to characterise properties of private vs. public goods. Access to codified knowledge and its uses are two sharply different things: the exclusionary effects of property rights can apply to either or both. To the extent that codified knowledge is a significant input to the innovative activities of developing country firms, the different sets of capabilities associated with the act of

Table 5.1 Taxonomy of various forms of codified knowledge in terms of conditions of use and conditions of access

		Conditions of access	
		Private	*Public*
Conditions of use	*Proprietary*	Patent database	Patent documents
	Non-proprietary	Electronic journals	Public Standards Open-source software Open-access e-journals

Source: UNIDO

accessing codified knowledge and using it can be differentiated.

Enter the capability issue

Consider the locally innovative activities required to use knowledge in a variety of tasks, such as problem solving, design, and the like. Performance of these tasks may benefit in varying degrees from access to specific sources of codified knowledge, but it cannot be reduced to the mere act of acquiring codified knowledge. To the extent that knowledge is acquired as a result of a search effort, the latter presupposes a set of skills and access to a physical and social infrastructure that are necessary in order to search, identify, and evaluate alternative sources. These capabilities for conducting a search are important in themselves. Moreover, using codified knowledge requires the skills and ability to identify its meaning for the design of tasks to be carried out, as well as access to an enabling infrastructure to actually carry them out.[6]

As the stock of codified knowledge grows, prospective users may need to achieve ever higher threshold levels of capabilities to actually benefit from access to it.

The range of possible uses of any given codified set of instructions may vary widely, depending on the purposes and capabilities of the individual or organisation acquiring it. The mere fact that increasing amounts of codified knowledge are stored, searchable and accessible does not have independent and direct implications for the range of uses of such knowledge that will emerge in developing economies. Indeed, the growing stock of codified knowledge might very well have only a modest impact on its realised uses insofar as its application requires a substantial increase in the level of a number of capabilities. In other words, as the stock of codified knowledge grows, prospective users may need to achieve ever higher threshold levels of capabilities to actually benefit from access to it.

The requisite capabilities relate to the intended uses of the knowledge acquired. These may range widely, from merely transmitting it to third parties to reproducing it in an experimental setting. There are also differences across sectors regarding how pervasively codified knowledge is available as a carrier of commercially useful technology, and how complex are the capabilities required by the potential users of available knowledge. Iron and steel making is often used as an example of a technology field where scientific knowledge has relatively weak linkages to industrial practice, and where the transfer of technology requires forms of communication between the source and the recipient that go far beyond merely providing access to codified technical blueprints. On the other hand, pharmaceutical technology draws heavily on scientific knowledge, so access to sources of codified knowledge significantly raises the effectiveness of technology dissemination. Questions arise as to why this dissemination is difficult, why advances in scientific knowledge do not lead immediately to new technological applications, and why the effectiveness of both processes varies significantly across sectors. Two fundamental explanations have been put forth.

Complex and costly infrastructure

The first explanation is that the output of scientific research is not information that can be used at trivially low costs in the production and implementation of new technology. Scientific activity relies upon laboratory conditions to construct predictability. These conditions include extensive reliance on a complex enabling infrastructure, which includes physical elements (instrumentation, apparatus, and analysis technologies) and intangible ones (mathematical methods, surgical procedures, design methods). The translation of scientific knowledge into technology is affected by the degree of predictability achievable through using the technology. Crucially, achieving predictability in the technology-use environment also entails an extensive tangible and intangible infrastructure – which will vary by technology area. Hence, 'both firms and nations need to invest in this infrastructure to exploit research, innovate, import technology or access the international science system' (Nightingale, 2004, p. 1277).

Mastery of tacit knowledge

Second, the mastery of tacit knowledge affects the efficacy of technology dissemination processes across firms or countries. The extent to which knowledge held by an individual or organisation can be expressed in codified form and the speed of technological learning in new activities depend on such mastery. Tacit knowledge is an important element of those intangible assets that define individual and organisational capabilities. Indeed, codified knowledge and its implications for the future activities of individuals or organisations acquire meaning only by reference to such capabilities – which embrace tacit knowledge and problem solving skills, and the extent to which they can be brought to bear on the tasks of interpreting the code and implementing activities informed by it. In the absence of those capabilities, the growing volume of processed information might make knowledge harder rather than easier to transmit. The growing codification of knowledge does not substitute or reduce the need for tacit knowledge or, more broadly, for the enabling technological infrastructure that firms need in order to learn and develop innovative technologies.

Standards and regulations

One example is that of technical standards and regulations affecting access to export markets. These are a key instance of the challenges faced by firms in developing countries with respect to a specialised body of codified knowledge. These standards and regulations are accessible forms of codified knowledge, but the capacity of firms to adopt them and ensure conformity depends largely on the ability to input knowledge into their activities, a task that relies heavily upon the availability of a domestic knowledge infrastructure (Chapters 7 and 8).

Generics and semiconductors

Another instance is the production of generic equivalents of branded pharmaceuticals, particularly in those countries where patent protection for pharmaceutical products is or has been available. Whereas conditions of access to (foreign) patent disclosures do not vary substantially across countries, the production of generic equivalents has not immediately followed this accessibility. This is because the capabilities for the production of generic equivalents (a use of the codified knowledge) rely upon access to a knowledge infrastructure that is available in some countries but not others. Likewise, access to integrated circuit design information cannot be used to replicate semiconductor chips unless critical capabilities are available to organise a production facility.

The collective dimension

The capabilities required for exploiting various forms of codified knowledge reside only partly within any given firm. A distinctive feature of an innovation system is the presence of multiple, interacting actors and institutions, so that firms'

The extent to which developing country firms can access and use available sources of codified knowledge depends on the diversity of the collective skills and capabilities they can rely upon.

capabilities are enhanced by access to those of other actors in the system (Chapter 6). Take three key sources of codified knowledge: S&T literature, patents, and international public standards. Each requires elements of a technology infrastructure that go far beyond the individual firm. The first calls for S&T education institutions, and public research laboratories; the second, for extension services, technology transfer, and information collection agencies; and the third, for agencies related to standards, testing and metrology, regulatory agencies and compliance services (table 5.2 presents a schematic overview of this; of course, significant differences across sectors and across firms need to be factored in).

To summarise, different bodies of codified knowledge pose different demands for specific technological capabilities. The extent to which developing country firms can access and use available sources of codified knowledge depends on the diversity of the collective skills and capabilities they can rely upon in order to introduce locally innovative technologies. This is crucial to gauge the varying patterns according to which those firms are able to participate in global value chains, and to enter various industry sectors.[7] Different industrial activities are characterised by different capability thresholds that need to be met in order to use available sources of knowledge. A remarkable mismatch is to be noted, however, between the increasing recognition of the need for domestic knowledge systems and a quite generalised recent decline in the allocation of resources to capability building in the developing world, a trend contrary to that found in the experience of the successful catching-up countries (see box 5.1 and Chapter 4).

Conclusion

Taking advantage of an ever growing stock of codified knowledge entails more than having access to it, which in and of itself poses difficulties; it also requires the ability to decode it and put it to use for the envisaged applications. This task is

Table 5.2 Sources of codified knowledge and related components of the technology infrastructure

Sources	Components of technology infrastructure
Scientific and technical literature	Scientific and technical education institutions; public research laboratories
Patents	Extension services, technology transfer, and information collection agencies
International public standards	Agencies related to standards, testing, and metrology; regulatory agencies and compliance services

Source: UNIDO

made no easier by disincentives to reverse engineering and imitation of foreign products involved in stronger IPRs –, although they may also shore up technology transfer activities structured around licensing agreements. Under these conditions, access to a growing stock of codified knowledge calls for ever higher threshold capability levels.

Box 5.1 Declining trends in investment for capability-building in developing economies

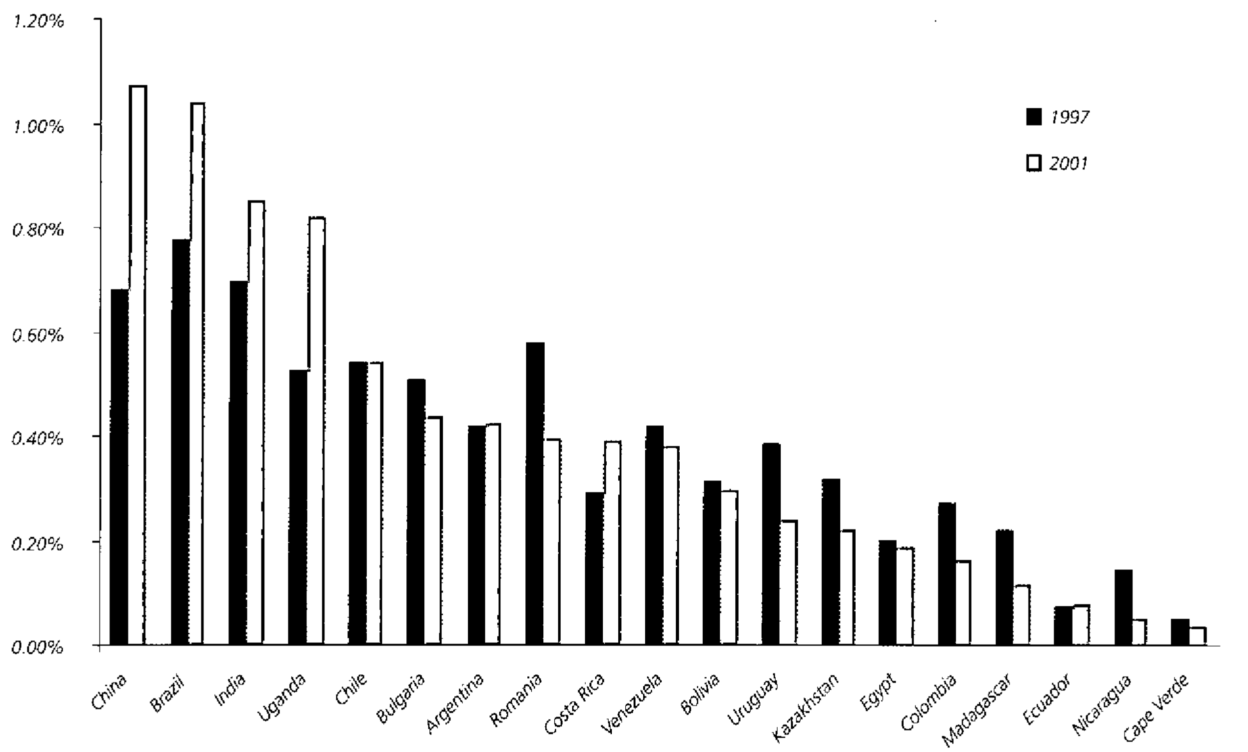
Data on overall capability building effort in developing economies are scarce, and time series data are especially so. However, the available statistics on R&D spending – which can be used as a proxy – show a declining trend in S&T effort in many developing countries at a time when building capabilities in this area is becoming even more crucial.

With the exception of Brazil, the trends are essentially flat or declining for the late 1990s in Latin America – the failure of Chile's R&D/GDP ratio to grow during this period is particularly striking, in view of this nation's relative success with economic liberalisation and macroeconomic stabilisation during the period. Various Latin American governments have been promising to augment public investment on R&D as a proportion of GDP, but little progress has been achieved – on the contrary, some countries have even reduced their national effort in this respect. In 2002, no economy other than Brazil exhibits an R&D/GDP ratio above 0.6 per cent. R&D spending grew during 1997–2002 period only in Costa Rica and Brazil, while declining in Venezuela, Ecuador, Uruguay, Colombia, Nicaragua and Bolivia during the same period (figure 5B.1). What's more there is some indication that when absolute spending in R&D is low, there is a natural tendency to concentrate on basic science, because it is 'cheaper' than applied S&T development. This is why some developing countries in Latin America make a disproportionately high contribution to the world basic science compared to their local R&D effort, without significant spillovers to innovative activity.

A similar experience with declining R&D investments – already from a very weak base – can also be observed in other developing regions in the world, although there is relatively little available data on Central and Eastern Europe, Middle East, Central Asia and SSA. The partial data available on countries such as Kazakhstan, Egypt, Madagascar and Cape Verde all register declines during the late 1990s. Uganda is the only country in SSA that has achieved growth in overall spending along with countries such as China and India, whose recent catching-up experiences have been partially emulating that of economies who drastically increased their S&T capability building effort in an earlier decade such as Republic of Korea and Taiwan Province of China.

For SSA, although international R&D spending statistics collected by UNESCO do not provide much information, there is some evidence from agricultural research spending since the 1960s that suggests a declining trend in S&T efforts. Most of the growth in public agricultural research spending in SSA took place in the 1960s as the real spending growth reached 6.8 per cent per annum. However, in the following decades the growth rate fell down to 1.4 per cent per annum – and during the 1990s it deteriorated to only 0.8 per cent. The funding has become increasingly scarce, irregular and donor dependent, with very few resources spared by the private sector. In this same period, average spending per scientist declined about half – as researcher numbers grew – and in some countries the decline in resources per research staff was even more extreme. In Burundi, Sudan and the Democratic Republic of Congo total agricultural R&D spending experienced negative annual growth – more than minus ten per cent. Only in Nigeria and South Africa was there an increase in total spending. However Nigeria still had one of the lowest spending-per-scientist levels and in South Africa spending contracted significantly in the later part of 1990s due to reductions in federal and provincial government funding. Excluding Nigeria and South Africa, total public agricultural R&D spending actually declined by 0.2 per cent per year since 1990 in SSA. In fact considering total public spending as a percentage of agricultural GDP, Africa invested US$0.70 for every US$100 of agricultural output in 2000 down from US$0.95 in 1981.

Figure 5B.1 R&D as percentage of GDP (1997 vs. 2002 or most recent year)



Source: UNESCO, 2005.

Sources: Walsh, 1988; Beintema and Stads, 2004.

Notes

[1] The number of patent applications filed with the USPTO and the EPO increased from 107 039 and 60 104 in 1991 to 179 658 and 109 609, respectively, in 2000 (Compendium of Patent Statistics, OECD, 2004c). The growth in patenting has been particularly noticeable in the fields of biotechnology and ICT, partly as a result of the broadening scope of patentability in these areas endorsed by the countries involved. (Just one company, Microsoft, has recently announced plans to substantially pick up the pace of patenting, raising its goal of patent applications submitted annually to 3 000 from 2 000. Indeed in 2004, Microsoft filed 3000 applications with the USPTO according to its own sources. This would not have been possible up to the late 1980s, when the US courts still regarded software as a collection of mathematical algorithms, not as an invention, and thus not patentable. However when the number of patent applications filed by Microsoft in the US is compared with the actual patents granted internationally to countries such as Italy, Switzerland or Finland, the sheer volume of Microsoft's patenting activity becomes clear. In fact in 2002 only eight countries out of 115 had more than 3 000 patents filed in the US). On the other hand, while patenting activity by developing countries at the USPTO and the EPO has increased quite rapidly, their global share of patents still remains pretty low.

[2] Chapter 7 discusses the relationships between IPRs and standards.

[3] See D. Mowery's chapter in Magariños and Sercovich (2003).

[4] An important aspect of the reaction against this trend has been the emergence of the open-source software movement. Open-source software constitutes an important form of codified knowledge that is freely accessible to users, who may or not be interested in making contributions to improving the software code (see further Chapter 7).

[5] A wordplay on copyright, 'copyleft' ensures that nobody can appropriate what is offered free to all; in a sense, it turns copyright on its head.

[6] Accessing a recipe from a database is not the same as using it. The latter requires various kitchen tools, measuring instruments, and the knowledge and skills necessary to carry out various tasks (such as dicing, whipping, sautéing, etc.) and to interpret the implications of ambiguous statements (cook at medium heat, until golden brown, etc.). At a more complex level, accessing the patent description of the technique of polymerase chain reaction is one thing, but actually using it requires a considerable range of capabilities and a great deal of infrastructure.

[7] To the extent that machinery is a form of codification of knowledge, this argument can be applied to the analysis of the range of capital goods imported by domestic firms in terms of the capabilities that are necessary for their effective use.

Part 2

The Policy Dimension

CHAPTER 6

Policy, knowledge and business innovation

Introduction

Domestic knowledge systems and, more broadly, knowledge-related variables, have – as we have seen – been crucial in accounting for countries' ability to catch-up throughout modern history. And their importance is on the rise. The next issue to address is how policy should factor this. For this, it is necessary to bear in mind that policy prescriptions do not stem straight from the historical and empirical analysis, no matter how persuasive or conclusive that analysis may be. Before moving to policy prescriptions it is necessary to spell out how policy may be expected to achieve the outcomes sought and how these outcomes, in turn, feed back on policy and forward on the IS development.[1]

We shall broach this by stages, over the three chapters of this second Part of the Special Topic section. This chapter is devoted to the overall policy analysis. The next two chapters examine two important dimensions of the policy issues at stake; first, the case of standards systems in relation to IPRs and competition policies (Chapter 7) and, second, that of food safety systems, including related technical regulations (Chapter 8). These two sets of issues are eliciting increasing attention. Yet, the capability implications involved still remain largely implicit, if and when dealt with.[2]

Upgrading the policymakers' compasses

Sizing the opportunities made available by entering and sustaining a path of industrialisation entails relying increasingly on the mastery of knowledge and skills. The diffusion of this mastery, however, is neither spontaneous nor instantaneous, nor can be taken for granted. This means that catching-up countries must pay much greater attention to domestic competence-building systems than has hitherto been the case.

Market failures, including those stemming from information asymmetries, incomplete or missing markets, increasing returns to scale, coordination problems, externalities and uncertainties, may serve as a partial guide for policy makers. However, because of their very ubiquity and pervasiveness, diagnoses of these failures, when at all possible, may not suffice to orient action. Policymakers may sense the search for Pareto optima, which assumes a full set of complete and contingent markets extending indefinitely into the future, as something much akin to a will-o'-the-wisp.[3]

Also hindering the generation of capability-focused policy responses is the dearth of appropriate tools, metrics, heuristics and needs assessment methodologies, including those relating to the policy capabilities themselves (see annex 6.1 and Chapters 7 and 8).

The major inadequacy of conventional policy approaches to development is the insufficient attention paid to the dynamic correspondence between competence-building policies and private sector development.

These constraints to the policymaking process help explain why factoring competence-building into the policy framework is still far from systematic and why competence-building has yet to be given the centre-stage position it merits both in the formulation of development policies and in the conceptual framework underlying these policies.

A major inadequacy of conventional policy approaches to development is the insufficient attention paid to the dynamic correspondence between competence-building policies and private sector development (PSD). To the extent that the mastery of innovative entrepreneurial capabilities (in a Schumpeterian sense of producing new combinations of resources leading to wealth creation) is the pivot of PSD, we shall use the expression 'business innovation' as a proxy for PSD from now onwards.[4] Policy-making to foster economic transformation from this perspective still awaits formulation both in terms of a general framework and of specific guidelines.[5] This is attempted below.

In this it is worth bearing in mind that economic restructuring and productivity growth are increasingly driven by innovation. As seen in Chapter 4, one of the keys to successful catching-up has been the matching of demand and supply of resources for innovative development. Often the lack of scientists and engineers or R&D labs is a problem, but just as often it is the lack of demand of knowledge by the business sector. The price system understates the demand for innovation because markets do not reward risky new activities enough, thus building in disincentives to the development of innovative entrepreneurship. In addition, system weaknesses often block the supply of potentially innovative resources, such as skills and expertise and their translation into innovative activity through interaction with the business sector. Both types of failure come together to cause a deficit of innovative development in potential catching-up countries.[6]

Uncertainty and imperfect knowledge afflict policymakers no less than businessmen. The former cannot just lie back and apply taxes or subsidies as neutral brokers helping to internalise externalities and keep the system in 'equilibrium' since, by its very nature, innovation means disequilibrium. They risk committing errors of omission no less than errors of commission. For this reason, a capability-focused public policy cannot do without eliciting information from the private sector on significant externalities and their remedies. Private/public cooperation is thus vital in learning about opportunities and constraints for innovation-driven economic transformation and structural change. In this, private entrepreneurship occupies the driving seat while governments a strategic and coordinating role through non-market interventions, market-based incentives and the supply of 'public goods' such as property rights, contract enforcement and macroeconomic stability (Rodrik, 2004).[7]

A capability-focused public policy cannot do without eliciting information from the private sector on significant externalities and their remedies.

The capability approach provides a privileged vantage point to address these issues. In articulating a capability-focused case for the emergence and growth of IS in developing economies key phases of IS transformation need to be identified. A good way to do this is in terms of the correspondence between policies, knowledge and business innovation.

Within this perspective, next we address, first, the elements, functions and subsystems of an IS and then discuss the evolving challenges involved in making these systems work for wealth creation in open developing economies facing global competition.

Innovation and knowledge systems

IS are interactive networks of agents, institutions and organisations involved in the process of technological change. Four dimensions of IS can be distinguished; the first one relating

Figure 6.1 Innovation Systems: triggering factors, components, subsystems and functions in the policy space

Structural and Framework Factors — Public/Private Governance
'Public goods' policies

Triggering factors
- *Natural advantages (resource abundance, location)*
- *Unique expertise (knowledge, skills)*
- *Changes in technology, markets and regulary conditions*

Components
- *Business sector*
- *Support structure*
- *Institutions and markets*
- *Links, networks and interactions*
- *Culture and social structure*

Sub-Systems

Knowledge
- *Universities*
- *Research labs*
- *Training institutions*
- *Standard agencies*
- *Technological extension agencies*
- *Technical and professional associations*

Business innovation
- *Innovative SMEs*
- *Networks of innovators*
- *Spin-offs from higher education institutions*
- *Social valuation of innovative entrepreneurship*
- *Venture capital*
- *Innovation financing*

Functions
- *Search*
- *Entrepreneurial experimentation*
- *Market formation*
- *Legitimation*
- *Resource mobilization*
- *Positive externalities*
- *Knowledge development and diffusion*

Incentive policies

Monetary | *Fiscal* | *External* | *Trade* | *Competition* | *IPRs*

Macroeconomic policies | *Microeconomic policies*

Source: UNIDO.

to their origin ('triggering factors'), the other three to their working and evolution (figure 6.1).

Triggering factors

The factors that ignite the birth of an IS include the possession of natural advantages, such as a favourable endowment of specific natural resources or geographical proximity to key markets; accumulated ability and experience resulting in unique advantages stemming from the mastery of knowledge or skills in specific fields; and changes in technological, market and regulatory conditions giving way to new business opportunities.

Components

These include the business sector; the support infrastructure; institutions and markets; links, networks and interactions, and culture and social structure (Teubal, 2000).[8]

The business sector and the support infrastructure include a multiplicity of actors distributed across production activities and the areas of research, technology, teaching and training. These actors operate within a particular institutional framework and a set of markets (for labour, skills, technology, capital). They relate to one another through a web of internal and external links, networks and interactions. Culture and social structure influence (and are influenced by) the operation and transformation of an IS over time. These components perform in the context of an IS, be it national, regional or sectoral.

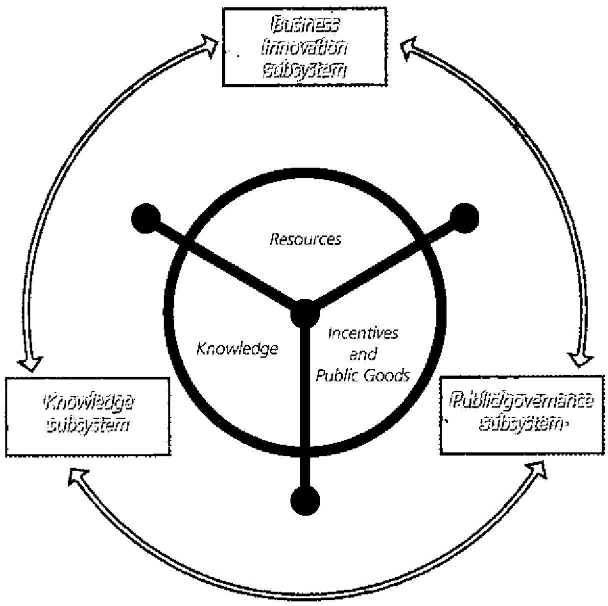
Subsystems

Three key subsystems drive the dynamics of an IS, often creating serendipitous patterns.

- **The knowledge subsystem** (the focus of previous chapters). This subsystem is made up of universities; research laboratories; training institutions; standards, patents and sector-specific regulatory bodies; extension and diffusion agencies and technical and professional associations.
- **The business innovation subsystem,** including innovative SMEs, informal networks of innovators, spin-offs generating higher education institutions, venture capital, innovation financing and social values relating to innovation.[9]
- The knowledge and business innovation subsystems interact in the **policy/governance subsystem's** space, in charge of administering incentives and supplying 'public goods'.

Flows of resources, knowledge, incentives, goods and services occur between the three subsystems, which feed the IS forward through their reciprocal interaction (figure 6.2).[10] By means of this interaction, they become the pivot of IS transformation in response to changes in technology, demand and regulations. The three subsystems are present at the various stages of IS evolution. However, they, along with their respective functions, get increasingly differentiated and specialised over time.

Figure 6.2 Steering the transformation of the innovation system



Source: UNIDO.

Functions[11]

- **Direction of search:** The search and investment behaviour is influenced by an array of market, technological, regulatory, and institutional and policy factors. As IS develop, new firms and organisations enter them seeking new opportunities prompted by competitive pressures and incentives.
- **Entrepreneurial experimentation:** the triggering factors can translate into an evolving IS only if there are first mover entrepreneurs ready to venture into uncertain markets and technologies. An IS cannot develop in the absence of an environment propitious to entrepreneurial risk-taking and experimentation into unknown territories.
- **Market formation:** initially markets may be undeveloped or inexistent simply because of the absence of market places, unarticulated demand, uncertain cost or quality performance, lack of complementary products and services and absence of non-market institutions such as those relating to property rights, contract enforcing and regulation (Rodrik, 1999). New markets result from precursor transactions once a critical mass of interacting transactions is reached and the necessary institutions are in place.
- **Legitimation:** new activities often need to be socially legitimised before they give rise to new industries by overcoming the 'liability of newness' (Zimmerman and Zeitz, 2002). A wide array of social actors is involved, not least competitors defending entrenched positions. It also includes an important element of reputation and good will.[12]
- **Resource mobilisation:** The inception of an IS entails mobilising human, technical, financial capital and complementary assets, such as organisational capabilities.
- **Development of positive externalities:** First entrants into an activity generate positive externalities by affording

the risks and costs of starting a new venture and thus opening the way to others that follow once at least some of the technological and market uncertainties have been dispelled (having carried out the necessary experimentation and catalysing subsequent mobilisation of resources, consolidating the direction of search, helping to legitimise the new line of activity and enlarging the respective knowledge base).

- **Knowledge development and diffusion:** this function is at the heart of an IS since it captures the breadth and depth of its knowledge base and disseminates it throughout the system.

Innovation systems development: patterns and hurdles

As poor countries get richer, sectoral production and employment become less concentrated and more diversified (Imbs and Wacziarg, 2003). This pattern persists until fairly late in the development process. Then incentives to specialise take over as the major force.[13]

A similar pattern can be expected in the allocation of resources to technological effort, defined as comprising not just formal R&D but also technological learning and assimilation as income growths (although the lack of data does not allow probing it quantitatively). The pattern described brings with it a demand for technological learning and related innovative development that tends to spread first across a broad range of activities, becoming gradually specialised and differentiated only once the economy attains higher levels of development. Once business enterprises, along with complementary agents, have acquired broad-spectrum innovative competences, can they afford to seek more specialised innovative capability development tracks.[14] The more advanced IS are, the higher their capacity to react innovatively to new business opportunities and drive innovation-led growth (box 6.1).

But there are powerful hurdles to the emergence of innovation-driven structural change. First, to the extent that the cost of engaging in new activities is unknown, entry is discouraged, since first comers have to afford sunk investments in learning, only to be followed by free riders once the information is made available by means, for instance, of managerial and labour turnover (Rodrik, 2004).[15] This information externality thus causes a discrepancy between private and social costs and benefits, calling for the necessary corrective action.[16]

In addition, the need for complementary investment due to scale economies and non-tradable inputs, such as those leading to clusters, also poses discrepancies between private and social costs, this time relating to the ability to coordinate the investment and production decisions of multiple entrepreneurs. In the case of nascent industries and weak private sectors this coordination is unlikely to occur spontaneously even though, ex post, it may benefit everybody involved.

Various kinds of mismatches ensue between the domestic knowledge and the business innovation subsystems that afflict most of the developing world and need to be identified and dealt with strategically.[17] They may consist of:

Box 6.1 Capability-building in cutting-edge activities

Three Asian countries have recently embarked in ambitious catching-up efforts in frontier areas. They are China, India and Singapore.

China has been making important strides in areas such as gene research, biomedicine and several aspects of electronics, with substantive investments to nurture homegrown technologies. The Chinese government's R&D spending has tripled since 1998, while scientific papers have more than doubled over the same period. By the end of 2005, the Shangai Institute of Antibodies – a new US$60 million facility in Shangai's Zhangjiang Hi-Tech Park, will start working towards developing new cancer treatments with 100 PhD researchers and 200 technicians with state-of-the-art scientific tools. This High-tech park is becoming the hotbed of new biotechnology activities, largely drawing on researchers with experience in the US. Eight government run labs, including the Shangai Transgenic Research Centre, are also located in the park, which in addition is home to 34 local and multinational drug makers. In parallel to the raising of capabilities in the knowledge subsystem of China's advance technology IS, business innovation is also catching-up. For example, Huawei Technologies, a networking company that makes routers and telecom gear is competition with Cisco, Alcatel and Lucent, is reported to have applied so far for 6 500 patents worldwide and be recruiting substantial contingents of young engineers. The development of China's business innovation and knowledge subsystems is opening the way for China's involvement in emerging global standards setting activities for technologies such as wireless communications, software applications, satellite positioning and even radio-frequency identification (ID).

Similarly, the raise in research capabilities in India is having significant spill-over effects. At the moment, more than 150 companies are performing R&D in India, especially in ICT and pharmaceuticals. During 2004, revenues from product development and R&D services in India stood at US$3 billion, up from US$2.3 billion a year earlier (still US$1.8 billion less than what Intel spends on R&D in a year).

China is the most popular destination for R&D funding, followed by the US and then India. Since much of market growth for global companies is likely to come from countries such as China and India, companies want to conduct more R&D there to better tailor products to the different consumer needs.

Yet, for all these achievements and prospects, a number of roadblocks are still to be removed to foster the growth of China and India's IS. Arguably, the uneven capability development in the policy/governance subsystem, weak linkages between the knowledge and business innovation subsystems, immature financial systems particularly for the funding of innovation need to be addressed for these countries to move forward in innovation-based growth.

On the other hand, Singapore's model for promoting cutting-edge research through the use of open-ended long term research grants through the country's main research organisation – Agency for Science, Technology and Research (A*STAR) – and fast-track scholarship programmes for young scientists provide an illustration of growing specialised sectoral IS. Over the last couple of years, A*STAR spent US$300 million building Biopolis, which houses research labs specialising in genomics, bioinformatics, bioprocessing and bioengineering. It is part of a multi-billion dollar investment in biomedicine, designed to nurture biotechnology sector in Singapore. By 2010, an expanded Biopolis is planned to be joined by an information technology hub and a complex designed to incubate spin-off businesses.

Sources: Cyranoski, 2005; Johnson, 2005; Einhorn, et al., 2005; EIU, 2004.

- Simultaneous deficit in investment in both, the domestic knowledge and business innovation subsystems;
- Investment in the domestic knowledge subsystem taking place well ahead of business innovation capabilities;
- Investment in business innovation capabilities not coupled with investment in the domestic knowledge subsystems.

Only when business innovation and knowledge subsystem capabilities advance in step, does a potential for catching-up IS emerge. This potential normally develops along sectoral lines. Nevertheless, the emergence of sectoral IS require conducive overall framework conditions, including those relevant to economy-wide innovative capability development.[18]

Incentives for evolving domestic knowledge and business innovation subsystems have become a necessary attribute of the basic economic framework conditions for a market-based system. These conditions are no less important than appropriate macroeconomic policies, currency stability and balanced budgets, regardless of the level of development. They are as 'public' in character as elementary education or basic health are. Investing in generating such conditions is akin to social overhead investments in physical infrastructure, knowledge, health and education.[19]

Dynamic processes of IS transformation are ignited by feedbacks between the domestic knowledge and business innovation subsystems, on the one hand, and between them and the policy-governance subsystem, on the other. In turn, the three subsystems can feed forward the IS, leading to better-performing components and subsystems. Whether at any given point greater emphasis needs to be given to the knowledge or to the business innovation subsystems depends very much on the initial conditions and the strength of the dynamic interaction triggered by policy intervention – which may be hard to predict. When extreme unbalances between the subsystems blunt the potential for such interaction, policy needs to devote priority attention to the weakest subsystem.

In most developing countries the domestic knowledge subsystems exhibit many deficiencies that must be addressed

Whether at any given point greater emphasis needs to be given to the knowledge or to the business innovation subsystems depends very much on the initial conditions and the strength of the dynamic interaction triggered by policy intervention – which may be hard to predict.

Box 6.2 Phases in IS development

- Phase 1: Establishing threshold conditions for the rise of IS
  - Very limited entrepreneurial capabilities and business engagement in innovation. Innovative networks missing.
  - Markets do not yet exist for innovative products and services.
  - Acute shortage of resources for innovation.
  - Domestic products and services afflicted by reputational disadvantages.
  - Non- or under-performing institutions of the support infrastructure, although some of them may be way ahead in certain sectors (for instance in agriculture).
  - Paucity of laboratory, S&T educational and training capabilities.
  - Very scarce policy capabilities, including for capability needs assessment skills. Search and experimentation instruments absent.
  - Little private/public cooperation
  - Key role of the state: establishing framework conditions for innovative entrepreneurship development. Targeted support of selected activities not ruled out.
- Phase 2: Formation and pre-emergence
  - Unstructured islands of business innovative performance, including some SMEs, with few points of contact between them and with elements of the emerging knowledge subsystem.
  - New lines of activity embedded in sectoral IS emerge involving special links with universities and the support infrastructure, which acquire the ability to react to current challenges.
  - A critical mass of innovative SMEs and new generic R&D and innovation capabilities develop in the business sector
  - Conformity with international standards spreads. Partial private public cooperation develops.
  - Key role of the state: creating conditions for internalising business innovation across the economy, enhancing networking and interactive learning
  - Policy capabilities emerge for monitoring and guiding search by means of specific policy instruments.
  - University and skills formation institutions begin to relate to demands from innovative businesses.
  - Firms in some productive subsectors acquire legitimacy in world markets or the ability to identify innovation-based business opportunities.
  - Resources begin to flow towards innovative ventures.
  - Technology extension activities develop increasingly close interactions with business enterprises.
- Phase 3: Growth and emergence
  - Full-fledged sectoral IS and new sectors emerge.
  - Business innovative performance becomes more knowledge-intensive, systematic, generalised and interactive by means of innovation networks.
  - The business sector accounts for most national R&D expenditures, most of which are privately financed.
  - The components of the domestic knowledge subsystem operate in close interaction with the business innovation subsystem in generating responses to emerging business opportunities.
  - A generic capability for innovation-based structural change develops.
  - New specialised functions (generic social technologies), such as a venture capital industry, develop to support innovative start-ups.
  - Active participation in international standard setting.
  - The training system is attuned to the emerging needs of the business sector.
  - The support structure proactively searches for innovative responses to emerging needs in close cooperation with the private sector.
  - Needs assessment and dynamic innovation policy capabilities are implemented.

urgently. This is a sine qua non to start thinking about catching-up. Even so, business innovation often is even less developed, constituting the *weakest* link from a systemic perspective. In other words, whatever potential innovative capabilities there are, they are not being made use of by the enterprise system. Most successful catching-up countries (e.g., Republic of Korea, Taiwan Province of China, Ireland, Israel) and prospective follow-up candidates (China, India, Chile) started from a minimum pre-existing development of domestic knowledge-based systems. The latter countries, and a fortiori those that follow, are still typically characterised by relatively weak domestic business innovation subsystems, often because of missing or undeveloped elements within these subsystems.

For instance, developing countries, particularly LDCs, lack competent quality, standards, metrology, and conformity systems able to ensure the necessary levels of compliance with health, safety and environmental regulations. Beyond problems related to scale, often calling for regional (inter-country) solutions, this situation needs to be addressed, first, by establishing a working system and, second, by adopting responsive policies. Again, market and system failures give rise to discrepancies between private and social benefits leading to under-investment in the respective facilities and competences (see annex 6.1). This calls for competence-building policies in this field involving coordinated action by both the private and public sectors at the early stages of IS development (see Chapters 7 and 8).

On the other hand, support of business innovation, particularly among SMEs, may take place through the transforma-

Box 6.3 A sectoral IS in the formative phase: the German solar cell case

By the late 1970s, institutional changes in Germany began to open up a space for solar power. Federal programmes provided opportunities for universities, institutes and firms to search in many directions, thus fostering knowledge development. This was sensible given the underlying uncertainties about technologies and markets. During 1977–1989, as many as 18 universities, 39 firms and 12 research institutes received federal funding. Although most of the research funding was directed towards cell and module development and the prime focus was on one particular design, that of crystalline silicon cells, funds were also given to research on competing designs; i.e. to several thin-film technologies. In addition, funds were allocated to the exploration of a whole range of issues connected with the application of solar cells, such as the development of inverters.

The first demonstration project was carried out in 1983, to be followed three years later by a demonstration programme that, by the mid-1990s, had helped to build more than 70 larger installations for different applications. The demonstration programme had only a minor effect in terms of market formation. However, it influenced the *direction of search* among smaller firms and led to a degree of entrepreneurial experimentation, which meant that it was effective as a means of enhancing knowledge development by means of downstream applications. Resource mobilisation took place not only in the form of federal funding but also by means of investments by these smaller firms as well as by four larger firms that entered solar cell production proper. These larger firms ran large losses over a protracted period.

The nuclear accident in Chernobyl in 1986 had a deep impact on Germany. The Social Democrats committed themselves to phasing out nuclear power; the Greens demanded an immediate shutdown of all plants. Also, a 1986 report by the German Physical Society warning of an impending climate catastrophe received much attention, and in March 1987 Chancellor Kohl prioritised the climate issue. As a result, a consensus developed among political parties to foster renewables (institutional change in terms of value base), thus easing the way for the subsequent legitimation of solar power. A second institutional change, the 1 000 roof programme for market formation and applied knowledge development was initiated in 1990, this time focused on small solar cell installations.

Thus, the initial investments in a knowledge and actor base furthered market formation and generated an opportunity for policymakers to respond to the perceived environmental threats.

Whereas the 1 000 roof programme met with success, the market formation that it induced was not large enough to justify investments in new production facilities by the solar cell industry, in particular as the industry was running large losses. The industry expected a substantial follow-up to the 1 000 roof programme, but that did not happen. For the industry to survive, the stimulus for market formation had to come from quarters other than the federal government. This led to intensified efforts to mobilise additional resources by means of efforts at legitimising the sector.

The most important help came from municipal utilities. In 1989 the federal framework regulation on electricity tariffs – the tariffs themselves are set at the Länder level – was modified in such a way as to allow utilities to conclude cost-covering contracts with suppliers of electricity using renewable energy technologies. On this basis, local activists together with representatives from a number of interest organisations formed, with industry, a sectoral IS-specific advocacy coalition and petitioned local governments to enforce such contracts on the utilities. After much effort, most Länder allowed such contracts, and several dozen cities opted for this model, including Aachen and Bonn. Due to this and other initiatives, a halt to market formation at the end of the 1 000 roofs programme was avoided.

A strengthened market formation began to impact the other functions which, through a subsequent feedback loop, strengthened market formation even further. In particular, two sequences are worth highlighting in this connection.

First, a number of new, often small firms entered into and enlarged the sectoral IS (SIS), thus strengthening resource mobilisation. This included both module manufacturers and integrators of solar cells into façades and roofs, the latter moving the market for solar cells into new applications. Individual firms were 'first movers' into new applications and provided positive external economies to follower firms in that they made visible new business opportunities, reduced uncertainties and influenced the direction of search of other firms. As a result, the range of entrepreneurial experiments was broadened and applied knowledge development was strengthened, as was market formation.

Second, the large number of cities with local feed-in laws revealed a wide public interest in increasing the rate of diffusion – the legitimacy of solar power was made apparent. Various environmental organisations could point to this interest when they drove the process of legitimation further. Lobbying by the German solar cell industry was also at this point intensified and industry representatives argued that to continue production in Germany without any prospects of a large home market would not be sustainable. A promise of a forthcoming market formation programme was then given and two large firms decided to invest in large new plants in Germany, dramatically strengthening resource mobilisation was.

The main system weaknesses in functional terms in this particular SIS in its formative phase did not lie in knowledge development or in entrepreneurial experimentation but in market formation and legitimation. In a 'bottom-up' process, activists, firms, interest organisations and politicians at the Ländern level drove a process of legitimation with the aim of changing the institutional framework (institutional weaknesses) to open up a larger market space. Eventually, the 'bottom-up' process was successful, and with the forthcoming programmes, the SIS shifted into a growth phase as from 1998.

tion of existing, not yet innovative, SMEs and through the stimulation of new innovative entrepreneurs and companies. This may entail direct support to specific pioneer activities and indirect support to the business innovation subsystem as such, for instance through institutional schemes aimed at accessing innovative resources (specialised skills, laboratories), lowering barriers to entry and speeding up technology diffusion. Opportunities for innovative SMEs may arise in all activities, regardless of whether they use high, medium or low technology, as much in manufacturing and agriculture as in services, and usually not requiring formal R&D but a broader range of innovative activities such as those involved in creatively using various sources of technical knowledge and production-based experience, designing and devising organisational solutions.[20]

Three phases in innovation systems growth[21]

Three phases can be distinguished in the ensuing dynamics of the interactions between the knowledge, business innovation and policy/governance subsystems. In terms of the respective strategic priorities, they consist of: first, establishing threshold conditions for the emergence of IS; second, promoting functional IS for innovation-based growth; and third, prompting the growth of differentiated and specialised IS, which systematically generate innovative responses to emerging opportunities.

Within the inevitable unevenness of these stages (they cannot be expected to evolve homogeneously across the board), each of these phases results in outcomes that are part of the initial conditions of the next phase and require evolving policies along with the increasingly differentiated and specialised capabilities and needs of the IS. In this sense, the phases are cumulative, since each of them presupposes that the previous one has produced the outcomes sought. Only countries entering the second stage may aspire to engage in sectoral catch-up (see box 6.1).[22]

Box 6.2 describes the key characteristics of each of these phases of IS development. They can be summarised as follows.

- As we move across phases, *strategic priorities* shift from stimulating generic business sector R&D and innovation to generating a critical mass of innovative SMEs, to the emergence of a venture capital/private equity industry market.
- The *private sector* performs and finances an increasing share of total R&D and innovation.
- The emphasis of the *support infrastructure* shifts from basic vocational training, information diffusion, metrology, standards and conformity to fostering the development of frontier technologies and specialised infrastructures.
- The *focus of policies* shifts from horizontal support of business innovation to targeted support of venture capital/private equity and, possibly, specific technology areas (alternative energies, biotechnology, software).
- *Learning and capability-building* move from individual 'learning to innovate' to collective, cooperative and interactive learning and capability development (often in the form of 'clubs').
- Finally, the *role of the state* shifts from a focus on establishing framework conditions for innovative entrepreneur-

Box 6.4 Salmon farming in Chile

Within a span of two decades Chile has become a major global player in the farmed salmon industry and the world's third largest producer. Chilean salmon and trout exports expanded from less than US$50 million in 1989 to around US$1 200 million in 2003, accounting for nearly 6 per cent of the country's exports. Accompanying the rise in exports, Chile's share in the world production of salmon and trout increased from about 1.5 per cent in 1987 to 35 per cent in 2002.

Developing a competitive business in an unpredictable environment with changes in raw material availability, production conditions, consumer tastes and quality expectations requires experimentation and technological capability-building. Salmon farming began in Chile with only a rudimentary level of knowledge. Hence, local institutions had to play a significant role in raising both awareness and capabilities in the sector to help firms satisfy the quality, safety, and environmental requirements of export markets. The government responded to these challenges during the early 1980s by establishing a regulatory framework and developing institutions with powers and capability to offer extension, research and technical services. For example, the National Fisheries Service (SERNAPESCA) has been responsible for ensuring that the salmon exporters comply with international standards, as required by FDA, Food and Agriculture Organisation (FAO) and WTO, as well as HACCP norms. Fish farming is one of 10 industries that receive support from a fund created to promote S&T developments to improve productivity and competitiveness of major economic sectors.

Fundación Chile, created as a private non-profit research institute through an agreement between the Chilean government and ITT Corporation of the US in 1976, together with the association of producers (APSTCH), helps firms upgrade their practices and develop pertinent technologies. Public universities and the *Instituto de Fomento Pesquero* (IFOP) also conduct research. Some public organisations such as the Agency for Economic Development (CORFO) and SERNAPESCA work with University of Chile in facilitating local salmon egg production. Annual R&D expenditures amount to nearly US$10 million, about a quarter of it coming from salmon firms.

Recently, partnerships between public research organisations and the private sector have also promoted advances in vaccine development for the salmon sector. *Fundación Ciencia para la Vida* (Science for Life Foundation), a private Chilean organisation that promotes collaborations between scientists and industry, has successfully helped develop a vaccine with support from CORFO, *Fundación Chile* and BiosChile, a biotech company. The Millennium Institute of Fundamental and Applied Biology, which developed the vaccine, has licensed Novartis Animal Vaccines Inc. to market it starting in 2006, subject to the approval of local authorities.

Although eggs and vaccines are now being locally produced, research in biotechnology and icthiopathology, the two areas considered to be essential for technological advancement in this sector, have not advanced at the same pace. While a state-of-the-art industry has developed considerably in Chile, it continues to be largely dependent on imported machinery and equipment and disembodied know-how developed elsewhere. Although there is some local knowledge generation, it is still a relatively weak aspect of an otherwise successful natural resource-based industry.

Source: Katz, 2004.

ial development to fostering a systematic interactive process of innovation-driven structural change.

The analytical succession of phases does not mean that one will necessarily follow the other in a linear fashion. Variations may exist within the same phase across countries, whereby their internal mix may differ. Some experiments will fail, so that some developments may become truncated (eg, the limited success of venture capital development initiatives in Chile and India).[23] The important thing to bear in mind is that, given the level of aggregation (national, regional sectoral) what will make the difference is the variety and quality of the linkages among the components, subsystems and functions (box 6.3 below illustrates the case of emerging IS in a developed country, while boxes 6.4 and 6.5 do so for the case of catching-up countries).

Final reflections

So far we have said little with respect to the degree of autonomy that the current international order allows domestic policymakers or to the interplay between the domestic and international knowledge and business innovation subsystems in countries attempting to catch-up.

The first aspect is addressed below. As to the second one, annex 6.2 reviews the experience of Ireland, which constitutes a textbook case of successful catching-up brought about by the blend of domestic and international knowledge and business subsystems, within which the (differentiated) role of the former is still to be more fully ascertained.[24] Nevertheless, it ought to be clear from the preceding discussion that catching-up strategies will not succeed in the absence of openness to international trade, investment and technol-

Box 6.5 Functional requirements in 'catching-up' countries' emerging innovation systems

The Republic of Korea's government attempted to increase variety and experimentation in industry by influencing the *direction of search*. The means used was 'field augmentation' – the broadening of the perceived range of opportunities available to businesses – so that they would enter new business areas. This was achieved in a number of ways. For example, R&D institute Electronics and Telecommunications Research Institute (ETRI) not only supplied the integrated circuit industry with its early designs, but also played a catalytic role in demonstrating that advanced integrated circuits could be made at home. This case, where initial advanced capabilities are formed at a government institute, is not unique. The case of numerically controlled machine tools provides similar evidence.

Similarly, in the case of salmon farming in Chile, because large potential natural rents were expected, the public sector took the initiative to induce capacity creation by demonstrating its feasibility with the start of the first commercial salmon-farming operation in the country. Along similar lines, the first experimental facility for semiconductors in Taiwan Province of China was set up by the Electronics Research and Services Organisation (ERSO), part of the Industrial Technology Research Institute (ITRI).

Catching-up involves substantial technological activities. Daewoo Heavy Industries, for instance, had to design six CNC lathes before receiving an initial acceptance from domestic customers. At the other end of the spectrum, salmon farming also involves firm-specific knowledge development, since ecological and environmental conditions sharply differ vary across locations (i.e., water quality, temperature, salinity, micro organisms, etc.).

Some knowledge development occurs at institutes and in universities. In Brazil, the origin of the internationally successful case of Embraer (currently the world's fourth largest aircraft manufacturer) dates back at least to the establishment of the School of Aeronautics Engineering, which in 1946 became the *Instituto Tecnológico da Aeronautica* and the formation of the Centro *Técnico de Aeronautica* (CTA) in 1950. By 1988, the former had graduated 800 aeronautics engineers, many of which worked in aircraft design in the latter. Similarly, the origin of the Brazilian steel industry dates back to the foundation of the Escola de Minas in 1876.

Similarly, Chilean public-sector agencies, especially the (private/public) Chile Foundation, played a vital role in the formative phase of salmon farming along with the adoption of legal frameworks to comply with international standards. The Foundation remains a key knowledge diffuser and provider of technological assistance to firms seeking to upgrade towards a more demanding export (higher priced) mix.

The case of salmon farming is not unique in Chile. The foundations of the fruit industry were laid through efforts of CORFO, the University of Chile and the National Institute of Agricultural Research. The Chilean fruit industry is a further illustration of a sustained economic boom generated by public investments in technological expertise combined with private sector dynamism. Similarly, the *Instituto Nacional de Investigación Agropecuaria* (INIA) – an agricultural research unit in Uruguay – has played a key role in raising productivity in the agricultural sector.

The Republic of Korea's government-sponsored Institute of Machinery and Materials (KIMM) assisted in developing user-producer interactions by testing and evaluating newly developed machines, thus helping them gain credibility in the domestic market. By this and other means a local market 'space' was formed in which firms were given the opportunity to build up an adequate size and enough capabilities to be able to respond to subsequent trade liberalisation. Similarly, Embraer was favoured by military procurement preferences in its early phase. Members of the CTA designed the first aircraft. Building on this, Embraer then supplied the military with 80 planes. Not only local knowledge formation but also local market formation preceded international expansion (by many years). It was not until 1997 that Embraer's civilian aircraft production overtook military aircraft production.

Resource mobilisation, in particular the training of engineers, has been central to these cases of success in the Republic of Korea and Brazil. In this, they differed from the pattern followed by the German chemical industry. Training was combined with early design developments in firms and a gradual and longer term development of design capabilities. This was also a key element in the development of the Brazilian steel industry.

Risk capital is another central resource amply supplied in the Republic of Korea in the 1970s and early 1980s. A huge financial and risk absorption scheme for the machinery industry was created in the 1970s. For instance, Daewoo Heavy Industries received US$44 million (a large sum in that industry at that time) when it entered the machine tool industry, at low or negative interest rates. Moreover, the government absorbed the risks of the venture. This funding allowed this new firm, and others, to accumulate capabilities rapidly. Investment guarantees were also frequent. Similarly Embraer's initial projects were generally underwritten by the Brazilian Air Force.

As regards externalities, lobbying in Washington to fight dumping allegations were a clear source in the case of Chilean salmon farming by making the industry more cohesive and gain legitimacy in the US market. In the Republic of Korea's case, there was a fierce battle over the (domestic) legitimacy of the entire machinery and transport industry in the 1980s. Whereas the large Chaebols received strong support (legitimacy) and direction from parts of the government, many argued *that fostering these industries was wasteful and questioned the whole* institutional set-up promoting the their development. Eventually, there was a policy shift, but not prematurely.

Sources: Broad et al., 2005; Dahlman and Fonseca, 1993; Frischtak, 1994; Hausmann and Rodrik, 2003; Hausmann et al., 2005; Jacobsson, 1986; 1993; Jacobsson and Alam, 1994; Jones and Sakong, 1980; Lim, 1997; Mazzoleni, 2005; 2003; Rodrik, 2004 and box 6.4.

Box 6.6 Capability-building spill-overs from FDI

The large variety of possible direct interfaces between the domestic and foreign knowledge subsystems may take the form of FDI, joint ventures, licensing, OEM, original design manufacturing (ODM), original brand manufacturing (OBM), subcontracting, franchising, management, marketing, technical service and turnkey contracts, overseas training, overseas acquisition of equity investments, strategic partnership or alliances for technology, R&D contracts, bilateral cooperative technology agreements and material sub-assembly. FDI is generally expected to bring in advanced skills, know-how, and technology. Direct effects from FDI inflows occur through its contribution to higher productivity, upgrading of technological and managerial practices, R&D, employment and training. Indirect spill-overs may occur through collaboration with local R&D institutions, technology transfer to local downstream and upstream operations and turnover of trained personnel.

The literature on FDI often assumes that FDI leads to substantial potential capability-building spill-overs through horizontal and vertical linkages. It is also recognised that local firms' degree of success actually benefiting from them largely depends on their absorptive capacity. The empirical evidence on productivity, wages and export spill-overs in developing, developed and transitional economies reveals, however, that it is far easier to identify potential spill-overs in theory than to actually verify them empirically.

Efforts have been made to identify differences in technological capability between foreign and local firms in various developing regions, seeking to estimate how public policy could best help to harness the latent diffusion potential. Not surprisingly, it was found that such potential indeed exists, although its realisation is hindered by foreign firms limited reliance on the whatever domestic IS there is. Since local product R&D activities pose stringent demands on the services of the R&D support infrastructure, foreign firms typically rely on their home base for those services. However, foreign firms do tend to utilise local personnel in their process R&D activities and, to a much lower extent, in product design and development activities.

Singapore provides an interesting case of leveraging FDI's potential capability-building spill-overs by turning domestic SMEs into attractive input and service suppliers. Through the Local Industries Upgrading Programme (LIUP), originally launched in 1986, the government encouraged transnational corporations (TNCs) to 'adopt' a group of SMEs and transfer technology and skills to them. LIUP covered the salary of a full-time procurement expert to work for specific periods with the 'adopted' firms and help them upgrade their production and management capabilities to international standards and precision norms. By December 1988, 21 MNCs had signed up as partners, most of them major players in the electronic, process and marine industries. LIUP encompassed three phases: (i) improvement of overall operational efficiency such as production planning and inventory control, plant layout, financial and management control techniques; (ii) launching of new products or processes and; (iii) joint product, process R&D activities with TNC partners. The sequencing of policy instruments in Singapore shows that first a critical mass technical trained workforce was developed and then incentives primarily in the form of research grants to encourage both local and foreign enterprises to increase their R&D investments were given. This stimulated a strong demand for innovation, particularly in activities serving foreign markets.

Sources: Dhungana, 2003; Girma, Gorg and Pisu, 2004; Gorg and Greenaway, 2004 and Rasiah, 2004;
http://www.sedb.com/edbcorp/sg/en_uk/index/startups/technopreneurship/local_industry_upgrading.html

ogy flows (box 6.6 reviews some evidence on capability-building spill-overs from FDI).

The crucial question is how far can developing countries at various stages of development conduct the kind of domestic capability-building policies discussed in this chapter under the current global policy environment. Can these policies be seen as the equivalent today *(mutatis mutandis)* of the interventions resorted to in successful catching-up experiences that are already 20 or 30 years old?

Can these domestic capability-building policies be seen as the equivalent today of the interventions resorted to by the successful catching-up countries of 20 or 30 years ago?

Doubtless, developing-country policymakers face severe constraints that were not there in the 1970s and 1980s; particularly those relating to stronger IPRs and the prohibition of export subsidies and much fiercer competition across the board. These constraints do make a difference, since they pose very stringent demands on the ability, particularly of the business sector, to assimilate technology and to export. While these controversial issues are dealt with, one way or another, valuable time must not be lost. The loss of policy autonomy can, but ought not, be exaggerated.

The essential constraint to the pursuit of catching-up policies today consists of the national capability to articulate the co-evolution of the domestic knowledge, business innovation and policy/governance subsystems so as to move IS forward. The emergence of this capability essentially depends of indispensable endogenous factors such as social consensus and framework conditions. As explained earlier, these conditions are not limited to the generic public goods of the conventional discourse (macroeconomic stability, rule of law, etc.), but also comprise, for instance, stimuli to innovative development, both on the supply and demand sides, their precise advisable degree of differentiation, specification and targeting depending on the stage of development achieved.

The scope for promoting innovation-driven catching-up, the only kind of catching-up feasible today, is indeed ample. Developing societies still have substantial degrees of freedom to foster the growth of effective, interactive, domestic knowledge, business innovation and policy/governance subsystems by means of appropriate framework conditions and complementary incentives systems, including subsidies to the development of innovative capabilities. Thus, for instance, trade rules do not block capability-building in the fields of entrepreneurial and innovative development, public private cooperation, regulatory design and enforcement and promotion of interactive technological learning, all of which are critical for catching-up. And yet, not enough effort is being made along these lines, largely because of deficient diagnosis and policy designing and making capabilities. This entails giving priority to the development of capability need assessment methodologies, as well as metrics, heuristics and other policy tools (see annex 6.1 and the food safety regulatory case study in Chapter 8).[25]

Annex 6.1

Metrics for capability-building: The case of the measurement and testing industry

The S&T supporting infrastructure has been long neglected. Major reports on metrics for science, technology, and engineering rarely contain data on it. The 1970 edition of the Frascati Manual notes that the report did not include 'related *scientific and technological activities*'. *Similar has been the* approach of the National Science Board (NSB) of the National Science Foundation, which estimated in 1958 that such activities accounted for some 8 per cent of all scientific activities. By the 1970s the NSB stopped reporting on them altogether (save for information and communications). In the late 1970s a report for UNESCO pointed out that proper attention to this deficit was necessary for a meaningful measurement of R&D's contribution to economic growth. But UNESCO lacked the resources to pursue it.

The measurement and testing (M&T) industry provides a good example of what is at stake. Only recently it has begun to attract attention. The emergence of the nano-technology industry has helped to attract the attention towards its broad-ranging implications for technological change.

Europe spends more than £83 billion per year, equivalent *to 1 per cent of the EU GDP on M&T activity (this figure does* not include social spending on health, environmental regulations and safety testing, which jointly account for around for £20 billion each year). It has been estimated that this spending generates direct benefits equivalent to 2.7 per cent of EU GDP through applications and from the impact the M&T industry on innovation driven growth, excluding benefits in the health, safety and environmental fields. The impact on growth factors in the important network externalities that this industry generates, for instance, by means of conformity to a traceability chain or to accepted standards. In the specific case of nano-technology, the ability to measure at increasingly small dimensions up to one billionth of a millimetre opens up a wide range of innovative opportunities in precision and ultra-precision technology (it is estimated that the costs of measuring in nano- and micro-industry are in the 15 *to 35 per cent range depending on the level of precision and* maturity of the industry).

The M&T industry is a vital part of Europe's economic, technological, and social infrastructure. And yet, market incentives do not guarantee enough investment in M&T capability development. To make matters worse, there is not official data on this industry.

M&T activity comprises that of national metrology institutions, legal metrology organisations, accreditation agencies, calibration and testing laboratories and companies (both, accredited and non-accredited), producers of measurement and testing and industrial use measurement.

The EU directives seek measurement standardisation and influence the industry indirectly. The EU provides direct funding for M&T projects. £173 million and £136 million have been allocated under the 4th and 5th Framework Programmes (DG-Research), respectively, for cross-country and cross-sectoral R&D in this area, encouraging the creation of collaborative *networks inside and outside the EU. DG-Trade and other* Directorates have also funded related activities. The Institute for Reference Materials and Measures (IRMM) founded under the Treaty of Rome is also directly funded. The EU has supported clubs and networks as partner in groups such as the European Collaboration in Measurement Standards (EUROMET) and Eurachem.

European national measurement institutions (NMI), the top layer of measurement infrastructures, are engaged from high science metrology to maintenance of reference materials as primary or national standards. They also play a key role in measurement networks for knowledge and technology dissemination and transfer. Their total yearly income amounts to £552 million, over 70 per cent coming from public sources. Commercial activity and industrial partnerships make up the remainder.

Industrial use of measurement is the most important single component of the M&T industry. Production of M&T equipment, by itself accounts in the EU for £49 billion per year or some one per cent of total EU industrial output (2 per cent in Sweden). Germany, Holland and Britain are the most important supplier countries. Finland, Sweden and Denmark are among the heavier users, reflecting their high degree of industrial specialisation. Although measurement activity within firms is not accounted for separately, such activity is estimated to amount to £34 billion per year (or one per cent of total costs).

Here is a summary of total M&T activity in the EU in £000s for the year 2000.

NMI turnover	552 249
Legal metrology	na
Accreditation services turnover	44 850
Certification costs to industry	1 940 852
Instrumentation demand	46 836 000
Internal spending in industry	33 915 276
Total	**83 289 227**

Source: Williams, 2002; Gostkowski, 1986; Godin, 2005.

Annex 6.2

Catching-up Ireland

Ireland's economic performance since the late 1980s has earned it the sobriquet of 'Celtic Tiger'. The contrast with the earlier postwar period is spectacular; during the Golden Age of European economic growth in the 1950s and 1960s Irish economic growth was most disappointing. From 1950 to 1973, real GDP per person grew at three per cent per year compared with five per cent per year in Italy, a country whose income level in 1950 was similar; by 1973 real GDP per person was only 65 per cent of the Italian level (Maddison, 2003, see graphs in Part I). By 1998 Ireland had regained parity with Italy in terms of real GDP per person. Thus, the Tiger phase of Irish growth can be seen as a belated catch-up that made good the earlier under-performance.

Ireland is a small open economy with a small market potential. In recent decades, integration into international markets has been promoted both by falling transport costs and by cuts in tariff and non-tariff barriers to trade. Most obviously, Ireland joined the EU in 1973 and has been part of the European Single Market since 1992. Ireland has been by far the most successful of the lower-income economies that acceded to the EU in the 1970s and 1980s. Since accession, not only did exports start exceeding GNP but the structure of exports has been transformed. Ireland has been a major recipient of FDI. Not only has Ireland outstripped Greece, Portugal, and Spain but it has also eclipsed the outer regions of Britain.

The welfare implications (and extent) of Irish catching-up and of the growth strategy-based on attracting FDI have to be evaluated in the light of the extraordinary openness of the Irish economy. GNP in 2003 was about 17 per cent less than GDP because of the substantial flow of profits repatriated by multinational companies. While real GDP per person grew at 6 per cent per year between 1987 and 2003, the growth of real per capita consumption was 4.1 per cent per year. The difference is partly a result of transfer pricing and partly a result of a large export surplus combined with declining terms of trade (table 6A.1).

A well-designed policy has been at the heart of Ireland's success: the country has benefited from the globalisation of capital markets and from the productivity implications of the ICT revolution, but nevertheless had to position itself to take advantage of these opportunities. The government has been playing two different but complementary roles in building social capabilities and promoting technology transfer (Abramovitz, 1986). First, with regard to social capability it has a key role in establishing and maintaining institutional quality. Most obviously this entails adherence to the rule of law and secure property rights, but beyond this it involves making the rules which relate to corporate governance, competitiveness of markets or the system of industrial relations, all of which impinge on decisions to invest or to innovate. Second, government investment strategies, for example, in terms of supplying infrastructure or education have impact on the attractiveness of technology transfer.

Table 6A.1 Growth of real GDP/head and labour productivity (% per year)

	GDP	GDP/ Head	GDP/ Worker	GDP/ Hour Worked	Employment	Population
1961–1973	4.3	3.6	4.2	5.0	0.1	0.7
1973–1987	3.5	2.5	3.2	3.9	0.3	1.0
1987–2003	6.7	6.0	3.5	4.7	3.2	0.7

Source: Groningen Growth and Development Centre (2005).

The delayed Irish catching-up was triggered by a belated decision to make good a deficit of human capital and by opening the economy after decades of protectionism (O'Grada and O'Rourke, 1996) (table 6A.2). In the late 1980s social capability was further strengthened by a 'social contract', which achieved wage moderation in return for tax cuts and was conducive to FDI and reductions in unemployment. Institutional quality was already high but incentives for investment were strengthened by fiscal policy and by reforms in wage bargaining. During the 1980s about £1.63 billion was paid in grants of which about 60 per cent went to foreign-owned firms. Most start-ups were aided – 77 per cent of foreign-owned and 70 per cent of indigenous firms (Industrial Policy Review Group, 1992). Furthermore, Ireland had a deliberate strategy to attract IT companies especially from the US by making serious investments in technical education and through the complete revamping of its educational system, including the setting up of a national system of technological institutes and a few internationally competitive university departments (Saperstein and Rouach, 2002). Therefore, technology transfer through FDI was enhanced by improvements in education and infrastructure, although it might be argued that more should have been done. In these aspects, the Irish example can be emulated given good governance and adequate public investment.

Table 6A.2 Educational attainment of the Irish labour force (%)

	1972	1982	1992	2002
Primary	50	36	22	8
Secondary	21	24	28	28
Higher secondary	20	24	29	29
Tertiary	9	16	21	35

Source: Bergin and Kearney (2004).

Capability-building policies

When Ireland's position relative to its EU peer group is viewed in terms of education, infrastructure, regulation, and taxation based on the most recent data available, the picture that emerges at first sight is one of relatively low taxation and light regulation, a strong performance in education but rather backward in terms of infrastructure (table 6A.3). In fact, Ireland is an outlier in terms of corporate taxation with a tax rate less than half the next lowest while its rating on maintenance and development of infrastructure places it a bit below India.

Table 6A.3 Aspects of today's supply-side policy in Ireland		
Indicator	*Score*	*Ranking in EU*
PISA		
Reading	515	2/14
Mathematics	503	7=/14
Science	505	6/14
Science & Engineering Tertiary Education (% age 20–29)	9.20	3/15
Educational System (1–10)	7.50	3/15
R & D (% GNP)	1.39	11/15
Maintenance and Development of Infrastructure(1–10)	3.83	14/15
Communications Technology (1–10)	5.83	15/15
Product Market Regulation (0–6)	1.10	2=/15
Employment Protection Regulation (0-6)	1.00	2/14
Direct Tax Revenues (% GNP)	20.90	2/15
Corporate Tax Rate (%)	12.50	1/15

Source: PISA: OECD (2004a); Tertiary Education, R & D: European Commission (2004a); Educational System, Infrastructure, Communications: IMD (2004); Product Market Regulation: Conway et al. (2005); Employment Protection Regulation: Nicoletti et al. (2000); Direct Tax Revenues: OECD (2004b); Corporate Tax Rate: Spengel and Wiegard (2004).

A more detailed consideration of the evidence confirms but also qualifies this picture in some respects. With regard to infrastructure in Ireland, econometric investigation finds that there was no significant effect of public-sector capital on private sector output in the years 1958 to 1990 (Kavanagh, 1997). A recent review noted that there had been substantial under-investment in public infrastructure especially in the years 1980 to 1993, with the result that the economy 'was unprepared for success' (Fitzgerald, 2002). On the other hand, telecom investments in the early 1980s were instrumental in facilitating Ireland's move into electronic commerce (MacSharry and White, 2000).

The acceleration of Irish economic growth coincided with a doubling of inflows of EU Structural Funds to about three per cent of GDP through the 1990s. These have been used for investment in infrastructure and human capital as well as subsidies to private sector investment. The direct impact of these inflows may have added about 0.5 percentage points per year to Irish growth during the 1990s and the long-run effect is estimated to raise the level of Irish GDP by about two per cent (Barry et al., 2001). The indirect effects remain to be researched but may have been more important if, for example, it could be established that the easing of the government budget constraint was important to cementing the social partnership along the lines that Eichengreen and Uzan (1992) suggested that the Marshall Plan made its main impact on early postwar European growth.

Ireland's approach to education and R&D has until recently emphasised S&T graduates but more in the context of complementing FDI than undertaking substantial domestic innovation. Thus Ireland has spent relatively little on research but has the highest proportion in the EU of college students studying scientific subjects. University enrolment increased from 19 500 students in 1971 to 63 100 in 2003 while the fraction studying science, computing and IT rose from 11.7 to 19.5 per cent over the same period. In order to encourage the location of ICT production in Ireland, there was a very rapid expansion of electrical engineering courses in the late 1970s, and Ireland now scores well on IT skills. That said, in the mid-1990s about 50 per cent of the Irish labour force had levels of competence inadequate to participate in the 'knowledge economy' compared with around 25 per cent in the best-placed country, Sweden (OECD, 2000).

The distinctive feature of the Irish educational system is its large number of non-university tertiary-level students (almost 40 per cent of all students at this level) who typically take two-year courses at sub-degree level, mostly in engineering and technology, science and computing, or business studies. Thus, in the 1970s, Ireland's successful response to the human-capital needs of FDI was rapidly to develop a low-cost way of producing a large volume of technical graduates and it was this rather than the quality of the educational system as a whole that facilitated their rapid growth (Wickham and Boucher, 2004).

Relatively little R&D has taken place in Ireland: expenditure only reached one per cent of GNP in the late 1980s and 1.4 per cent of GNP in 2001, well below the EU average. Business sector R&D was about 1 per cent of GNP in 2001 and a striking feature of recent Irish experience is the relatively low research orientation of the foreign-owned sector – their R&D expenditure was only 0.6 per cent of output in 2001, about half what it had been a decade earlier. Spending on innovation by firms has been modest. A survey by Eurostat showed it at only about 70 per cent of the EU average in 1996. Success in converting this into new products was just above average (Hinloopen, 2003). Ireland has no great tradition of research in its universities, which have primarily concentrated on teaching undergraduates, and it has been well behind the European leaders in both patenting and publication of science and engineering journal articles (table 6A.4).

Table 6A.4 Patenting and journal articles				
	Patents/Capita		*Articles/Capita*	
	1992–1994	*2000–2002*	*1992–1994*	*2000–2002*
Austria	41.4	67.9	391.6	547.5
Belgium	34.0	70.3	459.2	570.7
Denmark	38.6	85.5	813.6	926.9
Finland	63.7	140.4	724.7	962.9
France	50.5	67.3	467.9	527.4
Germany	86.1	132.9	436.2	529.1
Greece	0.9	2.1	175.7	294.1
Ireland	14.7	34.1	291.7	424.7
Italy	22.1	30.0	279.1	375.7
Netherlands	55.1	83.0	749.9	784.4
Portugal	0.4	1.2	81.6	194.9
Spain	3.8	7.2	252.1	373.5
Sweden	75.7	187.3	985.5	1 133.2
United Kingdom	40.1	65.0	748.4	823.8

Source: OECD Patent Database (2004c) and US National Science Foundation (2004).

Labour productivity

A distinctive aspect of the acceleration in growth is that, while there was a big increase in the rate of growth of GDP per person, labour productivity growth experienced only a modest rise. After 1987, employment growth was formidable, associated with rising labour force participation rates and a fall in unemployment from 17.5 per cent in 1987 to 4.6 per cent in 2003. Something quite dramatic changed in the Irish labour market which led to a substantial improvement in international competitiveness under the auspices of the social partnership. Real wages grew at 2.1 per cent per year compared with 3.4 per cent growth in real GNP per worker (Walsh, 2004). This suggests that complementarities have been central to Irish economic policy in creating an elastic labour supply to go along with FDI. Thus, the change in wage bargaining under the social partnership and investment in human capital allowed the incentives to FDI to have growth-rate effects. Resultant gains in cost competitiveness also underpinned Ireland's attractiveness for FDI (Barry et al., 2003). The speeding up of Irish growth from 1987 was based much more on an acceleration in employment than on labour productivity growth. Real GNP per hour worked grew at 3.1 per cent per year between 1973 and 1987 rising to 3.6 per cent per year in 1987 to 2003 (table 6A.5). Whereas a comparison of productivity levels based on GDP per hour worked suggests that Ireland had virtually caught up the US by 2003, in terms of GNP per hour worked there was still a gap of more than 17 per cent (table 6A.6). And because labour force participation and annual hours worked are greater in the US, the gap in real GNP per head is still about 30 per cent. However, the decline in unemployment may largely reflect enhanced investment in human capital. An index of human capital per worker based on educational attainment rose from 1.12 in 1966 to 1.24 in 1987 and 1.35 in 2002. A model of the Irish labour market suggests that, if there had been no further addition to human capital after 1982, GNP per person would now be about 20 per cent lower and unemployment would still be around 17 per cent since with many more unskilled workers to absorb generous unemployment benefits would prevent the required wage adjustment (Bergin and Kearney, 2004) (table 6.A.7).[26]

Table 6A.5 Growth of living standards (% per year)

	GNP	GNP/Head	GNP/Hour Worked	GNP/Head adjusted for TT	Consumption/Head
1973–1987	2.7	1.7	3.1	1.0	1.1
1987–2003	5.6	4.9	3.6	3.9	4.1

Source: own calculations from CSO estimates.

Table 6A.6 Real GDP and GNP per head and per hour worked (% United States)

	GNP/Head	GNP/Hour Worked	GNP/Head	GNP/Hour Head
1973	41.1	44.3	41.3	44.5
1987	44.5	63.3	40.0	57.0
2003	84.3	99.7	69.8	82.6

Source: Groningen Growth and Development Centre (2005) and own calculations. Measured on a PPP basis.

Table 6A.7 Sources of labour productivity growth (% per year)

	GDP/Hour Worked	Capital/Hour Worked	TFP Growth	TFP Growth on GNP Basis
1979–1989	4.41	1.43	2.98	1.68
1989–1999	3.31	0.24	3.07	2.51

Source: O'Mahony (2002) and own calculation for GNP basis.

FDI surge

Already by 1980 the inward stock of FDI per person in Ireland was more than ten times the average of the EU15. By 2003 it was about US$40 000 per person greater (UNCTAD, 2004) (table 6A.9). This FDI has been concentrated in clusters in IT, pharmaceuticals, medical and optical devices which were not sectors in which Ireland had traditionally enjoyed a comparative advantage and whose output is almost entirely exported (estimates for 2002 in table 6A.10 show Irish strength in IT and pharmaceuticals). These are new exportables, which have developed since accession to the EU; Ireland's traditional revealed comparative advantage centred on clothing & footwear and food, drink & tobacco (Barry and Hannan, 2001).

Table 6A.8 Contributions to labour productivity growth: Ireland vs EU (% per year)

	Ireland		EU	
	1990–1995	1995–2000	1990–1995	1995–2000
ICT capital-deepening	0.21	0.68	0.28	0.40
ICT TFP	1.17	3.02	0.14	0.20
ICT total	1.38	3.70	0.42	0.60
Other capital-deepening	0.43	0.93	1.05	0.40
Other TFP	1.79	1.25	0.98	0.43
GDP/hour worked	3.60	5.88	2.45	1.43

Source: van Ark et al. (2003).

Table 6A.9 Inward FDI Stock/Person (US$)

	Ireland	UK	EU15
1980	9 198	1 119	639
1985	9 091	1 131	780
1995	11 084	3 419	3 049
2003	49 259	11 183	8 767

Source: UNCTAD (2004).

Table 6A.10 Revealed Comparative Advantage, 2002

Sector	Index of revealed comperative advantage
Food and Live Animals	1.12
Beverages and Tobacco	0.97
Crude materials	0.34
Mineral Fuels	0.09
Animal and Vegetable Oils	0.11
Chemicals	3.30
Pharmaceuticals	4.80
Manufactured Goods	0.15
Machinery and Transport Equipment	0.77
Office Machines and Data-Processing Equipment	4.17
Miscellaneous Manufactures	0.79

Source: Addison-Smyth (2005).

Table 6A.11 **Sectoral Allocation of FDI Employment (2000)**

	Jobs in FDI Firms	FDI/ Total (%)	Location	IRS	S/L	Linkages
Food, drink & T.	13 170	27.4	CD	L	M	H
Textiles, clothing	3 703	33.7	DC	L	L	M
Wood	1 111	17.8	DD	L	L	M
Paper & printing	7 457	31.3	DD	M	H	M
Chemicals	17 874	77.0	R	H	H	M
Rubber & plastics	3 951	36.4	R	L	M	M
Non-M minerals	1 584	14.2	DD	M	M	M
Metal products	3 554	21.0	DD	M	L	M
Machinery	6 436	44.7	CD	M	H	M
Office & data pr.	18 303	88.3	CD	M	H	L
Electrical Appliances	9 438	62.3	CC	M	M	M
Radio, TV	12 785	85.3	CD	M	H	L
Instruments	15 335	84.7	CD	M	H	L
Transport equipments	5 365	55.8	DC	H	M	M
Other	2 912	25.5	R	L	L	L
Total	122 978	48.1				

Sources: Barry (2004) based on Census of Production; Midelfart-Knarvik et al. (2000) classify industries as C is spatially concentrated, D is spatially dispersed, R is residual with the first letter referring to 1970 and second letter to 1997, and allocate industries by top (H) middle (M) or bottom third (L) according to scale economies (IRS), skill-intensity (S/L), and linkages.

By 2000, foreign-owned firms accounted for the employment of almost 123 000 people, or 48 per cent of total employment in manufacturing (table 6A.11). They completely dominated employment in chemicals (pharmaceuticals), office and data processing, radio, TV & telecoms and in medical & optical instruments, which together comprised 52 per cent of foreign-owned manufacturing employment. On a Europe-wide basis none of these sectors was becoming more spatially concentrated and three were classified as CD (spatially concentrated in 1970 and dispersed by 1997) by Midelfart-Knarvik et al. (2000). Compared with industry in general, these sectors are high-skilled but do not have high linkage effects.

Analysis of decisions of American MNCs on the convenience of locating in Ireland suggests that agglomeration benefits have been important in terms of knowledge spill-overs and thick labour markets, but that there has also been a demonstration effect: initial success provided a strong signal to other firms to follow (Barry et al., 2003). For example, by 2000, 16 of the world's top 20 pharmaceutical companies had manufacturing plants in Ireland (MacSharry and White, 2000). Especially as Irish labour becomes more expensive and as competition from the EU enlargement countries intensifies, the strength of these external economies of scale will be a key determinant of whether foreign-owned manufacturing relocates away from Ireland. There are more signs that this will happen in computer assembly than in software (Barry and Curran, 2004).

The focal point of Irish industrial policy, at least since the establishment of the Industrial Development Agency (IDA) in 1969, has been FDI. The IDA has operated on the basis of targeting key sectors and seeking to persuade leading players to invest in Ireland. Two of these target sectors from the 1970s were electronics and pharmaceuticals, in which there were no domestic industrial tradition. The proactive approach of the IDA was to break the mould of Ireland's traditional comparative advantage and to deliver complementary investments, for example in upgrading telecoms infrastructure or boosting college courses in relevant subjects (MacSharry and White, 2000). A key selling point was Ireland's generous corporate tax regime. By the 1990s, the IDA was placing much more emphasis on targeting service-sector activities. Ireland has emerged as a very strong performer in terms of offshored business services. McKinsey Global Institute (2003) identified a market of US$25.7 billion in 2001 and found that by far the most popular destinations were Ireland (US$8.3 billion) and India (US$7.7 billion). UNCTAD (2004) reported that Ireland had 25 per cent of the global market for offshored IT and IT-enabled services. More recently, however, there are signs that Ireland's share of new projects is falling (table 6A.12). In view of its high labour costs compared with developing countries, it seems unlikely that Ireland can maintain a strong presence in offshored services, except in high-skilled activities in which there are significant agglomeration economies, say, software development rather than packaged software (Barry and Curran, 2004).

Both anecdotal and econometric evidence suggests that inward FDI has been greatly stimulated by Irish tax policy, the more so once Ireland was within the EU. The estimated tax elasticity of US FDI flows suggests that the stock of US manufacturing investment is about 70 per cent higher than if Ireland had had a tax rate equivalent to the next lowest in the EU (Gropp and Kostial, 2000). Ireland has been viewed by American multinationals as an attractive location from which to access European markets (Slaughter, 2003) and, although peripheral within the EU, Ireland is geographically much closer to world markets than the typical developing country (Redding and Venables, 2004).

Table 6A.12 **Export-Oriented FDI Projects (2002–2003)**

	Call Centres	Shared Service Centres	IT Services	Regional Head-quarters
World	513	139	632	565
EU 15	169	38	208	185
Ireland	29	19	14	15
UK	43	7	73	64

Source: UNCTAD (2004).

Economic theory suggests that a massive inflow of FDI resulting in the development of a large foreign-owned manufacturing presence might have both negative and positive implications for indigenous firms. Adverse effects would come in the form of some sort of 'crowding out'. This might be direct competition at the micro level, where more efficient foreign entrants displace incumbent domestic producers. Alternatively, the mechanism might be indirect, working through the price mechanism. For example, increased demand for labour might raise wage rates, or exports by foreign-owned firms might push the exchange rate up, affecting the international competitiveness of the Irish-owned sector. Positive effects could result either from technological spill-overs or pecuniary externalities resulting from backward linkages. The latter would not be relevant under perfect competition and constant returns to scale, but could benefit the economy if production in the indigenous sector is characterised by imperfect competition and scale economies, in which case costs may fall as employment rises (Markusen and Venables, 1999).

It is certainly true that employment in indigenous manufacturing has fallen in the last 30 years. From 1973 to 2000, this fell from 73 to 52 per cent of manufacturing employment and from 158 000 workers to 133 000. However, during the 'Celtic Tiger' phase employment in Irish-owned manufacturing rose by about 10 per cent. There is in fact relatively little direct competition between foreign-owned and indigenous firms either in the product or labour markets. Foreign-owned firms mainly produce for export and in sectors where there is little domestic-firm presence and they mainly employ workers who are much more highly-skilled. Investigations of crowding out through macroeconomic feedbacks have focused on the labour market and have concluded that these were of no importance throughout the 1990s given the elasticity of the Irish labour supply (Barry, 2004).

Over time backward linkages have become stronger. In the mid-1980s purchases of Irish raw materials and components were about 15 per cent of total purchases of foreign-owned manufacturing firms, but by 1997 this had risen to 21 per cent (Forfas, 1999). For the electronics sector the rise of purchases from Irish suppliers was greater, from eight to 24 per cent of total purchases, and there is a clear pattern that as the length of stay of a multinational increases it buys more intermediates from the local economy (Gorg and Ruane, 2001). Investigation of the input-output implications found that for each 100 jobs in foreign-owned manufacturing, backward linkages created about 100 jobs in services and about 10 indigenous manufacturing jobs (O'Malley, 1995). Econometric analysis also indicates that the arrival of multinationals has positive effects on the growth of domestic firms; a recent estimate is that holding constant multinational presence at the 1972 level would have implied about 800 fewer indigenous plants in 2000 (Gorg and Strobl, 2004).

The existence of these backward linkages opens up the possibility of favourable impacts on indigenous productivity through pecuniary externalities, but the magnitude of any such effects has not yet been established. However, there is evidence that the presence of foreign-owned firms has small positive effects on the productivity performance of domestic firms in the same sector, presumably through technological spill-overs. Ruane and Uour (2002) found for 1991–1998 that, controlling for use of physical capital and for labour force skills, at the four-digit level the larger the absolute size of employment in multinationals the higher the level of labour productivity in domestic firms.

In fact, there is now a clear recognition across Ireland's enterprise development agencies that the original 'Celtic Tiger' model is under threat since costs have risen and competition for FDI has intensified. This is informing a desire to attract 'higher-quality' FDI. A transition to higher-value manufacturing and more internationally-traded services is seen as the next phase of Irish growth (Forfas, 2004b). Among the sectors that might be in the forefront of this are bio-pharmaceuticals, supply chain management, cardiovascular technologies, and healthcare services. The aim is to build on expertise and clusters.

Looking into the future

The 'Celtic Tiger' model of growth that was so successful from the late 1980s to the turn of the century requires adaptation and, in any event, growth will be less rapid in future. The most obvious reason for this is that employment growth will be slower now that reserves of unemployed workers have been exhausted. The real challenge to policymakers, however, is to assist in enhancing Ireland's innovative capabilities and to facilitate a move to a more knowledge-intensive economy and thereby to reduce exposure to competition for FDI from low-tax, low-wage economies. The emphasis will switch towards provision of highly educated personnel and support for advanced technologies, with rather less reliance on low corporate taxes to underpin technology transfer through FDI.

Indeed, since the late 1990s there has been a new emphasis in supply-side policy on strengthening Ireland's capabilities in R&D with a view to making a transition towards a more knowledge-intensive economy, so as to move further up the ladder of comparative advantage. The National Development Plan has allocated €248 billion to public support for R&D in the period 2000–2006. A new agency, Science Foundation Ireland, was created in 2000 to administer a €646 million Technology Foresight Fund designed to improve links between the research community and the enterprise sector. The Programme for Research in Third-Level Institutions has established 24 major research centres with a particular emphasis on bio-science/medical research. The government economic development agency, Forfas (2004a), has stated that by 2010 it wishes R&D to be 2.5 per cent of GNP of which the business sector should do about two-thirds. A new R&D tax credit was introduced in 2004.

From the perspective of developing countries, however, Ireland may be a special case and not a role mode in some respects. First, very few countries can expect to equal the exceptional contribution of ICT to labour productivity growth because it will not be possible to establish similarly big ICT production sectors for export. Second, Ireland's attractiveness to

FDI has been based partly on its location close to European markets and its EU membership. Clearly, countries like the Czech Republic are similarly favoured, but most are not. Third, Irish practitioners themselves think that the IDA model is very hard to copy because it meets resistance from vested interests in the bureaucracy, is vulnerable to corruption and is unlikely to be adequately funded (MacSharry and White, 2000).

Notes

This chapter draws on background papers by Teubal (2005) and Jacobsson (2005). The annexes draw on Crafts (2005) and Wagner (2005). However, the views expressed here are of UNIDO and do not necessarily reflect those of the authors.

1 Except when indicated otherwise, the expression 'IS' refers to either national, sectoral or regional IS, with the necessary adaptations. For an elaboration see Edquist, 1997 (especially Chapter 1); Malerba, *2004 and Asheim and Gertler, 2005.*

2 Usually the trade perspective is given most of the attention.

3 In a Pareto efficient state it is impossible to improve one agent's state without worsening the lot of at least one other agent. With incomplete information about the agents' preferences, the notion of Pareto efficiency becomes ambiguous. An operational criterion of efficiency then depends on the resolution of uncertainty. The location and magnitude of market failures is often highly uncertain (Rodrik, 2004).

4 Innovative SMEs are major actors within the business innovation subsystem. They seek to exploit new technological and market opportunities. While large companies are also involved, the wide range of possible approaches and applications involved requires a large number of flexible and entrepreneurially oriented actors which, further along the way, may (and often do) become new, high impact, large companies operating in world markets, thus pivoting the emergence of new vibrant sectoral IS.

5 This is one of the reasons why, for example, so little is still known about how aid may help to develop absorptive capacity and thus the ability, particularly of LDCs, to use aid in a progressively more effective way (see box 1.2).

6 A system failure exists when the working of a subsystem or of specific components thereof is not functional to achieving the strategic priorities of the IS (for the concept of 'strategic priority' see below). Such a failure should not be confused with a market failure, i.e. one consisting of misallocation of resources due to lack of incentives. The former is due to more fundamental causes. Examples are lack of R&D capabilities due to remediable deficiencies in the higher education system *or an inadequate institutional framework governing the working* of the business sector. The system failures confronted by potentially innovative SMEs relate to innovation and information externalities, collective learning, cultural and institutional constraints, financing, network creation and coordination problems. Frequently, socially desirable new market building processes do not provide enough incentives to pioneers, inventors and discoverers to undertake the critical initial actions (see Teubal, 2002 and Avnimelech and Teubal, 2005).

7 Two extremes need to be avoided. One is to consider private firms as 'agents' of the policymakers (or 'principals'). The other is fully embedding policymakers in the private sector (Rodrik, 2004). Further, a distinction needs to be drawn between the strategic and operational levels of policy. The former is focused on scanning the environment, setting a vision and translating it into strategic priorities. The latter is about implementation.

8 In this context institutions are regarded (following Douglas North) as rules of the game. This includes organisations in charge of creating the rules and overseeing their application; thus, both IPRs and the Patent Office are 'institutions'. The creation of new markets (e.g. for skills, technology or advisory services) is a critical aspect of IS transformation. Completely new industries in their early phase do not yet operate in markets, although transactions may be taking place. Markets require a number of institutional underpinnings such as those relating to their regulatory and legal framework. While markets develop, intermediaries may vouch for the honesty and reliability of the parties to a transaction. Venture capitalists, for instance, perform such a role by linking innovative SMEs to clients, investors, suppliers and partners. Policy networks involving policymakers, stakeholders, experts, etc. may help define new policy priorities. The social value attached to innovative entrepreneurship is an important legitimising variable. In turn, the successful development of entrepreneurial activities may contribute to change perceptions about this.

9 Also included are the respective capabilities and institutions, such as those relating to bankruptcy laws, the ease of creating a company or hiring and firing employees, arrangements for stock options to R&D personnel and business associations.

10 'Feed-forward activation' is defined in biology as the 'activation of an enzyme by a precursor of the substrate of that enzyme'. Substituting IS for 'enzyme'; business innovation and knowledge subsystems for 'precursor' and functions for 'substrate' one get pretty close to the view in the text. The present approach also involves an integration of the synchronic (coetaneous) and diachronic (sequential, time) dimensions of IS (see below).

11 See Carlsson, et al. (2004).

12 For example, complying with standards may contribute to reduce reputation barriers to market entry. Standards setting and regulatory frameworks may support firms not just in knowledge development but also in their legitimating process in domestic and international markets (see Chapters 7 and 8).

13 The actual pattern of diversification results from the interplay between productivity growth and trade costs. Imbs and Wacziarg (2003) suggest that a first phase of diversification followed by one of concentration will occur, for instance, if it is increasingly harder to close the technological gap while transport costs decline linearly or if the technological gap falls at a constant rate but the decline in transport costs accelerates as capital is accumulated.

14 This certainly does not exclude that competitive capability in some activities may develop far ahead of the rest. Actually, this may be a prerequisite to allow progress in competence-building across-the-board to the extent that those activities may serve as 'cash cows'.

15 It should be noted, however, that most new activities in a developing country involve products that were previously imported or could have been imported, so the respective landed price in the domestic market is normally taken as the tap for local costs. In addition, there are often progressive learning steps towards local production, such as those related to performing as import agents and distributors, servicing agents; partial assemblers, etc., which may considerably narrow the margin of private uncertainty as to what those costs may be. Yet, to the extent that, even with the benefit of having gone through some or all of these stages, and having started local production, technological change continues *affecting production, organisational and management* practices and requiring a good deal of local adaptive innovation, a substantial scope for cost discovery will still remain. This is of course, a fortiori, the case for products *developed* locally under conditions that differ substantially from those prevailing elsewhere (see box 6.5). Note that the emphasis is not about 'new products' but about 'new' activities.

16 This is not at all rare. It is hard to figure on grounds of comparative advantage rather than of the random offsetting of these externalities why, for instance, countries with similar resource bases and factor endowments specialise in very different types of products (for example, Bangladesh in hats and Pakistan in soccer balls or the Republic of Korea in microwave ovens and Taiwan Province of China in bicycles).

17 The strategic dimension may be lost when looking into these mismatches as purely a matter of whether it is the market or the government who should lead the process.

18 Developing countries face the challenges of seizing new technological, world-market and growth opportunities along with new constraints. These consist not just of international and bilateral trade agreements regulating sensitive areas such as IPRs and export subsidies, but also extremely harsh competition from other developing

countries (much harsher than that experienced by the Republic of Korea and Taiwan Province of China in the 1970s and 1980s). Altogether, these factors would appear to lead to a small number of winners and a vast number of losers, except if the latter awake to the need to enlist national energies in prioritising rapid capability-building. Only this way can the distance between catching-up leaders and followers be narrowed. See this chapter's final policy reflections.

19 Many of the new infrastructures, such as technology centres, may eventually become privately owned (thus becoming 'club goods'), but the state and the international community should nevertheless assist in their initial establishment. Framework conditions partake the character of public goods whose wide availability is required for the efficient operation of a market economy. The act of consumption or use of these goods by an agent generates externalities to other agents in the system (use or consumption externalities). This applies to network externalities (see Chapters 7 and 8), whereby including initially disenfranchised groups of society may contribute to raise overall economic welfare.

20 The boundaries between the business innovation and the knowledge subsystems are fuzzy and changing. For instance, the first venture capital schemes and laboratory certification facilities may be initially government-run and then become part of the private sector. A technology centre collectively run and owned by an industry association would qualify as part of the knowledge subsystem. As a general principle, such would be the case whenever externality creating actions, rather than profit making, is the main motive.

21 See, for instance, Avnimelech and Teubal, 2004.

22 During the course of Phase 1 firms learn to search for market and technological information; to identify, screen, evaluate and choose new innovation projects; to generate increasingly complex new projects; to manage the innovation process and to leverage R&D to access complementary assets, particularly for export markets. Phase 2 consists of generalising the ability to generate innovation-driven structural change, particularly among SMEs, for instance by means of incubators and specific incentives schemes alongside increasingly well-defined search and entrepreneurial experimentation tracks. Markets for knowledge assets and services experience incipient development along with the evolving functions of emerging sectoral IS (eg, resource mobilisation and legitimation to facilitate market entry and the development of positive externalities, such as making essential inputs available early in the game (e.g. fishmeal, see box 6.4). Policy learning through, for example, experimental targeting of new activities, is crucial in Phase 2 as are supply/demand coordination by means such as the temporary absorption of high-skill returnees prior to the creation of a market for highly skilled personnel and the setting up of new knowledge-creating and training mechanisms. Progress in the governance of innovation by means, for example, of private non-profit organisations such as the Chile Foundation and the Pasteur Institute also becomes vital in this stage.

23 The rise of a venture capital industry is particularly tricky because of the wide range of market and system failures affecting it. The finance literature emphasises market failures faced by innovative SMEs in traditional bank-based loan/credit markets, such as asymmetric information and agency problems, high uncertainties in the markets and technologies underlying the activity, the fact that knowledge assets cannot be easily used as collateral and the lack of a track record. Under these conditions, banks are reluctant to extend loans or only do so at very high interest rates. The solution to this intermediation problem may come through a new form of financial institution, which offers equity finance to promising innovative SMEs, raising funds from outside investors and investing them in portfolio companies. These companies also provide value-added services (Gompers and Lerner, 2001). Only recently have studies been made of the system failures potentially blocking the emergence of an infant venture capital industry market (Avnimelech and Teubal, 2004; 2005). In the case of Chile the failure was owed to a limited deal flow (few innovative SMEs) and a weak business innovation subsystem, which in turn reflected the low scale of government support during the 1990s. A significant expansion of such support, now in the works, could lead to a deepening of the business innovation subsystem and promote the establishment of several hundred new innovative SMEs, thus offsetting the current deficit and opening up a promising market for the emerging venture capital industry. A continuation and expansion of public/private ventures similar to that in salmon farming (box 6.4) would also be required.

24 Ireland is no doubt a very special, idiosyncratic case, some of whose features may be relevant for other potential catching-up countries. Because most of the latter are highly unlikely to draw on the global high-tech dynamics to the extent that Ireland has, we have chosen to emphasise here the endogenous capability and policy processes that are in any case involved.

25 Aspiring catching-up countries may chose to heed the lessons stemming from the relevant priorities set by developed countries in their WTO negotiations. Thus, for instance, noting that, if enforced according to the 'Dunkel version', the subsidy agreement would have jeopardised by means of potential countervailing duty actions most of the government-sponsored R&D cooperative programs with industry (at that time the US was spending nearly US$30 billion in civilian R&D), the US Representative achieved an increase in non-actionable subsidies from 50 per cent for basic industrial R&D and 25 per cent for applied R&D to 75 and 50 per cent, respectively. The programs at stake at the time included biomedical research at the National Institutes of Health expected to develop commercial pharmaceutical and products; Semiconductor Manufacturing Technology (SEMATECH), the government-industry consortium to improve semiconductor manufacturing technology aimed at restoring the competitive edge of the US semiconductor industry and strengthening the semiconductor equipment industry; the Technology Reinvestment Program, on the development and commercialisation of dual-use technologies; and thousands of cooperative R&D agreements (CRADA's) that industry had signed with fed labs to develop new competitive technologies. Another lesson to heed is that of taking full advantage of protection to minor innovations, through utility models and industrial designs, a routed being pursued by Japan, the Republic of Korea and Taiwan Province of China. The East Asian experience suggests that petty patents and industrial design patents can be effective means of encouraging domestic enterprises to undertake minor adaptive innovations and foster innovation-based rivalry among them.

26 Ireland, however, is an exception to this generalisation since it has a very large ICT production sector based on American FDI. Irish total factor productivity (TFP) growth was given a large boost because of this as technological progress in ICT production accelerated. As table 6A.8 reports, growth accounting estimates by van Ark et al. (2003) attribute 3.70 percentage points per year of Irish labour productivity growth to ICT in the period 1995 to 2000 with 3.02 percentage points from ICT production while the contribution of other TFP growth at 1.25 percentage points was unremarkable, although well above the EU average.

CHAPTER 7

Standards, technical change and catching-up: the policy issues

Introduction

Technical standards help to focus the direction of collective technological search efforts. As such, they play a key role in the emergence and transformation of IS. However, not much is yet known about their role from the perspective of countries attempting to catch-up.

Innovation drives economic prosperity. But it is not enough for innovators to produce lots of new ideas. In order to render meaningful economic effects, these ideas need to be translated into products and process innovations, which in turn have to pass the test of the market and eventually get diffused. Standards foster diffusion, but they also pose hurdles for those developing and adopting new technologies and products. These compete with the existing ones, which are more familiar to users and result from past investments that may still need to be fully recovered. This ambivalence is crucial to any discussion on technical standards.

Technical standards limit product diversity and users' range of choices. They speed up selection.[1] But they also foster efficiency gains from specialisation, which enlarge the scope of mass production, reduce costs and prices and enlarge the potential market.[2] Technical standards also reduce demand-side search information costs and lower market risk by allowing a narrower, more manageable number of product R&D options.[3]

Compatibility standards make positive network externalities feasible, encourage product improvement, internalise external effects from consumption and production, and strengthen innovative competition. But they can also hinder the radical transition to new technologies without interfaces to old technologies, and provoke economically and technologically harmful strategic behaviour. Quality and safety standards in new technologies, however, tend to have a positive impact by easing the attainment of critical mass and, by cutting risks, support the change to a technology that creates new network externalities.

Technical standards contain information about the state-of-the-art and, when publicly accessible as formal standards, may prompt the generation of new ideas. A nearly free know-how transfer thus ensues between innovators and users and between leaders and followers, generating information flows and cost savings in the innovation process. The same occurs in standardisation committees and bodies, in which technical experts working in the same area exchange information. Standards codify technical knowledge, which may serve to foster technical progress.[4]

Variety-reducing technical standards cut transaction costs by allowing economies of scale. Quality, environmental and safety standards seek broader societal goals, such preventing damage to the environment. Table 7.1 provides an overview of the various types of standards and their effects.[5]

Regulatory quandaries

Regulation of technical standards by government bodies may improve outcomes in a market economy provided that very high order conditions are met (see endnote 5). The following market and system failures are involved:

- Not every new technology is necessarily better than the old one and not every old technology is so mature that it can-

Table 7.1 **Overview of the influence of standards on technical change**

	Positive Effects	*Negative Effects*
Compatibility/Interface	– More possibilities of combining system elements, forming network bridges	– Slow down the transition from old to new technology
Minimum Quality/Safety	– Reducing information asymmetries – Greater probability of market acceptance of new products	– Risks of lock in of technology status quo
Variety Reduction	– Cost reduction, which fosters the attainment of critical mass in new products	– Reduction of variety
Information Standards	– Information about the status of technology; source for new technological innovation (i.e. ideas generation)	

Source: Blind 2004, p. 28.

not be improved. Too early a shift to the new one may slow down technological progress and be economically inefficient (for instance, if a new technology is adopted whose potential for improvement is inferior to that of the technology it replaces ('blind giant' case).[6]

- If a technology in use is still relatively young and has some potential for improvement, new entrants are more likely than incumbents to adopt a newer technology with an even greater potential. The latter would remain stranded in the technology in use, thus missing both the external network benefits and the net advantage of adoption of the new technology ('angry orphans' case).
- All users shrink from change, as the opportunity costs are too high – but if their behaviour were coordinated, benefits may exceed costs. Society remains prisoner of ('locked into') the old technology and restricted to narrow windows: the possibility of a further technological development is limited to the further development of the inferior old technology.

Whether future technological development is constrained by existing technologies or by the development of a new technology with limited potential is obviously of great pertinence to the governance of official regulation.

To succeed in avoiding excess inertia or excess momentum in standard development, policymakers need to be able to anticipate technological change and time their decisions correspondingly (see endnote iv). As this condition is highly unlikely to be met, government bodies are normally left with the responsibility of creating appropriate framework conditions for standardisation, letting private committees manage the standard setting process[7] (table 7.2).

Strategic behaviour and differing interests of the participants in the innovation and standardisation process play a role in the emergence of standards – and thus in technological development. In the case of network externalities, latecomers and powerful suppliers can undermine a new standard, while the excessive enthusiasm of bureaucrats for standardisation can produce sub-optimal standards that drive technical change in the wrong direction. Compatibility standards that motivate strategic innovative behaviour may eventually lead to inefficiencies in the economy as a whole. A false standard or one introduced too early or too late may reduce or more than offset its potentially positive effects on technical change.

General implications for prospective catching-up countries

Direction and strength of the influence

The impact of the various types of standards on technical change is broadly analogous in industrialised and developing countries, although the specific stage of development of a country affects their relevance and impact. In addition, as technological pacesetters, advanced countries exert great influence on developing country standardisation processes.[8]

The positive effect of quality and safety standards can be expected to have an enhanced significance for developing countries, particularly for domestically produced new products and services, given relatively weaker consumer organisations and governmental product-approval and surveillance mechanisms.

The positive direct and indirect effects of interface standards on technical change can be expected to be similar but weaker in developing countries since they apply mostly to high-technology-related products markets for which the number of users is limited. Moreover, less variety of system components constrains indirect network externalities[9]. Negative lock-in effects due to the high costs of shifting from an outdated technology to a new one can also be expected to be less severe for developing countries. Moreover, compati-

Table 7.2 Co-ordination mechanisms

	Over-standardisation*	Under-standardisation*
Market (industry standards)	– Leeway for price setting, cross-subsidies – Result: sponsored standards	– Positive externalities via non-internalised costs of standardisation – Co-ordination problem – Lock-in effect
Committees (SDOs) (formal standards)	– Incentive for participants to produce too many standards – Interests of individuals influence standards	– Interests of individuals hinder standardisation
Governmental institutions (technical regulations)	– False estimation of technological development	
	– Blind giants	– Narrow windows – Angry orphans

Source: Blind, 2004.
Note: * By 'over-standardization' it is meant premature or inadequate standardisation and by 'under-standardisation' unduly delayed standardisation.

bility and interface standards can trigger a fast diffusion of related new products and services in emerging mass markets (e.g. mobile communications).

Quality and safety standards – affected more directly by regulations than interface standards – help to structure the relationship between demand and supply by reducing users' information asymmetries about the characteristics of products and services. This offsets users' risk and uncertainties created by technical change. Quality and safety standards matter especially for new products and services since factors reducing information asymmetry, such as company reputation and users' experience, become the more relevant and reliable the longer new products and services are in existence. The positive effect of quality and safety standards can be expected to have an enhanced significance in developing countries, particularly for domestically produced new products and services, given relatively weaker consumer organisations and governmental product approval and surveillance mechanisms (see Chapter 8).[10]

Information standards codify technical information about the status quo of technology and provide a source of information for new products and services. Their relevance for developing countries depends critically on their ability to make use of this information. The greater their competence, the broader the contribution of standards to domestic technological development.[11]

Most international standards originate in the advanced countries. This affects developing countries, for example through the efforts of industrial country Standard Development Organisations (SDOs) to foster the harmonisation or integration of standards across borders (see annex 7.1).

By embodying information about a particular technology, standards can spread know-how across borders. By expanding the scope for network externalities, compatibility and interface standards are likely to stimulate exports from advanced to developing countries. When large potential user groups abroad adopt international standards, industrial country firms can realise economies of scale and strategically exploit network externalities (Gandal and Shy, 2001). Developing country firms may find hard to compete with foreign firms serving much larger user bases and exploiting economies of scale and learning effects. Because of smaller markets, developing countries have little chance of creating a strong enough bandwagon effect to convince foreign suppliers to switch to the national firms' standard. However, while favouring imports initially, the technology based on international standards may later open opportunities for imitation and learning, the extent of the ensuing benefits depending on the domestic competence building efforts applied to this end.

Minimum quality and safety standards are on the whole more rigorous in industrial than in developing countries. For this reason, international spillovers in this area often create tension in the latter. This problem can best be addressed through convergence in income levels. However, the impact on developing country technical change of spillovers from quality and safety standards originated in industrial economies can be positive by reducing information asymmetries between users and suppliers of innovative products, and by increasing the acceptance of new products among lead users. But these effects are restricted when the relative income levels are so low that only a small group of users is involved. The negative impacts of safety and quality standards on technical change through lock-ins are also less severe in developing countries since the standards driven by the industrial countries are normally ahead of theirs, which reduces the danger of them becoming locked-into in outdated technologies.

In conclusion, the effects of the different types of standards on developing country technical change can be expected to differ in intensity rather than in direction, particularly owing to a lower diffusion of high technology products and systems based on complex standards. More important effects stem from international spillovers. In the short run, this may work by increasing import competition. In the longer run, imports that embody high technology and the progressive outsourcing by TNCs can foster imitation and, along with it, stimulate innovation capabilities. Large discrepancies in quality and safety preferences between industrial and developing countries may prompt the latter to create their own quality and safety standards. This strategy may serve domestic preferences, but it may also hinder export possibilities The fostering of areas with potential domestic competitive advantage in world markets must be accompanied by domestic standardisation activities, driven by innovative firms determined to acquire the competence to define standards reflecting the state-of-the-art and to adopt export friendly-specifications (see below).

Implications for standard-setting activity

Involvement of developing country experts in international standard setting activities contributes to enrich their tacit knowledge. However, the distribution of power in international standardisation processes is such that those experts cannot be expected to exert much influence over them[12]. Nevertheless, their active involvement in international standardisation processes may increase awareness about developing country preferences. Since standards are shaped not just according to technology requirements, but also to market needs and users' preferences, this may ultimately have a knock-on effect on the final specification of international standards and on the competitiveness of developing country firms'.

Meaningful participation in international standardisation processes requires developing country experts endowed with solid education and training. One way to address this is by providing training for these experts at developed country technical universities. They also need to have an in-depth understanding of the needs of both domestic users and producers.

Another step towards an effective interface with international standards is their timely linkage with the national standards. Although this is a responsibility of the national SDOs, what is crucially important is the absorptive capacity of the domestic companies to implement the international standards via the interaction between the domestic knowledge and business innovation subsystems.

Industrial countries enjoy head starts in standardisation at early phases of a technology' lifecycle. The diffusion-fostering effect of standards help to increase the base of users, who can in turn provide feedbacks to providers of technology and services, such as suggestions for improvements and new applications. In the long run, formal standards may exert a positive influence on developing countries' scope for catching-up as long as these countries acquire the ability to master the technical knowledge involved. A timely adoption of standards from the advanced countries can help narrow gaps ahead of new technological lifecycles.[13]

Intellectual property rights and standardisation

IPR regimes and formal standardisation are key institutions in IS evolution. But the nature of the incentives they provide sharply differs. Whereas patents are publicly granted incentives aimed at rewarding individual inventors in exchange for access to the respective information (not necessarily its actual use), standards are, for the most part, market-driven incentives to collective and participatory processes of innovation convergence.

Their respective roles are hence inherently complementary; the one fostering diversity, the other promoting selection. However, as attested by an increasing number of conflicts, their relationship has become increasingly uneasy during the past two decades, bringing patenting onto a collision course with formal standardisation activities, which does not necessarily bode well for the public interest[14].

Interaction between intellectual property rights and formal standardisation

The interaction between formal standardisation and IPRs is at the core of the economics of technological change.[15] In this setting, the evolutionary economics literature stresses two complementary processes driving technological development: the generation of variety and the selection process.[16] 'Fitness' in this context means success in navigating the selection environment through search and choice processes.[17]

While IPRs relate closely to the diversity and ownership of technological solutions, standardisation, particularly that by SDOs, is associated with variety reduction processes and with the creation of non-proprietary tracks.

The proliferation of different and incompatible versions of an emerging technology may lead to a damaging Tower of Babel situation (which is often the case in network technologies). The ensuing fight for dominance can be costly for manufacturers, service providers and customers alike, and might end up undermining the potential market for the emerging technology. Networks will simply not be sustainable and their value for the consumer will not be realised. Failing to reach a critical mass of users, the technology risks missing its window of opportunity.[18]

A complex set of factors induces and promotes the creation of diversity and complementary, intertwined selection processes, and feeds their dynamic interaction. IPR regimes and institutional standardisation are closely associated with these processes, although not tied to one another. In reality, their respective roles are not clear-cut. The way IPRs and SDOs are used mixes their roles with regard to the creation of variety and the promotion of selection. For one thing, the standardisation process has moved further and further upstream, even coming up with new solutions not provided for by the market.[19] For another, the increasing strategic use of IPRs to create 'defensive bulwarks' or 'patent ambushes' against competing technologies mimics a selection mechanism by limiting the scope for competing technologies to emerge and therefore reducing the gene pool from which new combinations of emerging technologies can develop and recombine (see box 7.1).

Box 7.1 Defensive bulwarks and patent ambushes

Although considerable progress is being made to allay conflicts between IPRs and standards (see, for example, annex 7.3), new evidence of tension keeps creeping up. In June 2005 the EC launched an investigation of the European telecoms standards-setting body (European Communications Standards Institute, ETSI) due to concerns that a flaw in its procedures could allow firms to carry out a 'patent ambush'. This happens when a firm withholds information about patents it holds that is essential to a proposed standard. If the standard is agreed, it cannot be implemented unless all firms in the industry pay discretionary royalties to the patent holder.

There are at least two key issues in this kind of situation. First, when a patent ambush succeeds, the patent holder can draw not just on the monopoly power legally conferred by the patent, but also on the fact that all firms in the industry are forced to license in the patent, which amounts to an extraordinary degree of market power – hardly in the public interest. Second, only third firms with 'essential' patents can bargain with the 'ambusher' and avoid being subject to discretionary royalties, thus creating a de-facto cartel among them.

The fact that, by late 2003, ETSI reported that 95 companies had claimed 8800 IPRs essential or potentially essential to the organisations' work, gives an idea of the scope of the problem. From an immediate and direct point of view, the challenge consists in agreeing on fair royalties (the parties to these conflicts are reported to treat each other fairly, provided that both sides own essential patents, but gouge those that do not). Beyond this, what is at stake is the inter-industry distribution of the future stream of income to be generated by the emerging technologies. Given the increasingly aggressive way in which IPRs are being used in this context, it is not surprising that the number of conflicts is proliferating in number, type and severity. These squabbles entail postponing the introduction of new technologies and drive prices up.

ETSI is expected to make sure that information about patents surrounding a proposed standard is made available, but it cannot force the patent holders to do so to the extent needed. And patent holders do not want to see their privileges constrained in any way. Keeping the playing field levelled under these circumstances is a tall order indeed.

Given similar conflicts afflicting other important players such as Ericsson, Qualcomm, Infinion, Broadcom, Rambus, Samsung, Microsoft and many others, it would indeed be surprising if the problems do not extend to the fourth generation of cellular telephony.

Source: Marson, 2005; FX Asia, 2005; CNET News, 2005; Iversen, 2004

The changing relationship between IPRs and standardisation is also illustrated by the new phenomenon of open source software (OSS), whereby the source code of an application is made available (via the Internet). Nobody enjoys the right of exclusive exploitation of a work. This offers the opportunity to develop the program further and adapt it to one own's needs. According to the widely spread Gnu Public License (GPL), OSS is to be provided free of charge and along with the complete source code of the application, even though a reproduction cost or service cost may be charged. Despite strong copyrights under the GPL regime, it does comply with the OS standards. A virtuous circle between IPRs and open standards in the context of OSS can be observed, because the incentive to contribute to OSS is triggered by building up reputation in the labour market for software development, and by providing complementary services as a condition to exploit the IPRs (Lerner and Tirole, 2000) (see box 7.2).

The interaction between IPRs and SDOs highlights a trade-off in the innovation process, involving both complementation and tension. Effective long-term adaptation calls for these two processes to be kept in balance (Carlsson and Stankiewics, 1999). The institutional framework can facilitate their coevolution (Nelson, 1994). The two-way interaction between rapid technological change and the institutional framework translates into changes that affect both IPR regimes and SDOs.[20]

Key aspects of an emerging conflict

Since the mid-1990s, various forces have augmented the tension between IPRs and standards to the point of risking the

Box 7.2 Open Source: beyond the IPR/standards conflict?

The underlining forces pushing competition and the technology frontier in ICTs are changing the parameters of the conflict between standards and IPRs. The open source (OS) approach, which is becoming increasingly mainstream in software, shows an alternative to standard theory of IPR protection to spur innovative activity. It is based on the understanding that, while protecting new technologies with patents may promote inventive activity, the protection of new ideas afforded by patent law may also come at the expense of diffusion. The latter can spur market development and cumulative learning, which are also the main functions of standard setting activities. Open standards, on the other hand, require the specifications for achieving a specific task to be publicly available, thus promoting interoperability and new waves of growth in the whole market.

Rather than focusing on the assignment of rights after knowledge assets have been already developed, the essence of OS is to change the innovation process radically before there exists something worthy of being assigned a property rights. This does not preclude strong copyright protection. Open source systems (OSS) are protected by a special copyright licence (most widely called a General Public Licence (GPL) or copyleft) that, contrary to what happens with closed-source or proprietary software, allows the source code to be universally accessible to be downloaded, used, modified and (re)distributed by anyone. Since changes are driven from a bottom up approach where end users both initiate and implement modifications based on real needs, it has the potential to reduce the time it takes to produce innovations, test their viability and safety and bring them to the market. Innovations made by and for users mean that real problems can be addressed collectively rather than relying on the limited knowledge of few within a company for the development of various possible applications. Many thousands of OSS projects already exist and the number is growing rapidly. One of the largest online depositories of OSS projects (Sourceforge.net) currently has more than 105 000 projects and 1.1 million registered users. Well known examples of applications that have been collectively developed by users in the recent years are the GNU/Linux computer operating system, Apache web server software and the Internet email-sending engine SendMail. In the space of four years and after many modifications by users, Apache has become the most popular web server software on the Internet, despite strong competition from commercial software developers – it is currently in use by approximately 60 per cent of websites worldwide.

Entry of the large software and hardware vendors into the open source market has been crucial to OSS market penetration. IBM, Sun Microsystems Novell and HP are examples of global IT services and product companies that have shifted their focus from exclusively proprietary operating systems to also include support for Linux. IBM has ported Linux across the board of its hardware and supports a number of different Linux distributions. Hewlett-Packard, which has announced Linux as a US$2 billion business in 2002, offers Linux pre-installed on its hardware and provides services including support and training to its customers. At the same time, many governments and international organisations are showing increasing interest in using OSS. For example, in 2004 the British Government began considering OSS alongside proprietary software on a value-for-money basis and with an eye to avoiding lock-in to proprietary software or services. The European Commission (EC) has also announced a policy that gives OSS preference over proprietary software wherever appropriate. China and Brazil have already signed deals with companies such as Sun Microsystems and IBM to foster the use of Linux and other OS programs domestically.

IBM has been a promoter of OS projects like the Linux operating system in its software business. Recently, the company made more than 500 patents, valued at over US$10 million, available to be used in any OS project. Although, the company is not forsaking its lucrative technology licensing business or pulling back on new patent filings, it is freely contributing the technology building blocks that allow broader communication across industry networks. The allure of the OSS development for companies such as IBM is that OS draws on the greatest possible division of labour in order to maximise the potential value of a new idea, which can then be used by firms to gain competitive advantage by providing cutting edge specialised applications. Similar to calls for frontloading the diffusion of technology, OS expands diffusion *ex ante* by drawing in as many users/developers as possible in the initial development of the idea. For example, while developing and maintaining a world class operating software costs a minimum of US$500 million a year, IBM gets an operating system which responds to customer's needs at a fraction of the cost, by hiring 600 programmers who work exclusively on improving Linux and reaping the benefits of investments made by all other companies and users who also contribute to the development of OSS. The company then channels the savings into developing proprietary software that works on Linux systems, which allows it to move higher up the technology ladder.

The OSS movement suggests a way to promote innovation and competitiveness beyond the conflict between strong IPR protection that often stifles collective learning and standardisation that reduces variety. OS, the economic rationale that is proving to be an attractive business venture, is based on the idea that a shared product becomes more valuable with increased participation; however the additional value is not just a network externality but the result of greater *participation* in the *production* of the good, which can then lead to the development of new markets. Finally, the concept of OS is becoming increasingly viable/attractive in sectors other than software. For example, outsourcing in manufacturing sectors such as pharmaceuticals might lead the way to development of OS concepts in other goods beyond software.

Sources: Levin et al., 1987; Kirkpatrick, 2005; Marson, 2005; von Hippel, 2001; Niman and Kench, 2004; Ouédraogo, 2005; Sourceforge.net, 2005; Niman, 2002.

balance between them (Iversen, 2000). There is a potential for conflict when applying standards requires the use of proprietary technology (the case of 'essential' patents). The codification of standards specifications may infringe the proprietary rights of one or more agents. When this is the case, the collective interest for the standard may collide with the private interest of the IPR holder[21] (see boxes 7.1 and 7.3). The conflict can be settled either by agreement between the parties or in a court of law.[22]

There is a potential for conflict when applying standards requires the use of proprietary technology (the case of 'essential' patents). ICTs, with high patent and standards intensities, suffer a higher likelihood of potential conflicts.

While progressively moving towards the coordination of technologies, standardisation has also been taking a more pivotal role in the knowledge-creation process. In this context, the influence of IPR pooling is exacerbated by the increasing intensity of patenting in particular areas such as mobile telecommunications and semi-conductors. The ensuing effects on the use of IPRs and standards, combined with trends such as market globalisation, convergence of technologies and the increasing pace of technological change, have put them on a collision course. Consequently, the dynamic balancing of the private and public dimensions of knowledge becomes a priority policy issue.

IPRs and standards may interrelate in three possible ways:

- Both are designed to complement one another, thus promoting a 'virtuous circle' of creation and diffusion of new knowledge;
- IPR, especially patents, are used to block standards;[23] or
- Efficient licensing mechanisms are adopted, such as equitable patent-pool schemes that allow the factoring IPRs into standards without infringing ownership rights. This is an emerging intermediate scenario, as the 3G patent platform illustrates (see annex 7.2).

Telecommunication technology, with by a high patent- and standards-intensity, suffer a higher likelihood of potential conflicts. The chemical industry, in contrast, has high patent and low standard intensity. The trend towards higher patenting across technologies increases the likelihood of conflicts between IPRs and standardisation activities, accentuating the need for new approaches. Figure 7.1 illustrates various technologies in the patent-standard-space based on the number of German patent applications at the EPO and the stock of German standards in 1999.

General policy implications

The interface between IPRs and standardisation can occur upstream or downstream of the value chain, from R&D to marketing. Policy approaches need to address R&D, IPRs, standards and competitive issues in a consistent manner. The following

Box 7.3 Surveying IPR and standards conflicts

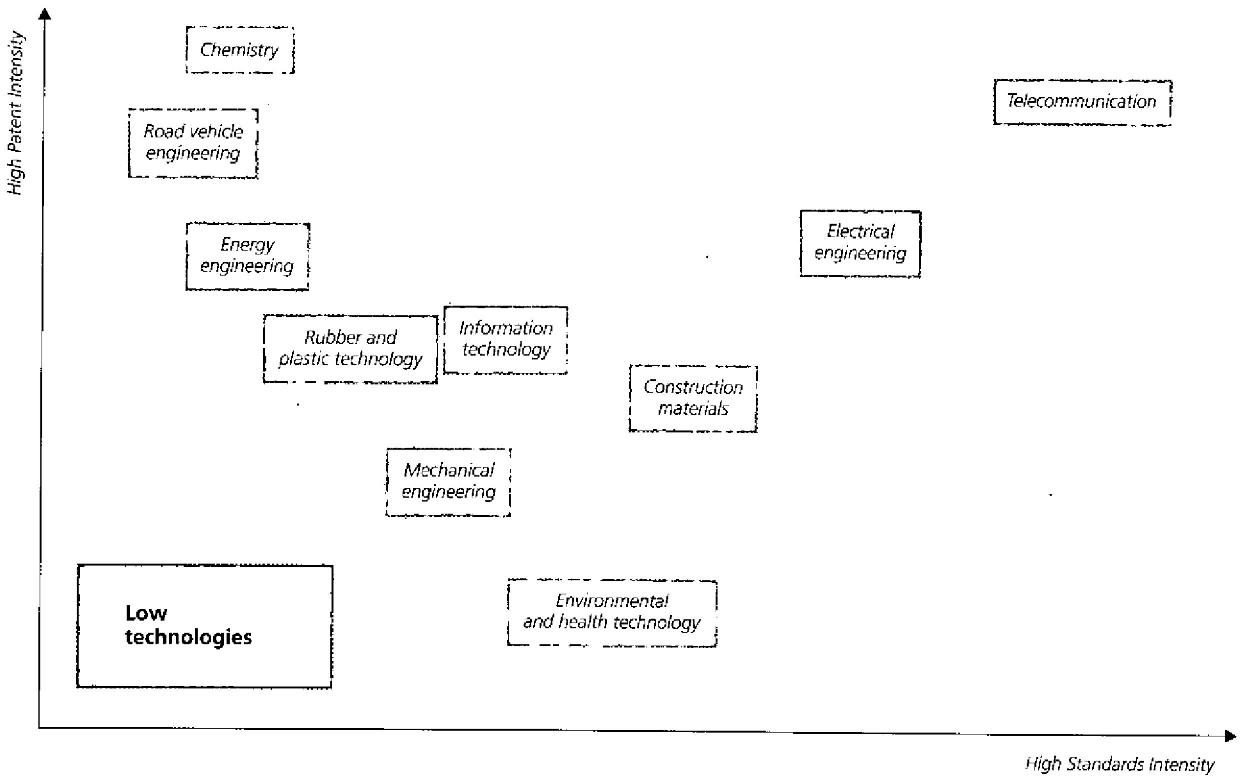
A EC-sponsored survey conducted among 800 R&D, IPR and standardisation managers of European manufacturing firms in 2001 produced the following results relating to the relationship between standards and IPRs:

- Many firms had problems in their standardisation activities relating to either their own patents (over 30 per cent of the firms) or to third-party patents (40 per cent). The incidence of these problems was higher than average for large and patent/R&D intensive firms.
- The most frequent reasons why standardisation/IPR conflicts are discretional licensing conditions and patent circumvention or infringement. Patents had been circumvented in over 40 per cent of the cases. More than 40 per cent of the large firms (which composed most of the sample) had their licensing conditions rejected and more than 35 per cent of patent-intensive firms reported infringement of their IPRs.
- 30 per cent of the firms reported infringement suits, too high licence fees, unclear IPR structures and problems with cross licensing with foreign patent holders. High R&D intensive firms get most frequently into conflict with foreign IPRs. Almost 50 per cent of the firms do not find a solution to their conflicts (the incidence rises to more than 55 per cent in the case of high R&D intensive and medium-sized firms).
- The most frequent reasons for not reaching agreement are excessively high licensing costs and failure to circumvent the IPRs or to create a patent pool. Mergers and acquisitions of the IPR holding firms are very rare. IPR-related problems are most crucial for R&D intensive and small firms.
- Except for R&D and small firms, mandatory licensing, reduced terms of patents and a shift of responsibility for screening of IPR involvement in standards to the IPR holders are not regarded as adequate solutions.
- Secrecy and related measures such as customer relations management, lead-time advantages and complex product designs are considered more important than patents for the firms to protect their inventions and innovations.
- Companies involved in standardisation procedures are much less patent intensive than those not involved, indicating that standardisation and patenting are often dealt with as alternative strategies.
- The most important barriers to transfer of research results into standardisation are institutional problems with the standardisation process. It is considered too expensive, particularly by SMEs, slow and inflexible.
- There is not enough coordination between research and standardisation.

Note: Some 60 per cent of the responding firms received funding from the EU's 4th or 5th Framework Programmes for research and technological development (RTD). 46 per cent of respondents suggest that these programmes' IPR provisions should be reduced to a minimum. More than 50 per cent of the firms have been involved in standardisation activities within the past three years, seeking to exert influence and to prevent certain specifications from being adopted.

Source: Blind et al., 2004.

Figure 7.1 Technologies in the Patent-Standards-Space



policy suggestions relate to all these areas in that order. When inconsistencies or conflicts arise between policy approaches across areas, an integrated, technology and market specific decision, is called for. Since these policies affect a wide range of institutions – from R&D funding organisations, patent offices and standardisation bodies to agencies regulating competition – consensus is not easy to achieve.

Research

Although research policies are not directly linked to standardisation, the origin of new standardisation projects can often be traced to publicly funded research projects. Clearly, the direction of research activities is more influenced by public policy than by standardisation activities, since the latter are largely driven by private interests. The evidence suggests the need for:

- Specific training of researchers on standards and IPRs and their relationships.
- Inclusion in publicly funded research of a provision relating to the use of results for the development of standards.[24]
- The design of research programmes focused on social or environmental problems should factor in the costs of developing the respective standards and these costs should be at least partially eligible for funding.
- All research projects aiming to develop test and measurement methods should establish at the outset the scope for the development of a new standard. Direct links with the standards organisations and the relevant committees should be established early in the life of the project.
- The research teams should get in touch with a member of the relevant standardisation committees to assist in translating the research results into standards.
- Specific incentives should be established to improve information flows between the public research institutes and standardisation bodies. The evaluation of research institutions should be based not just on their scientific output (publications and patents) but also on their technological contribution to standardisation processes.
- Developing common guidelines on IPR sharing in a pre-competitive environment and case studies showing the advantages thereof (see box 7.4).[25]
- Early warning on the IPR implications of standardisation activity to avoid conflicts and achieve best returns from research projects, in cooperation with industry.

Intellectual property rights

The following suggestions are focused on changes in the patenting regime or practice:[26]

- Minimise risks arising from patents with weak or doubtful claims.
- Match the harmonisation of international standards with that of national IPR regimes.
- Make IPR material easier to monitor by increasing its transparency and accessibility.
- Allow for highly selective, case-based, last resort compulsory licensing provisions in the court system so as not to prevent IPR-holders from participating in standardisation processes.[27]

Box 7.4 The GSM case

The Global System for Mobile Communications (GSM) standards, the most widely spread platform for digital mobile communications, are used in more than 60 countries around the world. The standardisation process culminating in GSM got under way in Europe 1982. At that time national operational and administration monopolies were still key players. But their position began to weaken when the radio-bandwidth around 900 Mhz was reserved for mobile communications in 1978. Bandwidth became a scarce resource. Analogue systems were facing capacity problems and they lacked cross-country roaming capability, which sealed-off markets and made cellular telephony unattractive to business.

Standardisation promised economies of scale in cellular telephony by unifying the hitherto isolated European markets, providing export opportunities for equipment manufacturers and new services, such as SMS (short message services). And it did set in motion the next-generation of the Universal Mobile Telecommunications System (UMTS) coalition (SMG5).

During the late 1980s, work towards GSM changed playing field: from that of the national telecoms monopolies to that of the ETSI. This was influenced by equipment manufacturers seeking to realise economies of scale across Europe. Traditional allegiances between them and the national post and telecoms administrators began to be disrupted. The wild-card presence of Motorola, the fifth largest equipment manufacturer after Ericsson, Nokia, Siemens and Alcatel, which was looking for a stronger position in the European market, also helped. Moreover, EC was actively pursuing a unified European market.

Telecoms operators and equipment manufacturers pursued very different IPR strategies. There were also differences among the latter, particular between those European-based (as part of their alliances with the national telecoms monopolies, which discouraged IPR-based strategies) and Motorola. While the EC was seeking the deregulation of the European telecoms markets, the national telecoms operators were still stipulating that, when tendering for network technologies, suppliers had to grant their IPRs freely and without geographical limitations. The most vocal opponents to this were not the traditional national champions (Alcatel, Siemens) but Motorola. This stand was eventually also adopted by the European suppliers, which forced in most cases an abandonment of that approach to IPRs. Motorola, by refusing to such agreements and entering a limited number of cross licenses arrangements, helped reduce the number of equipment suppliers to itself, Alcatel, Ericsson, Nokia and Siemens.

GSM entailed a co-ordinated design for the digital mobile system and its orchestrated launch in the whole of Western Europe in a timely manner. The underlying imbalance between the IPR portfolios of the various players was made evident by the comprehensiveness of the standardisation process. The duration of this process (over a decade), its scope (comprising several interfaces) and level of detail (over-specified to ensure interoperability) increased the probability of IPR-centred conflicts. 'Essential patents' were claimed at all levels by various actors. By the late 1990s over 20 companies claimed to hold about 140 cumulative patents, which they construed as essential to the GSM standard, comprising several types of technologies (switching, speech-coding, radio transmission). More than 60 per cent of the patents had been applied for *after* the GSM system took shape. Many of these may have been motivated by Motorola's use of its patent portfolio, an approach that extended progressively to its European rivals.

The conflicts re-emerged in connection with the UMTS system, partly ignited by the growing use of IPRs as strategic tool among the European companies (including events such as Ericsson purchase of Qualcomm's infrastructure business).

Source: Iversen, 2004

- Set up IPR helpdesks to increase awareness about conflicts between IPR and standardisation.

Annex 7.3 contains additional policy suggestions in three specific fields, that is, disclosure rules, licensing policy and patent pools.

Standardisation

The proposals that follow are addressed to the SDOs.[28]

- Encourage SDOs to identify promising new technologies at their very early stages, when basic research activities are all-important, and to start related standardisation processes straight away, rather than waiting until private firms are already involved in pilot production and therefore less inclined to share their knowledge in standardisation processes.[29]
- Promote awareness among those participating in standardisation processes of possible inputs from elsewhere in the knowledge subsystem, especially regarding incipient technologies.
- Establish incentives for standards that do not specify the design of components but their performance, so as to avoid conflicts with patents protecting these components.[30]
- Limit the duration, scope and level of detail of standardisation processes. Develop guidelines for the treatment of IPRs during (long) standardisation processes.[31]
- *Provide incentives for innovative R&D-intensive companies* to join standardisation processes (e.g. attractive licensing schemes).
- Improve SDOs performance by making them more expeditious and flexible, reducing participants' costs and facilitating the transfer of research results into standards.

Competition

Standards may impose a number of costs on users', but they may also foster competition by levelling the playing field. Competition policymakers would benefit from a better understanding of the scope of conflict between IPRs and standardisation and its impact on competition policy issues. A closer dialogue between all parties involved is a first step in this direction. The following proposals focus on the consequences for competition of the interaction between IPR and standards.

- Consider the restrictive use of compulsory licenses when IPR-protected technologies integrated in a standard lead to an increase of the monopoly power of the IPR holder.
- *In the case of mandatory standards, regulate the case of* IPR holders who refuse to give licenses at reasonable fees or gratis.
- Use standardisation as a substitute for regulation to solve some competition problems.[32]
- *Consider standards as a means to speed up the substitu*tion of a patented technology when the patent holders attempt to extend their monopoly after the protection comes to an end by means of relying on brand loyalty built up during the terms of patents.
- Encourage policies seeking to increase the net pro-compet-

itive effects of patent pools, for instance by involving competition authorities in laying out allowable licensing terms or promoting a patent pool notification scheme to increase awareness on the scope of conflict between IPRs and standardisation and simplify the decision making process.

All in all, since the rationale and objectives of the four policy areas differ, there are inevitable tensions between them, which are dealt with by various institutions. The best way to deal with this multiplicity would appear by means of coordinated action seeking to improve the relationship between standardisation and IPR, taking research and competition policy aspects also into account. A first step towards this is to bring the responsible authorities together and encourage an intensive exchange of ideas.

Policy implications for developing countries

The policy recommendations above are broadly applicable to developing countries, keeping in mind the asymmetries stemming from their status as latecomers. Some aspects, however, require adaptation their specific conditions.[33] These are examined below.

Research

Clearly, shortage of resources (financial or human skills) inevitably imposes severe constraints to the range of areas to be targeted for investment in domestic R&D capability. Hence, there is a need to pay particular attention to the early integration between R&D and standardisation activities at the project, programme and institutional levels. Developing countries building up new research and standardisation capacities have a window of opportunity to do so, in contrast with the often broken up systems in industrialised countries, which are just beginning to address the problem.

Intellectual property rights

The economic costs and benefits from stronger IPRs vary considerably according to a country's level of industrial and technological development (Lall, 2003). Because of their relatively low inventive intensity, developing countries face less manifest conflicts between national standardisation activities and domestic IPR holders. However, their national standardisation activities do confront the massive accumulation of patents in industrialised countries. In order to gain international acceptance, national standards set by the domestic SDOs need to take into consideration the IPRs held by firms in industrial economies. Furthermore, the domestic institutions involved need to ensure a high quality of patents and serve also as information providers both about domestic and international IPRs. Domestic companies also need to be encouraged to build up high quality patent portfolios as a precondition to being able to influence the specification of international standards.

Standardisation

Since most developing countries are members of or have links with ISO, they are aware of their various guidelines, including IPR rules. These should also be followed in the domestic standardisation system. By setting integrated incentives and institutions for a stronger integration between R&D and standardisation, developing countries can take advantage of the lessons from the potential conflicts reviewed above.

Clearly, disclosing IPRs relevant for standardisation processes in developing countries affects especially the rights of foreign residents. Therefore, the standardisation bodies in developing countries need to have expeditious access to the databases of the most important IPR offices, including the World Intellectual Property Organisation (WIPO), USPTO, EPO and the Japan Patent Office (JPO).

Patent pools may enable developing-country firms with IPR portfolios pertinent to specific international standardisation to gain influence in international standardisation processes.

Securing reasonable licensing fees is as important as securing the transparency of IPRs pertinent to standardisation. However, mandating that a royalty should be 'fair, reasonable and non-discriminatory' (FRAND) gives little guidance for the determination of the final price. There may be large differences of opinion about the meaning of FRAND when dealing with the typical relation between an advance-country IPR holder and an SDO or firm based in a developing country. The infringement of foreign IPRs involved in a domestic standard needs to be avoided. To facilitate and speed up the respective negotiation process, an international database on this area, including information exchange capabilities, should be built up.

Patent pools may enable developing country firms with IPR portfolios relevant to specific international standardisation to gain influence in international standardisation processes, as entry tickets into pools of international firms trying to co-ordinate their technological capacities and find a common consensus within a standardisation process. Besides their patent portfolio, the former firms also possess know-how about specific user and consumer preferences. This expertise may increase the likelihood that an international standard will become successful worldwide.

Competition

Developing country markets are often exposed to large international companies that strongly influence the specification of a standard based on the possession of the relevant IPRs.

Their overwhelming market power may exert an even more powerful influence on the specification of international standards. In this case, the levelling-the-playing-field effect of standards obviously does not work, at least not in the short run, because of the asymmetries involved. The way out of this predicament is for domestic firms to acquire the competence required to implement the international standards in their products, thus developing the ability to compete successfully both in the domestic and, eventually, international markets.

To an extent, the diffusion of international standards may offset weak developing country self-regulation via standardisation and reduce the need to rely on governmental regulations, which may lead to selecting the wrong technological specifications.

Especially important for the diffusion of (formerly patent protected) products in developing countries is the role of standards in devaluing the brand loyalty that is built up that works to preserve a quasi-monopolistic position once the patent term expires. Although this function of standards facilitates only the imitation and diffusion phases, it also has an impact on the speed of technical change in developing countries. The possibilities of this strategy have to be investigated further.

Standards and developing country competitiveness[34]

What follows deals, first, with the macro- and micro-economic determinants of firms' decision to invest in quality and standards-related capability and, second, with industry needs for services required to conform standards and technical regulations (STRs) from advanced industrial economies.[35]

Determinants of the decision to invest in quality-related capabilities[36]

The involvement of developing country firms in international trade is crucially affected by developed country product and process STRs. As tariff and quota barriers to trade in agricultural, food, and manufactured products continue to decline due to the multilateral trade agreements, public debate is increasingly focusing on the impact of STRs. Seeking to minimise health and environmental risks, prevent deceptive practices and reduce transaction costs in business by providing common notions of 'quality', 'safety', 'authenticity', 'good practice', and 'sustainability', they have become a more common, though subtler, hurdle to trade.[37] Depending upon particular industry or market circumstances, STRs can either raise or lower economic efficiency; promote or block competition; facilitate or constrain international trade; and enable or exclude the participation of the poor in remunerative economic activities.[38]

Even in a semi-industrialised country like Argentina, the commitment of manufacturing firms in the field of quality and conformity has not been extensive so far. Firms with certified quality management systems are a minority, fewer than 30 per cent of the total (see table 7.3). Most of them, except the largest and more established ones, do not appear to assign a distinctive role to quality capabilities within their organisational structure, budget and management. These low levels of commitment to such capabilities is consistent with the fact that a large number of manufacturing firms lack the technological competence required to export goods subject to stringent STRs in industrial economies. In addition, the incidence of firm-specific investment in quality capability varies a lot. Very few firms keep separate account of these expenses. Most consider them as part of expenses in human resource management, R&D, procurement, investment, logistics and marketing (packaging and labeling).[39]

Two factors move firms to certify compliance with quality management system standards. One is the need to enhance reputation and credibility. The other is the contribution of the standards to increased productivity when they are used to improve production processes. For the first factor to actually count, the adaptation to the standard must be done effectively. Otherwise, the cost of compliance may end up exceeding the gains (or avoidance of losses) in market share. The effectiveness of compliance differs according to cumulative capability and the nature of the respective efforts.[40]

Standards certification by firms building trade competence is sought when:

- It is required by foreign clients;
- Firms' export-led growth augments the operational complexity, certifications helping to demonstrate success improved internal consistency;
- Expansion towards more mature markets, like the EU or the US is expected.

In these cases certification (and the ensuing compliance effort) is perceived as a useful tool to improve operational practices – although some complain about the short-term opportunity costs of adapting to the required standards by having to divert time from other productive activities. Firms claim that investing in improving quality managements systems is a must, regardless of firm size and markets targeted. They sense that the effective application of a quality management system triggers off a better environment for productivity gains[41]. Traditional cost-benefit analysis of this type of

Table 7.3 Diffusion of quality management systems

Firms that have or use	*Quantity*	*Percentage of total panel (1688)*
Quality control points	982	58.2
Follow up spreadsheets in each control point	701	41.5
Frequency distributions	311	
Cause-effect diagrams	242	
Control of variables graph	414	
Attributes statistical control	376	
Pareto diagrams	228	
Certified quality management systems	495	29.3
General norms	415	24.6
Sector specific norms	174	10.3
Certified products	211	12.5

Source: UNIDO based on the survey of National Innovations and Technological Behaviour of Argentine firms, 1998/01, INDEC.

investment may lead to the wrong conclusions by failing to capture intangible benefits, both current and future.

Many firms proactively investing in quality development have been engaged in exporting for quite a while, including to some sophisticated markets, before they decided to certify their quality management systems.[42]

The decision to invest in quality development is usually part of a non-linear process. In some cases, firms decide strategically to target a market with stringent STRs and invest in building compliance capability beforehand. In other cases, they engage in preliminary sales to markets with more stringent requirements without the ability to meet them since the enforcement may not be too strict; as they learn about the market and seek to secure market share, they begin to build compliance capability. Once the export contract is secured, the firm undertakes the investment, particularly if it plans to expand its customer base, which would allow it to adequately amortise the cost of the investment.

Investments in quality development rarely, if ever, result from government initiatives. The exception may occur when the government enacts domestic technical regulations equivalent to foreign ones, but this required proper enforcement.[43] While enforcement of domestic technical regulations is not per se a requirement to enter foreign markets, it is part of the necessary framework conditions to build standards and conformity assessment (SCA) capability.

The government often lacks the capacity to test whether the products comply with domestic technical regulations equivalent to foreign regulations. It also often fails to provide accreditation to private laboratories for conducting these tests. This unduly raises the costs of compliance for domestic manufacturers.[44] Despite the availability of public programs to support certification activity, surveyed firms do not report to have used them and/or consider them a meaningful factor.[45]

> ***Investments in standard and quality development are more closely associated to export activity than to the general expansion of the domestic market***

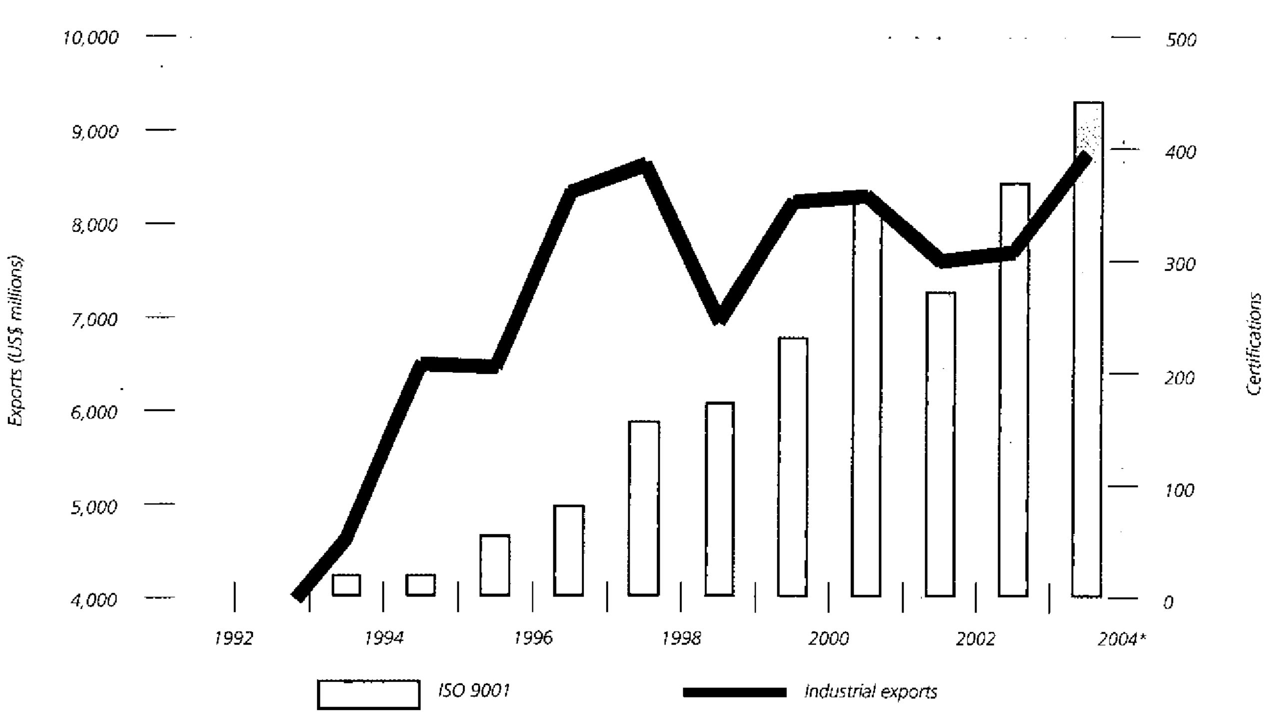
A high correlation between manufacturing exports and ISO 9001 certifications suggests important feedbacks between both (see figure 7.2).[46]

Characteristics specific to industries and firms

Approaches to certifications of quality and environmental management systems, products and quality development in general appear to vary significantly across industries. At first sight, a high correlation is found between the inter-industry distribution of ISO 9001 and 14001 certifications (including

Figure 7.2 **Manufacturing exports and ISO 9001 certifications**

ISO 9001 certifications (manufactures)



Source: UNIDO based on INTI and INDEC

services) and that of the share in GDP, suggesting no intrinsic differences in certification intensity across industries. However, if services are excluded, the correlations drop significantly, suggesting that inter-industry heterogeneities in manufacturing matter when it comes to investments in quality development.

The inter-industry pattern of ISO 9001 certification intensities further reinforces the view that investments in standards and quality development are more closely associated to export activity than to the general expansion of the domestic market. Activities with relatively large certification intensity include electronics, informatics and telecommunications and metal-mechanics. These have export shares that exceed 50 per cent.[47] All activities with export propensities below 50 per cent have relatively low certification intensities. Two interesting outliers are food and rubber products, which have relatively low certification intensities, but high export intensity.[48]

Size

Certification intensity varies positively with size (proxied by total sales). Four concurrent reasons may account for this pattern.

- The direct cost of certifying does not increase significantly with size, thus making it relatively cheaper for large firms.
- Compliance with certification requirements can be more burdensome for smaller, less established firms, which have not yet acquired sufficient internal consistency in their operations.
- Large firms are more likely to target (and be able to serve) more demanding customers, thus making certification more necessary.
- Large firms are more likely to be the targets of inspections and auditing by regulation enforcing authorities.

Large firms also show higher rates of implementation of quality control points and quality control spreadsheets. This would make SMEs the major beneficiary of an expanded investment in SCA infrastructure – although their demand also needs to be specifically promoted (see Chapter 6). At the same time, large firms would enjoy an immediate bonus in terms of costs reduction.

Foreign capital participation

Quality certification intensity is positively related to foreign capital participation, though there is a discontinuity in this. The intensity jumps upwards when shifting from full local ownership to less than full local ownership. Once the minimum threshold of foreign ownership is crossed, there are no further remarkable increases. Demands and transfers of managerial and manufacturing practices from abroad may make firms with at least some foreign capital participation more inclined to develop quality management systems. As a result, locally owned firms would, in principle, be the major beneficiaries of an expanded investment in SCA infrastructure, albeit their demand will also need to be fostered. However, foreign-owned firms would also benefit from reductions in the compliance costs.

A sharp increase in the certification intensity of the Argentine food industry has been observed of late. This relates to an increasing exposure to numerous emerging STRs, including good agricultural practices (GAP), good manufacturing practices (GMP), HACCP and standards like the Euro-Retailer Produce Working Group Good Agricultural Practices (EUREP-GAP), British Retail Consortium (BRC), and International Food Standard (IFS).[49] Food exports account for 26 per cent of Argentine exports. The current international environment makes it crucial for the food industry to invest in building SCA (see Chapter 8). For this reason, the fast rate of growth of certifications with industry-specific standards is a positive development, although it does not appear to match their diffusion abroad, particularly in the case of the most stringent standards. However, the low participation of the food industry in ISO 9001 certifications and the relatively deficient testing and calibration infrastructure, suggest that quality management in this industry still has a long way to go. Crucial to this will be a better provision of SCA infrastructure services and the promotion of the demand for these services.

Compliance costs

Firms need to incur in STR compliance costs regardless of whether they export. This includes expenditures in GMP; process, raw material and inputs control; personnel training; occupational safety; suppliers development; packaging; equipment maintenance; in-house laboratories for mechanical, chemical, metal and corrosion tests; certification of API and TÜV norms (steel industry); metrology, quality auditing and assurance; laboratories; weights tracing for calibration tests; compliance with electric security regulations and testing and product certification. There is a significant dispersion across industries, and even across firms within the same industry, in the incidence of these costs arising from differences in size, stage of growth and capability-building endeavour, and from inter-industry STR heterogeneity[50] (Table 7.4 provides the range of these costs, normalised by sales across various industries).[51]

Table 7.4 Inter-industry distribution of quality expenditures

Activity area	*Incidence of expenditure in quality on sales' price (%)*
Chemicals (granular enzymes)	0.29
Metals (aluminum and steel)	0.058–0.27
Vehicle parts (shock absorbers and engine valves)	0.92–3.19
Electric machinery (digital weighing machines and fitness equipment)	0.93
Beef	1.50
Dairy products (cheese, powder milk)	0.66–9.5
Footwear (leather shoes)	2.50
Processed food (fruit juice and canned tomato)	0.2–2
Oil seed products (peanut and peanut butter)	0.33
Refined fuels	0.04

Source: UNIDO Survey.

Clearly, making adaptations to conform with STRs, which usually entail both internal and external training, significant cultural changes and considerable opportunity costs, is much more costly than the certifications per se. These costs are hard to quantify and are relatively larger for smaller and poorly organised firms. In the case of small firms, high opportunity costs may arise from having to allocate scarce management time to dealing with the heavy paperwork that these certifications involve, which may be worth it since an effective compliance effort prompts a more productive operational environment.

A deficient SCA infrastructure undoubtedly increases firms' compliance costs and detracts from their international competitiveness

Certification costs tend to be higher for developing country firms than for their advanced country counterparts. This relates to the need to meet STRs that differ among advanced trade partners and to the lack of mutual recognition agreements. Nevertheless, the unit costs of adaptation, installation and certification of these norms are usually very low, even for small firms. The most significant compliance costs appear to be those related to quality assurance, laboratories, and metrology (table 7.5 provides the respective range.). A deficient SCA infrastructure undoubtedly increases firms' compliance costs and detracts from their international competitiveness. The ability to meet basic domestic STR related requirements and the respective SCA infrastructure are today part of the threshold framework conditions for IS development.[52]

Exporting to advanced country markets involves investments in STRs compliance ranging from product and process certification to product and process redesigns. Additional costs may also have to be incurred as a result of duplication of inspections, delays of shipments and so on. One time costs (R&D to adapt products or processes; new equipment), recurrent fixed costs (a minimum administrative and lab staff devoted to standard compliance activities; maintenance of equipment and labs; validation of product and process certifications; costlier quality control process), and/or higher variable costs (more expensive inputs and raw material) may also be involved. Fixed costs of compliance may affect negatively firms' decision to enter, or remain in, a given market with restrictive standards. Variable costs of compliance may reduce exports and the exporter's net price. (Table 7.6 shows the range of total compliance costs with EU and US STR as a percentage of the value of sales).

The incremental cost of compliance with foreign STRs is negligible in many activities, either because the STRs are highly diffused internationally (case of shock absorbers for automobiles) or because the firm is part of a global production network and already works with an integrated total quality system, which does not distinguish between domestic and foreign STRs. In those industries where compliance with foreign STRs involve non-negligible incremental costs, these can reach 11 per cent of total sales (leather shoes). Incremental costs differ by industry, and include investments such as: product redesigns related to GMPs, re-tooling, improvements in raw materials, personnel training, improvements in quality control, certification of market-specific product STRs, duplication of inspections, labelling and packaging.[53]

These incremental costs may come from complying with public standards (i.e. certifying BRC norms for exporting food to the UK), proprietary standards (i.e. requirement to install faucets with automatic sensors for an exporter of canned vegetables to the EU), and technical regulations (i.e. US labelling requirements for leather shoe products). The main costs of compliance usually arise from machine re-tooling (eg, one-time fixed costs such as in machines for assuring the size of canned tomatoes) or adjustments in product characteristics (e.g. refined oil products that must meet new requirements in terms of sulphur content). Costs of compliance related to public standards are usually low in monetary terms, although they can have large opportunity costs in terms of the time required to deal with paperwork (like in the case of certifying Underwriters Laboratory (UL) norms for exporting electric machinery to the US).

Quality-related incremental costs of exporting to the US and the EU can be as large as, or even larger than, the basic costs of quality development, management and assurance.

Table 7.5 Certification costs

Certification	*Cost relative to total sales* (%)*
ISO 9000	0.0004–0.35
ISO 14000	0.02–0.18
HACCP	0.001–0.006
IRAM 92/98 (electrical safety)	0.025–0.075
API (steel)	0.0013
TÜV (steel)	0.0001

Source: UNIDO Survey.
Note: * Includes certification and adaptation to norm requirements.

Table 7.6 Basic and incremental STR-related expenses

Activity area	*Incidence of expenditure in quality on sales' price (%)*	*Incidence of incremental costs on sales' price (%)*
Chemicals (granular enzymes)	0.29	0
Metals (aluminum and steel)	0.058–0.27	0–4.20
Vehicle parts (shock absorbers and engine valves)	0.92–3.19	0–4.66
Electric machinery (digital weighing machines and fitness equipment)	0.93	4.30–8.33
Beef	1.50	S/d
Dairy products (cheese, powder milk)	0.66–9.5	1.77–3.19
Footwear (leather shoes)	2.50	10.73
Processed food (fruit juice and canned tomato)	0.2–2	2.44
Oil seed products (peanut and peanut butter)	0.33	2.04
Refined fuels	0.04	2.50

Source: UNIDO Survey.

Their incidence appears to be greater in activities with high certification intensity, such as electric machinery and vehicle engine parts, and in labour intensive industries with smaller economies of scale (like leather shoes). Additionally, firms in the electric machinery industry and in the dairy products sector (which also has relatively high costs of compliance) report important deficiencies in the public SCA infrastructure.

The sizable costs of complying with both domestic and foreign STRs in several activities raise the concern that firms' decision may be significantly discouraged from investing in SCA if domestic technical regulations are not properly enforced or if the related infrastructure and overall policy and institutional environment are not geared towards developing the required capabilities.[54]

In sum, the incidence of compliance costs results from a combination of the following factors:

- An inadequate SCA (public and private) infrastructure (e.g. insufficient public testing capabilities, lack of international accreditation of local inspections and inadequate capabilities for local product certification).
- Lack of harmonisation with foreign STRs and insufficient capability to demonstrate their equivalences when settling disputes.
- High costs of importing and adapting equipment required to meet more stringent foreign STRs.
- Low scale of production due either to domestic market structure, poor export performance, and unfair competition from 'technically informal' local firms that benefit from poor enforcement of local regulations.

Assessing the needs for a trade related knowledge/business infrastructure

Developing country firms appear to afford relatively higher STR-related costs than their developed country counterparts. This asymmetry owes much to the quality of the SCA infrastructure and the ensuing impact on the ability to meet and demonstrate the equivalence between domestic and foreign STRs, tests and certifications. Hence the need to invest competitively in the domestic provision of the respective services, which in turn demands a careful needs assessment and economic evaluation,[55] in addition to ensure the congenial working of the business innovation and knowledge subsystems (for the case of sanitary and phytosanitary measures, see Chapter 8). Table 7.7 provides a summary of private sector views on the services of the Argentine SCA infrastructure.

The SCA infrastructure, a key component of the knowledge subsystem, represents the collective capability to satisfy private sector requirements in the areas of metrology, standards and conformity assessment. These capabilities require a vast range of technological facilities, programs and institutions, including an adequate endowment of accredited, and technologically updated testing and calibration laboratories; an internationally accredited local infrastructure of accreditation and certification; research institutes; training, financial and technical assistance to private firms seeking to comply with STRs; standard harmonisation; an adequate endowment of skilled labour force; and dynamic institutional capabilities to deal with, and anticipate, frequent changes in foreign STRs.[56]

An adequate provision of SCA infrastructure services can significantly reduce private firms' compliance costs and enhance their export competitiveness. It can also help them to upgrade their technological and managerial and quality-assurance management practices, further enhancing their competitiveness. SCA infrastructure services are largely non-excludable.[57] The management of existing SCA institutions and programs is fundamental to effective IS development policies.

The key specialised components of the SCA infrastructure are:

- The bureau of legal metrology;
- The standardisation bureau;
- A national conformity assessment system, which comprises accreditation, certification, testing and calibration; and,
- National technical regulation agencies.

The ability of the SCA infrastructure to deal with fast changing STRs from industrial economies is normally constrained by inconsistent budgets, skills availability, managerial practices and agendas of the various intervening institutions.[58]

The workload of developing country SCA systems is experiencing very rapid growth. Table 7.8 provides evidence for Argentina, suggesting a fast decline in unit certification costs during 1999–2004.[59]

A preliminary UNIDO/IRAM *(Instituto Argentino de Normalización y Certificación)* estimate suggests that the annual cost of running the SCA infrastructure, such as it presently stands, is below US$50 million (this excludes food and pharmaceutical products). Most of this cost is accounted for by the running of testing and calibration bodies (67 per cent), followed by products and systems certification (16 per cent); metrology and standardisation (six per cent each); technical regulations (three per cent) and accreditation (two per cent).[60] Within testing and calibration, the former accounts for almost 90 per cent of turnover, two thirds of which is estimated to have been carried out by private organisations.[61]

Final remarks

We have examined the role of standards in two very different scenarios. The first is that of the standard setting economies, where this activity is largely privately driven and plays a strategic role in interactive innovation processes. In this scenario, rapid technical change, by giving raise to technological variety, generates a demand for standards development to reduce uncertainty and excessive competition while standards development, by focusing search and reducing uncertainties, tends to make multiple innovative tracks converge and thus gain in impact. The public and private dimensions of the knowledge involved translate into tensions between IPRs and standards, which only very recently begun to be addressed.

Table 7.7 Private sector views on the supply of SCA-related services	
Services	*Firms' perception*
International accreditation of local tests, inspections and certifications	Lack of harmonisation between local and foreign technical regulations in several sectors (dairy products, beef) and/or the lack of physical capacity for testing different technical requirements (electrical machinery, motor valves) unduly raise the costs of compliance for local firms. Lack of mutual recognition agreements increases the costs of testing and inspections and the probability of rejection of shipments (wine sales to Germany). Lack of local certifiers for several norms (SA 8000, for instance) raises the costs of certification.
Knowledge creation	INTI appears to be biased towards testing activities and away from quality-related research and technical assistance.
Availability of testing laboratories and metrology services	Personnel in public research institutions is not sufficiently trained and updated to perform certain tests. Adequate material resources (machinery and equipment) are frequently not available. Firms in several activities are forced to perform many tests abroad, at a high cost. These deficiencies prevent the realisation of joint R&D on new products between the public and private sectors. The public sector does not offer all the calibration services that are required to test compliance with different STRs in several industries.
Response time	Large delay of public institutions in response to demands of technical assistance, the approval of new models, and in testing activities. Delays in accreditation of private laboratories have led to bottlenecks for the approval of compliance with new technical regulations in the electrical machinery industry.
Institutional dynamic capabilities	As cellular phones have changed EMI technical regulations in the EU, manufacturers of electrical machinery fear that new facilities for testing and certifying compliance with these regulations may not be installed in time.
Enforcement of local technical regulations	Poor enforcement (weighing machines, dairy products) leads to unfair competition that deters complying firms from passing to prices the costs of quality development and compliance with regulations.
Facilitation or obstruction of coordination	INTI did not allow manufacturers of weighing machines (70 per cent of which are located in the city of Rosario) to fund the installation of testing facilities for the approval of new models and the tracing of scales and masses in the city of Rosario. As a result, these tests have to be undertaken at the Miguelete technological park in the province of Buenos Aires, more than 300km away from the location of production.
Access problems	Many surveyed firms report a geographical mismatch between the location and production and the location of laboratories and other testing and trade-creating facilities.
Education of firms, workers and customers	The government does not play an active role in training and assistance activities leading to a cultural change regarding investing in, and demanding, quality. When new technical regulations are introduced, like in the case of auditable quality systems in the weighing machines industry, the government has offered no assistance of any sort, leading to sizable costs of compliance.
Assistance to certification programs	Programs of support to certifications lack practicality in their implementation.
Financial assistance to quality development	Fiscal incentives to quality-related training programs have proved useful. The financing of the one-time investments required to meet foreign STRs, which often represent a large initial disbursement, is not readily available. While the FONTAR program offers financing for new machinery and equipment, there is a mismatch between the response time demanded by foreign customers and the speed of access to credit. This is particularly critical for SMEs.
Inter-institutional coordination	Lack of agreement between INTI and Metrología Legal regarding the tests required for the approval of new models of weighing machines has prevented the approval of new models since September 2003.
Collective action	In many industries, inter-firm heterogeneity regarding size, productivity, technological development, attitude towards quality, and conformity to regulations prevents a collective action leading to privately-funded provision of SCA services.

The second scenario is that of a developing, potentially catching-up country, in which case the information and the practices and routines entailed by standards (particularly those relating to quality management) are an input for improved competitiveness, credibility and reputation. As it is to be expected for the case of a standard-follower country, this occurs pretty much across the board rather than in frontier technology areas. Because the very recent and rapid diffusion of public technical standard in developing countries, governments have a key role in helping set up the necessary standards and conformity assessment infrastructure as part of the threshold framework conditions for PSD. In fact, an efficient infrastructure of this kind, still largely absent in most of the developing world, is indispensable to offset the competitive disadvantages suffered by manufacturing firms from latecomer countries.

Standards are also important for developing countries embarking upon high technology sectors such as ICTs whose products and services are getting rapidly diffused globally. Adoption of standards in this case may entail important tradeoffs requiring careful monitoring of technological trends.

Because of the differences between these two scenarios, the policy implications obviously also differ greatly. While in the first scenario, public policy issues are largely about stimulating the private sector to better handle the production and distribution of knowledge by means of the necessary institutional innovations, in the second scenario they are essentially

Table 7.8 Evolution of certification activity 1994–2004				
	1994	*1999*	*2001*	*2004*
ISO 9001 certification[1]	23	1 388	2 324	3 100
ISO 14001 certification[2]	0	84	175	400
Conformity marks	750	3 002	10 981	16 691
Estimated unit cost (US$/certificate)[3]	2 174	1 262	1 045	910

Source: UNIDO/IRAM.
Notes: 1 and 2: Total number of certificates issued in Argentina by all the certification bodies operating in the country;
3: Includes ISO 9001 and 14001 certification costs only.

about investing in capability-building and in creating the incentives and institutions for the development of a responsive standard and conformity assessment infrastructure to assist enhancing firm's quality management and international competitiveness. Only in very few cases are potential catching-up countries beginning to play a role in standard setting in emerging technology fields. This experience may show the way for the countries that follow and for that reason warrants close monitoring.

Annex 7.1: National and international standard development activities

Table 7.A.1

Country	ISO status	Staff directly employed by ISO member	Annual budget 2002 (Thousands of Swiss francs)	Number of organisations to which standards development work is delegated	Government subsidy in % of total revenue	Total number of standards published at 31/12/2002	Voluntary standards in % of total number of standards	Number of International Standards adopted as national standard 31/12/2002
Africa								
Algeria	Member	75	602	130	71.5	6 177	98	5 360
Angola	Correspondent		341		100			
Benin	Subscriber	10	300	120	60	4	50	
Botswana	Member	66	4 503		77	181	93	64
Burundi	Subscriber		44		100			
Cameroon	Correspondent	7	90		80	204	95	170
Congo,	Correspondent	141	7 375			2	100	
Côte d'Ivoire	Member	23	483		12	560	60	186
Egypt	Member	825	7 269		100	4 183	91	959
Eritrea	Subscriber	34	495	17		334	0	
Ethiopia	Member	328				389	0	
Ghana	Member	367	2 744		73.25	226	0	370
Kenya	Member	657			56.5	3 021	35	1 243
Lesotho	Subscriber	11	100		100			
Libya	Member	40			90	479	0	
Madagascar	Correspondent		175		53	67	90	
Malawi (1999)	Correspondent	145	2 100		52	450	70	155
Mali	Subscriber	45	250		100		75	
Mauritius	Member	71	1 600		63	149	92	38
Morocco	Member	25	600	8	100	3 707	98.4	1 221
Mozambique	Correspondent	15	97		82.4	16	93.7	5
Namibia	Correspondent	6			100			
Niger	Subscriber	7	48 953		100			
Nigeria	Member	164	331	10	77	578	96	9
Rwanda	Correspondent		639		100	6	50	6
Seychelles	Correspondent		1 500		73	67	88	8
South Africa	Member	1 032	45 000		26	4 966	99	1 430
Sudan	Correspondent	720	3 500	4		628	0	1 100
Swaziland	Correspondent	3			100			
Tanzania	Member	123	1 884		39	738	68	328
Tunisia	Member	104	2 154			5 401	85	4 320
Uganda	Correspondent	85	1 696		75	467	70	121
Zambia	Correspondent		216	1	85	400	97	12
Zimbabwe	Member	72	2 565		50	1 195	96	195
Asia								
Australia	Member	478	68 573	2	2.5	6 664	75	1 877
Bangladesh	Member	478	2 347		10.9	1 729	91.73	115
Brunei Darussalam	Correspondent				100	25	100	14
Cambodia	Subscriber			25	100	10	80	3
China	Member	60	16 580		100	20 206	86.2	8 931
Fiji	Subscriber	5	54		100	17	65	4
Hong Kong SAR China	Correspondent	214	26 700		100			
India	Member	1 996	23 844			17 764	99	1 070
Indonesia	Member	123	2 077	14	100	5 868	96.8	1 100
Japan	Member	108	26 500	588	100	9 009	100	

Table 7.A.1 (continued)

Country	ISO status	Staff directly employed by ISO member	Annual budget 2002 (Thousands of Swiss francs)	Number of organisations to which standards development work is delegated	Government subsidy in % of total revenue	Total number of standards published at 31/12/2002	Voluntary standards in % of total number of standards	Number of International Standards adopted as national standard 31/12/2002
Korea, Dem. People's Rep. of	Member	187	100	204	100	11 100	0	752
Korea, Rep. of	Member	244	32 732		100	15 176	100	7 054
Macao, China	Correspondent	60	5 000		92	10	0	
Malaysia	Member	40	2 500	1	100	3 702	98	1 064
Mongolia	Member		587	102		3 776	21	1 057
Nepal	Correspondent	104	387		100	654	99	30
New Zealand	Member	48	5 800	2		2 371	95	911
Pakistan (1999)	Member	152	630	2 000		4 602	99	1 902
Papua New Gunea	Correspondent	13	286		23	1 400	86	1 400
Philippines	Member	87	679	25	100	1 941	95	1 167
Singapore	Member	544	28 910		82	824	76	273
Sri Lanka	Member	304	1 774		20.8	1 627	98.3	448
Thailand	Member	485	11 997		100	2 347	97	272
Viet Nam	Member	964			60	5 370	94	1 400
Central and Eastern Europe, Baltic States, CIS								
Albania	Correspondent	25	250	70	95	7 038	100	3 479
Armenia (1999)	Member	420	1 055	20	4	272	70	8
Azerbaijan	Member		1 440	8	70	567	10	6
Belarus	Member	46	1 000	39	100	20 593	50	2 319
Bulgaria	Member	1 174	300	75	43	17 194	100	929
Czech Rep.	Member	176	6 790		36	26 082	100	5 379
Estonia	Correspondent	20	621	22	50.9	10 266	100	1 978
Georgia								
Hungary	Member	120	6 715		26	22 283	100	1 488
Kazakhstan	Member	28	3 867	48	100	400	0	22
Kyrgyzstan	Correspondent	136	296	3	100	515	50	6 000
Latvia	Correspondent	29	466	40	70	10 739	100	4 207
Lithuania	Correspondent	58	1 415	745	80	11 743	100	708
Moldova, Rep of	Correspondent	185	299		100	574		110
Poland	Member	294	8 738	8	75.23	25 613	97.57	6 843
Romania	Member	86	885			22 710	100	5 718
Russia	Member	190	9 440	28	82	22 219	60	560
Slovakia	Member	108	2 948	420	57.1	26 295	100	2 031
Turkmenistan (1999)	Correspondent	22	4 010	8	2	600	0	12
Ukraine	Member	132	1 242	1	100	23 585	75	3 010
Uzbekistan (1999)	Member	925			15	2 679	0	
Latin America								
Antigua & Barbuda	Subscriber		139		89.68	1	0	
Argentina	Member	170	6 261			7 710	91	101
Barbados	Member	20	1 200		89.8	200	77.5	70
Bolivia	Correspondent	43	1 200	11		1 300	65	200
Brazil	Member	73	5 771		17	9 271	100	340
Chile	Member	50	1 738		11	2 583	60	651
Colombia	Member	170	7 200	5	2	5 000	100	1 370
Costa Rica	Member	16	885		2	344	100	80
Cuba	Member	1068	6		60	4 278	94	2 353
Dominica	Subscriber	6	250		100			
Dominican Rep. (1999)	Subscriber	60	503		62	523	77	24
Ecuador	Member	87	1 399		3.6	2 318	75	27
El Salvador	Correspondent		375	2		904	92	835
Grenada	Subscriber	9	267		65	117	89	21
Guatemala	Correspondent	7	88	5	100	706	9	16
Guyana (1999)	Subscriber	42	28		98	172		94
Honduras	Subscriber					12	80	12
Jamaica	Member	149	8 412		20	343	56	45
Mexico	Member	104		7	100	5 570	85.5	
Nicaragua	Correspondent		204		100		10	
Panama	Member	8	167		100	522	85	10
Paraguay	Correspondent	173	2 532		70	529	99	17
Peru	Correspondent	273	15 270		10.8	3 800	99	202
Saint Lucia	Correspondent	11	333	25	100	57	63	10
Trinidad & Tobago	Member	200	4 225		39	505	70	255
Uruguay	Member	35	1 500			1 561	91	254
Venezuela	Member	67	2 435	17		3 804	90	454
Middle East								
Bahrain	Member	21	977	2	95	1 685	75	245

Table 7.A.1 (continued)

Country	ISO status	Staff directly employed by ISO member	Annual budget 2002 (Thousands of Swiss francs)	Number of organisations to which standards development work is delegated	Government subsidy in % of total revenue	Total number of standards published at 31/12/2002	Voluntary standards in % of total number of standards	Number of International Standards adopted as national standard 31/12/2002
Iran	Member	1 322	33 551	1	29	6 400	93	4 800
Iraq	Member							
Israel	Member	730	59 700		3	2 475	76	906
Jordan	Member	165	6 502		100	1 607	65	326
Kuwait	Member		2 250	5	88	1 247	72	62
Lebanon	Correspondent	6	1 000	2	100	655	85	86
Oman	Member	70		4	100	1 780	93.88	137
Palestine	Subscriber	91	730		100	621	42.7	55
Qatar	Correspondent	123	6 112	2	100	1 071	79	222
Saudi Arabia	Member	522	27 000		88.88	2 136	11.17	268
Syrian Arab Rep.	Member	110	300		100	2 250	18	
United Arab Emirates	Member	18	3 750	10	100	1 062	75	
Yemen	Correspondent	134	965		84.84			
North America								
Canada	Member	88	11 000	4	56.1	2 143	100	1 053
USA	Member	77	24426	194	3		100	836
Western Europe								
Austria	Member	120	18 000	1	11	14 106	74	2 219
Belgium	Member	42	6 570	2	29.4	17 170	99	11 000
Bosnia & Herzegovina	Member	23	423	194	60	13 626	40	2 158
Croatia	Member	149	4 925		49	6 057	100	2 699
Cyprus	Member	13	1 087	3	85	10 000	97	10 000
Denmark	Member	176	27 235		29	17 496	95	
Finland	Member	60	9 000	15	28	16 532	99	2 698
France	Member	630	119 500	28		26 544	99	9 911
Germany	Member	727	140 000	15	11	27 179	100	8 860
Greece	Member	89	7 140		36	12 384		1 897
Iceland	Member	9	1 296	1	63	13 106	100	4 754
Ireland	Member	167			24	272	100	12 619
Italy	Member	120	21 905	14	24	15 561	95	1 197
Luxembourg	Member	7	1 106	52	100	14 197	100	5 560
Macedonia, the former Yugoslav	Member		70		100	11 657	100	2
Rep. of Malta	Member	25	1 000	8	90	12 000	100	113
Netherlands	Member	220	32 200		1	22 053	100	10 092
Norway	Member	14	2 760	4	33.1	11 775	89	2 650
Portugal	Member	11	12 710	48	19	5 241	100	732
Serbia & Montenegro	Member	105	1 133		100	13 933	39	1 533
Slovenia	Member	31	2 828		75.4	15 055	100	1 776
Spain	Member	430	66 797		5	19 735	80	3 611
Sweden	Member	160	31 400		10	21 800	100	4 675
Switzerland	Member	30	8 000	5		13 950	100	3 500
Turkey	Member	1 408	76 252			26 572	100	6 550
United Kingdom	Member	5 175	500 626	38	1.5	22 589	100	10 145

Source: ISO Members Directory 2003 cited in the WTO Annual Report 2005.

Annex 7.2 The 3G Patent Platform

A. Background History

Business Context (circa 1998)

The patent concerns associated with third generation (3G) mobile communication were first raised officially in 1998. It was known that a very large number of companies owned technologies, in terms of 'essential' patents, necessary for the realisation of 'standardised' 3G systems. This was an unprecedented situation: in GSM, for example, there were less than 20 companies with essential patents. The key strategic choices for the 'standardised' technologies were made during 1998 within the major international, regional and national standards making bodies (International Telecommunication Union (ITU), ETSI, ARIB, Telecommunications Technology Association (TTA), Telecom Training Centre (TTC), Telecommunications Industry Association (TIA), etc.)

The choice of the 3G radio access technology for Europe, for example, was ratified by ETSI in January 1998 – the so-called UTRA (UMTS Terrestrial Radio Access) compromise solution. In reaching this compromise agreement the major concerned parties recognised officially the need to establish an industry accepted arrangement for handling the complexities and uncertainties of the IP situation. At that time industry was uncertain whether:

- The potential essential patent owners would in actual fact grant licenses on the 'standardised' technology, and whether
- The cumulative maximum license costs (royalties) would be consistent with the commercial viability of equipment costs and service provision, and whether
- The industry would establish opportunely a collective arrangement for the cost effective management and administration of all the concerned essential patents

Similar concerns were expressed in all standards bodies. The industry nominated Alcatel, in January 1998, to organise the launch of an industry-wide initiative to address this matter.

Industry IPR initiative

Definition phase

The initial definition of the 3G Patent Platform was the responsibility of the UMTS IPR Working Group comprising 41

Entities that participated in some or all of the definition activities

European-based	*Asian-based*	*North American-based*
Alcatel	China Academy of Telecommunications Technology (CATT)	Air Touch Communication
Bosch	ETRI	Analog Devices
British Telecom	Fujitsu	Conexant Systems
Cegetel	Korea Telecom	Golden Bridge Technology
CSEM/Pro Telecom	Korea Telecom Freetel	InterDigital
Ericsson	LG Telecom	Lucent Technologies
France Telecom	LG Electronics	Motorola
KPN	Matsushita	Nortel Networks
Mannesman	Mitsubishi Electric	Qualcomm
Nokia	NEC	Sipro Lab Telecom
Philips	NTT DoCoMo	Texas Instruments
Sagem	Oki Electric Industry	
Siemens	Samsung	
Sirius	SK Telecom	
Sonera Corp.	Sony	
T-Mobil		
Telecom Italia Mobile		
Telit Mobile		
Viag Interkom		
Wavecom		
3G.Com		

Organisations

ETSI
ETNO (European operators)
GSM Association
UMTS Forum

major international companies (operators, equipment manufacturers and chip vendors). The Group worked within a legal entity called the UMTS Intellectual Property Association (UIPA). The 3G Patent Platform specification was first approved and published in June 1999 by the UIPA General Assembly. Beyond that date, and up to April 2002, the definition of the 3G Patent Platform has been substantially enhanced to ensure compliance with antitrust regulations and a better understanding of industry requirements.

Implementation phase

The actual commercial implementation of the 3G Patent Platform was assigned to the 3G Patent Platform Partnership (3G3P) comprising 19 major operators and manufacturers ('Partners'), four Promoters and two Associate Partners. The role of the 3G3P was (1) to seek antitrust approval from the major antitrust regulatory authorities including the Japanese Fair Trade Commission, the EC and the US Dept of Justice Antitrust Division, (2) to set up the legal structurally framework, and, (3) to establish an operational evaluation and certification process and the necessary support administrative structure. The 19 Partners provided the necessary financial support to undertake these tasks for three years. The implementation phase was completed in December 2002.

Commercial phase

The commercialisation of the 3G Patent Platform commenced in January 2003 with the start of commercial evaluation and certification services within 3G Patents Limited (a common service company set-up to support the Platform Companies which are responsible for the actual licensing of the certified essential patents for a specific technology). The W-CDMA Patent Licensing Programme became operational in January 2004.

On 21 October 2004, Platform WCDMA announced the publication of a Joint License for W-CDMA Essential Patent Rights for Terminals (Joint License Agreement or JLA). The JLA is being offered grouping together all relevant W-CDMA FDD certified essential patents from several patent holders under the W-CDMA Patent Licensing Programme, effective from 1 January 2004 until 31 December 2006. Beyond that date the JLA is renewed automatically for periods of two years without limit. For each renewal the royalty rates are strictly controlled within defined limits thus ensuring total certainty from a business case perspective. Licensees do not pay royalties on certified essential patents covered by an existing bilateral agreement between any of the patent holders, thus avoiding double payments. The licensing terms offered are considered to be fair, reasonable and non-discriminatory. In particular, the royalty rates are considered concessionary and it is considered unlikely that a licensee would negotiate independently a better cumulative deal with all the patent holders. Licensees taking a JLA by 31 December 2004 will not be expected to pay royalties on licensed terminal products sold prior to 30 June 2004 and, in addition, for the first term of the license the licensee will be entitled to a 20 per cent discount on the royalty rate payable (that is, during the period 1 July 2004 to 31 December 2006).

It is anticipated that by end-2004 there should be almost 50 patent families available for licensing based on the existing membership of patent holders; the objectives is to achieve more than 100 patent families by 2006. The attainment of 50 patent families represents potentially in excess of 300 individual certified essential patents available for licensing (these will be certified in time by an independent evaluator as they are granted within their respective countries). As more patent holders join, which is anticipated during 2005, these numbers will increase significantly. All parties that make, use, sell or import terminals that are covered by the licensed product, including all products that claim to conform to the W-CDMA FDD standards including ODM, OEM and EMS manufacturers (that is, the actual manufacture of the terminal) must take either a JLA or an individual license from each patent holder. The nominated Licensing Administrator (LA) will be contacting, henceforce,

Companies associated with the 3G3P during Sept 1999 to Dec 2002

Partners		Partners	
Manufacturers	*Operators*	*Manufacturers*	*Associates*
Alcatel Bosch ETRI (Research Institute) Fujitsu LG Electronics NEC Matsushita Mitsubishi Electric Siemens Samsung Sony	Cegetel France Telecom KPN Korea Telecom Freetel NTT DoCoMo Telecom Italia Mobile SK Telecom Sonera	Huawei Technologies Kyocera Sharp Telit Mobile Terminals	GSM Association ETNO (European Operators)

potential licensees inviting them to take the JLA or to start independent negotiations with each patent holder. The LA has been given some discretionary powers to offer more favourable terms for those licensees taking a JLA in the short term.

B. Platform specification

The 3G Patent Platform means the rules of operation of a generic scheme designed to deliver licenses of 'essential patents' as defined in the Platform specification, "3G Patent Platform for Third Generation Mobile Communication Systems: *Definition, Functions, Structure, Operation, Governance*". The 3G Patent Platform is not a corporate entity. All functions are performed within a defined structure given below.

Functional features

The scope of the services cover the 3G systems standardised family of technologies defined in the ITU within the framework of IMT 2000, plus any regional adaptation defined by 3GPP and 3GPP2, approved and published by the recognised standards bodies (e.g. ARIB, ETSI, TIA, TTA, TTC, CCSA, etc.).

The three functional services are:

- An evaluation of patents submitted voluntarily by patent holders (or third parties) and certified by the Evaluation Process to be essential to the pertinent published standards or to parts thereof:
- An arrangement for licensing the certified 'essential patents' under a flexible and cost effective regime,
- An identification of 'essential patents' necessary to realise 3G systems.

The submitted patents will be evaluated and certified in accordance with an Evaluation Process demanding the highest quality performance. In the absence of a credible industry recognised evaluation and certification process 'essential patents' cannot be licensed meaningfully worldwide. Licensing under the 3G Patent Platform is straightforward and, by design, very flexible. The following licensing options exist:

- Standard License Agreement (SLA): a 'default license' available immediately to licensees
- Interim License Agreement (ILA): a 'time-limited' SLA permitting bilateral negotiations between licensors and licensees
- Independent bilateral licensing arrangements between Members and non-Members

Flexibility in the licensing arrangements permits companies to maintain the freedom to tailor their licensing arrangements to suit their business interests. The Platform specification currently defines the generic terms and conditions of a SLA/ILA (annex B and C of Platform Specification). The actual 'pricing' elements, such as the Standard Royalty Rate (SRR), Maximum Cumulative Royalty Rate (MCR) and the Reference Market Value (RMV), are established by a Platform Company (technology-specific). The rationale for this approach is explained below under Antitrust Clearance.

Structure and Governance

The 3G Patent Platform has been structured within a legal and organisational framework to preserve and stimulate competition among the various radio interface technologies defined in the 3G standards. Completely independent Platforms shall be established, one for each radio interface technology, operating within a legal structure (a Platform Company). Each Platform Company will be incorporated under English law and the Board of Directors will comprise the essential patent holders of that technology i.e. governance limited to the licensors. The administrative aspects of licensing will be outsourced to a Licensing Administrator with specialist skills. Today, a Platform Company for the W-CDMA technology has been created.

Antitrust Clearance

The 3G Patent Platform has been approved by the major antitrust regulatory authorities (Japanese Fair Trade Commission, June 28, 2002; European Commission, November 11, 2002 and US Dept of Justice, November 12, 2002), giving the 3G mobile industry better access to patents.

The overall Platform structure, as now defined, provides for a more flexible arrangement enabling the concerned licensors to adjust the 'pricing' element of the royalty rate regime for different technologies as they think appropriate to meet the requirements of competitive pressures. The patent-cost element, in the establishment of a product sales price, is an important factor in producing cost-effective competitive equipment. The ready availability of cost-effective equipment should assist mobile operators in reducing their capital investment in the 3G infrastructure roll-out and make new generation terminal devices more affordable for the individual end-users. These factors should accelerate the introduction of new 3G mobile services. Obtaining antitrust clearance for the business conduct proposed was a significant milestone. No other antitrust approved collective industry patent arrangement exist for the 3G mobile business. The US DoJ gives an overview of the pro-competitive nature of the 3G Patent Platform.

Benefits for all the players

If industry commits to the 3G Patent Platform, there is a win-win situation for all players in the 3G business chain (particularly manufacturers and operators), as it:

- Secures knowledge of which patents are essential and their holders (only about 30 per cent of claimed patents appear to be essential: those declared to the standards bodies)
- Achieves substantial cost and time savings in identifying essential patents
- Reduces hold-up problems that can occur in negotiations
- Reduces substantially the internal licensing negotiation costs for a more global licensing programme i.e. increases licensing revenue with a lower operational cost
- Reduces exposure to patent infringement litigation through a more global license coverage and, by virtue of

the fact, that royalties are payable by the last manufacturer in the chain

- Intrinsically limits the cumulative royalty rate thus reducing the IPR cost-element of a product i.e. creates an industry bench-marking effect for more reasonable royalty rates
- Ability to control IPR cost-element of a product for a given technology i.e. a strategic commercial tool for licensors to promote technology in a competitive market
- Patent holders retain control over their essential patents providing flexibility to license outside the Platform (a real freedom to license to suit best business self-interest of licensor)
- Ensures a non-discriminatory approach for licensors and licensees
- Ensures a minimal unlicensed usage of patents due to a more expansive licensing arrangement globally i.e. awareness of the existence of certified essential patents facilitates access for licensees.
- Eliminates documented patent licensing deficiencies prevalent at the start of GSM e.g. unfair, discriminatory, complicated, time consuming, expensive (some observers claim also anti-competitive)
- Catalyses market growth through easier access to the patents and through equipment cost reductions to operators and end-users
- Reduction in the capital expenditure by operators due to a limiting and more competitive royalty regime for each of the radio access technologies
- Service provision may take place in a more certain IPR environment i.e. the fear of infringement litigation recede providing a greater 'comfort' level to operators
- No antitrust or competition concerns associated with patent licensing: any other collective industry arrangement for 3G essential patents would need antitrust approval
- IPR certainty, in all respects, creates a more favourable stock market view (stock markets sensitive to IPR uncertainty).

Source: Third Generation Partnership Project (3GPP) (http://www.3gpatents.com/).

Annex 7.3

Disclosure rules, licensing policy and patent pools

Disclosure Rules

Disclosure rules enable the SDOs to obtain information about whether technologies under consideration for inclusion in the standard are proprietary and subject to licensing. They thereby reduce the potential for a technology to be included in a standard without the knowledge that a technology owner, with IP that impinges on the standard, may try to extract royalties for the use of the technology.

- Because of differences across industries in the reward afforded by patent protection and in the needs for compatibility and standardisation, no rule can be optimal for all situations. Because of this heterogeneity across industries, the best policy choice may be that which leaves the disclosure rule and the rigor of enforcement up to the respective technical committees themselves. They may be the best suited to optimise the trade-off between the benefits and costs of disclosure that these rules entail.
- Consequently, the shifting of responsibilities for the identification of relevant IPR from the members of the standardisation committee to the IPR holders is not assessed as being an adequate solution. However, the current attribution of responsibilities seems to rely too much on the standardisation committees. Therefore, the identification and disclosure problem has to be tackled, since erroneous decisions at a very early stage of the standardisation process which have later to be withdrawn may cause massive misallocation of resources.
- In order to increase the transparency of IPR relevant for standards, the SDOs following ETSI 's example, should build up publicly available databases with IPR that are potentially 'essential' for their standards.

Licensing Policy

Having learned through disclosure which elements of the standardised technology may be proprietary and subject to royalties, the SDOs are still left with the problem of setting guidelines for the determination of licensing fees the technology owner should charge after the standard is agreed. Mandating that a royalty be 'fair, reasonable and non-discriminatory' gives little guidance for royalty determination because 'reasonable' can be appraised differently by a technology owner and a technology buyer.

- The extent to which a royalty is 'reasonable' may be assessed in terms of the division of gains from licensing between licensor and licensees. While there is no single right answer, royalties that leave the patent owner worse than he would have been had he not joined the standardisation process and royalties that absorb all of the gains from standardisation can be ruled out as unreasonable extremes. The threshold for what is reasonable will depend on the nature of the invention that is chosen as the standard. In order to avoid excessively high licensing fees, 'reasonable' should mean the royalties that the IPR holder could obtain in open, up-front competition with rivals, rather than the royalties he can extract once other participants are effectively locked in the technology covered by the patent.
- Databases containing the relevant details of exemplary cases should be made available. This increased transparency provides guidelines for the negotiations between the IPR holders and potential licensees, making the negotiation process faster and more effective.
- If alternatives between technologies are available, the IPR holders ' pre-selection negotiation and conclusion of licenses with individual licensees should be a positive factor of some weight in the standard selection process.
- Since the empirical evidence has made obvious that conflicts often cannot be solved because of large discrepancies between license fees demanded by the licensor and the willingness to pay of the licensees, SDOs might set up some means of dispute resolution within the organisation to help resolve royalty disagreements. Resolving reasonable royalty disputes within the organisation will almost certainly be quicker and cheaper than resorting to the courts.

Patent Pools

Since usually a number of patents have to be considered for integration into a standard, patent pools may represent a solution for some conflicts of IPR in standardisation processes. Patent pools can serve several key functions, like the identification of essential patents, both inside and outside the standardisation group, and the differentiation between patents essential to the core standard those that are peripheral. In addition, they are an organisational model to save transaction costs regarding both disclosure and IPR licensing. They may also help to resolve conflicts both among IPR holders and between IPR holders and standards users. In general, patent pools may support the diffusion the standards as broadly as possible, while promoting third party licenses on fair, reasonable non-discriminatory basis. On the other hand, if completely unregulated, they may also induce cartelistic behaviour.

Nevertheless, to establish and run patent pools efficiently and to make them work for the public good, some potential conflicts and disadvantages, like their misuse as of price fixing mechanism, have to be taken into account. The following recommendations should be considered:

- The pooling of patents should not take place too late so as to avoid them being driven by interests that may eventually enter into conflict with hybrid standards development.
- Public non-profit research institutions may act as key gravitational force for creating patent pools, since they can more easily balance the often controversial interest of the companies involved.
- Despite the attractiveness of a pool solution, standardisation based on a pool of patents does not automatically mean that a technologically or economically superior solution will prevail. Because of the strong common interests

and the economic power of the patent pool members, the technologically superior solution of an outsider who is either not able or not willing to join the patent pool may not be consider in the standard specification, and this may therefore lead to the development of products and process of inferior quality or higher costs. Hence, even if comprehensive patent pools may solve conflicts between IPR holders, they have to be watched carefully because they may exclude better solutions from individuals or smaller consortia with weaker IPRs or economic power.

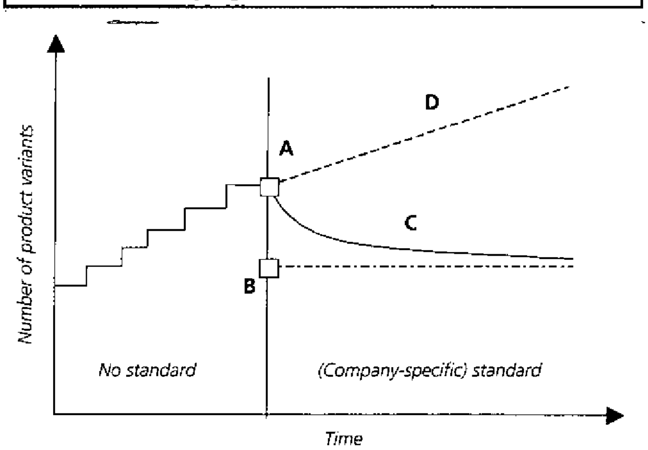
- The involvement in patent pools of companies which are successful in distributing new products and technologies may guarantee the successful acceptance of a new standard, which is economically more beneficial than the failure of a technologically superior standard.

Notes

This chapter draws on background papers by Blind (2005) and Sanchez and Butler (2005). However, the views expressed here are of UNIDO and do not necessarily reflect those of the authors.

1 This applies especially to the use of so-called company-specific standards, which limit the exchange of single components. The phenomenon of variety reduction is represented graphically in figure 8.1, which depicts four different cases: 'A' describes the number of product variations, which are available at a given time in an enterprise (e.g. due to product modifications and different specifications). 'B' describes the number of product variations once national (or international) standards enter the picture. Curve 'C' represents the progressive adoption of own, company-specific standards. 'D' shows the average growth of product variations is the absence of company- or industry-specific standardisation.

Figure 7E.1 **Development of product variety within a company**



Source: Blind 2004, p. 26.

The concept may be used for entire sectors or economies. By preventing possible product variations and potential new product development standardisation can also influence technical change. This may also have negative impacts on economic growth (Saviotti, 1991). Inflexible standardisation may 'cement of the state of technology', that is, cut down useful variations and block change towards other standards. Defining the standard more broadly may lessen this effect.

2 These gains result from a decrease in the number of system elements caused of variety-reducing standards and an increase in the combination possibilities of single elements through interface compatibility.

3 Standards that do not determine the exact content or design, but only certain characteristics of product performance, can alleviate the problems of variety reduction. They also avoid biases in the definition of 'quality' (Liphard, 1998). Product and process innovations that meet the minimum requirements of the formal standards (e.g. for quality and safety), face in principle lower market risks since they help reducing consumers' information asymmetries. This increases the innovator' probability of success when introducing new products.

4 Coordination for standardisation can take place in three ways: governmental regulation (laws and directives), coordination by voluntary committees (formal standards) or market coordination (industry standards). The danger of over-standardisation would follow from price-setting practices (imperfect competition). A supplier may subsidise his own product, increase its market share and thus lay the foundation for an industry standard which corresponds to the characteristics of his own product (sponsored standards). In this form of industry standardisation, technical change would be guided in a direction pre-determined by a single enterprise. Only in rare cases does this option lead to technologically and economically desirable outcomes (Fredebeul-Krein, 1997). Inadequate (under-)standardisation results if costs from the standardisation process are borne exclusively by the standardisers and the positive external effects (e.g. network externalities and positive environmental and health impacts) cannot be internalised. The positive effects of standardisation on technical change would thus not be completely realised. Generally, markets with network externalities tend towards inertia and prevent the adoption of new technologies through lock-in effects. The standardisation of new products is impeded by the above mentioned coordination problem and by positive network externalities. The problems of network externalities speak against a purely market-driven solution – although the school of New Institutional Economics argues that standards are so efficiency-enhancing by their capacity to decrease transaction costs that standardisation should be left to the market (Wey, 1999). A cooperative committee (optimal) solution is possible if there is a common interest among the actors involved to agree on a formal standard and these actors adequately represent the demand and supply sides. Furthermore, the power structure of the standardisation committee must be well balanced, as much in technological as in economic and social competence (see endnote xii). Bodies such as SDOs try to meet these requirements by being accessible to those 'interested parties' that can provide these competences. Over-standardisation results when standardisation committees are not evaluated by the economic and technological efficiency of their released formal standards, but by quantitative output. An exaggerated propensity towards standardisation can lead to premature of inadequate technology being established by standards. Moreover, the possibility exists that non-participating suppliers are deliberately disadvantaged by the standardisation committee, either through one-sided standardisation or when a strong confluence of interest among a few powerful participants influences formal standards in a way harmful to the technical change Böhm et al. (1998, p. 42), suggest, in contrast to current practice, restricting the duration and number of the memberships, as well as appointing representative actors to the committees.

5 In addition to the above, process standards (e.g. safety or environmental standards in manufacturing) do not hinder product innovations while the product standards (e.g. compatibility standards or safety standards in consumption) do not hold back process innovations. Product standards, however, do affect product innovations, since they establish or reinforce customers' preferences which may only be overcome by a vastly improved technological innovation (Willgerodt and Molsberger, 1978). Differing standardisation preferences by participating actors or non-participation by key suppliers may lead to under-standardisation. David and Monroe (1994) examine, on a game theory basis, the probability that an agreement will be reached and come to the conclusion that under certain conditions, depending on the strategies of the participants, the role of the mediator and information asymmetries, the agreement will not take place in time. Economic losses through non-utilisation of network effects, rationalisation and economies of scale as well as technologically unsatisfactory standards can be the result. It can be generally stated that the problem of network externalities can be better solved with this cooperative solution than through the market mechanism, with the danger inherent in the

strategic behavior of the participating actors and thus the tendency towards a technical change strongly influenced by interest groups. On this subject see. also Steffensen (1997), and Böhm et al. (1998). Lim (2002) describes in an abstract manner pre-standardisation in ICT as a negotiation process, whereas Chiesa et al. (2002) highlight the important role of standard development organisation in the mediation process between different interests illustrated by two case studies. Regulation by governmental institutions results in an optimal solution, if the standardisation succeeds in internalising external effects. This target can only be aspired to: government bodies should represent the interests of all the members of an economy and possesses the necessary authority to issue binding regulations and instigate punitive measures in the case of non-observance. A sub-optimal standardisation takes place when the state cannot adequately foresee the technological development and a technical regulation is introduced too early or too late.

6 The 'blind giant' quandary is referred to in the literature as consisting of a situation where the agencies entrusted with developing standards are most powerful when they know the least about the technology (see David, 1986).

7 Cf. Helbig and Volkert (1998, p. 5).

8 In the absence of a strong business innovation subsystem with sophisticated self-regulatory mechanisms in developing countries, public regulation on standards may be expected to be relatively stronger by default. The extent to which this is so, however, is affected by spillovers from the standardisation activities in by the industrialised countries (see below).

9 With increasing income levels, the demand for product variety also expands (see Chapter 6).

10 Relatively simpler products with little prior market exposure can thus gain, in a very short time, a reputation as high quality and less risk (or as low quality and high risk) products, in contrast to the case of more complex products introduced in advanced country markets, which may need longer while users detect their real performance. Depending on the kind of quality and safety standards, they may foster a lock-in of the technology status quo, if they are defined as design standards requiring a narrowly defined product specification. The lock-in effect is less crucial in the case of performance standards, which just specify some minimum requirements.

11 The WTO reports results from studies showing that the key reason why developing countries have a very poor participation in international standard-setting activities is the lack of analytical and technical capacity, concluding that simply increasing funding for participation would not suffice (WTO, 2005a).

12 Developing countries, while accounting for the overwhelming majority of ISO membership, account for just three out of the 12 members of the Technical Management board (ISO/TMB) and are responsible for barely five per cent of its Technical Subcommittees, which set policies, actions and standards. In contrast, the US, Germany, the UK, France and Japan hold among them 65 per cent. The remaining 30 per cent is held by other developed nations.

13 For example, China is currently moving into a leadership position in standardising nano-technological dimensions. It is not clear yet, however, whether this strategic move will generate a position of technological leadership in this area since China still lags behind in output of research activities with respect to the US and Europe.

14 This problem is being addressed at the institutional, policy and multilateral levels (see annex 7.2). So far, however, this issue has been treated rather narrowly. The literature has been focused on the patent-based conflicts that have emerged in the area of ITCs either in general theoretical (legal or economic) or in empirical terms, mostly casuistically. The issues are however not necessarily limited to ICTs, although the drive towards patenting and standardisation is particularly strong in this area. Nor is it necessarily confined to patents, although this is the most obvious front for conflict. Nor does it involve only the areas of standardisation, IPR, and competition policy only, but may extend to research policy more generally.

15 In what follows the attention will be focused on patents and trade secrets. Copyright has also become a large issue in standardisation due to its uneasy association with software (see Besen and Raskind, 1991, pp. 11–14). The question how software should best be protected against imitation by copyright or by patent protection has recently arisen again in the European context. This question suggests one aspect of the changing environment that increasingly brings IPR into conflict with SDOs in new ways (for example Blind et al., 2004). In general, IPRs have a role to play in organising knowledge production, promoting new R&D, promoting further utilisation of and coordinating the use of new knowledge, while avoiding underutilisation losses (for a short presentation of the role of IPRs in the innovation process, see e.g. Iversen, 2002 on which this section draws). For the economy as a whole, the way IPRs do this implies both costs and benefits. IPR-protection brings with it social costs in the form of higher prices (monopoly pricing). But it also provides the economy with an incentive to innovate (based precisely on the innovator' expectation of monopoly pricing). The monopoly profits provided by IPRs may benefit the economy as a whole if they are ploughed back into production and innovation. David (1993) emphasises the following dimensions: (a) full disclosure of information in patent applications. This allows dissemination, verification, and application by others engaged in intellectual pursuits; (b) allocative efficiency; an efficient focusing of research effort entails, among other things, avoiding excessive concentration on the same research and the 'deadweight burden' of monopoly (the case where rights become too strong, barring close substitutes and raising royalties while lowering the benefit to consumers). It also helps coordination of R&D activities. thus facilitating common standardisation activities; (c). Avoiding unproductive competition for monopoly profit (Kitch, 1977; Beck, 1983), including, wastage of resources on premature invention, duplicative R&D, substitute inventions, and excessively rapid spending on research. The non-disclosure of patents in standardisation activities provides a poignant example in which patenting contributes to unproductive competition for monopoly profits. The 1988 Stambler v Diebold case, on ATM cards is an early conflict in which a patent holder attempted to assert his patent for what manufacturers believed to be an open and available standard.

16 For a review of the issues and their genealogy see Saviotti (1991).

17 In market economies the market is the ultimate selection mechanism, whereby the fitness of an individual technology comes down to the choice of consumers. In an ideal situation, a technological design may fit differentiated niches of heterogeneous users (see, for example Frenken and Nuvolari, 2003 for an evolutionary explanation of such processes). However, many other factors may affect choices in the selection environment; e.g. network externalities will shape preferences and affect the diffusion of new technologies. The case of launching large technological systems, like cellular telecoms, provides a special challenge in successfully navigating the selection environment. Coordination in developing and selection is especially needed here to concurrently design and select the large set of design dimensions involved, which interact in complex ways.

18 Examples of this situation are Betamax (Liebowitz and Margolis, 1999) or, more recently, the CT-2/Telepoint system (Grindley and Toker, 1993).

19 The semantic web standards are one example.

20 The OECD report on ICT standardisation in the new global context discusses some of the relevant changes standardisation is facing, including the IPR concern (OECD, 1996).

21 See Miselbach and Nicholson, 1994 for a description of essential IPRs.

22 IPRs that definitely block the process are called 'blocking IPRs'. This can result mainly from two situations. First, the IPR holder may refuse to license at all or to license on a basis considered as fair, reasonable and non-discriminatory. The threat to withhold IPR in this situation may be used as a bargaining chip. A flat refusal would be regarded with extreme suspicion. The existence of essential IPRs among individual rights-holders outside the standardisation work is much less predictable. Absent the necessary search processes, such rights may appear at any time during the life of the standard. The willingness of the rights-holder to license at agreeable terms is not a bygone conclusion, especially if added to already agreed royalty-schemes. Second, there may be a plurality of rights and rights-holders. This case is testimony to the fact that IPRs and the work of SDOs have become much more intertwined. A variety of rights-holders complicates the licensing process, which is supposed to be fair both for the licensee and

licensor. If the *cumulative royalty costs,* while fair to the individual rights-holder, become too high for potential licensee, the standard is likely to die.

[23] This is the worst-case scenario (Blind, 2002).

[24] The need may not be evident at the beginning of the project and hence the implications regarding standards should be reviewed at regular project meetings and seriously considered by the funding institutions. After the completion of research project, the research consortia should be ready to undertake additional work related to the development of standards.

[25] Interesting cases from this perspective are those of the MP3 technology and the European GSM mobile communication standards.

[26] Patents clearly dominate the relationship between IPR and standardisation. In addition, patents claim the broadest protection of a technical invention, whereas trademarks matter more for market visibility and copyrights can be more easily circumvented. The US Federal Trade Commission conducted a public hearing on Competition and IP Law and Policy in the Knowledge-Based Economy in 2001 and 2002, where the role of IPR in standardisation activities was also explicitly addressed. (http://www.ftc.gov/opp/intellect/index.htm; (3-07-2002)).

[27] R&D intensive companies at the leading edge are not very keen on bringing their knowledge into standardisation processes. For evidence concerning Germany Blind, 2006-forthcoming.

[28] The existing ISO/IEC directives related to patents, which are implemented by most SDOs have proven be effective and efficient in most circumstances. Nevertheless, the proposals in the text are mostly directed to general strategic standardisation policies, including licensing and disclosure rules (see Rapp and Stiroh, 2002).

[29] In the very early pre-competitive stage of technology lifecycles characterised by high risks, the main actors are aware that they need to form alliances with their customers and suppliers, but also with their competitors. This constellation already causes some pressure on the actors to converge their interests. With progress in the technology lifecycle, this pressure on the companies will decrease and the likelihood of single actions will increase.

[30] This aspect is especially relevant for the development of measurement and testing standards.

[31] The case of the GSM mobile communication shows that extending these dimensions increases the likelihood and gravity of IPR conflicts.

[32] Standard processes allow all interested parties influence both the specifications and implementation of a standard, thus favouring a level playing field.

[33] The relationships between standardisation and IPRs, as well as their implications for competition policy, also affect technological choices and the direction of capability development even in the less developed regions such as SSA. For example, in the field of cellular communications, while the European GSM standard has enjoyed greater diffusion, efforts are being made to promote the US CDMA 450 wireless loop technology, used in Eastern Europe and India. Since GSM has enjoyed an early led and most African operators have locked into international roaming agreements using GSM, it appears unlikely that CDMA will succeed to be as widely diffused in Africa as in Latin America (Momo, 2005 and Financial Gazette, 2004).

[34] For a conceptual and empirical assessment of systemic competitiveness in development countries, see F. Sercovich (1999).

[35] STR-related requirements cover the areas of product safety, metrology, product and process standardisation, conformity assessment and documentation. Compliance with public standards is not legally compulsory, but it is usually demanded by consumers in order to reduce problems of asymmetric information, credibility and reputation. Typical public standards are the certifications of quality management systems (ISO 9001), of environmental management systems (ISO 14001), of food innocuity (HACCP), of good manufacturing practices (GMPs), of good agricultural practices (GAPs), and many other general and product- and process-specific norms. Public standards affecting public health, safety and the environment that become sufficiently widespread and scientifically founded are often turned into legally compulsory technical regulations. There are of course many technical regulations that were not previously public standards. Typical examples of technical regulations include the electrical safety regulations set by the CE policy of the EU (these technical regulations usually previously were public standards set by the International Electrotechnical Commission), the sulphur content of refined fuels (set by national governments), the ban on the manufacture and use of freon, and most of the sanitary and phytosanitary barriers to food imports, to name a few. Proprietary standards on processes and products are set by a specific client in a foreign market, and need not extend to other sales in this foreign market.

[36] This section is based on a survey on the Argentine industry experience commissioned for this Report. The survey comprised 17 enterprises across 16 activities at the five digits level of the International Standards Industrial Classification (ISIC), Rev. 3. The enterprises surveyed are based in 7 provinces. Their size distribution is: 47 per cent, large, 35 per cent medium-sized and 17 per cent, small. As to export orientation, 82 per cent are established exporters, 12 per cent have recently started exporting to OECD countries and 6 per cent are about to start exporting to the EU. With regard to activity, 41 per cent are in food and beverages, six per cent in refined fuels, 12 per cent in basic fabricated metals, 17 per cent in automobiles and parts and 24 per cent in other manufactures.

[37] The 1947 the General Agreement on Tariffs and Trade (GATT) accord allowed the use of minimum standards to protect human, animal and plant health, as well as bring order to the market. The WTO established that standards can differ from internationally accepted levels only when there is scientific evidence supporting the decision.

[38] Sometimes protection is the only goal. Standards usually apply to both domestic and foreign production thus matching the classical form of protectionism, which openly discriminates against imports. In practice, STRs may be used strategically to enhance the competitive position of countries or individual firms and can potentially impede international trade, for example, by imposing unnecessary costly and time consuming tests or by laying out unjustified different requirements in different markets.

[39] Many of the firms provided only aggregate information on this kind of expenses. Some only gave information on the costs of certifying ISO 9001 and 14001 norms. Interestingly, two comparable firms within a same industry (dairy products) had different views regarding which type of expenditures qualify.

[40] Experts consider that some 70 to 80 per cent of all the ISO 9001 developments in Argentina are poor in nature, while 30 to 40 per cent are downright bad If this appreciation is right, it would signal that most of these developments obey a (shortsighted) marketing strategy rather than a genuine intention of improving the management of quality systems, with little if any significance in terms of improving competitiveness via enhanced credibility and reputation.

[41] This of course depends on how effective the application of the quality management system is. If the firm's effort consists of just obtaining the certification, the compliance effort becomes a purely sunk cost.

[42] A firm that has been manufacturing high-tech weighing machines for commercial use for 40 years, is one of the leaders in the domestic market and has been exporting to Latin America for a number of years, the decision to certify compliance with the ISO 9001 and 14001 standards came after deciding to start developing a new model to be marketed in the EU. In the case of a manufacturer of fitness equipments, which has been exporting to various destinations in the extended EU and to the US, the decision came not as a requirement from importers, but rather as a strategy to improve their own managerial procedures.

[43] For instance, the *Instituto Nacional de Tecnología Industrial* (INTI) and the Legal Metrology body began requiring manufacturers of weighing machines to have auditable quality systems. However, the lack of enforcement of this rule means that only ten per cent of the firms in this sector comply with the regulation. This results in a cost advantage for the firms that do not comply, which diminishes the overall incentive to invest in compliance. The negative impact would be avoided if consumers were willing (and able) to pay more to the compliant firms.

[44] For instance, a new Electrical Safety law, equivalent to the International Electrotechnical Commission (IEC) standards, was enacted in 2000, but there were not enough accredited laboratories to test com-

pliance with the new regulation. As a result, the deadline for compliance had to be significantly extended. In the meantime showing the application forms for the tests sufficed for firms to be allowed to continue producing and selling. The problem was compounded by the shortage of technical assistance services, either from private or public laboratories. The situation was normalised only when more private laboratories were accredited. On a more positive note, manufacturers of car parts report that the tax-credits on training expenditures were very helpful. However, these firms also asserted that the programs of support to certifications lacked practicality and were unsuccessful.

45 Programs of this type include PROCAL (Program of Norms and Quality Accreditation), which seeks to support the development of the demand for accreditation services; FONTAR provides financing and fiscal incentives for technological modernisation, product and process upgrading, personnel training, and quality certification; and the Program of Argentine Food Quality supports the diffusion and intensive implementation of systems of quality management and assurance in the food sector with the goal of ensuring compliance with food safety standards.

46 In contrast, the correlation between these certifications and overall economic activity, measured by GDP, is close to zero. At the same time, the correlation between industrial production and ISO 9001 certifications in the manufacturing sector is also very low, which suggests that certification of these norms is associated more to increased exports than with the expansion of the domestic market. Moreover, a Granger (temporal) causality test suggests that the expansion of total exports drives QRC investment of all kinds, including non-tradables.

47 The relatively high certification intensity of these activities may also arise from technical characteristics of production or the need to certify relatively more goods/processes.

48 The low certification intensity of the food industry appears due to the fact that ISO certifications are not strictly required by the market (as opposed to HACCP, Eurep-GAP, GMP), although this will change soon with the introduction of the ISO 22000 certification (see Chapter 8). However, some experts consider that ISO 9001 certifications are a complement of all the other industry-specific certifications, and that the low certification intensity in this sector simply reflects poor levels of compliance with standards, coupled with exports to destinations with relatively weaker standards. The correlations between certification intensities and export propensities are 0.36 for the whole group, but rise to 0.60 when food is excluded and to 0.84 when rubber products are excluded as well.

49 Product-wise, the greatest incidence is that of PFI (Integrated Fruit Production) certifications, required for exporting fruit to Europe. However, the need to invest in SCA is spreading to non-fruit products, particularly relating to HACCP, GAP, and GMP.

50 For instance, in the dairy products industry, two comparable firms reported compliance costs of 0.66 per cent and 9.5 per cent of total sales, respectively.

51 Most firms regard ISO 9001 and 14001 certifications as part of SCA regardless of whether they export or not, although in practice they usually certify compliance with these norms mostly when they export (or plan to do so). The monetary costs of ISO 9001 and 14001 and product specific STRs certifications (including the respective adaptations) are usually relatively low, making up a very small share of the overall STR related compliance costs.

52 An example of the costs of inadequate provision of Technological Public Goods (TPGs) is given by the differences in the cost of locally certifying different standards. Certifying an ISO 14001 or an OSHA 19800 (occupational safety) standard costs 50 per cent more than certifying an ISO 9001 standard. This cost differential is due to the shortage of local certifiers for the more expensive standards. This circumstance is more evident in the case of standards such as the SA8000 (Social Accountability, for which there are no local certifiers. The cost of certifying this standard abroad is in the US$10 000–30 000 range, about two and a half times what it costs to locally certify an ISO 9001 norm.

53 This does not include other (non-quantifiable costs), such as the opportunity cost (losses of sales and diversion of managerial time from other activities) involved in adapting with foreign norms, dealing with the required paperwork, and so on.

54 The incremental costs for Argentine industry reported here can be compared to those obtained by the World Bank Technical Barriers to Trade Survey (WBTBTS) for the average developing country and the average Latin American country. Bearing in mind that the interviewed firms may be considering different items as being part of the incremental costs in both surveys and that the firms included in each industrial classification may differ across surveys, it is possible to observe that the costs of compliance in Argentina are relatively bigger in the electrical machinery and dairy products industries (highly intensive in certifications), and in the shoe sector (labour intensive, low economies of scale). On the other hand, costs of compliance appear as relatively lower in Argentina in industries such as basic metals and refined fuel (industries with low certification intensities where production is highly concentrated and done on a large scale, and where there is evidence of significant provision of industry-specific SCA servicess by industrial associations and in processed food (that has a low certification intensity). The Argentine Institute for the Steel Industry (IAS), financed by steel producers, has an accredited testing laboratory located in San Nicolás, province of Buenos Aires, where most steel production takes place. The laboratories of the main oil refiner, Repsol-YPF, are used for interlaboratory comparisons by INTI.

55 The World Bank Technical Barriers to Trade Survey (WBTBTS) suggests that the average costs of compliance in developing countries range between 0.26 per cent of sales for Photographic and Optical Instruments to 11.21 per cent of sales for Fabricated Metals. The median costs are 4.44 per cent and 3.17 per cent respectively. The reported costs include one-time fixed costs (like machine re-tooling, new equipment, etc.), recurrent fixed costs (like the operation of improved quality control systems, periodical certifications, etc.) and variable costs (like using more expensive raw material and inputs, or more expensive labelling and packaging). Higher fixed costs raise the probability that exporters may be unable to enter (or be forced to leave) certain markets, while higher variable costs reduce export shares (and the net price to exporters). Both types of expenditures will cause trade costs in the form of fully foregone producer surplus (when exporters have to leave or cannot enter a given market) or partial losses (when marginal exporters are forced to leave, and infra-marginal exporters endure partial reductions in their producer surpluses. Chen et al. (2004) perform an econometric analysis using the WBTBTS data, finding that technical regulations in developed countries adversely affect a firm's propensity to export in developing countries. Their results indicate that testing procedures and lengthy inspections processes reduce export shares by 9 per cent and 4 per cent respectively. They also find empirical evidence that standards and testing procedures impede exporter' market entry, reducing the likelihood of exporting to multiple countries by 13 per cent and nine per cent. Maskus, Otsuki and Wilson (2004) use the same data to estimate translogarithmic cost functions and find that fixed set-up costs of compliance also raise the variable costs of production. According to their estimates, strict standards raise variable costs of production at least as much as set-up costs.

56 For countries with small domestic markets regional (inter-country) capability-building may be called for.

57 There are however, different shades in their publicness. Some of these services must be provided by the government (e.g. an internationally accredited and technologically updated food safety agency); others are industry-specific and can be provided by the private sector (e.g. facilities for testing the compliance with electrical safety standards) but face a coordination (free-riding) problem that may undermine cooperation in their provision. This coordination failure can be overcome either by government intervention (offering, for instance, tax deductions to those that contribute to funding the facilities) or by having a private association offer club goods.

58 This can be illustrated with an example related to electrical safety. A typical technical regulation faced by exports of electrical machinery to the EU deals with parameters of electromagnetic interference (EMI). In order to test compliance, complex and costly lab facilities are required. But these regulations change frequently with the emergence of new technologies, like cellular telephony, that alter the previously defined EMI parameters, rendering the facilities obsolete. Under these

circumstances, private laboratories are unlikely to set up these testing facilities, and if these exports are to be promoted, the public sector would have to intervene in two ways. First by being willing to fund updated testing laboratories. Second by being a member and participating actively in technical committees of IEC, which would allow it to anticipate the upcoming changes in standards and regulations and help the private sector build trade competence ahead of the changes in technical requirements. This same example can be easily extended to other areas like food safety.

59 The national standards, quality and certification system set in 1994 (decree No. 1474/94) formalised a system made up of components that had been operating since 1935 (standardisation) and a new conformity assessment component, thus lying the foundations for the creation of the accreditation body. 1999 witness the start of mandatory certification resolutions by the national government. Aimed at setting minimum safety and quality standards, these resolutions so far comprise electric products, toys, personal protection elements, automobile parts, bicycles, gas lighters, steel product safety and agricultural machinery. The mandatory resolutions factor in the existence of mutual recognition agreements with foreign certification bodies. The activity of international certification bodies in the country encouraged the national body to seek international alliances. In 2002 the accreditation body initiated actions aimed atits integration with the multilateral agreements of the relevant international organisations: International Accreditation Forum (IAF) and International Laboratory Accreditation (ILAC).

60 Argentina has 62 accredited testing and calibration bodies. They can be referents for product certification both in both the mandatory and voluntary arenas and for validation in the industrial sector. Thirteen of them do calibration and forty nine testing, (36 of which are private).

61 During the period 1990–2004, the number of standards issued annually by the Argentine SDO, IRAM, experienced steady growth, from 4,137 in 1990 to 7,103 in 2004, with a compound rate of growth of 4 per cent per year. The key industrial activities involved were industrial chemicals, stone, clay and glass, instruments, basic metal industries, and food drinks and tobacco. Between them they account for over half of the total number of standards issued. The industrial activities with the quickest pace of growth over the period are other manufacturing (7.1 per cent); stone, clay and glass (6.9 per cent), instruments (6.9 per cent) and paper and printing (5.3 per cent).

CHAPTER 8 Building Capabilities for Food Safety

Introduction

The ability to compete in agricultural and food products is increasingly about meeting safety, quality, and environmental requirements (above and beyond price and basic conditions).[1] Furthermore, the forces shaping the rules of the game favour more stringent requirements. Not only is there greater scrutiny of production and processing techniques, but there are also stricter traceability and labelling requisites across the food supply chain. This poses a complex problem as it involves raising capabilities across multiple sectors and multiple agents and the technologies involved span from the most traditional to the most R&D intensive. The management of risks in the farm-to-table continuum requires policy synergies with the control of plant protection, animal health and welfare, feedstuffs, veterinary medicine and other non-food products. Therefore food safety and agricultural health risk management are becoming core competences in the competitiveness of developing countries.

World trade in agricultural products amounted to US$583 billion in 2002, 40 per cent of which came from developing regions (WTO, 2004). While the international debate largely focused on the controversy over agricultural subsidies in trade negotiations, apart from the 'special and differential treatment' and technical assistance provisions of the Sanitary and Phytosanitary (SPS) Agreement, much less attention was being paid to the capability building needs of developing countries in the face of increasingly stringent requirements to trade in agricultural products.

In particular, developing countries compliance with SPS measures provides a very good illustration of the need to raise threshold capabilities across a wide range of activities and actors in the pre-emergence state of the Innovation System (IS). Even in semi-industrialised developing economies with developing IS, growth of capabilities in the food safety area can be uneven. Since SPS compliance is also a 'moving target', the three subsystems of the IS – the knowledge, the business innovation and the policy/governance subsystems – need to co-evolve to keep up with the demands of the international 'rules of the game'.

While many in developing countries perceive the increasing requirements as a potential and significant barrier to trade, the ability to raise capabilities in this field also presents itself as a major opportunity for upgrading and catching-up with other high-value food exporting developing countries. Costs of compliance largely depend on the prevailing level of administrative, managerial and scientific capabilities, private sector structure and conditions, the strength of existing technical extension services and the supply of 'public goods' through the effective partnership of public and private sector. As a result, while the level of overall development seems to be a good indicator of outstanding needs, even more industrially developed countries need to make adjustments to their food safety and agricultural management system to comply with the most stringent standards. Unfortunately, while costs are much more immediate and easier to account for, the benefits from compliance tend to be much more difficult to ascertain. This is largely because of the existence of feedback mechanisms and system-wide spill-overs: for example a well-functioning traceability system creates network externalities so that, as more agents participate, benefits increase for all.[2]

In order to continue to trade, developing countries have little choice but to enhance private firms compliance with the new requirements as well as strengthen the institutional infrastructure, that helps demonstrate that compliance is being achieved.

In order to continue to trade, developing countries have little choice but to enhance private firms' compliance with these requirements as well as strengthen the institutional infrastructure, that helps demonstrate that compliance is being achieved[3]. However, responding to such challenges requires more than adopting good practices and new technologies – it involves raising domestic capacity to interact with the international system, enhancing the knowledge base, building legitimacy and trust in the domestic institutions and guiding the direction of search, experimentation and market building for a growing business innovation system. These institutional aspects of capability building and the interaction between the various actors are the focus of what follows.

The driving forces

In the last decade, changes in how the risks involved in the food chain are understood and approached have resulted into increasingly stringent standards and regulations. Food scares such as BSE (bovine spongiform encephalopathy, commonly known as mad-cow disease) and the increasing consumer awareness of health, environmental and safety concerns in industrialised countries – and especially in Europe – have influenced the way in which risk management and regulation-setting activities are performed.[4]

More stringent and over-arching regulations have also arisen from improvements in the scientific understanding of food-borne diseases and the development of more precise testing methods for potential contaminants, toxins and additives. In fact, probably more than in any other sector, we witness the role of science permeating the entire food supply chain, from most low tech to the highest value added. The development of more rigorous scientific methods and codification of this scientific knowledge through public standards can help improve market performance of producers, retailers and exporters everywhere through better information flows. At the same time, the new approaches to food safety regulation requires a certain degree of technical competence on the part of the private sector to introduce new production methods to comply with SPS measures since there are also many tacit elements affecting scientific uncertainty and risk assessment.

The growing use of risk analysis, the farm-to-fork measures, which include higher degrees of traceability[5], and the increasing demand for the use of HACCP, are important aspects of the emerging food safety system (Roberts and Unnevehr, 2003). For example, the new EU rules on food hygiene require all food businesses after the primary production stage to put in place, implement and sustain HACCP-based procedures (box 8.1).

While most SPS measures, such as those relating to human health and safety, are embodied in technical regulations, there is also a discernible upward trend in the development of private standards, as retailers in developed economies, motivated by commercial strategies of mitigation and differentiation, impose conditions along the supply chain (for a broader conceptual discussion on standards refer to Chapter 7). Although from an international policymaking point of view there is a clear separation between mandatory regulations and private standards, this distinction is not felt so clearly by the producers and exporters. Furthermore, with the dawn of the new ISO 22000 standard on food safety, the

Box 8.1 European Commission's new rules on hygiene of foodstuffs and official controls

The new rules on food hygiene and official food controls established by the European Commission, including the General Food Law of 2002 which established the European Food Safety Authority (together with Regulations (EC) No 852/2004, 853/2004, and 854/2004) and Regulation (EC) No 882/2004 (which will come into force 1 January 2006), are some of the most comprehensive and stringent rules that impact importing countries. Although these regulations leave considerable scope as to how effective systems of traceability and official control are to be established, they require 'food and feed imported into the Community for placing on the market within the Community to comply with the relevant requirements of food law or conditions recognised by the community to be at least equivalent thereto or, where a specific agreement exists between the Community and the exporting country, with requirements contained therein'.

The Regulation contains general provisions for traceability (applicable from 1 January 2005), which cover all food and feed business operators, without prejudice to existing legislation on specific sectors such as beef, fish, GMOs etc. For example, the food law does not specify what types of information are to be kept by food-and-feed businesses in order to facilitate traceability. However, the guidance note prepared by the Commission state that the following information should be kept: (i) name, address of supplier, nature of products that were supplied; (ii) name, address of customer, nature of products that were delivered; (iii) date of transaction/delivery. It further recommends that the following information should also be kept: (i) volume or quantity; (ii) batch number, if any; (iii) more detailed description of the product (pre-packed or bulk product, variety of fruit/vegetable, raw or processed product). The guidelines note that 'the traceability provisions of the General Food Law' do not have an extra territorial effect outside of the EU. It does however cover the stage from 'the importer up to the retail level' and importers are required to identify by whom the product was exported in the country of origin. Unless specific provisions for further traceability exist, the requirement for traceability is limited to ensuring that businesses are at least able to identify the immediate supplier of the product in question and the immediate subsequent recipient, with the exemption of retailers to final consumers (one-step back, one-step forward).

However, 'it is common practice among some EU food-business operators to request trading partners to meet the traceability requirements and even go beyond the 'one-step back, one-step forward' principle, although it should be noted that such requests form part of food-business contractual arrangements and not requirements established by the regulation'. From a developing country perspective it is important to note that the primary liability for traceability under EU regulations falls on the importer. This ultimately affects the relationship between the suppliers and the EU importers leading to the proliferation of a small number of 'preferred supplier' contracts. Thus disruption of exports on traceability/food-safety grounds are likely to arise via the cancellation of 'contractual arrangements' or their non-renewal, rather than as a result of any formal closure of the EU market. Hence developing country exporters need to comply with these internal requirements if contractual arrangements with EU importers are to continue or be developed.

More significantly, from the perspective of development of domestic knowledge infrastructure and food safety institutions, the new regulation on official controls authorises the European Commission to request third countries to provide accurate and up-to-date information on their SPS regulations, control and risk assessment procedures, which supplements the existing system whereby information is requested by the Commission's Food and Veterinary Office during inspection visits to the third countries. Furthermore, the new rules seem to usher in a new trend in pre-approval requirements to export. Accordingly, international suppliers of live animals, plants and certain food products need to be pre-approved. The Commission has plans to develop guidelines on how such information shall be presented to assist importing countries, however under the regulation there is no requirement for third countries to submit a control plan before 1 January 2006. Similarly, although the new regulation does not require third countries to have reference laboratories, it requires laboratories engaged in verifying compliance with EU standards to be accredited and provides for a transition period of four years for third countries to adapt to the new situation.

Source: European Commission, 2004b and 2005.

> ***There is a discernable trend towards the development of private standards, as retailers in developed economies, motivated by commercial strategies of mitigation and differentiation, impose conditions along the supply chain.***

boundaries between private and public aspects of standard setting in this field are becoming even more blurred (see box 8.2). In food safety, private standards and protocols are comparatively more stringent and more effectively enforced.[6] On the other hand, technical regulations continue to exercise more influence over market access in relation to plant and animal health matters (Jaffee et al., 2005). The distinction between technical regulations and private standards is fundamental as regards the obligations of WTO members to notify their technical regulations under the SPS agreement[7] (box 8.3). Furthermore, despite the framework set by the SPS agreement that favours 'equivalence' of measures, exporters often observe a multiplicity of requirements for different markets.[8]

Beyond SPS, there are other compliance issues faced by developing country food and agricultural product exporters – such as IPR protection in agricultural technology and labelling requirements for GM crops in the EU or for trans-fat content in the US to name a few. These health and environment related concerns are expected to increasingly translate into specific requirements to enter not only high-income but eventually also other developing country markets.[9] For example, public perception of the safety of biotechnology products in European countries is much less favourable than in other developed regions, which affects the traceability and labelling requirements for genetically modified organisms (GMO) products, and hence has significant consequences for the exporters from countries where these crops are being harvested on a large scale.[10]

In light of these emerging trends, it is clear that developing country food and feed exporters need to improve their control systems to remain competitive. SPS-related risks are often not limited to one stage of production or processing. As a result, interventions are required not only at the final product testing level but also upstream of the supply chain for effective quality and food safety control. This involves:

- Building policymaking capabilities, including the updating of legislation to enable food safety control agencies to respond to current challenges that go beyond basic control of hygiene and supporting participation in international standard setting and planning activities;
- Setting and fine tuning of public-private cooperation for the effective functioning of the food safety system;
- Reinforcing the technological capabilities within the institutions of the domestic knowledge subsystem, particularly those of the food standards and quality control agencies, through investments to upgrade their testing and measurement, risk analysis and certification capacity, R&D efforts, ICT resources, training and organisational changes for enhanced performance;
- Helping to build capabilities in the private sector to deal with increasingly stringent standards and to gain competitive advantages through experimentation and new market formation by promoting investments in HACCP, good agricultural practices (GAP) and good management practices (GMP), information systems for traceability and labelling, and uptake of environmental technologies.

Although most developing countries have widespread weaknesses in food safety and agricultural health management, which augment other weaknesses in competitiveness such as lack of infrastructure and high transaction costs, there is evidence that even low-income countries can overcome problems gradually by selectively adopting different technologies

Box 8.2 ISO 22000 standard for safe food supply chains

ISO 22000 is the new standard for food safety management systems developed by an ISO Working Group with representatives from 14 countries and from organisations such as the Codex Alimentarius, the Global Food Safety Initiative (GFSI) and the European food industry organisation (CIAA) to be published in September 2005. ISO 22000 specifies the requirements for a food safety management system in the food chain where an organisation needs to demonstrate its ability to control food safety hazards in order to provide consistently safe end products that meet both the requirements agreed with the customer and those of applicable food safety regulations.

The new standard can be applied to organisations ranging from feed producers, primary producers through food manufacturers, transport and storage operators and subcontractors to retail and food service outlets – together with inter-related organisations such as producers of equipment, packaging material, cleaning agents, additives and ingredients.

The standard identified three kinds of requirement:

- For good manufacturing practices or pre-requisite programmes
- For HACCP according to the HACCP principles of the Codex Alimentarius
- For a management system

The requirements for GMPs are not listed in the standard but the standard makes reference to 'existing practices'. The new standard requires the establishment of a 'one-step back, one-step forward' traceability system and has specific measures for validation, verification and improvement of the food safety management.

The standard can be applied on its own, or in combination with other management system standards such as ISO 9001:2000, with or without independent (third party) certification of conformity. The publication of ISO 22000 will be complemented by an ISO Technical Specification (ISO/TS 22004) giving guidance on the implementation of the standard, with a particular emphasis on small and medium-sized enterprises. In the following months, another Technical Specification (ISO/TS 22003) will be published explaining certification requirements applicable when third-party certification is used.

Source: ISO, 2005.

Box 8.3 The International Governance of SPS measures

Currently, the international infrastructure governing the SPS and technical requirements in the food and agricultural products sector is multilayered and relatively complex. World Trade Organization's SPS Agreement has been in force for 10 years for developed country members, 7 years for developing country members and 5 years for least-developed country members as of 2005. The SPS Agreement identifies three organisations to promote the adoption of international standards: Codex Alimentarius Commission for food safety, International Plant Protection Convention (IPPC) for plant health and OIE for animal health. WTO members are encouraged (but not required) to base their domestic legislation on standards developed by these international organisations, though the SPS agreement protects the right of a country to choose its own 'appropriate level of protection' while taking into account 'the objective of minimising negative trade effects'. As a result, there is a multiplicity of standards and requirements in different countries and food groups largely due to significant differences in tastes, diets, income levels and risk perceptions. Standards also often reflect the feasibility of implementation depending on the initial level of technical, scientific, administrative capabilities.

The SPS Agreement has provided a multilateral framework to guide the development, adoption and enforcement of SPS measures in a harmonised way to minimise the negative effects on trade, including a mechanism for notifications, exchange of information and dispute settlement. As of May 2005, 139 (94 per cent) of WTO members had identified a national notification authority, 130 (87 per cent) had established a SPS enquiry point, and 87 (59 per cent) had notified at least one new or revised SPS measure. Between 1995 and 2004, over 300 disputes were formally raised under the WTO's dispute settlement system, of which 30 alleged violation of the SPS agreement. Although developing countries seem to be actively participating in the notification and counter-notification procedures and raising trade concerns, the same cannot be said of least developed economies and certain regions particularly Africa and the Middle East. For example, compared with the 101 issues raised by developing countries and 143 by developed countries, least developed member states only raised two SPS related trade concerns in the SPS Committee. Furthermore, no LDC has been a member of a group of countries to support a concern or brought a measure to the dispute settlement body.

Similarly, participation of least developed countries in the international standard setting bodies such as CODEX has been very limited, becoming a major concern in the SPS Committee. Partly in response to these concerns, FAO/WHO (for CODEX) and IPPC have established trust funds and OIE is in the process of establishing a fund to enhance the participation of developing countries in standard-setting meetings and activities, training programmes and regional consultations.

Beyond the provisions of the SPS Agreement to help harmonise SPS requirements on as wide a basis as possible, equivalence of specified measures, conformity of control, inspection and approval procedures and recognition of pest- and disease-free areas are also important tools mentioned in the Agreement. For example, Codex's "Draft Guidelines on the Judgment of Equivalence of Sanitary Measures Associated with Food Inspection and Certification Systems" addresses the equivalence of conformity assessment procedures.

Source: WTO, 2005b.

or streamlining management systems in certain sectors and government functions (Jaffee and Hensen, 2004).[11] Beyond improved competitiveness, there are many other spill-overs such as the increase in demand for technically skilled workers, local sourcing of infrastructure and technological services.

However, as mentioned in Chapter 6, there are important obstacles to the emergence of IS in developing countries. Since the requirements for a well-functioning SPS system are relatively complex, it is unrealistic to expect all the actors and sub-sectors in developing economies (and especially the least developed ones) to evolve concurrently in a smooth fashion and to achieve sufficient capabilities to undertake a decisive approach to food safety in a short period of time[12]. Both policy makers and the private sector need to build capabilities to broaden the strategic options available to producers and exporters – first by meeting threshold requirements to respond to current challenges and then developing the capacity in the three IS subsystems to adopt a pre-emptive strategy where the agents involved can foresee coming challenges and convert them into strategic opportunities for market development.

There is evidence that even low-income countries can overcome problems gradually by selectively adopting different technologies or streamlining management in certain sectors and government functions.

Upgrading capabilities of the actors and institutions in food safety

Interactions between the subsystems

The responsibility for safe food supply is shared by those intervening in production, processing, and trade along the entire food chain. The official control and food safety legislation-enforcing agencies play an important role in building consumer trust. Modern food control systems have shifted from removing unsafe food and punishing responsible parties after the problem has occurred, to a preventive approach, which relies heavily on risk assessment and risk management, and hence on the development of a knowledge base.[13] Largely due to the demands of the international system, food safety control agencies in developing countries have become a core part of the emerging knowledge systems through their upstream (policy framing, training and R&D) and downstream activities (monitoring, surveillance and inspection), thus requiring sufficient credibility. At the same time, business sector associations, marketing boards and producers' cooperatives play an increasingly important role in the transfer and diffusion of technologies and organizational innovations that are required for compliance, which also affects policy making. Therefore, the relationship between food safety agencies and sectoral associations is one of the keys to building the necessary information flows and transfer of technologies.

> ***The way in which risk management is handled by food safety institutions and reflected in relevant legislation can drastically enhance or diminish the potential for technological and entrepreneurial innovation in the private sector.***

Central to the effectiveness of policies related to food safety is the concept of risk assessment and management. In particular, public policy concerning human health and food safety requires a process by which different control options are evaluated and compared to bring hazards to an 'acceptable level of protection' (ALOP). However, risk assessment and management are strongly influenced by social and political factors such as values, assumptions and vested interests. In a sense it is a political process in which risk managers decide how much of the scientifically determined risk should individuals be exposed to or society accept. These factors often complicate the decision-making process. For example, the often cited precautionary principle states that if there are reasonable scientific grounds for believing that a new process or product may not be safe, it should not be introduced until there is convincing evidence that the risks are small and outweighed by the benefits. Dealing with such uncertainties requires significant scientific and managerial capabilities, as well as credibility in the eyes of the consumers and producers.

Food safety legislation can help (or hamper) the experimentation, resource mobilization and market formation functions of the IS. The way in which risk management is handled by food safety institutions and reflected in relevant legislation can drastically enhance or diminish the potential for technological and entrepreneurial innovation in the private sector. Ideally, policymakers would base their ALOP on public health goals; for example, by determining the level of disease control that is expected and then translating that to a measurable parameter that can be controlled by food producers, rather than selecting (or often mandating) an 'optimal' risk management option. This provides the greatest flexibility in that the industry is given clear goals to achieve, but the specific manner of achieving them is left to the discretion of the manufacturer. This allows firms to be innovative in terms of their direction of search and enable experimentation in achieving food safety. For example, legislation mandating that milk must be heat pasteurised for a certain length of time at a certain temperature, instead of stating the performance criterion that should be achieved, virtually assures that new technologies such as high pressure processing would not be used, though it may actually result in a product that is equally safe and even superior in other respects (Buchanan, 2002).[14]

Building capabilities in the knowledge and policy/governance subsystems

Strengthening national food safety institutions is vital in countries where existing institutions cannot keep up with emerging requirements. Consumer trust (or mistrust) in official control functions can greatly affect the performance of whole sectors and countries, especially as food scares spread more swiftly. For example, the reduction in the consumption of beef products was much less drastic in the US following the discovery of BSE in the domestic herd than in Germany, partially due to the American public's higher level of trust in the FDA.[15]

Modern food safety systems require the traditional inspection/monitoring institutions to take on a more active role in the development of the knowledge system. The multiplicity of demands for the services of national food safety and quality institutions can be met by means of different organizational structures depending on the size of the economy, political considerations and the weight and structure of the food industry. In some countries, several agencies are responsible for food control – often along sectoral and regional lines – but more often there is a single, unified agency with wide-ranging powers. In view of the emerging challenges, an integrated approach can be expected to become a good practice option; with normative activities (such as formulation of policy, development of standards and regulations and coordination) entrusted to an autonomous national food control agency, and other agencies in charge of inspection and enforcement as well as communication and education/training aspects (FAO and WHO, 2004).

A particular problem facing the formulation of policies in this area is the lack of metrics and heuristics in defining the needs of domestic institutions (see Chapter 6). A needs assessment exercise of the Argentinean food control agency (Servicio Nacional de Sanidad y Calidad Agroalimentaria, SENASA), reviewed below provides an example of how needs assessment can be applied in response to this apparent deficiency.[16]

Assessing the upgrading needs of food control agencies

Created in 1904 as an animal sanitary inspection agency, SENASA became the National Sanitary and Food Quality Service in 1996.[17] SENASA's traditional practice has been to approve the inspections, satisfy claims and prevent sanitary outbreaks. In 2003, the Agency was responsible for the certification of US$14.2 billion of food exports and US$600 million of food imports, as well as controlling US$15 billion of food for domestic use.[18] The budget of SENASA was approximately US$100 million up to 2001, but since then it has shrunk to approximately US$30 million as a result of the January 2002 devaluation.[19] Funding, far too low to accomplish the mission, comes mainly from fees and charges to the farmers and economic operators, while the government's contribution accounts for less than three per cent of the total. The shortage of resources in relation to the volume of exports and production can be ascertained when compared with other food safety systems, such as those of Chile or the US (table 8.1).

As in many other developing country food agencies that were established under legislation responding to the requirements of earlier decades, SENASA's organization and mandated mission does not provide for modern food safety approaches based on prevention and risk analysis. Not only are current regulations not coherent and accessible enough, but the agency finds it difficult to anticipate international developments as it has few scientific staff and insufficient resources to attend international committees.[20]

SENASA's main facility, the Reference Laboratory – the core of a network of regional laboratories – is a complex of installations near Buenos Aires specialised in sanitary, phytosanitary and food security analytical controls. This Lab also certifies product quality, agricultural chemicals and veterinary drugs. However, growing analytical demands and the need to improve their services in order to provide adequate answers to the requirements of foreign countries in due time, mean that the lab's resources are stretched to their limits.[21]

A modern food control agency requires a unified system of data processing and information network on sanitary and phytosanitary activities, food manufacturing and transportation.

Currently SENASA does not conduct or contract R&D in food safety. However, as a food control agency it needs to establish risk assessment committees for each of the main production chains as well as institute multidisciplinary groups assessing 'horizontal' risks with the necessary scientific capabilities. Currently, the National Institute of Agricultural Technology (INTA) has R&D teams working on some of the subjects related to food chains and 'horizontal matters'. However substantive R&D capabilities are required within SENASA to help adapt available technologies to local conditions and to find solutions to local problems where there are no readily available technologies. A further spill-over effect from building R&D capabilities within SENASA would be the potential for its trained scientists to contribute to local entrepreneurial development by transferring to the private sector their experience with knowledge-based activities. However, currently SENASA does not have enough specialists to undertake R&D contracts, follow up projects, and monitor intellectual property issues. Therefore there is a need to organise systematic training programmes and secondment opportunities with foreign counterparts to raise capabilities among current staff as well as to recruit more qualified specialists to respond to demands for SENASA's services.

Finally, the demands of the farm-to-table approach to food safety including traceability and risk assessment requirements mean, that in order to properly discharge its duties, a modern food control agency requires a unified system of data processing and information network on sanitary and phytosanitary activities, food manufacturing and transportation. In the case of SENASA, no such network is in place to connect the central office with all the branches (currently more than 300) to enable them to operate in unison. The investments in digital infrastructure also needs to be complemented with investments in physical infrastructure and logistics.

A UNIDO-sponsored needs assessment exercise done in cooperation with SENASA reveals cost estimates for the upgrading needs of the Agency based on reactive and proactive strategies.[22] The investments in the case of the reactive scenario would require US$53.4 million over five years whereas the proactive scenario would require US$133.6 mil-

Table 8.1 **Expenditures of the food safety system institutions – Argentina vs. Chile and US**

	United States	Chile	Argentina	
	1999	2000	2001	2003
Food Safety Expenditures (million US$)	1 300	66.5	100.5	33.5
Expenditures/Exports	3.08%	1.43%	0.88%	0.25%
Expenditures/Trade	1.67%	1.15%	0.81%	0.22%
Expenditures/Production	0.25%		0.24%	0.12%
Expenditures/Diseases	3.51%			

Source: GAO (2001), USDA-ERS; SAG (2001) and ODEPA; SENASA, INDEC and COPAL.

Table 8.2 **Summary of SENASA's investment needs (annual totals, in US$ millions)**

Scenarios and Items	Year 1	2	3	4	5	TOTAL	ANNUAL AVERAGE
Scenario REACTIVE Total	**15.7**	**14.8**	**8.1**	**7.4**	**7.4**	**53.4**	**10.7**
Human capital	0.4	0.4	0.4	0.4	0.4	2.2	0.4
Inputs and services	5.4	5.4	4.4	4.4	4.4	24.1	4.8
Hardware and software	9.8	9.0	3.2	2.5	2.5	27.1	5.4
Scenario PROACTIVE Total	**28.0**	**26.8**	**23.4**	**26.2**	**29.3**	**133.8**	**26.8**
Human capital	2.5	2.9	3.2	3.6	4.0	16.2	3.2
Inputs and services	11.6	13.3	14.3	16.3	18.7	74.2	14.8
Hardware and software	13.9	10.7	5.9	6.3	6.6	43.4	8.7

Source: UNIDO estimates.

lion. These figures represent increases of 32 per cent and 80 per cent, respectively, on the current budget of US$33.5 million. The annual averages are US$10.7 million for the reactive and US$26.8 million for the proactive scenarios (table 8.2). While some one-off investments are required initially to upgrade existing capacity, recurrent expenditures are also required to ensure that dynamic capabilities are built to manage emerging needs. That said, it should be noted that such resource mobilization is a necessary but not a sufficient condition to build a legitimate and trusted institution, which requires significant policy/governance capabilities as well as effective links with the business innovation system.

The composition of the investments highlights the differences between the reactive and proactive scenarios. In the former the most important item is hardware and software (51 per cent).[23] In the latter it is inputs and services (55 per cent), which includes R&D and a larger provision of inputs and services for the technical departments. Also there are large differences between the two strategies in inputs and equipment, installations and software, both needed to increase laboratory performance (table 8.3).

The reactive scenario already demands a substantial increase over the current budget. For example, to maintain a sufficient level of technical support, it will be necessary to increase the current level of expenditures of the Reference Laboratory from US$4 million per year to US$10.5 million; an additional US$6.5 million per year. Furthermore, even in this scenario there is a need for significant investments in ICT and physical infrastructure.

On the other hand, a proactive scenario would allow SENASA to maintain a capacity large enough not only to meet all the requirements expected from the most stringent standards, but also to anticipate future changes. Larger capacity requires reinforcing the regional laboratory network, increasing the number of available tests and integrating results with other departments to improve the performance of the whole organisation. The annual investment for this purpose would be US$18 million, in addition to the current US$4 million (US$72.3 million in five years). The proactive scenario also requires building capabilities in organised risk assessment and local R&D to help producers and exporters. Local R&D capacity is also needed to participate in the international scientific community to deal with subjects that will eventually inspire legislation, policies and private decisions in the future. The estimate for investments in R&D capacity also includes those that are needed to improve decision making processes. In return SENASA might engage local institutes and universities in R&D contracts to help absorb, adapt and transfer relevant technologies to the private sector.[24]

Table 8.3 **Summary of SENASA's investment needs (total for five years, in US$ millions)**

Items	*Scenario* Reactive	Proactive
Laboratories	32.7	72.3
Personnel	2.2	8.7
Inputs	13.6	31.5
Services	6.1	11.7
Hardware and software	10.8	20.3
Information Technologies	15.6	15.6
Inputs and Services	4.4	4.4
Hardware and software	11.2	11.2
R & D	0	27.2
Personnel		1.3
Inputs and Services		25.9
Training	0	6.8
Personnel		6.2
Services		0.6
Vehicles and other facilities	5.1	11.9
Total	53.4	133.6

Source: UNIDO estimates.

Sanitary and phytosanitary measures in the development of a business innovation system

The business innovation subsector is, as pointed out in Chapter 6, a critical but often the weakest component of an emerging developing country IS. An emerging IS assumes a threshold level of technical competence on the part of the intervening actors such as that required to introduce new production methods to comply with SPS measures and other requirements involving technological choices, in addition to financial resources and legal/technical knowledge about how to access low-cost technologies and transfer them. Normally there is a need to adapt the technologies to local conditions, so catching-up in this area requires indigenous capabilities to co-evolve within the firms as well as within the technological support infrastructure to help absorb and adapt necessary technologies to the local needs.

Furthermore, threshold requirements involved in achieving compliance with SPS measures are often unevenly distributed across the production chain and across commodities. Commercial risks involved are not static and may increase as market conditions, scientific knowledge, and regulatory stringency change. Moreover, investments are often necessary to achieve productivity gains, increase unit value-added and promote experimentation and innovative activity in the business sector.

A good example is the adoption of HACCP-related upgrading in the private sector. HACCP requires an approach to production that oversees the risks involved throughout the production chain and adapts processes to minimise them. Implementation of HACCP can yield process innovations and help the enhancement of managerial capabilities in the business sector. For example, application of HACCP principles is resulting in a rationalization in the organization of processing and packaging activities, with producers increasingly opting for a management system that integrates both (Process Engineering, 2005).

Various private standards as applied by major European retailers and distributors also affect experimentation and market development for new services and products across the food chain, as well as the logistics of distribution. For example, the German directive for avoidance of packaging waste, published in 1991, has led major retail chains to adopt

Another area where consumer expectations and private certification schemes are shaping the high-value food trade is organic farming. It requires small farmers and cooperatives to adjust their processes in important ways that require considerable capability-building.

a returnable transport packaging system even though the use of reusable packaging was not itself mandatory. The International Fruit Container Organization (IFCO), a private German company, took the lead to market and manage the production and distribution of foldable fruit and vegetable crates, which gave them a considerable advantage as more retailers across Europe were persuaded to adopt these recyclable packages instead of the local packaging made from wood and fibre from exporting countries. This measure posed major problems for some exporting developing countries because of the cost, time and logistic difficulties involved in returning packaging.[25] While, this example illustrates the challenges involved with keeping up with private standards (partially promoted by regulatory bodies), it also provides an example of how food safety and quality requirements can be turned into competitive advantage and create new markets.

Another area where consumer expectations and private certification schemes are shaping the high-value food trade is organic farming. Beyond having implications for a whole range of technologies used in production, certification procedures established by private organizations require small farmers and cooperatives to adjust their processes in important ways that require considerable capability building. For example, the need to segregate organic from non-organic produce along the production and distribution chain may mean that if small-scale farmers choose to market their organic products, they may no longer be able to benefit from the scale economies provided by cooperatives and marketing boards, unless these organizations make process changes to ensure that goods can be segregated (Rotherham, 2003).

Similarly, adoption of international agreements such as the Cartagena Protocol on Biosafety or Montreal Protocol on Substances that Deplete the Ozone Layer, can have important implications for the development of business innovation capabilities in the food industry. An example is the phasing out of methyl bromide in developing countries – a pesticide used in soil fumigation, post harvest protection and quarantine treatments – which requires capabilities to research and adapt suitable alternatives but can also help developing countries to comply with stricter quality and environmental requirements through investments that improve pest management and risk control (UNIDO, 2003).

Future challenges and technical assistance needs

The ability to comply with requirements in the food safety and quality area are clearly becoming a core prerequisite for developing countries to stay competitive in the international food trade and to catch-up with other high-value food product exporters. As prerequisites are proliferating, all the actors within the emerging innovation systems of developing countries are being challenged to raise their capabilities to respond to emerging demands (box 8.3).

Between US$65 and US$75 million has been spent by bilateral and multilateral agencies in recent years to build trade-related capacities, which sounds like a drop in the ocean.

As argued thus far, capability building needs have not received the attention they warrant – partially due to the scarcity of metrics and needs assessment methodologies. Along these lines, the strategic partnership between WTO and UNIDO, to help developing and transition economies to remove supply-side constraints and prove conformity to standards and regulations, to complement the Integrated Framework and JITAP initiatives, have resulted in diagnostic studies to establish the needs for nine pilot countries[26] (UNIDO/WTO, 2004).

Recently, increasing attention has also been paid to the technical assistance needs in the field of compliance with SPS and technical requirements. The SPS agreement calls for increased technical assistance to strengthen food safety and agricultural health management capabilities in developing countries. In September 2002, the Standards and Trade Development Facility (STDF) was established through agreement between WHO, FAO, WTO, Office International des Epizooties (OIE) and the World Bank at the Doha Ministerial Conference to explore new technical and financial mechanisms to promote the efficient use of resources in SPS-related activities and enhance the capacity of developing countries in the standards area (WTO, 2005).[27]

Jaffee and Henson estimate that between US$65 and US$75 million has been spent by bilateral and multilateral agencies in recent years to build trade-related capacities which sounds like a drop in the ocean (2004). The EU has established an online help desk that will provide a tool for developing country exporters to access the EU market more easily, including information on product-specific import requirements such as SPS rules.[28] There are also private sector initiatives to improve the compliance capacity of their developing country suppliers. However, considering the rate at which stricter SPS and technical requirements proliferate, there is a strong rationale for extending and improving the technical assistance delivery for specific supply-side constraints and conformity with requirements.

Notes

The case study presented in this chapter draws on a background paper by Gargiulo(2005). However, the views expressed here are of UNIDO and do not necessarily reflect those of the authors.

[1] Sanitary and phytosanitary measures are laws, regulations, requirements, and procedures instituted to protect human, animal and plant health including end product criteria; processes and production methods, testing, inspection, certification and approval procedures; quarantine treatments and requirements for the transport of plants and animals; provisions on the relevant statistical methods, sampling procedures and methods of risk assessment; and packaging and labelling requirements directly related to food safety (WTO, SPS Agreement). Safety of food, as a public policy concern, is understood within the context of specific risks to human health stemming from chemical and microbial contamination, natural toxins, mislabelling of allergens, additives and preservatives which are present throughout the food chain. Food quality, on the other hand, while being closely related to food safety relates to a number of other aspects, such as nutritional value, additives, granting of organic status, marks of quality and protected geographical indication.

[2] On the contrary, the existence of double standards – where a different set of requirements exists for trading in the domestic versus the export markets – reduces such externalities although it might also cut private costs in the short run.

[3] As an example, outbreaks of foot-and-mouth disease in 2000/2001 have cost Argentina around US$1.2 billion in forgone exports due to the slow reaction both from producers and the control agency. According to private experts, Argentina loses up to US$1 billion every year due to sanitary problems that forces the exporters to accept lower prices for their products. While over half of these losses accrue due to Argentina being not certified as a foot-and-mouth free country, there are other ongoing problems with mycotoxins in nuts and sunflowers, citrus canker and nitrofurans – a microbial substance – in honey, just to name a few.

[4] For example, in Japan, recent food safety crises, including discovery of BSE in domestic cattle herd and a series of labelling scandals, have resulted in the implementation of new regulations including legislation requiring traceability of beef muscle meats from the farm to retail outlet as of 1 December 2004 and the creation of the new Food Safety Commission. Many of these new regulations and assurance programs are based at least in part on traceability systems. Although attempts to require traceability for imported meats have failed, it is certain that traceability requirements will play an increasing role in the upcoming years (Clemens, 2003).

[5] The EC argues that the new system is more flexible than the old one, as the HACCP-based procedures can be adapted to all situations and as member states were already required to ensure that foodstuffs imported into the Community were submitted to the official controls to check that HACCP-based procedures had been observed.

[6] For example, in the EU countries the EUREPGAP, a consortium of major retailers, sets standards for fruits, vegetables, beef and fish products that require private certification, which in almost all instances are stricter than the technical regulations.

[7] For example, in a recent meeting of the SPS Committee in June 2005, St Vincent and the Grenadines, supported by Jamaica, Peru, Ecuador and Argentina, filed a complaint about the private sector requirements for exporting bananas and other products to European supermarkets, which are tougher than the governments' requirements. The 'EurepGap' requirements are 'good agricultural practices' (GAP) set by the Euro-Retailer Produce Working Group. The EU said in reply that it is not in a position to intervene because the private sector organizations say they are reflecting consumer demands, and that if any of these organizations claim that their standards are EU standards, the WTO members should take this up with Brussels. Otherwise the concerns should be raised with the non-governmental organizations involved (WTO, 2005c).

[8] For example, out of a total of 67 different tests applicable to compliance for different fish and shellfish products, FDA, EU and Japan all require different combinations and total number of tests.

[9] In May of 2004 the Assembly of WHO approved a Strategy on Diet, Fitness and Health, directed to prevent obesity and the consequences of unbalanced diets or lack of exercise The initial draft of the Strategy included a list of *unhealthy foods*, and a proposal for extra-economic duties for them as well as incentives for the *healthy foods*. The proposal did not include those concepts in the final presentation.

[10] The 2003 Eurobarometer study has uncovered that on average just over 50 per cent of European citizens support genetically modified (GM) foods, with highest approval rate being approximately 70 per cent in countries such as Spain, Ireland and Finland. However, when asked about their intentions with regards to purchasing and eating of GM foods, more Europeans say that they would not buy or eat GM foods than those saying they would.

[11] Jaffee and Henson (2004) give the example of relatively large number of low and low-middle income countries that have been considered by the EU as having standards of hygiene at least equivalent to those of EU in the capture, processing, transportation and storage of fish and fishery products. Over the period 1997–2003, the number of countries achieving this status as outlined in Commission Decision 2001/111/EC went up from 27 to 83, more than half being low and low-middle income countries. However, such progress is not observed simultaneously in all other sectors. For example, China, which is one of the 83 countries found to have EU-equivalent hygiene standards in fish products, is reported to waste more than 20 per cent of its estimated annual food production worth US$300 billion due to deficiencies in its cold chain technology (this includes US$8.63 billions just in fruit and vegetables). Cold-chain refers to comprehensive refrigeration treatments to keep food frozen and fresh from fields all the way to the dinner tables. While for domestic markets these problems increase the risk of food-borne illnesses, for international markets they can preclude access altogether (*Industry Updates*, 2005).

[12] For example, developing countries like Brazil, India and Mozambique (and more recently Viet Nam) are trying to develop local capacity in technical rules for unfragmented and unscorched cashew nuts. However they use substantially different machinery and have varied managerial and organizational skills at different stages of the business system. The array of institutional responses has differed across countries in the same sectors, underlying that the evolution of both regulatory and production systems is context-specific even when meeting the same technical standards and regulations (Srinivas, 2005).

[13] Subsequently, producers and exporters are expected to develop and implement in-house control systems based on HACCP while food safety organizations are expected to be responsible for fostering implementation of HACCP, transfer of relevant technologies and conducting risk-based audits.

[14] This principle is also reflected in the SPS Agreement and CODEX, which aim for an international framework based on the concept of 'equivalence' of food control approaches even when the actual processes are dissimilar rather than one based on optimality. What constitutes an optimal process is often related to other concerns such as resource and capability endowments. For example, to achieve a reduction of pathogens on the surface of citrus fruit one might follow different methods in a developed country than in a developing country. In an industrialised country where labour costs are high, the use of advanced, high-speed steam surface pasteurization technologies may be the optimal system for achieving the desired reduction. However, in a developing country where labour costs are low but capital costs are high, it may be more effective to hand wash the fruit in an appropriate sanitising solution. Thus, if the criterion for what constitutes optimal is minimal labour cost and speed then the former is optimal whereas if the criterion were minimization of capital expenditures and full employment, then the latter would be the desired approach (Buchanan, 2002).

[15] Following the discovery of a BSE case among domestic herd in US in 2003, 77 per cent surveyed still responded that they did not reduce their consumption of beef products. In fact, in the first quarter of 2004 domestic consumption of beef was growing. (Coffey et. al., 2005). In contrast, a survey conducted by GfK in Germany in 2001, following a case of BSE in November 2000, concluded that more than 50 per cent of respondents did not trust the food safety in the country and would be reducing their consumption of meat. Beef consumption had plum-

meted, with households buying 41 per cent less beef in November 2000 than in the same month the previous year (GfK, 2001).

[16] This exercise was prepared as an input for this Report, with a view to exemplify how needs assessment methodology can be used in various contexts.

[17] It is part of the National Food Commission, which includes provincial health ministries and a national agency (INAL), devoted to control of food for domestic consumption.

[18] In 2004 the number of lab tests grew 15 per cent in relation to the previous year, to 200 000. During the same period, 24 analytical methods were already certified and 24 more were being certified.

[19] According to the draft National Budget, SENASA's budget was to be increased to approximately US$53 million in 2005, but this figure includes the income from fees and charges.

[20] For example, a lack of resources prevented SENASA staff from attending the Codex Committee on Fats and Oils, and as a result the fat and oils sector – which is the main food exporter in Argentina – could not be helped to foresee some of the emerging requirements.

[21] In 2004 it received 15 inspections of foreign countries that audited several sanitary and safety risks, paying attention to the equipment, personnel, procedures, performance and relevant management skills.

[22] The cost estimates for the proactive approach below are on the conservative side. Argentina with its developing sectoral IS, will need a significant evolution in capabilities in the three subsystems that drive an IS to achieve a proactive stance in all sectors involved (see Chapter 6). The pace of development might be different in different food products as well as plant and animal health depending on a large number of conditioning factors.

[23] The reactive strategy means that the organisational strengths barely suffice to avoid the detention and rejection of exported food. After receiving the claims, controls are increased and food chain operators are instructed on the practices needed to avoid commercial problems.

[24] The estimate for the costs involved with the establishment of R&D teams assumes that each team would require a team leader, a senior scientist, three junior scientists, and a lump sum for inputs, services (training was not included), hardware and software. Three selection criteria are used to select which food chain groups would require the set up of a research team: importance of current and future exports, risks identified by the food chain and impact or relevance of the risks. Using those criteria the food chains were grouped in: beef, poultry, other meat, dairy, honey, fish products, vegetables, fruits, cereals, oilseeds and derived products, other foods, forestry and woods. Taking into account that some activities would require several teams, the total R&D units estimated are 16. Biotechnology, organic production and veterinary products and chemicals used in agriculture were included as 'horizontal' groups. The resource needs for the three teams was estimated lower than for the previous category because of the availability of the equipment needed. The last category includes international legislation, international negotiations, harmonisation of the local food security regulations and technological surveillance of risks and appropriate technologies. These R&D teams relate to capacities to be built inside SENASA.

[25] For example, the EU and the FAO aid helped Guinea regain competitiveness due to packaging requirements imposed on their fish and pineapple juice exports (UNCTAD, 2002).

[26] Cambodia, Cuba, Bolivia, Egypt, Mauritania, Kenya, Jordan, Armenia and Ghana were selected as the initial pilot countries. For each country, a quick industrial and trade competitiveness analysis and assessment of barriers to trade and conformity requirements was undertaken, resulting in detailed action plans for each country. For example, in Bolivia, the diagnostic analysis focused on the SPS problems faced by the Bolivian Amazon (Brazil) nuts exporters to comply with the maximum level of aflatoxin allowed by the EU, leading to the design of a targeted technical assistance project for which Switzerland expressed interest in funding (UNIDO/WTO, 2004).

[27] A proposal has been put forward to develop an inter-agency business plan to redress the under-provision of international public goods for economic development, including those relating to standards and sanitary and phytosanitary measures (see Magariños, 2005).

[28] In addition, starting from 2006 the European Commission is planning to spend more than €2 million for training programs in EU food standards, HACCP and Avian flu in third countries (European Commission, 2005b).

Section II

A review of world industry

Introduction to this section

The two chapters of this section present a comparative assessment of patterns and trends in the manufacturing industry.[1] The geographic scope of the assessment is global, its range comprehensive – covering all branches of the manufacturing sector as well as both domestic and international developments – and its basis quantitative, formed by a set of empirical measures, the 'indicators'. Within this framework, the notion of 'industrial performance' is used to cover and connect the various parts of the review. Industrial performance is seen from two angles. From one of them, it is associated with the performance of a whole economy: developments in and around industry are compared and pictured as closely linked with the aggregate economy, in particular with its level of overall development. From the other, performance is taken to be that of the industrial sector itself, its levels of domestic and international activity and its changing structure. This duality of performance informs the measurement, analysis and interpretation of developments in world industry presented in this section.

The review is divided into two chapters. Chapter 9 is devoted to a description and analysis of the level of manufacturing around the globe. First, 'industrial inequality' across countries is measured in a comprehensive way and presented graphically. Next, differences in output levels among broadly defined country groups are assessed and the rankings of individual countries by industrial output discussed. Also examined is the relationship between activity levels and industrial growth rates. Finally, measurement and analysis are extended to the international scene, leading to an investigation of trade levels, complementary to the one of production levels.

Chapter 10 outlines a set of six performance indicators, their conceptual background and relationships, and some broader aspects reflected in this 'set-of-six'. The remainder of the chapter deals with the features of industry which emerge from the four structural indicators within the set-of-six. Here, use is made of the various aspects of symmetry inherent in the indicators system, and structural traits are visualised in the form of a 'structural diamond'. In analogy to the combination of arithmetic and geometric tools in the analysis of industrial inequality, this structural diamond is associated with an index of 'industrial-cum-technological advance' (ITA). Using these assessment tools, structural features are identified, global patterns as well as changes over time discussed and the relationships between indicators and the overall level of development analysed.

On the whole, this review is intended to present an account of global industrial performance, built around an application of quantitative indicators. Its main goal is to achieve clarity and simplicity without sacrificing soundness and accuracy. Another objective is to exploit, in measurement, analysis and interpretation, the concepts, distinctions and relationships underlying indicator construction.

CHAPTER 9

Monitoring global industrial activity

The immediate goal of this chapter is to measure the level of industrial activity in economies around the globe and – on the basis of that measurement – assess differences in activity between groups of countries as well as between individual countries. Within industrial activity, the production side is emphasised for two reasons: first, for the conceptual reason that per capita output is the pre-eminent indicator of industrial performance and second, for the practical reason that an analysis of trade performance would yield results similar to those obtained on the production side.

Measuring 'manufacturing income'

If relief, reduction and ultimately eradication of poverty are the prime objectives of international development, economic growth is indispensable for achieving them. This basic relationship renews and enhances the significance of industry to any economy striving for vigorous and sustained growth. From the viewpoint of sustainability it is important that output expansion feed not only on factor accumulation but also on a continuous rise in productivity, which is tantamount to technological progress. It is at this point where industry almost by necessity enters the growth picture, since in the industrial sector technological advance, created domestically or sourced from outside, is at work to bring about growth through productivity increase. Industry is at the core of modern-style productivity-based growth, which in turn is the source of a sustained rise of welfare throughout a society and, consequently, of a lasting reduction of poverty.

An obvious effect of industry on growth is its direct contribution to total output. There are also indirect effects, dispersed through various channels and enhanced through spillovers into other sectors. While the latter defy comprehensive empirical assessment, the former is captured by a simple measure, that of value added originating in manufacturing industry (MVA). Just as the relationship between total income and population size, expressed as income per capita, measures observable average income, the relationship between 'industry income' and population size, expressed as MVA per capita, defines average level of industrial income. This average reflects the hypothesis that all income in an economy would have to be drawn from an industry sector of the size actually observed. In addition – and other things being equal – MVA per capita can be expected to indicate the order of magnitude of indirect effects from industry on average income.

MVA per capita plays a dual role as an empirical measure. In the same way as GDP per capita is the measure of average income and an indicator of the overall level of development, MVA per capita measures average 'industry income' and indicates the overall level of industrial development of a country. This duality will be noted frequently in what follows. At the same time, MVA per capita will be emphasised as the 'correct' measure in comparisons – with a view to industrial production, income and welfare – between the overall productive potential of industry on the one hand and the number of people who can expect to benefit from it, directly or indirectly, on the other.

The disparate geography of industry

Industrialised countries still claim nearly three-quarters of world industrial production, in spite of a drop of their share by almost five percentage points between 1990 and 2002. By contrast, industrial production of all developing countries together still falls somewhat short of the one-quarter of world production that was once postulated as the target to be reached by the beginning of the new millennium[2] – despite the fact that the expansion of industry in the South over the 1990s was remarkable by any standard, raising the developing country's share by almost eight percentage points over the period. Finally, the third group, the transition economies, saw a halving of their contribution to world industrial output, which left the group aggregate at slightly over three per cent by 2002 (a rough impression of how industrial production is distributed among different parts of the world can be gleaned from table 9.1 and figure 9.1, where the 156 countries for which comparable data were available are grouped by 'type of economy' – industrialised, transition and developing).

Among the developing countries regional differences are wide. The leading role of East and Southeast Asia is underlined by the fact that it accounts for more than 60 per cent of the developing world's share in global industrial production. Even if China, which contributed more than 45 per cent of region's output, is excluded from the aggregate, East and

Table 9.1 Industrial output, by region (1990 and 2002)	Share in world output (percent)	
	1990	2002
Industrialized economies	78.17	73.25
Transition economies	6.10	3.18
Developing economies	15.73	23.58
Sub-Saharan Africa	0.79	0.74
excluding South Africa	0.24	0.25
Latin America and Caribbean	5.26	4.95
excluding Mexico	4.29	3.85
Middle East and North Africa	1.46	1.91
excluding Turkey	1.00	1.37
South Asia	1.01	1.51
East and South East Asia	7.17	14.42
excluding China	4.99	7.84
Other countries	0.05	0.05
Least Developed Countries	0.18	0.24
World	100.00	100.00

Source: UNIDO Scoreboard database.
Note: Industrial output is measured by real value added (in 1995 US$) in the manufacturing sector (MVA).

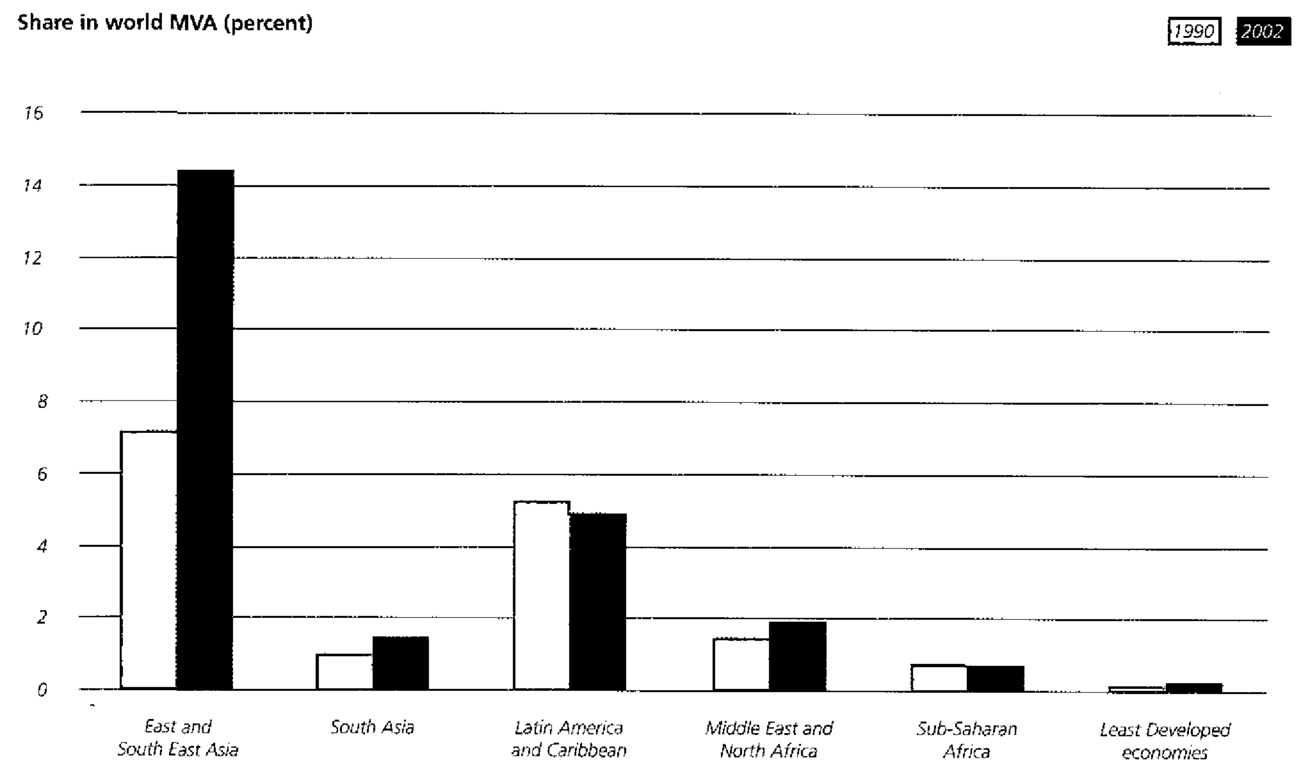
Southeast Asia still lead the developing regions by a wide margin. Latin America and the Caribbean (LAC) is a distant number two, recording in 2002 a little more that a third of Asian industrial output, whereas in 1990 it had accounted for almost three-quarters. The output shares of the Middle East and North Africa (MENA) region, South Asia and the whole of SSA are all of the same order of magnitude, ranging from close to two per cent of the world total for the first of these regions to significantly less than one per cent for the last one. Without South Africa's production, SSA 's share falls to a quarter of one per cent. This is the same proportion of world production as that recorded for the 32 least developed countries included in the sample. While on the one hand a share of this size is certainly miniscule, on the other its 2002 value represents an increase of a third over that of 1990.

Certainly the most remarkable case of a country 'gaining industrial weight' over a short timespan is that of China. Its share in world industry tripled over the 1990s, rising to 6.6 per cent by 2002. The ten largest industrial economies in 2002 include not only China as number four, but also the Republic of Korea and Brazil as industrial 'heavy-weights' with more than 2.0 per cent of world production. All the other top countries are industrialised economies, with the US in the lead (see table 9.2). This picture contrasts starkly with that of twelve years earlier when not only was Japan the world leader and Brazil at the top of the developing economies, but also the Russian Federation was found close behind the leading industrialised economies.

Representing industrial unevenness

An indication of how industry is distributed relative to population can be obtained from per capita levels of industrial production. As in the case of total production, measured by GDP, this approach is ideal for comparing one geographic space like a country or a geographic region with another such space

Figure 9.1 Industrial output, by region (1990 and 2002)



Source: UNIDO Scoreboard database.

Table 9.2 **Industrial output: the top ten economies**

1990	Share in world output (percent)	2002	Share in world output (percent)
Japan	22.5	United States	23.3
United States	20.7	Japan	18.1
Germany	10.2	Germany	7.9
France	4.7	China	6.6
United Kingdom	4.1	France	4.7
Italy	4.0	Italy	3.5
Russian Federation	3.2	Korea, Republic of	3.3
Brazil	2.5	United Kingdom	3.2
China	2.2	Brazil	2.2
Spain	2.0	Canada	1.9

Source: UNIDO Scoreboard database.

or with the 'rest of the world'. However, when the question is about how homogeneous or heterogeneous the global distribution of industry is as a whole, another approach has to be used, one that allows for a comprehensive assessment of industrial unevenness.

One graphical tool that fits the bill is a modified version of the Lorenz-curve, the device usually employed to visualise income inequality within a given economic space. In figure 9.2 it is used as a *diagrammatic exposition*[3] of industrial 'inequality' at the level of global distributions of population and MVA. Normally the Lorenz-curve is applied at country level to the income of predefined strata of a country's population. For our purpose we deviate from normal usage in three respects. First, the economic space considered here is the world (or some large group of countries, as in the examples that follow figure 9.2). Second, total income is replaced by manufacturing income as the variable whose distribution is to be assessed. Third, due to data restrictions, the stratification of population is that determined by the size of individual countries instead of the ideal of strata of identical size.

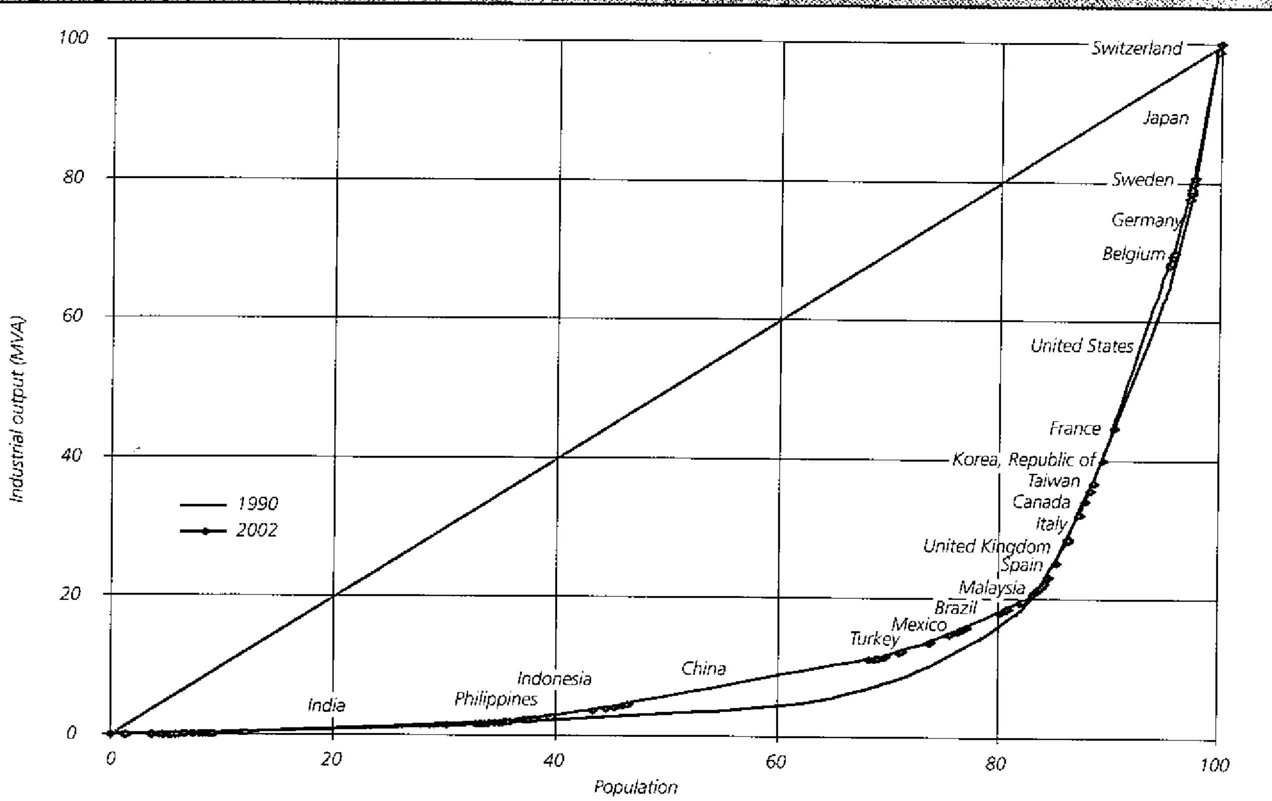
The Lorenz-curve modified in this way has the necessary features to serve as a tool to assess industrial 'inequality':

- It summarises all the information about the joint distributions of population (N, expressed as a share of the sample total and plotted along the horizontal axis) and manufacturing income (y_m, expressed analogously and plotted along the vertical axis) across the countries included in the sample.
- Each individual country is represented by a triangle with its sides given by the country's share in world population (horizontal), its share in world MVA (vertical) and the country's straight-line part of the Lorenz-curve.
- The slope of any country-specific portion of the curve is equal (up to a constant factor)[4] to the country's average manufacturing income (MVA per capita), where countries appear in ascending order of their values of MVA per capita.[5]

The 45-degree line in figure 9.2 is the graphic representation of two special cases of distribution:

- The global case outlined above where all countries are aggregated into one economic space.

Figure 9.2 **Global industrial inequality (1990 and 2002)**



Source: UNIDO Scoreboard database.

- The case of perfect equality, where manufacturing income is distributed uniformly among many countries so that all of them show the same per capita MVA.

This latter case suggests the standard interpretation of the Lorenz-curve traced out by individual country pieces as showing 'manufacturing inequality' within the country sample. The intuition is clear: the more inequality there is among countries, the farther away the curve must be from the perfect-equality line. This notion of 'being farther away' can be given geometric and quantitative substance by comparing two areas in figure 9.2: that between the perfect-equality line and the Lorenz-curve on the one hand, and that of the triangle under the perfect-equality line on the other. The ratio between these two areas is an index of inequality, ranging between the values of zero for perfect equality and one as the hypothetical case of maximum inequality where all manufacturing income would accrue to one infinitesimally small country[6]. In the literature the index thus defined is known as the Gini coefficient of inequality, which in the version presented here is used to assess manufacturing inequality among economies.

The striking feature of the Lorenz-curves (for 1990 and 2002) shown in figure 9.2 is a highly uneven global distribution of manufacturing income.[7] In quantitative terms this matches the high values of the corresponding Gini coefficients (table 9.3), with an indication of a slight decline in global inequality between the beginning (0.765) and the end (0.733) of the time period covered by the data.[8] The upper branch of the curve, lying to the right of the centre and containing less than 40 countries, which together account for 20 per cent of population and 80 per cent of output, carries all the industrialised economies as well as a few transition and Asian economies. By contrast, all developing economies, except ten, lie on the lower branch.

Table 9.3 Industrial inequality, by region (1990 and 2002)

	Gini-coefficient	
	1990	2002
Industrialized economies	0.222	0.193
Transition economies	0.251	0.316
Developing economies	0.633	0.573
Sub-Saharan Africa	0.746	0.741
excluding South Africa	0.498	0.510
Latin America and Caribbean	0.240	0.244
excluding Mexico	0.258	0.282
Middle East and North Africa	0.354	0.357
excluding Turkey	0.361	0.378
South Asia	0.075	0.049
East and South East Asia	0.545	0.400
excluding China	0.579	0.600
Other countries	0.771	0.770
Least Developed Countries	0.298	0.350
World	0.765	0.733

Source: UNIDO.
Note: Across groups of economies and regions, sample size varies considerably. As a consequence, Gini-coefficients are not strictly comparable across all rows of a given column. They are, however, comparable – for a given country group – between the two years surveyed here.

The developing economies branch of the 2002 curve in figure 9.2 deserves closer scrutiny for at least two reasons:

- First, the slight reduction in global industrial unevenness over the period studied here was almost entirely due to an upward shift of that branch while the upper, industrialised-economies branch hardly moved.
- Second, in view of the high degree of heterogeneity of the developing-economies group, more information within that group is of special analytical interest.

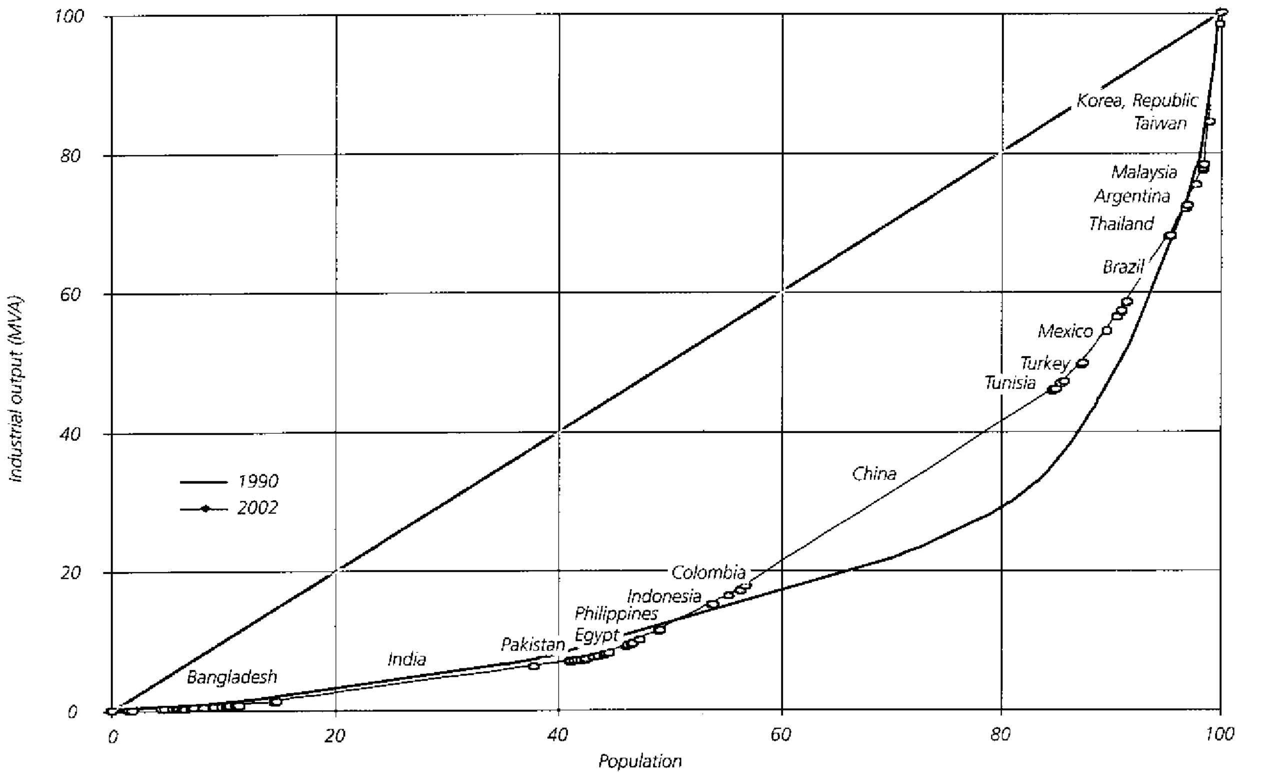
'Zooming in' on unevenness within the developing world reveals that over the period the spread of industry across these economies has become significantly less unequal (see in figure 9.3 the curve for the 111 developing economies included in the exercise, together with the corresponding Gini coefficients in table 9.3, which show a corresponding decline from 0.633 to 0.573). It also reveals that, as in the case of the worldwide distribution, in that of the developing-economies group the overall reduction of inequality was greatly influenced by what happened in a few countries (in the graphic representation, essentially the upper-half of the Lorenz-curve – except the countries in the uppermost five per cent of the distribution – produced all the gains towards more equally distributed manufacturing income). The performance of the two most populous countries in the group was strikingly different (as the curve clearly shows). Between 1990 and 2002 India maintained stable shares of the developing-economies total for both population and MVA. By contrast, China's star performance was the decisive factor in the comprehensive decline of inequality over the same period, based on the reduction of its population share and the concomitant doubling of its MVA share.

The industrialised economies as a group experienced a decline in unevenness, whereas for transition economies a notable increase was recorded (table 9.3). Across geographic regions the experience of developing economies varied between stability on the one side and reduction of intra-group unevenness on the other. Stable Gini coefficients were observed for the SSA, LAC and MENA countries. As has already become evident from the aggregate picture, China's performance dramatically reduced unevenness in the East and Southeast Asian region, while the seven countries of South Asia also grew less uneven. Finally and contrary to overall developments among the developing economies, inequality between the 32 LDCs included in the sample rose remarkably over the period under study.

The Lorenz-curve of figure 9.2, with its intriguing features of symmetry, suggests still another kind of comparison, which is likely to shed more light on the issue of industrial unevenness. As was noted above, from that world curve emerges a conspicuous division between the South (the economies accounting for the industrially poorer four-fifths of world population), and the North (the industrially rich fifth). The simplification of the world curve in figure 9.4 leads to a back-of-the-envelope calculation that reveals a 16 to 1 ratio for the North-South industrial output per capita.[9]

The above result holds for a comparison between the two broad country groups. Analogous computations can be car-

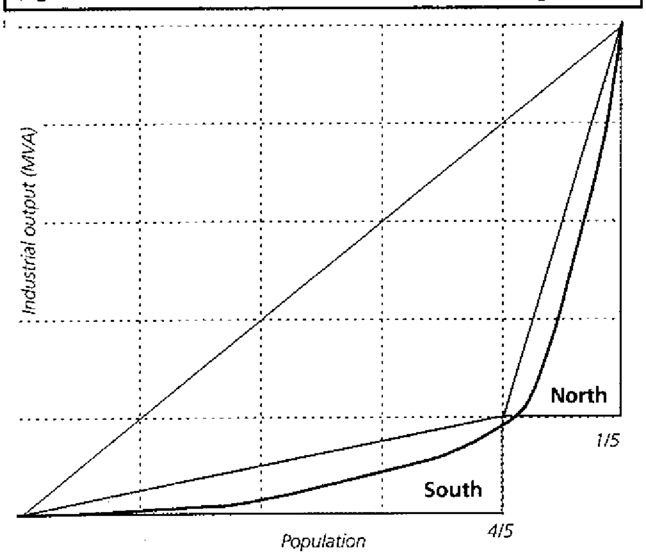
Figure 9.3 **Industrial inequality among developing economies (1990 and 2002)**



Source: UNIDO Scoreboard database.

ried out for other parts of the distributions of population and output, giving substance to the terms industrially richest versus industrially poorest countries. The comparisons of particular interest in the present context are those comparing the high end and the low end of the world Lorenz-curve where the length of the ends can vary. Table 9.4 shows the results for four different choices of the length of the 'ends' and for both 1990 and 2002. Each entry in the table is the ratio of output of the industrially richest segment over the output of the poorest segment. The first comparison is between the upper half and the lower half, the second between the first and the last quarters, the third between tenths and the last between twentieths. The pattern emerging from table 9.4 is clear. For a given year, the ratios increase from the top to the bottom row, indicating a steep increase in inequality the more the comparison approaches the ends of the distribution.[10] Between 1990 and 2002 there was also a clear trend. If comparisons are made between large ends of the distribution (50

Figure 9.4 **The North-South divide in world industry (2002)**



Source: UNIDO Scoreboard database.

Note: The curve traced out in the figure is the world Lorenz-curve of figure 9.2. The two triangles 'South' and 'North' are simplifications of the real-world curve that represent a hypothetical world of two regions with the above connotation.

Table 9.4 **Industrially rich versus poor economies (1990 and 2002)**

p	Output ratio of top p over bottom p percent of world population: 1990	2002
50	28	21
25	91	57
10	308	356
5	615	652

Source: UNIDO.

Note: Here again, industrial output is measured by real value added (in 1995 US$) of the manufacturing sector (MVA). As an approximation to the output associated with percentage p the nearest-neighbour value in the country-based cumulative distribution of world MVA was chosen.

Table 9.5	Country impact on industrial inequality (1990 and 2002)		
1990		2002	
	Impact indicator (percent)		Impact indicator (percent)
United States	1.067	China	1.438
Japan	0.558	United States	1.166
China	0.507	Japan	0.396
Germany	0.164	India	0.211
India	0.132	Germany	0.112
Russian Federation	0.097	Brazil	0.066
Brazil	0.075	France	0.048
France	0.053	Italy	0.035
United Kingdom	0.046	Russian Federation	0.033
Italy	0.045	Indonesia	0.032

Source: UNIDO.
Note: The impact indicator is that defined in the text, i.e., the area of the 'impact triangle' as a percentage of the global triangle of the underlying Lorenz-curve.

per cent or 25 per cent), the ratios of rich over poor show a downward trend, quite in line with the comprehensive reduction of inequality indicated by Gini coefficients. However, the same comparisons between the industrially richest and poorest economies (ten per cent or five per cent) show a significant widening of the gap over the 1990s.

Finally, table 9.5 shows the influence of the ten highest-impact economies on unevenness in 1990 and 2002, respectively.[11] Once more, the rise of China, also in terms of its impact on the global distribution, is documented by a threefold increase in its impact measure. A high increase in impact was also recorded for India, whereas that of the Russian Federation fell to a third of its 1990-level.

The core ranking

Value added per capita in the manufacturing sector (y_m) is the immediate measure of the benefits from industry for a given country or region relative to its size. For each country in the sample, the Lorenz-curve discussed above provides an indication of the level of y_m relative to the global average: the slope of that piece of the curve that pertains to the country is a relative measure of y_m. The geometric pattern of country-specific linear pieces with an increase in slope from left to right is reproduced in the values of MVA per capita shown in tables 9.6 and 9.7, as well as in figure 9.5.

Table 9.6 gives an overview of industrial activity in the country groups discussed earlier. The differences in activity levels, which reflect differences in industrial potential between the three large groups of different types of economies highlight in a striking manner the picture of inequality drawn above. In 2002 the activity level of industrialised countries was nearly 10 times that of transition economies and more than 16 times that of all developing economies together. These relations are the result of two opposing movements in the gaps between industrialised and other economies over the period 1990–2002. On the one hand, transition economies have fallen behind dramatically due to an annual decline in activity of about three per cent. On the other hand, developing countries have increased industrial activity by four per cent annually, narrowing the gap with the industrialised economies from a ratio of more than 23 in 1990 to the aforementioned ratio of more than 16 in 2002.

The five geographic regions of the developing world show a wide range of levels of industrial activity, with a ratio of close to nine between the highest and the lowest group averages. In both of the years shown in table 9.6 the leading region was LAC, with activity levels that remained virtually the same over the decade surveyed. By 2002 East and Southeast Asian industry had attained a level not far below that of LAC, the result of a growth rate of seven per cent per annum for that region's industry output per capita. A medium level of activity was recorded for the MENA in both years, with only a modest increase over the period. At the low end of industrial output are SSA and South Asia, with the former declining over the period observed and the latter achieving a remarkable increase. Still, activity levels of these two regions are only about a tenth of that of the leader, LAC. Even the trailing South Asian region shows output per head more than twice as high as that of the LDCs, which with growth in activity of over two per cent per annum have seen their industrial output per capita remain below three per cent of the world average.

The group averages of table 9.6 paint a world picture of industrial activity with a broad brush. The numbers in table 9.7 fill in as much country detail as possible. One feature that emerges is that, striking as income differences between countries may be in the global economic picture, differences in levels of industrial activity appear even more striking. Two comparisons can help to illustrate this point. First, the ratio between the activity of the leading economy (Switzerland) and that of the country ranked last (Liberia) exceeds 2,400. Second, the ratio between the highest and the lowest decile[12] in the distribution of countries by industrial activity exceeds 190.[13]

Table 9.6 Industrial-production level, by region population-weighted averages (1990 and 2002)	MVA per capita (1995 US$)	
	1990	2002
Industrialized economies	5 161	5 839
Transition economies	863	596
Developing economies	221	356
East and South-East Asia	247	576
excluding China	682	1 170
South Asia	48	75
Latin America and Caribbean	670	674
excluding Mexico	683	656
Middle East and North Africa	273	365
excluding Turkey	234	324
Sub-Saharan Africa	99	89
excluding South Africa	33	33
Other countries	163	163
Least Developed Countries	25	33
World	1 071	1 190

Source: UNIDO Scoreboard database.

Another way of gauging the order of magnitude of inter-country differences is to compare industry production per capita in the leading economy (Switzerland) with total production per capita in other economies, in order to illustrate the economic power of the industrial sector in the leading country with the overall productive potential elsewhere. In 2002, there are only 26 economies whose *total* output per capita exceeds Switzerland's *industrial* output per capita. Among these 26 economies there are only four from the developing group: the four Asian 'Tigers'.[14]

For the following discussion of the core rankings shown in table 9.7, some general reflections, a few simple statistical concepts and a systematic approach to comparison will form the basis of an overall assessment:

- Here a good though somewhat rough guide, to judge actual levels and ranks, is that of the three classes of

Table 9.7 Industrial-production level, by country (1990 and 2002)

	MVA per capita (1995 US$)				Average annual growth of MVA, 1990–2002
	2002		1990		
	Value	Rank	Value	Rank	(percent)
Switzerland	12 191	1	9 583	2	2.4
Japan	9 851	2	9 697	1	0.4
Finland	8 389	3	5 231	6	4.4
Sweden	8 154	4	4 849	9	4.7
Ireland	8 121	5	3 142	19	9.2
Luxembourg	7 591	6	6 856	4	2.2
Austria	6 751	7	5 309	5	2.4
Germany	6 649	8	6 871	3	0.0
Singapore	6 583	9	4 410	10	6.3
Belgium	6 025	10	5 089	7	1.7
Denmark	5 799	11	4 929	8	1.7
United States	5 568	12	4 325	12	3.2
France	5 444	13	4 387	11	2.3
Korea, Republic of	4 859	14	2 238	25	7.6
Netherlands	4 841	15	4 197	13	1.8
Taiwan Province of China	4 397	16	2 842	21	4.6
Canada	4 292	17	3 266	18	3.3
Italy	4 224	18	3 740	16	1.1
Norway	4 026	19	3 801	15	1.0
Iceland	3 912	20	3 470	17	2.0
United Kingdom	3 749	21	3 808	14	0.2
Slovenia	3 226	22	2 967	20	1.1
Spain	3 153	23	2 767	22	1.4
New Zealand	3 000	24	2 659	23	2.2
Australia	2 797	25	2 588	24	1.9
Israel	2 608	26	2 146	26	4.5
Portugal	2 368	27	1 985	28	1.6
Czech Republic	1 607	32	1 378	36	1.2
Malaysia	1 516	34	758	51	9.9
Hungary	1 461	36	841	47	4.3
Greece	1 435	37	1 445	34	0.6
Argentina	1 258	39	1 096	42	2.7
Hong Kong SAR	1 133	41	2 043	27	−3.2
Croatia	1 085	42	1 688	30	−3.8
Slovakia	1 067	43	1 579	31	−3.0
Thailand	1 000	44	521	62	6.8
Poland	885	47	470	65	5.5
Brazil	865	48	914	44	1.0
Saudi Arabia	846	50	681	53	4.8
Chile	765	52	574	59	3.9
South Africa	754	53	789	48	1.3

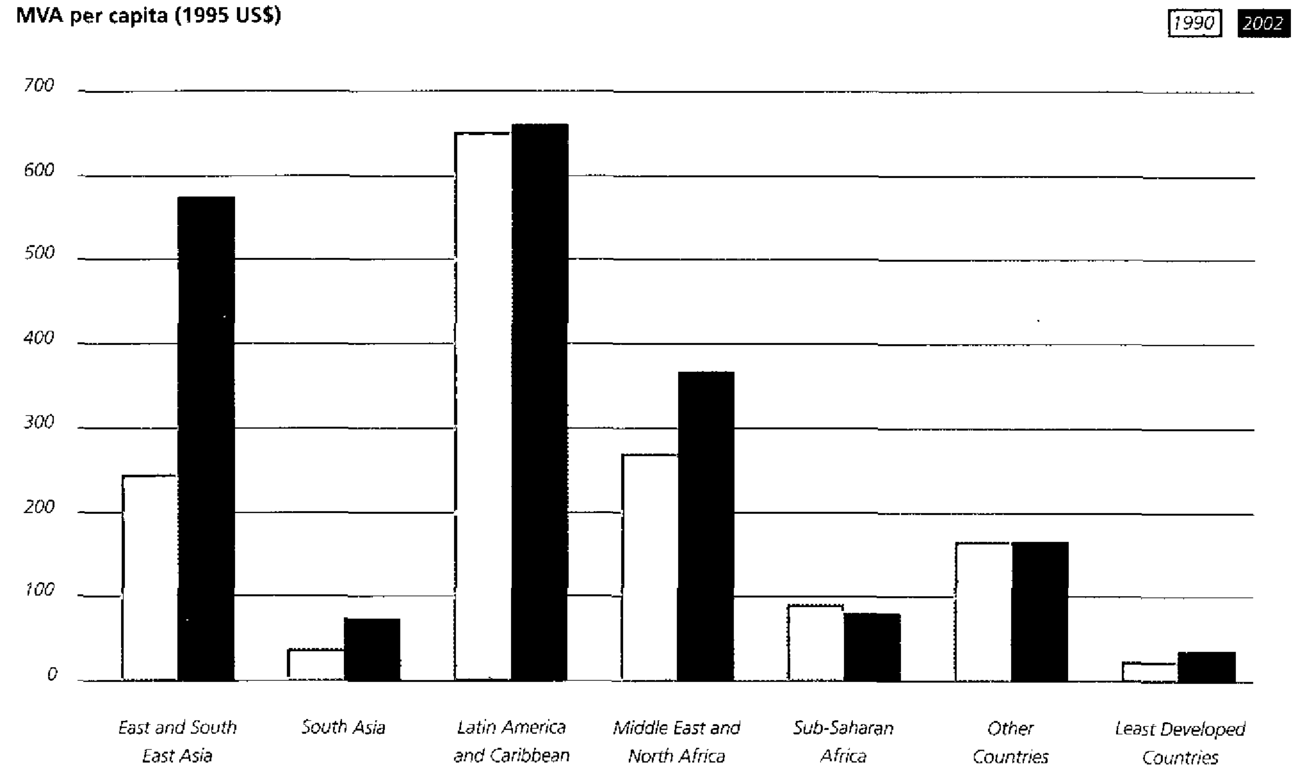
Table 9.7 Industrial-production level, by country (1990 and 2002; *continued*)

	MVA per capita (1995 US$)				Average annual growth of MVA, 1990–2002
	2002		1990		
	Value	Rank	Value	Rank	(percent)
Mexico	746	54	619	55	3.3
Libyan Arab Rep.	655	55	424	69	6.6
Russian Federation	645	57	1 165	39	−5.0
Belarus	643	58	616	57	0.2
Turkey	538	61	427	68	3.6
Tunisia	492	64	314	77	5.3
Venezuela	481	65	569	60	0.7
El Salvador	427	68	302	79	4.9
Bulgaria	366	73	497	64	−3.7
Romania	364	74	501	63	−3.5
China	359	75	101	114	12.1
Peru	343	76	289	81	3.3
Ukraine	333	77	847	46	−9.3
Colombia	313	78	437	67	−1.0
Iran, Islamic Rep.	303	79	168	101	6.7
Indonesia	279	82	162	102	6.2
Philippines	269	84	252	85	2.7
Morocco	250	87	218	92	2.9
Paraguay	248	88	297	80	1.0
Turkmenistan	244	89	396	72	−2.3
Ecuador	236	90	270	83	0.7
Jordan	235	92	195	97	5.8
Egypt	225	93	142	106	6.0
Kazakhstan	214	95	320	76	−4.6
Guatemala	198	96	204	95	2.4
Bolivia	155	102	137	109	3.3
Syrian Arab Rep.	155	103	81	118	8.6
Sri Lanka	134	105	71	122	6.4
Algeria	130	106	201	96	−1.7
Honduras	122	108	106	113	4.0
Cote d'Ivoire	109	109	113	112	1.9
Zimbabwe	102	111	137	108	−0.9
Senegal	91	114	74	121	4.3
Cameroon	88	115	85	117	2.8
Papua New Guinea	79	118	67	123	4.0
Pakistan	79	119	65	125	4.3
India	78	120	49	130	5.8
Nicaragua	67	121	77	120	1.7
Tajikistan	64	123	216	94	−10.2
Georgia	64	124	192	98	−10.7
Bangladesh	57	126	34	137	6.7
Zambia	43	129	45	132	1.8
Benin	41	130	28	140	6.2
Ghana	39	131	35	135	3.5
Togo	39	132	36	134	3.4
Burkina-Faso	34	133	24	144	6.1
Yemen	33	134	38	133	2.9
Uganda	30	135	11	156	11.9
Rwanda	27	137	26	143	1.6
Sudan	27	138	19	149	5.3
Guinea	26	139	28	142	2.8
Kenya	26	140	28	139	1.8
Angola	25	141	30	138	1.1
Nepal	23	143	11	157	9.9
Haiti	19	144	51	129	−6.5
Mali	18	147	17	151	3.1
Burundi	17	150	28	141	−2.8
Madagascar	15	151	20	148	0.7
Tanzania, United Republic of	14	152	13	154	3.2

Source: UNIDO Scoreboard database.

Note: This table presents data for 100 countries that were selected by the following nested criteria. First, the top 25 countries of the ranking in 2002 are shown, irrespective of their size. Second, 75 more countries along that ranking are presented, except for small countries with a population size of less than 4 million in 2000. Additional data can be found in Annex Table A2.1.

Figure 9.5 Industrial-production levels in developing regions (1990 and 2002)



Source: UNIDO Scoreboard database.

economies defined by type: industrialised, transition and developing.

- The statistical tool that proves useful in the present context is that of a subdivision of the country sample into portions of equal size (along the median, quartiles and deciles).
- Comparisons and assessments are made with respect to country membership in the various portions of the distribution by output per capita.

The highest quarter: the big 'divide'

Starting with the highest quarter of the activity distribution, the range of levels within it appears remarkable, with a ratio of nearly 10 between the highest-ranking member (Switzerland) and the lowest-ranking one (Argentina). Unsurprisingly, the 39 economies in this quarter include *all* the industrialised economies, whose (population-weighted) average is about half of the maximum level. From the group of transition economies only three (Slovenia, the Czech Republic and Hungary) are found in the highest quarter. By contrast, East and Southeast Asia is visibly present in that part of the distribution: Singapore among the top ten economies; the Republic of Korea and Taiwan Province of China among the top 20; and Malaysia near the lower end of the quarter, together with a number of MENA economies. This lower end, the dividing line between the first and second quarters, is only slightly higher than the (population-weighted) world average of industrial activity. Thus, the world average of activity can be said, by and large, to separate the Northern from the Southern countries as far as industrial potential is concerned.

The second quarter: leaders of developing regions

In the second quarter there are a dozen each of transition and LAC economies, quite in line with the average activity levels for these two groups (table 9.6). Just as predictably, half-a-dozen MENA economies are found here. Apart from these predictable cases of members of the various geographic groupings, there are also some surprising cases of individual economies in this range of activity levels. One of them is a negative surprise: Hong Kong SAR, China has lost its place in the first quarter of 1990, due to a decline in industrial activity at a rate of nearly five per cent per annum. Also in the second quarter are four large countries whose performance has a strong impact on their respective regional aggregates: South Africa, Mexico, Turkey and China. Thus, this quarter contains a sizeable portion of each one of the developing-economy regions, save only South Asia. As a consequence, developments of economies in this quarter assume a large weight in developments of the corresponding developing regions.

Among the four large countries representing different regions, once more China deserves special attention for at least three reasons:

- First, from a purely statistical perspective it holds a key position in the global distribution of industrial activity discussed here. The most populous country in the world, it is also close to the global median of output per capita, implying that half of all economies have higher levels of industrial activity than China, and the other half lower levels. At the same time and largely due to population size, China's output per capita is virtually identical with the average for all developing countries.[15]

- Second, the sheer size of China's population also makes the average for East and Southeast Asia wholly dependent on whether it is included or not. In fact, excluding China from the regional aggregate raises the average activity level by a factor of two, reinstating the region as the industrial leader of the developing world.
- Third, China's industrial growth performance over the period surveyed was unrivalled: its industrial output per capita more than tripled between 1990 and 2002.

The third quarter: between the mid-point and Sub-Saharan Africa

The third quarter – below the middle of the global activity distribution, marked by China – extends to a level around the regional average of SSA.[16] There are in this quarter nine African countries with activity levels exceeding, for example, the average level of South Asia. Conversely, out of the latter group only two economies – Sri Lanka and the Maldives – are in the same quarter with activity levels similar to those of the relatively more advanced African economies. Apart from the presence of these two geographic regions, membership of the third quarter runs across all the other developing-economy regions as well as the less advanced transition economies. Somewhat surprisingly, the two lowest ranking East Asian economies (Indonesia and the Philippines) are found in the lower half of the global distribution, with levels significantly below the developing- economy average. And with only a few exceptions, the remaining members of LAC and MENA are spread across the third quarter.

The fourth quarter: the least industrialised

At the top of the lowest quarter of the global distribution by industrial activity are two South Asian economies, Pakistan and India. The latter accounts for over 20 per cent of total developing-economy population and is therefore representative of the average level of activity of the countries at the low end of the global distribution. Moreover, India's industrial output per capita is a fifth of the developing-economy average, a mark which separates the less industrialised of these economies from the *least* industrialised ones; the latter group being, with only a few exceptions, identical with that of the LDCs. Indeed, all but three of the economies with industrial activity levels below a sixth of the developing-economy average are LDCs – the exceptions being three non-LDC African economies: Ghana, Kenya and Nigeria. That 'least developed' implies – with a small number of exceptions – 'least industrialised' emerges also from a simple comparison of the statistics underlying tables 9.6 and 9.7. The average activity level of LDCs (US$33 per person) is close to the midpoint of the range (from US$5 to US$79 per person) of the lowest quarter.

This discussion of the global distribution of industrial activity invites two observations which touch upon more general features in this distribution. The first observation, which is rather startling, is that global industrial unevenness is the result almost entirely of differences between, not within, the four quarters of the world distribution of industrial activity. This can be verified by taking the sample of 156 countries divided into its four quarters and measuring the respective Gini-coefficients within each of the quarters.[17] The remarkable result of comparing the four coefficients is that within each quarter the distribution is relatively even, with values of intra-quarter Gini-coefficients between 0.21 and 0.23.

The second observation ties in with the first. It focuses once more on the difference between the industrially most advanced economies in the world and the least advanced. Empirical evidence shows that differences in per capita income between rich and poor countries are staggering; here we find additional evidence that such differences are exacerbated when comparisons relate to manufacturing income or, alternatively, to levels of industrial activity. An illustration of this point is obtained from the subdivision of the country sample into the quarters discussed previously: The ratio between the industrial activity levels of the highest and lowest quartiles[18] of the global distribution exceeds 15, whereas the corresponding ratio for GDP per capita is below 12. Thus, the gap between the industrially rich and the industrially poor quarters is larger by a third than the corresponding income gap, which is so abundantly measured, discussed and analysed in the growth and development literature.

So far, the discussion of the core ranking of economies has been confined to the static picture of inter-country differences in activity levels, with only occasional remarks on changes over time. Below we broach the latter and attempt to relate levels of industrial activity to the growth of industrial production, much in the spirit of two different lines of investigation in the growth literature: the one on the role of sector development for growth and the other on convergence or divergence of levels of per capita income.

Levels of activity and growth rates

It seems to be common practice in the reporting on cross-country indicators, to rank countries by a given indicator in different time periods and then compare the rankings as a whole as well as changes in ranks for individual countries. The main reason for this approach is that most indicators can only be given an ordinal interpretation, which is expressed in country rankings. The case of the indicator of industrial activity used in the present analysis is different. The constant-price value of industrial output per capita is a cardinal measure of the activity level, not only an ordinal indicator. This implies that comparisons can be carried out both for levels and for ranks, and that the assessment can be comprehensive as well as at the level of individual countries.

A first point of interest in this connection is that of stability over time of the activity ranking. Here the result is abundantly clear: a rank correlation coefficient of over 0.96 indicates a very high degree of stability. This is an overall result and as such does not preclude sizeable changes in the ranks of individual countries. However, on the whole the ranking observed in 2002 was not significantly different from that in 1990. More than that, the overall relationship between country values was largely preserved between the two years, witnessed by a highly significant standard correlation coefficient, also with a value greater than 0.96, i.e. approaching total concordance between the distributions in the two years.

At the level of individual countries, direct comparison of industrial activity in the two years produces a picture of considerable variation. Here country growth rates of output per capita are best gauged by the world activity growth rate of 0.9 per cent per annum over the period 1990 to 2002. The only double-digit rate of activity growth was recorded by China with a value of 11.2 per cent per annum for output per capita, which corresponds to an expansion of total industry output of 12.1 per cent per year. Growth of this order of magnitude catapulted the most populous economy in the world from a position near the end of the third quarter (rank 114) in 1990 to one close above the median (rank 75) in 2002. In other words, China's leap forward was of the size of exactly one quarter of the global distribution. Another case of spectacular growth and change in ranks occurred among the industrialised countries. Ireland, with growth rates of 8.2 per cent for per capita output and 9.2 per cent for total MVA moved to rank five in the world of 2002 from the rank 19 in 1990. Outstanding growth performance of a similar order of magnitude was also observed for Malaysia and the Republic of Korea, with similarly large gains in ranks for both economies.

At the other end of the country distribution in terms of industrial growth, very high rates of industrial contraction were observed for some small transition economies and for several LDCs. To give just two examples: the Ukraine saw an annual decline of industrial output of –8.9 per cent per capita and –9.3 per cent total, which led to the country falling from the 46th position to the 77th over about one decade. For Haiti the rates of industrial contraction were –7.9 per cent and –6.5 per cent, respectively, resulting in a descent of this LDC from rank 129 in 1990 to rank 144 in 2002. Many more examples of a notable experience of expansion or contraction of individual countries might be given for the purpose of illustration. One may stand for all of them, also because it documents a remarkable break with recent history. Hong Kong SAR, China, previously one of the East Asian industrial star performers, experienced a dramatic contraction of industry, both in per capita terms (–4.8 per cent per annum) and total (–3.2 per cent per annum). The consequence was a fall in the global ranking from position 27 to 41 in the course of little more than one decade.

A casual review of country experience as regards activity levels at the beginning of the time period surveyed here and the growth performance over the following decade creates the impression of great variability across the sample. A more systematic search, however, for a relationship between activity levels and growth rates needs to invoke hypotheses as, for example, the following two that are drawn from growth analysis:

- The first one derives from the role that industry is usually assigned with respect to aggregate growth. Here the conjecture is that a higher level of industrial development is conducive to higher growth, both of industry itself and of the aggregate economy, due to higher rates of technological progress and the ensuing increase in productivity.
- The second hypothesis has its foundation in standard growth theory, in particular in its prediction of long-run convergence of income levels. It holds that higher initial levels of income and development (including those from and of the manufacturing sector) would entail relatively lower rates of income growth.

Somewhat modified for the present context and cast into the simplest possible statistical form, the first hypothesis leads to expecting a positive correlation between the level of industrial activity on the one side and growth of per capita industrial output as well as the aggregate economy on the other; the second a negative correlation. Thus, depending on which of the two opposing effects had a stronger presence in developments over the 1990s, the sign of the respective correlations should be positive or negative.

In both cases – that of the effect on industry output as well as that on aggregate output, both measured in per capita terms – the growth-enhancing effect of industrial activity seems to prevail over the growth-dampening effect of convergence. Both correlation coefficients are positive and significant at the ten-per cent level. The first of the two relations, that between the initial level and the growth rate of per capita output of industry, is weaker, with a correlation coefficient of 0.132. The second relation, between the initial level of per capita output of industry and per capita aggregate output, is considerably stronger with a coefficient of 0.178, which is significant at the five per cent level. The latter result indicates a positive association between a country's level of industrial activity and the rate of growth of aggregate productivity. This association seems to be noticeably stronger than the conventional trends towards convergence in productivity levels.

Manufacturing trade: the international dimension

So far only industrial output per capita (y_m) has been used as an indicator for the level of industrial activity. This is only one side of the 'activity coin', the domestic side, measured by the level of production. Another aspect of industrial activity can also be considered, namely, the international dimension. An obvious candidate for the latter is international comparative advantage in manufactured goods, for which trade theory proposes the ratio of manufactured exports over GDP as an empirical measure. The level indicator used here is exports of manufactures per capita (x_m), which represents the international side of the 'activity coin'.

With per capita income as a common denominator, the two level indicators, y_m and x_m offer two different views of the level of development, both in an industry perspective. More specifically, the output level (y_m) views development through the lens of domestic structure, the trade level (x_m) through that of international comparative advantage. Due to their basis in income, the two indicators exhibit a strong positive correlation, which is, however, clearly less than perfect.[19] As a result, the ranking by the international-activity indicator differs visibly, but not dramatically, from that by the domestic-activity indicator.

Table 9.8 presents the top 50 economies in a ranking by per capita exports of manufactures, with values for both 1990 and 2002. Out of the top 10 economies in this ranking seven were also among the top 10 in the domestic ranking. And like the y_m ranking, that by x_m also shows Singapore as the only developing economy in this highest portion of the distribution. Viewed through the international lens, that East Asian 'Tiger' economy appears as the activity leader,[20] ahead of all industrialised economies. When comparisons of activity rankings are extended to the highest quarter of the international distribution another five developing economies enter the scene. Four of them are Southeast Asian countries, namely, the three other Asian 'Tigers' (Taiwan Province of China, the Republic of Korea and Hong Kong SAR, China), and Malaysia. The fifth developing economy in these ranks is Kuwait, for which also a domestic-activity level close to that of Malaysia was recorded. Thus, unsurprisingly the two versions of the activity-level indicator produce quite similar pictures of the highest portions of country rankings. High industrial activity, whether it is viewed from a domestic or an international angle, is the prerogative of the industrialised economies, still. Most impressive exceptions to this rule are found in the star-performance of a handful of East and Southeast Asian economies.

The remaining 25 economies within the upper half of the international distribution are spread across almost all of the country groups discussed so far. The rest of the industrialised-economy group, including the US, is found at the top of this portion of the distribution, with the exception only of Greece, which is ten ranks behind. Transition economies are spread equally between the first quarter (Slovenia, Hungary and the Czech Republic) and the second (Croatia, Poland and Romania) of the x_m ranking. Among the developing regions, MENA (seven economies) and LAC (six economies) record the largest presence in the second quarter, while East Asia and Africa are represented by two countries and one country, respectively. The highest-ranking South Asian economy (Sri Lanka) is found five ranks below the median. Also just below the median, with closely similar international-activity levels, are three of the largest developing countries – China, Indonesia and Brazil – whereas a significantly lower value of per capita exports leaves India more than twenty ranks behind those three.

Table 9.8 Industrial-trade level, by country (1990 and 2002)

	Exports of manufactures per capita (US$)			
	2002		1990	
	Value	Rank	Value	Rank
Singapore	33 106	1	16 266	1
Ireland	20 835	2	5 575	6
Belgium	16 908	3	9 616	2
Switzerland	10 515	4	8 464	3
Netherlands	9 164	5	6 986	4
Sweden	8 419	6	6 357	5
Finland	8 002	7	5 136	8
Denmark	7 865	8	4 819	10
Austria	7 153	9	5 158	7
Canada	7 042	11	3 348	14
Taiwan Province of China	6 564	12	3 149	16
Germany	6 512	13	4 665	11
Slovenia	4 751	16	3 104	17
Israel	4 681	17	2 355	21
Norway	4 679	18	3 930	13
France	4 448	19	3 240	15
Malaysia	4 121	21	1 287	29
Italy	4 027	22	2 805	18
United Kingdom	3 885	23	2 656	20
Japan	3 595	24	2 264	22
Korea, Rep.	3 591	25	1 455	28
Kuwait	3 464	26	221	56
Hong Kong SAR	3 212	27	4 843	9
Hungary	3 102	28	763	36
Czech Republic	2 669	30	1 473	27
Spain	2 533	31	1 233	30
Portugal	2 418	32	1 557	25
New Zealand	2 192	33	1 476	26
United States	1 948	34	1 182	31
United Arab Emirates	1 632	35	246	52
Mexico	1 450	37	159	62
Australia	1 390	38	688	38
Costa Rica	1 006	41	162	61
Croatia	920	42	902	34
Thailand	870	43	339	47
Oman	791	44	260	51
Poland	782	45	225	55
Saudi Arabia	723	46	676	39
Greece	721	47	593	42
Tunisia	604	48	330	48
Uruguay	496	52	311	49
Philippines	482	53	70	73
Venezuela	475	54	127	68
Romania	452	55	236	54
Algeria	419	57	141	67
Chile	398	58	152	64
Turkey	389	59	177	59
South Africa	337	62	288	50
Argentina	334	63	198	58
Libya	296	65	538	43

Source: UNIDO Scoreboard database.

Note: The table shows data for 50 countries selected by criteria similar to those of Table 11.7. The basis of selection is the ranking of countries by exports per capita for the year 2002. Along that ranking all countries with a population of less than 2 million in the year 2000 were excluded. Again, additional information can be found in Annex Table A2.1.

Notes

1 For the sake of convenience, the full statistical-technical term 'manufacturing industry' is replaced by 'industry' or 'manufacturing' throughout this chapter.

2 This target for industrial development is known in the literature as the Lima target, referring to the long-term objectives stated in the 1975 Lima Declaration and Plan of Action on Industrial Development and Co-operation.

3 This term is borrowed from P. Samuelson, 1955.

[4] This factor is given by the inverse of world MVA per capita.

[5] The result (shown in figure 9.2) is a piecewise linear, increasing and convex curve (convexity meaning that at no point of the curve does its slope decrease), which is composed of 'country pieces', starting with the flattest and ending with the steepest of these pieces. For each one of these pieces the 45-degree straight line drawn between the end-points of the whole curve serves as the reference regarding slope. Since the slope of this 'global' line (unity by definition) represents the world average of manufacturing income, a country's deviation from slope one indicates a corresponding deviation from global MVA per capita.

[6] Within the sample used for the present study, the real-life maximum of inequality would be achieved if all industrial production were concentrated in a country of the size of Antigua and Barbuda.

[7] For the income interpretation of industrial inequality, MVA numbers would have to be expressed in international US dollars, for example, by use of data adjusted by PPP. However, since for most of the discussion the output side is more important than the income side, MVA data are expressed in constant US dollars using conventional exchange-rate conversion. A brief account of the two methods of international comparison is provided in endnote 13, together with an estimate of differences in results arising from different conversion methods.

[8] Inequality of manufacturing income is certainly overestimated in the present calculations, but inequality of industrial output levels is not. For this reason, the terms industrial output or industrial production will be used for MVA per capita for the remainder of this discussion.

[9] The simplification of the world curve achieved by the two approximating straight lines means simply to ignore inequality within the North and the South and to treat the two parts as homogeneous economic spaces.

[10] If the global distribution of industrial production were perfectly equal, all ratios in table 9.4 would have the value of one. Hence, deviations from one indicate deviations from perfect equality. And in similar fashion, an increase of output ratios with the comparison approaching progressively shorter ends of the distribution is indicative of rising inequality between industrially rich and poor economies.

[11] There is a simple tool to assess, in relative terms, the impact that an individual economy has on overall unevenness as illustrated by a Lorenz-curve or measured by a Gini coefficient. Taking again the world curve of figure 9.2 as a point of departure, one form of geometric representation of a given country in relation to that curve is the triangle under the country's portion on the curve. The larger the area of this country triangle, the stronger is its impact on the overall shape of the curve. In line with this view, the South and the North portion of the Lorenz presented in figure 9.4 have an equal impact on the shape of the total curve.

[12] The upper (lower) quartile is the dividing line between the highest (lowest) quarter of (country) observations in the sample and the other observations.

[13] As was indicated earlier, the two views of MVA per capita are associated with two different scales for international comparison and therefore imply gaps of different size between economies. Output levels measured in US dollars in the conventional way (as in the case of tables 9.6 and 9.7) produce a larger variation across economies than do income levels measured, for example, in international dollars using a PPP adjustment method. The most popular version of the latter is that of the Penn World Tables, which can be applied to MVA per capita figures if manufacturing income is to be compared internationally. If the comparisons quoted above for conventional output levels are translated into PPP-adjusted income comparisons, ratios between the levels of industrialised and developing economies are reduced by up to one order of magnitude (that is, up to a factor of 10). It should be noted in this context, however, that the approach used for constructing the World Penn Table is likely to underestimate income differences between countries (J. P. Neary, 2004).

[14] If an analogous comparison is made for manufacturing income using PPP-adjusted numbers, the result is not dramatically different from that for output levels. In the case of income there are 13 developing economies whose GDP per capita exceeds the manufacturing income of Switzerland. These economies are spread across almost all regions and include the four Asian 'Tigers' plus Malaysia; South Africa; Argentina, Chile, Costa Rica and Mexico; Kuwait, Oman and Saudi Arabia. Together they account for less than six per cent of total developing-country population.

[15] Thus, in the present context the notion of China as the 'middle kingdom' is vindicated statistically when the level of industrial activity is the criterion.

[16] In this average South Africa is included.

[17] Since each quarter contains the same number of countries, these coefficients can be compared with each other providing an indication of which portion of the distribution accounts for more or less inequality globally.

[18] The upper (lower) quartile is the dividing line between the highest (lowest) quarter of (country) observations in the sample and the other observations.

[19] The correlation coefficients are 0.73 and 0.71 for 1990 and 2002, respectively.

[20] While the result for Singapore is qualitatively correct, its quantitative basis is likely to exaggerate the leadership of this economy. The reason is that from the export number, on which the international-activity level is based, the value of re-exports could not be deducted due to lack of detailed information.

CHAPTER 10

Structural traits in industrial development

The design of a scalar measure of the level of industrial development for the purpose of cross-country comparison can be addressed in a simple way. The per capita level of industrial output, measured as value added of the manufacturing sector, as used in the previous chapter, is such a measure. In close analogy with per capita GDP, industrial output per head is the contribution by industry to total output per head. Inasmuch as the former is the key indicator of overall development, the latter is that of industrial development. The dual role of GDP as output and income is carried over to its industry component.

Six performance indicators

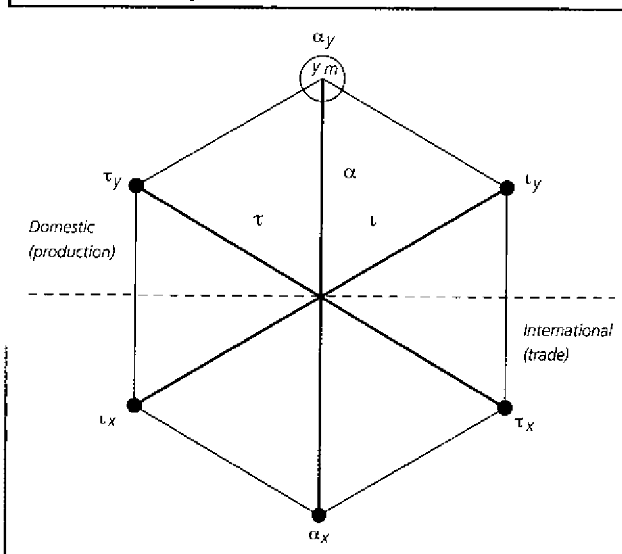
There are, of course, other aspects of the industrial-development process that are essential to a more detailed description and analysis of industrial performance. A schematic representation of those taken into account here is shown in figure 10.1, which serves at the same time as an indicator diagram. In this hexagonal scheme the six vertices represent indicators, while the three diagonals are representative of aspects or dimensions of industrial development. The six indicators are inserted into the hexagon so as to define their notional positions in the 'set-of-six' as well as to visualise relationships between them. A reading of the hexagon would best start from its apex and trace out its construction, as outlined below.

Industrial output per capita (y_m), which is at the top of the hexagon in figure 10.1, is the 'anchor' indicator of the set-of-six, for the reasons outlined above. Within this set it also plays the role of a measure of the level of (industrial) activity. More specifically, y_m is the production-based domestic indicator of activity and as such placed at one end of the activity axis α. The other end of this diagonal axis is the trade-based international indicator of activity, namely, manufactured exports per capita (x_m). These two indicators, which define the activity dimension of the set-of-six, were used in Chapter 9 to assess industrial performance simply by the level of industrial activity, measured with a domestic (α_y) and an international (α_x) yardstick. The distinction between production-based domestic indicators and trade-based international ones runs through the whole set-of-six. Its visual counterpart is the horizontal axis of the indicator hexagon, which divides the domestic upper half from the international lower half of the figure.

The second dimension considered here is that of industry in comparison with the rest of the aggregate economy. It is represented in figure 10.1 by the diagonal axis ι, which connects two indicators that are representative of the industry dimension: the share of industry in total production (ι_y) and the share of industry in total exports (ι_x).[1] The industry dimension ι can be said to reflect one side of the concept of industrial performance, namely, that of industry in relation to the aggregate economy.

The third dimension represents one particular part of the other, specific view of industrial-performance – that of technology, and particularly the part that the relatively more advanced technologies play in production and trade. Even though this is only one aspect of developments within industry, it is probably the most important one. Its prominence has

Figure 10.1 Six performance indicators



Note: Indicator dimensions and the pertinent variables are designated by Greek symbols where α stands for the activity, ι for the industry, and τ for the technology dimension. Each one of the six indicators is assigned to one of the three dimensions on the one hand and to production (subscript y) or to trade (subscript x) on the other. The definitions of indicators are given in the text and their statistical background is outlined in the Statistical notes.

to do with the role of industry as the source and engine of modern-style productivity-enhancing growth. The technology dimension is represented by the diagonal axis τ, which connects the remaining two indicators: the share of medium-or-high-technology goods in industrial production (τ_y) and the analogous share in manufactured exports (τ_x).[2]

Viewed as a whole, the set-of-six and its diagrammatic presentation in figure 10.1 exhibit a number of features that appear conceptually and analytically attractive. First, among the indicators there is an overall balance achieved between domestic and international measures, which results from balance in each one of the three dimensions where a production indicator is complemented by a trade indicator. This balance is represented geometrically in the various symmetries of the indicator hexagon. Second, a number of useful dichotomies find an expression in the set-of-six. One is between the level of activity (α) on the one hand and structural features (ι and τ) on the other. Another one is that between industry and the aggregate of all other sectors in the economy. A third one is the distinction between relatively technology-intensive activities and other manufacturing. And finally, geometry helps to put in relief a more general property of the indicators set: both conceptually and visually the six indicators appear as a structured set with three pairs of measures assigned to the three dimensions of activity, industry and technology.

ITA: an index of industrial and technological advancement

The illustration of the six performance indicators in figure 10.1 is in terms of parallels, which are symbolic for conceptual parallels, too. The four vertices representing structural indicators are those that are connected by the two vertical sides of the hexagon. These 'structural' sides in turn are parallel to the central activity axis. Thus, the geometry of figure 10.1 is suggestive of conceptual distinctions insofar as activity indicators (y_m and x_m) and structural indicators (ι_y, ι_x, τ_y and τ_x) are not combined but treated in parallel. Conceptual and geometric parallelisms can be further carried over into an empirical discussion that parallels the one above on activity levels.

The procedure to combine the four structural indicators contained in the set-of-six, first into two partial indicators and then into a single structural index, is outlined in the following in two alternative approaches, one bottom-up and the other top-down. The idea behind both approaches is that all four indicators in a way reflect not the level but the orientation of industrial activity and that this orientation is best described by the term industrial-cum-technological advance, a notion for which the acronym ITA will be used.

Bottom-up approach

The initial step in the bottom-up approach to index construction is that of defining two indicators that reflect the aforementioned orientation of activities. The first one is labelled industrial advance (ι). It stands for the industry dimension of the indicator set and therefore combines the two share variables at the two ends of the industry axis in the scheme of figure 10.1. The industrial-advance indicator is thus defined as the arithmetic mean of the share of manufacturing in GDP (ι_y) and the share of manufactures in total exports (ι_x). In analogy to the construction of an indicator of industrial advance, a similar one can be formed for technological advance (τ). It is representative of the technology axis in figure 10.1 and is obtained as the arithmetic mean of the share of medium-or-high-technology activities in MVA and the corresponding share in exports. The values of both indicators ι and τ, which are averages of shares, lie between zero and one.

The second step in the bottom-up approach combines the newly derived indicators of industrial advance (ι) and technological advance (τ) into one index of industrial-cum-technological advance, the ITA index. Here, an important point is that the new indicator, which is intended to have the form of an index with values ranging between zero and one, should reflect the interaction between industrial and technological advance, as the linking *cum* in the name of the index indicates. Consequently, the ITA index is defined as the product of indicators ι and τ.

With the above rules for deriving the ITA index it is easy to imagine the special case where the shares ι_y and ι_x are identical and the same holds for the shares τ_y and τ_x, too. Then, indicator ι will be identical with the share ι_y and indicator τ with the share τ_y. In this case, the ITA index – the product of shares ι_y and τ_y – will simply be the share of the more technology-intensive activities in total (not in manufacturing) production.

Top-down approach

This points the way to the alternative, top-down approach of deriving the ITA index. It starts with the general notion of an activity variable A that can be applied to the entire economy or to particular sectors. The concept of the ITA index can then be realised by the share of the technologically more advanced industrial activities ($A\tau$) in activities of the entire economy (A). The share $A\tau/A$ can in turn be expressed as the product of industrial activities $A\iota/A$ and that of the technologically more advanced activities within manufacturing industry $A\tau/A\iota$. Finally, the abstract notion of activities can be given substance by substituting for A production or trade, or a combination of the two. If the last one of these three options is chosen and the respective activity shares are defined as the arithmetical means of the corresponding production and trade shares, the ITA index as defined in the bottom-up approach is the result.

The ITA index, obtained from the four structural indicators in the set-of-six, is intended as a proximate assessment of the part that industry and technology have together in production and trade. Somewhat more ambitiously, the ITA value for a given economy is also expected to help gauging the impact that industrial-cum-technological advance is likely to have on its development. While assessing the compound weight of industry and technology is of prime interest here, another goal of the analysis is to disentangle the contributions made separately by industrial advance and technological advance, as well as to appraise the respective parts of production and trade.

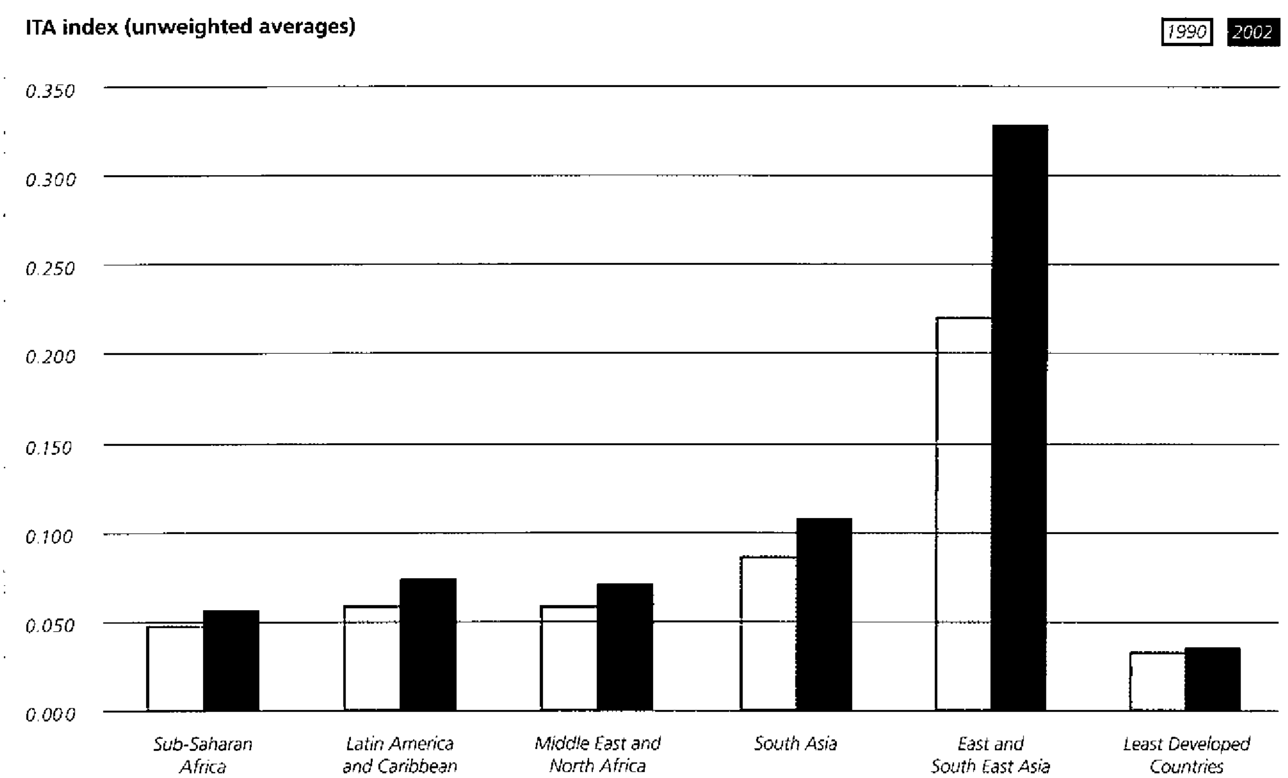
Patterns in industrial-cum-technological advance

The structural index introduced above captures core characteristics of an economy with a view to discerning the role that industry and technology play in tandem. It is better applied at the level of individual countries than that of larger economic spaces. Nevertheless, and for the purpose of a preview of country-specific results, index values can be averaged across country groups in order to assess broad differences. With regard to the broadest grouping by type of economy these differences emerge as expected. For the industrialised economies one-fourth of activities are industry-cum-technology-oriented, whereas for developing economies the corresponding share is one-tenth. Over the period surveyed the associated structural gap between North and South has narrowed, due to an increase in the Southern average ITA index by two per cent annually.

Within the developing-economy group structural differences are enormous, as is witnessed by the geographic-group averages shown in figure 10.2. As expected, East and Southeast Asia was the leader already in 1990 and has made huge structural gains since then. By contrast, the average ITA index for other developing economies remained at a level significantly below a third of that of industrialised economies in 2002. This was the case despite a notable increase of its value over the 1990s. Finally, for the eight LDCs in the sample the index stayed virtually at the same level between 1990 and 2002. By the end of the period, its value had reached only half the average ITA of developing economies other than East and Southeast Asia – and a seventh of that of the industrialised economies.

Average index values provide only a first glimpse of structural differences. They mask the immense variation of ITA between economies, which gives substance to the common perceptions of the North-South divide on the one hand and of a wide range of structural characteristics of developing economies on the other. Table 10.1 presents this country detail for both of the years surveyed here. It shows the ITA index for individual economies ranges between a maximum of slightly over 0.5 and a minimum of virtually zero. This can be taken as an empirical indication of the technologically more advanced industrial activities covering half of the aggregate economy 'at best' and being virtually non-existent 'at worst'. At the same time the index values of table 10.1 reveal a world of structural difference between the above polar extremes.

Figure 10.2 Industrial-cum-technological advance, by developing region (1990 and 2002)



Source: UNIDO.

Note: The definition of the ITA index is provided in the text. Each regional figure is the unweighted average across those countries in the region, for which data were available for both 1990 and 2002. For country coverage, table A2.2 of the annex tables can be consulted.

The following discussion of ITA patterns is guided by the interpretation of the associated index as the compound of shares. Alternatively, the ITA measure is viewed as an empirical approximation to the 'true' share of industry-cum-technology in the aggregate economy. Figure 10.3 illustrates the index ranges as vertical planes inserted into an 'ITA cone' such that the economy of a borderline country industry-cum-technology have a presence that is half (twice) as strong as that in the economy of a preceding (following) borderline country. In other words, each range (or plane) is half that of its right-hand neighbour and twice that of its left-hand neighbour.[3]

High performers

The highest and consequently widest plane (plane I) within the ITA cone has 0.5 and 0.25 as its top and bottom limiting index values. Out of roughly one hundred economies, 28 had values in that range in 2002; the corresponding number for 1990 was 22. Hence there was overall industry-cum-technology advance at the high end of the ITA-index distribution. This advance has a regional name, that of East and Southeast Asia. Not only did Singapore take over ITA leadership from Japan, and the Republic of Korea and Taiwan Province of

Table 10.1 Industrial-cum-technological advance (2002)

	ITA index		Industrial advance (ι)		Technological advance (τ)	
	Value	Rank	Value	Rank	Value	Rank
Singapore	0.520	1	0.625	6	0.832	1
Malaysia	0.457	2	0.646	2	0.707	3
Japan	0.456	3	0.590	13	0.772	2
Korea, Rep.	0.439	4	0.652	1	0.674	7
Taiwan Prov. of China	0.410	5	0.632	3	0.649	10
Germany	0.407	6	0.589	14	0.690	6
Hungary	0.396	8	0.626	5	0.633	13
Ireland	0.389	9	0.593	12	0.657	8
Switzerland	0.389	10	0.604	9	0.644	12
United States	0.371	11	0.529	27	0.702	4
Sweden	0.370	12	0.570	18	0.649	11
Philippines	0.362	13	0.602	10	0.601	14
United Kingdom	0.353	14	0.509	35	0.694	5
Finland	0.334	15	0.597	11	0.560	21
China	0.324	16	0.631	4	0.515	27
Mexico	0.320	17	0.533	26	0.599	16
France	0.315	18	0.525	28	0.600	15
Thailand	0.311	19	0.605	8	0.514	28
Austria	0.311	20	0.550	22	0.565	20
Netherlands	0.308	21	0.515	34	0.599	17
Italy	0.308	22	0.586	16	0.527	26
Israel	0.307	23	0.564	20	0.545	24
Spain	0.297	24	0.522	29	0.568	19
Belgium	0.291	25	0.522	31	0.558	22
Canada	0.284	26	0.484	39	0.587	18
Brazil	0.252	27	0.478	42	0.528	25
Denmark	0.250	28	0.451	51	0.555	23
Hong Kong SAR	0.247	29	0.518	33	0.477	30
Poland	0.236	30	0.554	21	0.426	36
Costa Rica	0.218	31	0.461	46	0.473	32
Portugal	0.209	32	0.548	23	0.382	42
South Africa	0.206	33	0.419	54	0.491	29
Turkey	0.199	34	0.546	24	0.365	44
India	0.198	35	0.508	36	0.391	41
Indonesia	0.194	36	0.519	32	0.374	43
Romania	0.171	37	0.581	17	0.295	54
Jordan	0.159	38	0.460	48	0.347	47
Argentina	0.153	40	0.362	63	0.423	37
Greece	0.137	41	0.455	50	0.302	52
Pakistan	0.129	42	0.570	19	0.226	63
El Salvador	0.129	43	0.468	45	0.275	56
Tunisia	0.127	44	0.522	30	0.244	61
New Zealand	0.127	45	0.405	57	0.313	51
Australia	0.125	46	0.275	77	0.454	34
Egypt	0.124	47	0.483	41	0.257	59
Morocco	0.115	50	0.460	49	0.249	60
Cyprus	0.114	51	0.435	53	0.263	58
Zimbabwe	0.107	52	0.272	78	0.395	40
Norway	0.106	53	0.225	87	0.471	33
Senegal	0.104	54	0.370	62	0.281	55
Guatemala	0.104	55	0.301	70	0.344	48
Colombia	0.097	56	0.280	75	0.347	46
Uruguay	0.093	57	0.461	47	0.202	67
Grenada	0.079	58	0.387	60	0.204	66
Bangladesh	0.072	60	0.541	25	0.134	91
Bolivia	0.070	61	0.359	64	0.197	68
Chile	0.070	62	0.237	83	0.297	53
Venezuela	0.067	63	0.277	76	0.243	62
Sri Lanka	0.065	64	0.477	43	0.137	90
Trinidad and Tobago	0.063	65	0.477	44	0.133	92
Saudi Arabia	0.060	66	0.144	96	0.420	38
Peru	0.057	69	0.307	69	0.184	72
Nepal	0.056	70	0.405	56	0.139	88
Mauritius	0.054	71	0.587	15	0.092	102
Algeria	0.053	72	0.327	66	0.163	77
Honduras	0.046	73	0.247	80	0.187	70
Kenya	0.044	74	0.240	82	0.184	73
Bahrain	0.043	75	0.483	40	0.088	103
Oman	0.040	76	0.116	100	0.341	49
Qatar	0.038	77	0.289	73	0.131	93
Togo	0.038	78	0.250	79	0.150	82
Kuwait	0.037	79	0.373	61	0.100	98
Jamaica	0.035	81	0.233	84	0.151	81
Fiji	0.034	82	0.445	52	0.077	105
Ecuador	0.033	83	0.222	89	0.149	83
Panama	0.031	84	0.217	90	0.142	86
Madagascar	0.028	85	0.301	71	0.094	100
Nicaragua	0.026	86	0.193	91	0.138	89
Cameroon	0.026	87	0.222	88	0.119	96
Papua New Guinea	0.026	88	0.314	67	0.083	104
Central African Republic	0.025	89	0.158	93	0.159	80
Malawi	0.024	90	0.151	94	0.162	78
Libyan Arab Jamahiriya	0.024	91	0.191	92	0.127	95
Paraguay	0.022	92	0.229	85	0.097	99
Syrian Arab Republic	0.021	93	0.225	86	0.094	101
Haiti	0.018	94	0.414	55	0.045	108
Nigeria	0.012	96	0.025	105	0.474	31
Yemen	0.009	97	0.056	103	0.161	79
Ethiopia	0.005	98	0.093	101	0.051	107
Mali	0.002	99	0.058	102	0.041	109

Source: UNIDO.

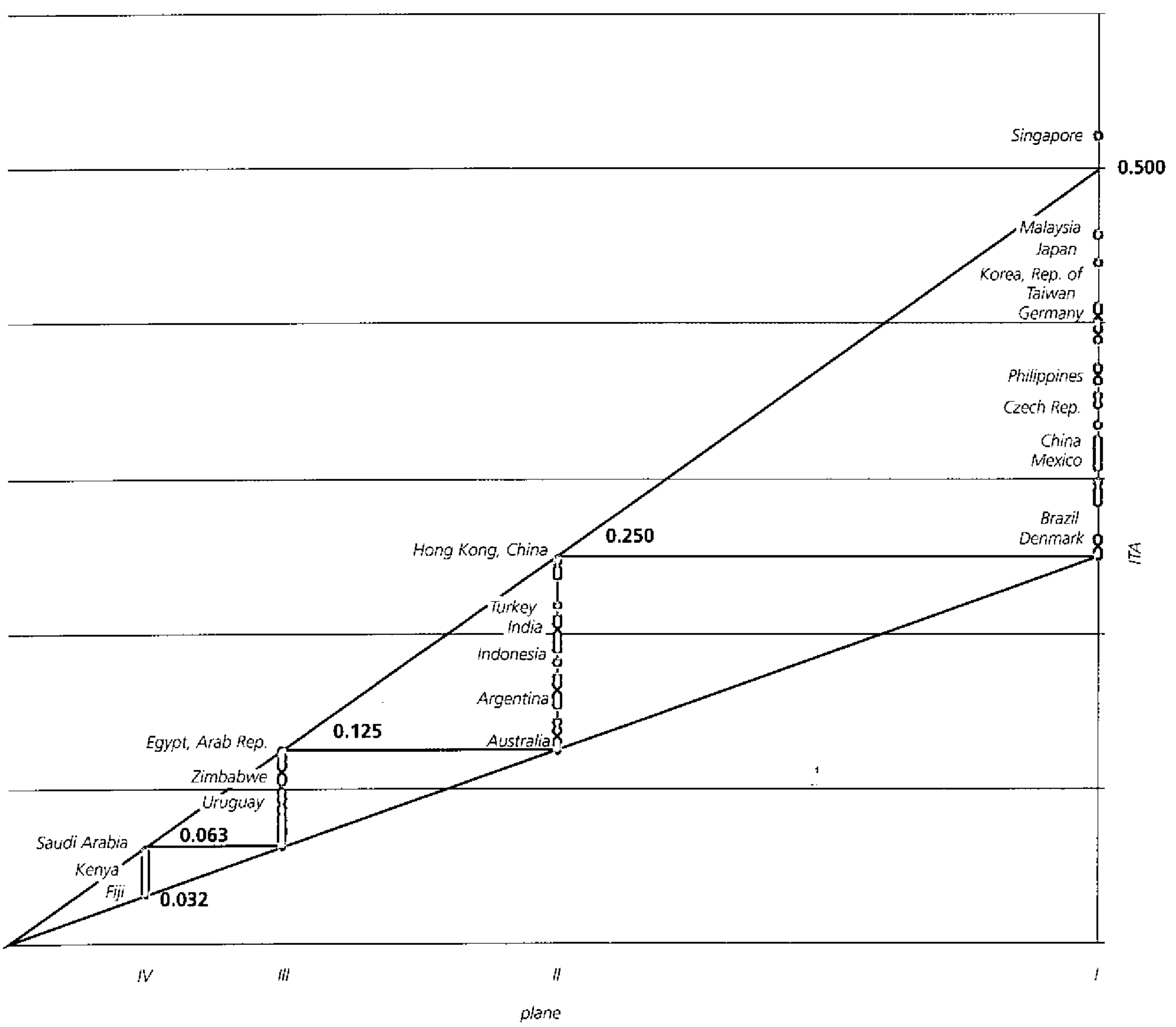
Note: The 90 countries shown in this table meet two criteria: First, they have data for both 1990 and 2002. Second, their population size exceeded 5 million in the year 2000. ITA values for a sizable number of other countries and for the year 1990 can be found in Table A2.2.

China advance dramatically, but there were also four more economies from the region, among them China, that moved into the highest portion of the ITA range. In addition, the two large LAC economies, Mexico and Brazil, have joined the ranks of the structurally most advanced economies. The former has seen its index rise by over three-quarters of its 1990 value. In addition to these economies, plane I holds industrialised economies, and Hungary as the sole representative of the transition-economy group. Thus, the index by-and-large reproduces the conventional picture of the North-South divide, also with respect to the structural orientation of economies. At the same time, the rankings shown in table 10.1 make clear in which way and to what extent the above divide is becoming blurred: through the exceptions of a handful of industrialised economies with low index values on the one side and the inexorable progress of the best performing developing economies on the other.

Distant followers

The second plane in the ITA cone of figure 10.3, with a range between 0.25 and 0.125, covers fewer countries than plane I. In line with previous explanations, economies on plane II can be said to have an industry-cum-technology portion of total economic activity which is half that of plane I. Countries with this structural characteristic are spread across all types of economies and all developing regions. There are four industrialised economies (Portugal, Greece, New Zealand and Australia) with ITA values in this range – with the latter three countries approaching the low end of the plane – as well as

Figure 10.3 The industrial-cum-technological advance cone (2002)



Source: UNIDO.

Note: The approach to picturing the distribution of ITA values across countries in the form of the above cone is outlined in the text. The basic idea is that of progressively halving the ITA range and inserting each new half as a new plane (I, II, III, ...) into the above cone. The numbers underlying this graphic are those of table 10.4.

two transition economies (Poland and Romania) in its upper portion. East Asia is represented by Hong Kong SAR, which leads on plane II after a slight index increase over the 1990s, and Indonesia, which has moved into these ranks from a lower portion of the distribution, after having more than doubled its ITA index between 1990 and 2002. The one larger Latin American economy on plane II is Argentina, which showed a modest index increase over the 1990s. SSA and MENA are represented by a large country each – South Africa for the former, Turkey for the latter. Finally, the most populous country of South Asia, India, had an ITA index value around the middle of the range of the second plane already in 1990 and increased it over the subsequent decade.

Third tier countries

The third plane in figure 10.3, including the countries with index range between 0.125 and 0.063, covers the same number of countries as plane II, with members drawn from the same breadth of geographic regions. Three features seem to be worth noting. First, in this range there is one industrialised-economy outlier (Norway), which saw a dramatic decline of its index value over the period. Second, SSA is present through Zimbabwe and Senegal (the latter having experienced a significant rise in ITA). Third, the largest of the LDCs, Bangladesh, is also located on plane III, i.e., displaying a structural orientation that is relatively more advanced than that of the other economies in its country group.

Least industrialised countries

Finally, the fourth and last plane inserted into the ITA cone of figure 10.3 holds economies with index values lower than 0.063 (the equivalent roughly of one over 32).[4] This is the range where the 'typical' LDC is located. Within the country sample underlying table 10.1 and figure 10.3, the 10 economies from this group are spread over the whole of the last plane, with Nepal near the top and Mali at the end of the lowest index range. While the positions of the least industrialised economies are similar to expectations, other country groups present surprises. First, Iceland, the extreme outlier among the industrialised economies, falls in the lowest ITA index range. Second, seven out of the eight low-ranking economies from the MENA region are oil countries, but there is also Syria, which saw its index plummet over the 1990s. Finally, some small LAC economies are found deep in the ranks of the least industrialised countries, like Panama, Nicaragua and Paraguay. All three countries would lie on the next lower plane in figure 10.3, with values of the ITA index falling below the threshold of one over 64.

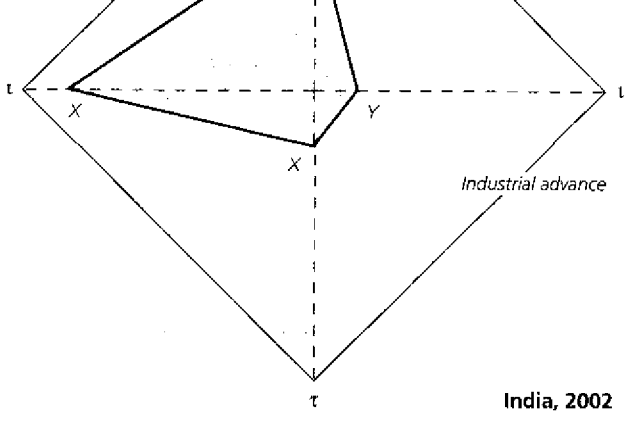
If the ITA-index value of each country in the sample were marked by a point on the respective plane in figure 10.3, the picture would be one of increasing density from higher to lower planes. More precisely, planes I and II would show about the same density of country points, whereas between II and III as well as between III and IV density would be seen to double. This is just another indication of the dramatically unequal distribution among countries of industry – in the present case more specifically that of industry-cum-technology – substantiated here with the help of information on the structure of production and trade.

Structural diamonds

The index of industrial-cum-technological advance is a compound of four structural indicators. The way in which the ITA index is constructed leads to a straightforward geometric exposition, which has two functions: to map the ITA value onto a geometric measure, and to provide an indication of the role that each one of the component indicators plays in the aggregate index. The geometric device to achieve these functions is the structural diamond sketched in figure 10.4. It is obtained by extracting from the indicators scheme of figure 10.1 two of the three axes, namely, the 'industry axis' ι and the 'technology axis' τ, together with the share variables plotted as endpoints on these axes. Rotation of the ι axis into the horizontal position and of the τ axis into the vertical one produces the coordinate system of figure 10.4. In line with the scheme of figure 10.1, the production shares ι_y and τ_y are now plotted in the 'positive' directions; the trade shares ι_x and τ_x in the 'negative' directions.

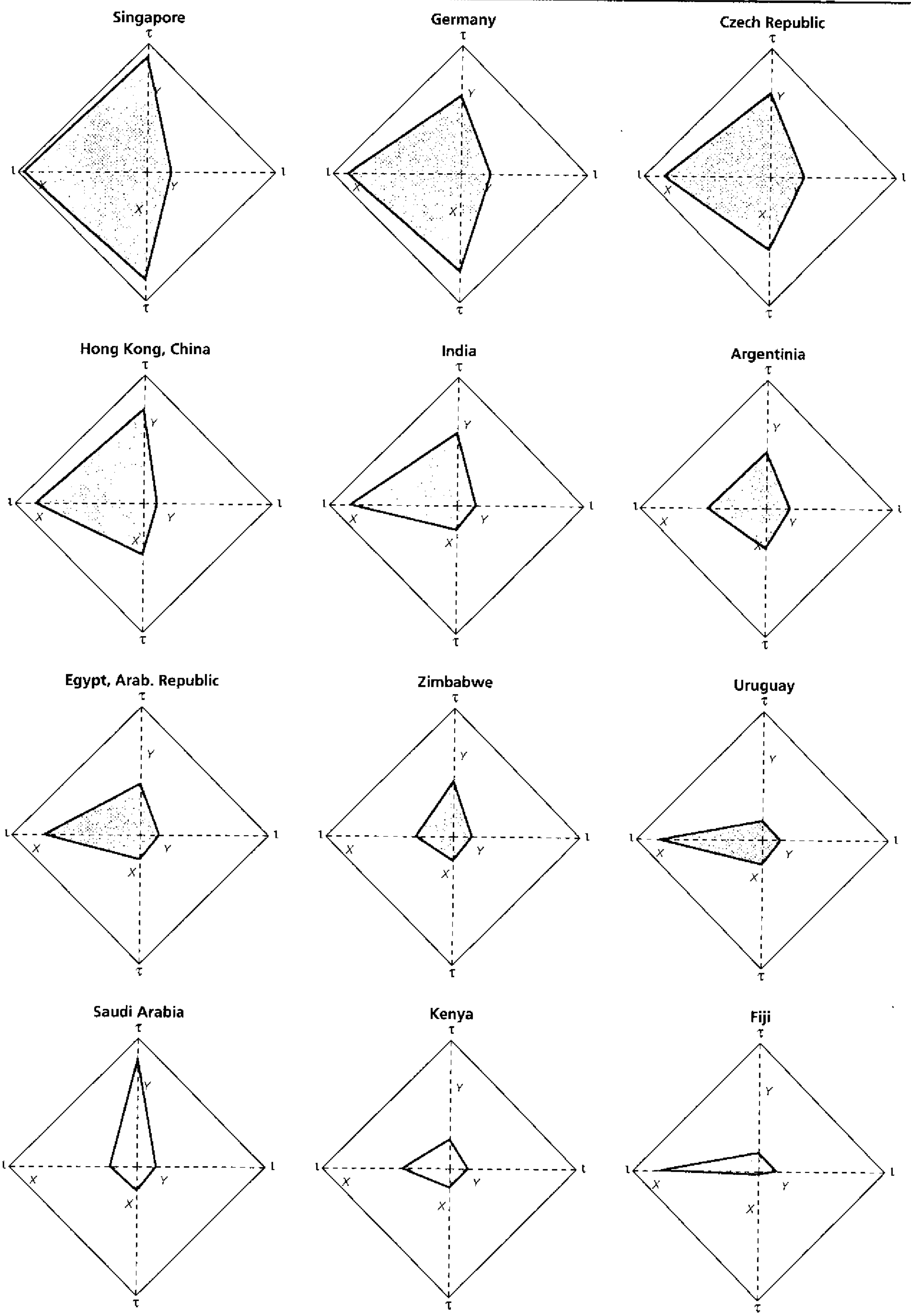
The four structural-indicator values, represented as outlined above, mark the corners of a diamond shape, which will henceforth be called the structural diamond. The shape of this diamond depends in a straightforward manner on the structural characteristics of the economy which it describes – in the case of figure 10.4, India in the year 2002. The figure indicates also the limiting case of a circumscribed hypothet-

Figure 10.4 A structural diamond



Source: UNIDO.

Figure 10.5 A dozen diamonds (2002)



Source: UNIDO

Note: The data underlying the above diagrams are taken from table A.2.

ical diamond, in which all shares reach their maximum values of one. This corresponds to the case where all production and trade is composed of manufactures that, in addition, are relatively technology-intensive. An obvious interpretation of the area of the structural diamond (expressed as a share of the maximum area of the limiting diamond) is that of a measure of industrial-cum-structural advance, too. As can be verified quite easily, this interpretation coincides with that of the ITA index introduced earlier: The area of the (observed) structural diamond as a fraction of the area of the (hypothetical) maximum diamond equals the value of the ITA index, calculated from the values of the underlying four structural indicators.

An application of the above graphic procedure to some of the country data underlying ITA calculations produces shapes such as those presented in figure 10.5. The twelve diamond shapes shown there include economies from all the country groups discussed in this chapter. They are arranged in descending ITA order and relate to figure 10.3 in an obvious way: From each one of the planes of the ITA cone three countries are selected as examples of structural diamonds. Accordingly, the diamond areas (ITA index values) are seen in figure 10.5 to decline from the upper-left corner to the lower-right one. The shapes of the twelve diamonds, with all the differences between them, reveal a number of features. First, the production share of industry makes the smallest contribution to the ITA measure, for reasons discussed earlier. Second, for two-thirds of the countries exhibited in the figure, the share of manufactures in total exports marks by far the largest extension of the diamond. Third, those economies with the highest industrial-cum-technological advance indicators approach fairly closely the theoretical maximum of one in all directions except that of ι_y, while low-ITA economies show a broad variety of diamond shapes.

The industry dimension

The indicator of industrial advance (ι) can be said to cover the conventional half of the ITA index, accounting for the contribution of the manufacturing sector both to total production and to total exports. Its geometric measure is the length of the horizontal diagonal of the structural diamond for a given economic space. As can be gleaned from the examples presented in figure 10.5, the diamond shapes are highly asymmetric with respect to the vertical axis. The reason for this is the asymmetry in the composition of the industrial-advance indicator. While the share of manufactures in domestic production, which includes a sizeable portion of non-tradable goods, normally does not exceed a third, the corresponding share in exports, that is, of tradable goods by definition, can approach the value of one.

Across a wide range between a maximum of over 0.65 (Republic of Korea) and a minimum of little over 0.05 (Yemen), the index of industrial advance for 2002 (shown in tables 10.1 and A2.2) was quite uniformly spread, where the upper half of the ι-distribution was somewhat more densely populated than the lower half.[5] Remarkably, among the top 10 economies with ι-values between 0.65 and 0.60 there was only one industrialised economy (Switzerland) and one transition economy (Hungary), whereas the others were developing economies of the East and South-East Asian region. The majority of industrialised economies have lower ι-values (with a lower bound of around 0.50), which spread them across the lower part of the first quarter of the distribution and the higher part of the second. However, outliers of the industrialised-economies group are found in all the other quarters, down to the lowest one.

Among the top 10 economies in 2002 there were four Southeast Asian countries that showed a spectacular rise in their ι-values over the 1990s and thus entered the highest ranks from positions at least ten ranks lower. China is one of these 'advance' economies, with an increase of its industrial-advance indicator of more than eight percentage points. Even higher were the gains, both in value and rank, recorded for Malaysia, which by the end of the period had attained the second position in the ι-ranking, as well as for Thailand and the Philippines, with large gains in ranks for the ι-indicator.

Within the highest industrial-advance quarter, values of the trade indicator ι_x – the share of manufactures in exports – are consistently high, with most of the economies exceeding the 90-per cent mark. In fact, with the exception of only three countries, all the economies of the highest ι-quarter are found in the highest quarter of the ranking by the trade indicator ι_x too. Hence, it is with respect to the production part ι_y – the share of manufacturing in GDP – that economies differ in the uppermost portion of the ranking along the industrial dimension. Thus, out of the top 10 economies in the ι-ranking for 2002, eight were also among the top 10 in terms of the share of manufacturing in GDP. And the relationship between industrialised economies and developing economies with regard to membership in the first quarters of the respective distributions was virtually the same for ι and ι_y.

The second quarter of the ranking by the industrial-advance indicator shows values roughly between 0.50 and 0.45. Industrialised countries are spread across the whole of this range, with the US and France at the top and Greece and Denmark at the bottom. Three of the large developing economies – Indonesia, India and Brazil – fall in this quarter, and so does the fourth of the East Asian 'Tiger' economies, Hong Kong SAR, China. Apart from these remarkable cases of individual economies, membership of the second quarter is widespread, drawing on all developing regions.

The lower half of the ranking by the ι-indicator extends from the median value of around 0.45 to levels as low as 0.05. Somewhat surprisingly, its composition covers all three broad groups of economies. It includes the four outliers of the industrialised-economy group – New Zealand, Australia, Norway and Iceland – with ι-values ranging from 0.40 down to 0.14. In the lower portion of the ι-distribution, the group of transition economies is represented by the Russian Federation, as well as several of the Central Asian republics. Developing economies from three regions are found over virtually the whole range of lower indicator values. SSA has South Africa (0.42) at the top and Mali (0.06) at the bottom of the lower half. Similarly, LAC is represented in the higher portion, for example, by Argentina (0.37), and in the lower one by

Ecuador, Panama and Nicaragua (around 0.20). For the MENA economies the range is between Kuwait (0.37) and Oman (0.12). By contrast and with the exception of Nepal (0.40), there is no Asian economy in the sample with a low value of the industrial-advance indicator.

The technology dimension

The indicator of technological advance (τ) is based on those structural features that reflect the role of the technologically more advanced activities in industrial production and trade. Its geometric measure is the length of the vertical diagonal of the structural diamond for the country or area considered. The examples of figure 10.5 seem to suggest that diamonds are rather more symmetrical with respect to their horizontal axis, reflecting fewer unequal contributions from production and trade to the τ-indicator than to the ι-indicator. Part of an explanation of this feature is that both components of technological advance refer to the manufacturing sector and are therefore not influenced by the presence of non-tradable goods.

The range of the technological-advance indicator is considerably wider than that of industrial advance, extending between a maximum of 0.83 for Singapore and a minimum of 0.05 for Haiti. Across this range, differences between economies become smaller with declining levels of technological advance, as is indicated by a decrease in inter-quartile ranges of the indicator τ from 0.29 down to 0.11. Unlike the case of the industrial-advance indicator, in that of technological advance membership among the top 10 economies is shared equally between industrialised and developing economies, with the latter, as expected, mostly from the East and Southeast Asian regions. The remainder of the highest τ-quarter belongs to the industrialised economies almost entirely. In fact, only five member of this group are found in the second quarter and one outlier (Greece) below the median-value of the present sample in 2002. In short, conventional wisdom – that the so-called industrialised economies are the technologically advanced economies – is conspicuously supported by data on the structure of production and trade. At the same time and based on the same kind of information, the assessment of countries with respect to technological advance shows that about a third of the uppermost portion in the ranking by the τ-indicator are developing economies.

The high similarity between the production and the trade sides of the τ-indicator[6] implies that technological advance is reflected in largely equal measure in the corresponding production and trade shares. This feature of high concordance between the technological-advance indicator and each one of its components emerges clearly from the data for economies in the highest quarter of the τ-distribution. Out of the top 10 economies in that distribution, eight are among the top 10 in terms of the corresponding production share and seven among the top 10 in the ranking by trade share. And with a view to the full first quarter in the ranking by the τ-indicator, concordance was even more striking. Out of the 24 economies in this top quarter, there were only two (the Philippines and Mexico) that were not at the same time members of the top quarters of the rankings by both component indicators. More specifically, the high technological-advance indicators of these economies are the reflection of high ι_x values,[7] whereas their structural features of industrial production place them in the second quarter of the corresponding τ_y component.

The second quarter has at its top a number of developing economies, which showed a remarkable increase in τ-values over the decade surveyed here. They include Brazil, China, Thailand, South Africa, and Hong Kong SAR, all with τ-values around 0.50 in 2002 and increases in the indicator between 0.07 (Hong Kong SAR) and 0.23 (Thailand) over the 1990s. Immediately below this group of developing economies are four industrialised economies (Norway, Australia, Iceland and Portugal) with unusually low τ-values spread over the interval of the 0.40s and below. The middle portion of the second quarter contains a number of developing economies that are notable for their size (India), for their large increase in τ-values (Argentina) or for both (Indonesia). The lower end of this quarter approaches the median τ-value of around 0.33, with Turkey as the largest economy with this level of technological advance reflected in its manufacturing production and trade.

In the second quarter, too, concordance between the technological-advance indicator and its two components is high. Thus, all but four economies in this part of the τ-distribution are found in the same quarter of the ranking by the corresponding production share. And the number of exceptions is reduced to only two in a comparison of membership in the second quarter between the τ-indicator and its τ_x component.

Near the top of the lower half of the distribution by the technological-advance indicator there are two outliers of the group of industrialised economies, New Zealand and Greece, with values of around 0.30, which nevertheless represent significant improvements over 1990. Another characteristic of the third quarter is the high number (nine) of LAC economies, ranging from Chile near the top to Peru near the bottom of this part of the τ-distribution. In general, membership of the third quarter draws on virtually all groups and geographic regions (except East and South-East Asia), with Romania as the one transition economy, four SSA countries, four North African economies, as well as one South Asian country (Pakistan).

Finally, economies with values for the technological-advance indicator of 0.15 and less form the bottom quarter of the τ-ranking. Relatively large numbers of countries in this part of the distribution are from LAC (six) and MENA (five), while the number of SSA economies (four) is smaller than expected. Interestingly, within the lowest quarter LDCs are spread between the top (Togo) and the bottom (Haiti). The first of these two economies recorded a significant increase in its τ-value, the second a considerable decrease over the 1990s. In between these two limiting cases of indicator values, Bangladesh, the one large LDC, and one other South Asian economy (Sri Lanka), are found in the upper range of this quarter.

Table 10.2 **Relationships among indicators (2002)**

	Correlation coefficient					
	Y_m	X_m	ι_Y	ι_X	τ_Y	τ_X
MVA per capita (Y_m)	1	0.705	0.395	0.431	0.671	0.631
Manufactured exports per capita (X_m)		1	0.349	0.381	0.581	0.466
Share of MVA in GDP (ι_Y)			1	0.522	0.507	0.484
Share of manufactures in total exports (ι_X)				1	0.524	0.497
Share of medium- or- high technology in MVA (τ_Y)					1	0.731
Share of medium- or- high technology in manufactured exports (τ_X)						1

Source: UNIDO.
Note: The numbers in this table are Pearson-correlation coefficients. Each coefficient is significant at least at the 5% level.

Industrial indicators and level of development

While each one of the three dimensions discussed above and the variables representing them are of interest in themselves, relationships between dimensions and variables can shed additional light on patterns and regularities in the performance of industry. The standard tool to indicate such relationships is that of correlations as they are shown in table 10.2. The table presents correlation coefficients for 2002 only, since relationships among the different indicators were virtually the same for 1990. By and large, correlations are as expected, both confirming the architecture of the set of six indicators on the one hand and hinting at some traces of association between dimensions.

As regards architecture and application of the indicators system, each one of the three dimensions shows the necessary coherence between the two indicators – one for production (Y) and one for trade (X) – that represent it. In fact, for any of the six indicators, the highest correlation is with its 'dual' counterpart within the dimension to which it belongs. And among the three dimensions, technological advance shows the highest production-trade stringency (with a correlation coefficient of 0.73), industrial advance the lowest (0.52). Ex post, this pattern of relationships provides the statistical basis for viewing the six indicators along the three dimensions of industrial activity, industrial advance and technological advance.

Relationships between the three dimensions are reflected in other correlation coefficients of table 10.2. First, there are the associations of industrial activity indicators with those of industrial advance, production on the one hand and trade on the other. The relationship between activity level (per capita MVA) and industrial advance is of course significantly positive (like all correlations in the table) – albeit only of moderate strength, with values of 0.40 for the production component and 0.43 for the trade component. Somewhat paradoxically, it is not necessarily the industrially most advanced economies – as indicated by the share of manufacturing in total production – that also show the highest α-levels. One factor behind this result is certainly that of de-industrialisation in the richest economies of the world, but there may be others too.

Second, the association between activity levels and technological-advance indicators is considerably stronger, as is reflected in correlations of 0.67 on the production side and 0.63 on the trade side. These numbers are perfectly in line with the role usually ascribed to technological progress in industrial development and the growth of income. And without indicating a direction of causation, they point to two hypotheses about causal relationships:

- Technological advance, through its effect on productivity, is a root cause of relatively high levels of (industrial) output.
- Conversely, economies with high activity levels are the ones that tend to specialise in the more technology-intensive portion of industrial production.

Finally, there is a relationship of medium strength between industrial advance and technological advance with correlation coefficients of 0.51 on the production side and 0.50 on the trade side. Again, this can be viewed as a plausible result, given that a high share of manufacturing in total production is not necessarily based on a high contribution of the technologically more advanced industries. International comparative advantage in industry can take many forms, depending on the resource profile of a given country, and yet lead to a sizeable share of manufacturing in total output.

The pattern of inter-dimensional relationships that emerges from table 10.2 largely meets expectations about the association between activity levels and the structure of industrial production and trade. In addition and more importantly, it poses a bigger question, one that has a long tradition in the analysis of development and might be phrased in the following way: what is likely to happen in the three major dimensions of industrial development when the level of overall development rises?

An answer to this question, even if it is partial and proximate, can inform the perception of industrial development. In the much narrower context of the present discussion it can simply connect, by way of an empirical summary, the end of a descriptive account of industrial performance with its beginning in the construction of indicators.

The conventional indicator of the level of overall economic development, per capita income (y), is employed also in the present context. The industrial-activity dimension (α), measured as industrial output per capita or industrial exports per capita, must by necessity exhibit a strong positive association with per capita income. It would be a task for intricate econometric analysis to find out more about the functional form of this association – a direction not pursued here. The industry dimension (ι) and the technology dimension (τ), expressed through structural indicators, also show a positive association with income, which is, however, far from perfect. The correlations of table 10.3 provide an indication of the strength of this association. While industrial advance shows a moderate correlation with income (0.32), that of technological advance with income is high (0.64). The correlation coefficients pertaining to the component indicators detail this difference, whereas the relationship between the ITA index and income represents an average, which shows the expected technology bias. On the whole, the strength of association has declined slightly over the 1990s.

That the relationship between the ITA index and its component indicators on the one hand and income on the other is far from straightforward is illustrated by the graphics of figure 10.6, where each indicator is plotted against (the logarithm of) income. Here the plots of the industry and technology shares in production are of special interest, since they reproduce patterns that have given rise to a whole strand of development studies, namely, those dealing with structural change of production, trade and employment.[8] That the income level – and the bundle of characteristics it is often taken to represent – is only one, doubtless important factor behind such change emerges clearly from the information summarised in the figure. Hence, attempts at explaining structural differences between economies found in the literature had to invoke, in addition to the income level, other country characteristics such as size, natural-resource endowment or trade orientation. By the same token, any 'explanation' of the variation across economies of the indicators used in the present analysis has to follow a similar approach.

The results of the simplest possible versions of regression analyses with per capita income as the central explanatory variable are presented in table 10.4. These regressions, which are based on 2002-data, follow the plots of figure 10.6 inasmuch as they use a so-called semi-logarithmic specification with the independent variables expressed in logarithmic terms and the respective dependent variables as simple shares. In addition to the income level (y), the size of an economy, measured by population (N), is included as an explanatory factor.

The first set of coefficient estimates is based on the simplest semi-logarithmic equation where the logarithms of income and population enter only as linear terms. In all seven regressions income and size are significant determinants whose coefficients carry the expected positive signs. The estimation results suggest that the proportion explained by income and size of inter-country variation in a given indicator varies between a maximum of three-fifths for τ_y and a minimum of one-fifth for ι_y. The corresponding share for the ITA index is one-half, with one-fourth and over one-half for the industry-dimension and the technology-dimension indicators, respectively.

Inspection of the data plots of figure 10.6 reveals a major drawback of the above set of so-called log-linear estimates: The proposal that a straight line would produce a good fit to these data points seems hard to defend, and a similar argument seems to hold for the case of more than one explanatory variable.[9] In addition, for each one of the dependent variables the value one is an upper boundary, and there are reasons to suggest that some of them will level off at considerably lower values or even decline beyond a certain threshold level of income.[10] Taken together, these arguments provide the rationale for trying to fit to the data points a curve that is different from a straight line (or a plane). And while there are several candidates for the shape of such a non-linear curve, one of them appears particularly attractive with a view to perceived indicator patterns that show fairly steep increases at lower income levels on the one side and a leveling-off at high income on the other: It is that of an S-shaped curve, which corresponds to a so-called logistic function.

The second set of regression coefficients in table 10.4 per-

Table 10.3 Indicators and income levels: correlations with GDP per capita

Indicator	*1990*	*2002*
ITA index	0.645	0.569
Industrial advance (ι)	0.389	0.320
Production (ι_Y)	0.180	0.179
Trade (ι_X)	0.401	0.324
Technological advance (τ)	0.677	0.644
Production (τ_Y)	0.622	0.580
Trade (τ_X)	0.607	0.625

Source: UNIDO.
Note: All these Pearson correlations are significant at least at the 10% level.

Table 10.4 Structure, income and size (2002)

A. Log-linear regressions

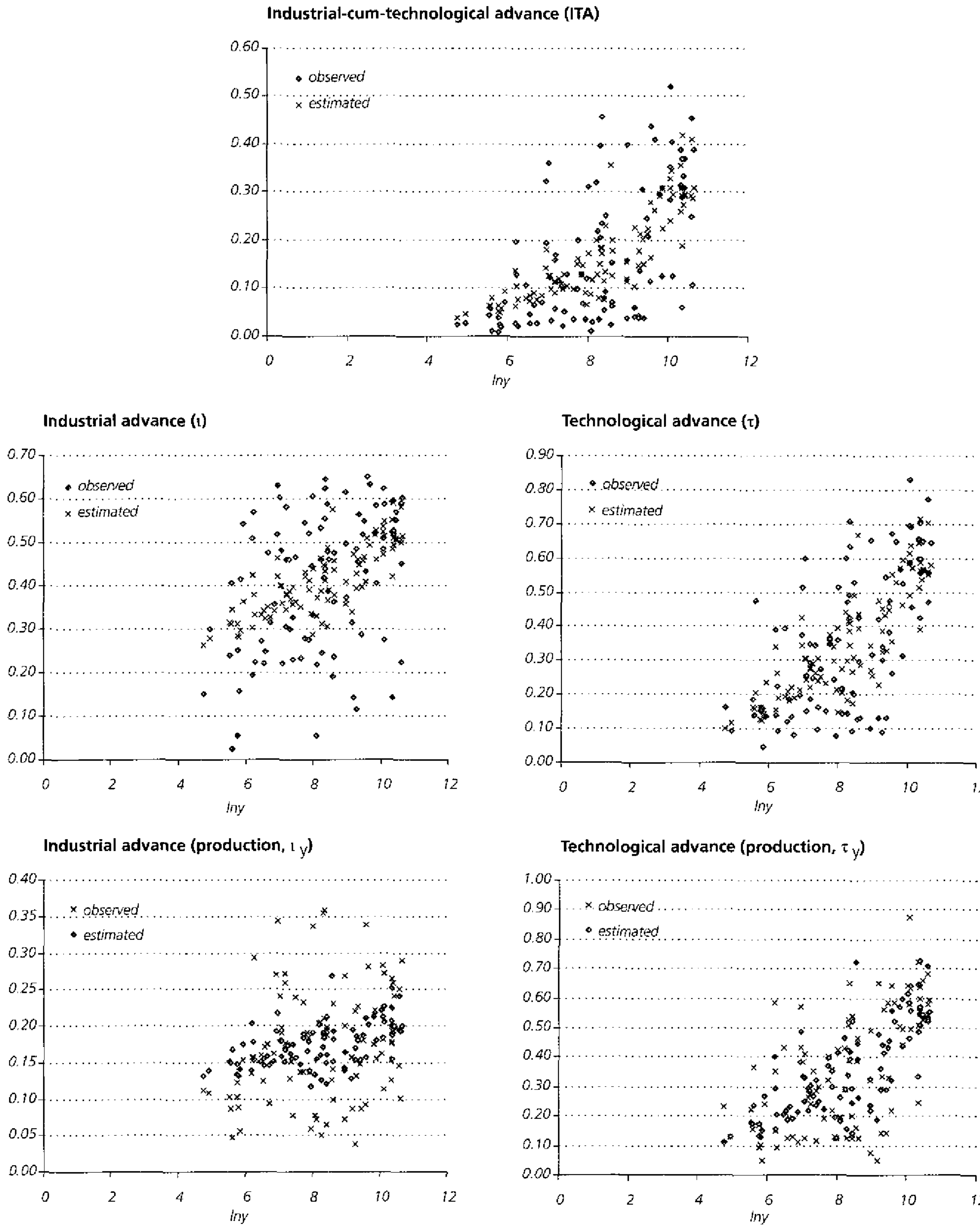
Dependent variable	*Coefficients* Income	*Coefficients* Size	*Adjusted R^2*
ITA	0.058	0.027	0.48
Industrial advance (ι)	0.047	0.024	0.23
Production (ι_Y)	0.015	0.014	0.17
Trade (ι_X)	0.080	0.033	0.21
Technological advance (τ)	0.009	0.007	0.55
Production (τ_Y)	0.086	0.051	0.60
Trade (τ_X)	0.100	0.032	0.40

B. Logistic regressions

Dependent variable	*Coefficients* Income	*Coefficients* Size	*Adjusted R^2*
ITA	−0.147	−0.164	0.78
Industrial advance (ι)	−0.193	−0.099	0.90
Production (ι_Y)	−0.092	−0.087	0.87
Trade (ι_X)	−0.391	−0.178	0.88
Technological advance (τ)	−0.443	−0.197	0.89
Production (τ_Y)	−0.410	−0.241	0.90
Trade (τ_X)	−0.478	−0.153	0.81

Source: UNIDO.
Note: Set A of the above regression results is obtained by OLS estimation of linear equations. All coefficient estimates carry the expected positive sign and are significant at the one-percent level, except for the size-coefficent in the regression of trade-related industrial advance, which is significant at the five-percent level.
The estimates of set B are those of coefficients in the logistic equation $(1 + e^{a + b \ln y + c \ln N})^{-1}$ where y stands for GDP per capita, N for population and ln for the natural logarithm. Coefficients b and c are expected to carry negative signs so that the dependent variable is an increasing function of both income and size. The estimation method used here is that of non-linear OLS. As a consequence, only asymptotic approximations are available for the usual statistics including t-values. In these asymptotic terms, all coefficients of set B are significant at the one-percent level.

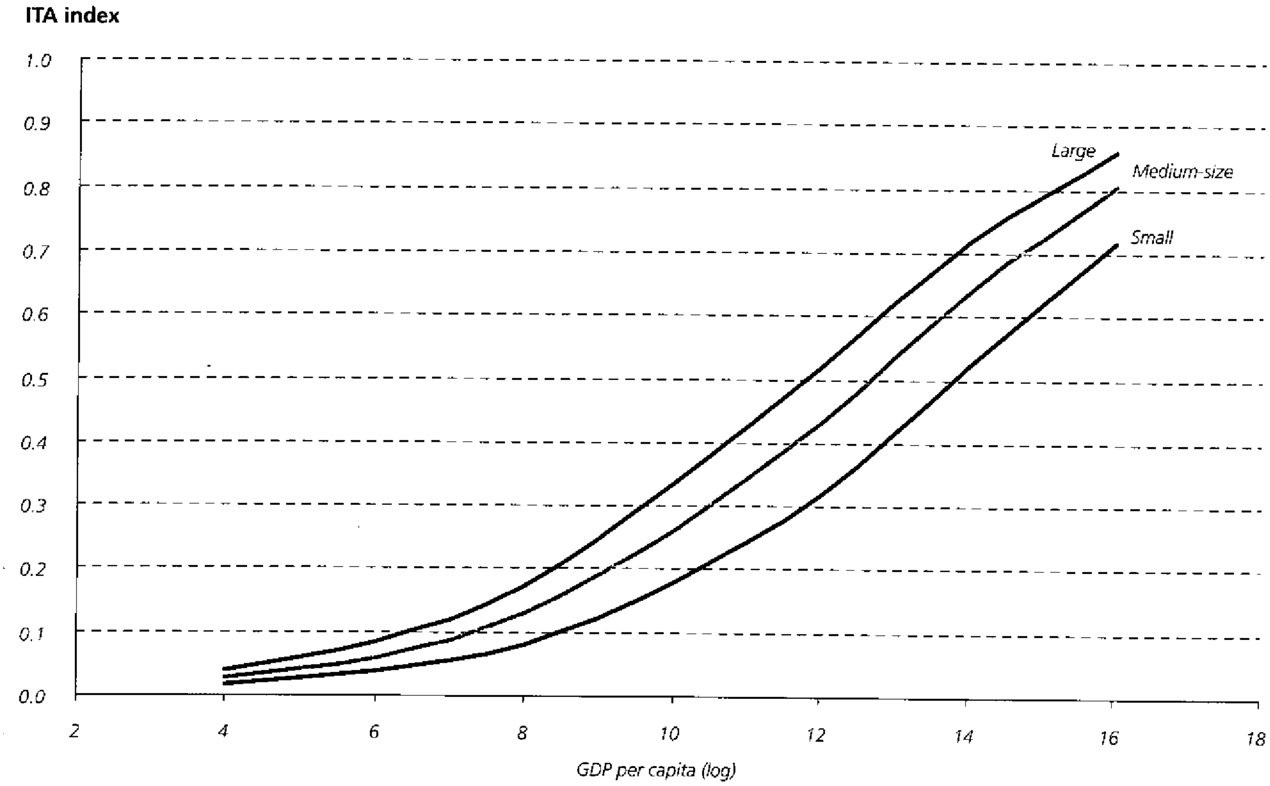
Figure 10.6 Advance indicators and income levels (scatter plots, 2002)



Source: UNIDO.

Note: The above plots are semi-logarithmic: While income per capita is expressed in logarithmic terms (lny), each one of the advance indicators takes the form of a ratio as defined in the text.

Figure 10.7 Industrial-cum-technological advance vs. income (estimated curves, by country size)



Source: UNIDO.

Note: Each one of the logistic curves traced out in the diagram corresponds to a particular choice of the parameter of country size. The choices corresponding to categories large, medium-size and small are the highest decile, the median and the lowest decile, respectively, of the world distribution of countries by population in 2002. The logistic parameters are those reported for the first regression of part B of table 10.4

tains to a logistic function of income and size as the basis for fitting the data points for each one of the seven indicators. As in the case of the log-linear regression, the coefficients of the logistic equation, too, are all significant with the correct (in this case, negative) sign. What is striking, however, is the improvement in the goodness-of-fit of the S-curve over the straight line (plane). The share of the variation across economies explained by income and size is significantly higher for each one of the seven indicators. And although a strict comparison between the two sets of estimates is not feasible, the goodness-of-fit of the logistic set is high.[11]

Judging by the results of table 10.4, all the aspects of industrial performance covered in the present discussion are seen to have a clear positive relationship with the overall level of development. *In particular,* if an S-shaped curve is taken to represent the relationship between a given performance indicator and income, this positive association is conspicuous. This feature is depicted by the estimated curves shown in figure 10.7. In this figure the logistic relationship between ITA and per capita income is traced out for a large, a medium-size and a small country,[12] based on the estimates of table 10.4. For a given population size the ITA-income relationship shows the logistic S-shape, most clearly for the highest curve, that of the large country.[13]

Regressions of the kind discussed here indicate what may be expected as the 'normal' state of industry in its major dimensions when an economy has reached a certain range of income, tantamount to a certain level of overall development. This direction of hypothesised causation, implicit in the regression approach, forms the basis of explanations of industrial performance such as those reported in table 10.4. It also allows for a rough assessment of whether or not an economy has achieved 'its' industrial performance.

The reverse direction of causation in the income-structure association seems, however, as important as the original one. It can be invoked here in a fairly plausible way as follows: the major aspects of industrial performance are no doubt also the consequences of key characteristics of an economy, often summarised in its level of per capita income. This performance, however, especially its industrial-cum-technological advance dimension, can be expected to exert a sustained positive impact on economic growth, that is, on the growth of income. Thus, higher levels of industrial activity and of ITA, while being the result also of key factors behind the attainment of higher levels of income, at the same time feed back into income growth. For reasons such as these, the aspects of industrial performance analysed here appear to be crucial for an understanding of the role of industry in a virtuous circle of growth and development.

Notes

[1] The statistical variables used to compute these two shares are MVA and GDP for production, and manufactured exports and total merchandise exports for trade.

[2] The statistical variables used here are value-added for production and export value for trade. Detailed definitions of medium-to-high-technology branches (for production) and products (for trade) are given in the Statistical Notes.

[3] To construct the planes, the theoretical range of index values (between one and zero) is divided into n portions of size 2^{-n}, by first halving the full interval and then progressively halving the lower half of what remains in each step. The resulting subdivision of the full index range allows for straightforward comparisons of the n^{th} sub-range with the preceding as well as the following ones.

[4] For reasons of practicality, plane IV is merged with all the planes that would follow to its left.

[5] The observation derives from the values of inter-quartile ranges, which are 0.12 and 0.09 for the upper pair and 0.17 and 0.22 for the lower pair.

[6] The attendant correlation coefficient is 0.73 and significant at any customary level.

[7] Here a significant upward bias of the value of medium-or-high technology exports must be allowed for, due to inclusion in the gross figure of the total value of products that are only assembled in the country.

[8] A core reference with a comprehensive bibliography is M. Syrquin, 1989.

[9] In this case, however, intuitive judgment would have to be based on a three-dimensional data plot, in order to see how well a plane fits the observations.

[10] The phenomenon de-industrialisation could be taken as a motivation for modelling a decline, at least of some share variables, at high income-levels. The levelling-off at different levels of saturation would be argued for by differences among the dependent variables examined here.

[11] Strict comparison between the statistics of regressions A and B is precluded, since for the latter only asymptotic values of the major statistics can be obtained.

[12] The three categories of size are defined in terms of the world distribution of population in 2002. Large is taken to be the highest decile (about the size of Turkey or Ethiopia), medium size the median (for example, Haiti or Bulgaria) and small the lowest decile (about the size of Suriname or Malta).

[13] An empirical analysis similar to the one reported here can also be found in UNIDO, 1979.

Section II Annex: Statistical Notes and Tables

The following notes relate to information in the UNIDO Scoreboard database, which formed the statistical basis for most of the narrative of Section Two.

Production data

Total manufacturing value added (MVA)

Data source: UNIDO National Accounts database.

Data adjustments: Data for total MVA refer to the two benchmark years 1990 and 2002. They are based on information obtained from various national and international sources, including the World Bank, OECD, the Statistical Division of the United Nations Secretariat (UNSD), the International Monetary Fund and regional development banks. This information was supplemented by estimates generated by UNIDO.

Value added of branches within the manufacturing sector

Source: UNIDO Industrial Statistics database.

Data adjustments: Because only some of the sample economies report industrial statistics according to the International Standard Industrial Classification of All Economic Activities, Third Revision (ISIC Rev.3), data reported according to ISIC Rev. 3 were converted to ISIC Rev. 2. To fill in missing values, the ISIC Rev. 2 series were supplemented with ISIC Rev. 3 series and UNIDO estimates.

In order to obtain value added in medium-or-high-technology activities data were aggregated using the classification of ISIC Rev. 2 outlined below:

Technology category	ISIC Rev. 2
Resource-based manufacturing	31, 331, 341, 353, 354, 355, 362, 369
Low-technology manufacturing	32, 332, 361, 381, 390
Medium-or-high-technology manufacturing	342, 351, 352, 356, 37, 38 (excl. 381)

Note: Because of differences in compilation methods and statistical definitions, the figures for technology categories do not necessarily sum to total MVA as reported in the national accounts data.

Trade data

Data source: UN Commodity Trade Statistics (COMTRADE) database.

The technological classification of trade is based on the Standard International Trade Classification (SITC), Revision 2.

Technology category	SITC Rev. 2
Resource-based products	01 (excl. 011), 023, 024, 035, 037, 046, 047, 048, 056, 058, 06, 073, 098, 1 (excl. 121), 233, 247, 248, 25, 264, 265, 269, 323, 334, 335, 4, 51 (excl. 512 and 513), 52 (excl. 524), 53 (excl. 533), 551, 592, 62, 63, 641, 66 (excl. 665 and 666), 68
Low-technology products	61, 642, 65 (excl. 653), 665, 666, 67 (excl. 671, 672 and 678), 69, 82, 83, 84, 85, 89 (excl. 892 and 896)
Medium-technology products	266, 267, 512, 513, 533, 55 (excl. 551), 56, 57, 58, 59 (excl. 592), 653, 671, 672, 678, 711, 713, 714, 72, 73, 74, 762, 763, 772, 773, 775, 78, 79 (excl. 792), 81, 872, 873, 88 (excl. 881), 95
High-technology products	524, 54, 712, 716, 718, 75, 761, 764, 77 (excl. 772, 773 and 775), 792, 871, 874, 881

Data exceptions (by indicator)

Exports of manufactures per capita

Year 2002: Algeria: 2000; Antigua and Barbuda: 2000; Australia: 2000; Bahrain: 2000; Bangladesh: 2001; Barbados: 2001; Belize: 2000; Benin: 2000; Bolivia: 2000; Botswana: 2001; Bulgaria: 2001; Burundi: 2000; Cameroon: 2000; Canada: 2000; Cape Verde: 2001; Central African Republic: 2000; Chile: 2000; China (Hong Kong SAR): 2000; China (Taiwan, Province): 2000; Comoros: 2000; Costa Rica: 2000; Croatia: 2001; Cyprus: 2001; Czech Republic: 2000; Dominica: 2000; Egypt: 2000; El Salvador: 2000; Estonia: 2001; French Polynesia: 2000; Gabon: 2000; Georgia: 2001; Gambia: 2000; Ghana: 2001; Grenada: 2000; Guatemala: 2000; Haiti: 2000; Honduras: 2000; Iceland: 2000; India: 2000; Indonesia: 2000; Israel: 2000; Jamaica: 2000; Japan: 2000; Kazakhstan: 2001; Jordan: 2000; Kenya: 2000; Korea, Rep. of: 2000; Kuwait: 2000; Latvia: 2001; Lebanon: 2001; Lesotho: 2001; Libya: 2000; Madagascar: 2000; Malawi: 2000; Malaysia: 2000; Maldives: 2000; Mali: 2000; Malta: 2000; Mexico: 2000; Namibia: 2001; Nepal: 2000; New Zealand: 2000; Nicaragua: 2000; Nigeria: 2000; Norway: 2000; Panama: 2001; Papua New Guinea: 2000; Philippines: 2000; Poland: 2001; Qatar: 2000; Romania: 2001; St. Lucia: 2001; St. Vincent and the Grenadines: 2001; Singapore: 2000; Sri Lanka: 2000; Sudan: 2000; Suriname: 2000; Switzerland: 2001; Syrian Arab Rep.: 2001; Tanzania: 2000; Tajikistan: 2000; Thailand: 2001; Togo: 2000; Tonga: 2000; Trinidad and Tobago: 2000; Turkey: 2001; Turkmenistan: 2000; United Arab Emirates: 2001; United States: 2001; Uruguay: 2000; Vanuatu: 2000; Venezuela: 2000; Yemen: 2000; Zambia: 2001; Zimbabwe: 2000.

Year 1990: Belize: 1992; Benin: 1992; Central African Republic: 1989; Croatia: 1992; French Polynesia: 1988; Ghana: 1992; Hungary: 1992; Nigeria: 1991; Slovenia: 1992; South Africa: 1992; Yemen: 1991.

Share of manufacturing in total exports

For this indicator the same data exceptions apply as for exports per capita.

Share of medium-or-high-technology production in MVA

Due to the lack of more recent information data were taken from the *Industrial Development Report 2004* where the year 2000 was substituted for 2002.

Share of medium-or-high-technology products in manufactured exports

For this indicator the same data exceptions apply as for exports per capita.

Table A2.1 **Six indicators of industrial performance (1990 and 2002)**

	Manufacturing value added (MVA) per capita (1995 US$)		Manufactured exports per capita (US$)		Share of manufacturing in total output (GDP) (percent)		Share of manufacturing in total exports (percent)		Share of medium-or-high-technology production in MVA (percent)		Share of medium-or-high-technology products in manufactured exports (percent)	
	1990	2002	1990	2002	1990	2002	1990	2002	1990	2002	1990	2002
Albania	411.2	143.5	..	88.2	36.9	10.7	..	88.1	..	27.4	..	4.0
Algeria	201.4	130.1	141.4	418.8	10.4	7.8	31.9	57.6	35.3	28.7	5.6	3.8
Angola	30.2	25.1	..	..	5.0	4.0	1.5	..	6.2	..	..	..
Antigua and Barbuda	185.6	172.8	..	44.4	3.3	2.0	..	85.0	12.1	12.4	..	1.0
Argentina	1 095.7	1 257.9	198.3	334.0	26.8	23.1	52.2	49.3	37.7	46.3	23.6	38.4
Armenia	251.1	105.6	..	32.8	30.3	24.4	..	61.8	45.3	47.9	..	36.0
Australia	2 587.6	2 796.5	687.5	1 389.7	12.8	11.4	32.8	43.7	50.6	49.5	31.3	41.3
Austria	5 308.8	6 750.6	5 158.0	7 152.6	20.6	20.0	95.2	90.1	50.0	52.9	53.6	60.0
Bahrain	1 456.8	2 347.2	714.2	7 141.2	16.7	21.9	59.7	74.8	10.0	14.1	13.0	3.5
Bangladesh	34.3	57.3	12.1	37.5	12.7	15.3	85.6	92.9	28.3	24.0	2.4	2.8
Barbados	634.2	560.4	791.3	585.8	8.7	7.1	95.3	92.1	24.2	32.2	25.8	31.4
Belarus	616.2	643.5	..	713.2	38.2	30.7	..	94.0	45.3	47.9	..	44.4
Belgium	5 089.1	6 024.8	9 616.4	16 907.9	20.9	19.3	84.3	85.0	54.2	55.5	51.6	56.0
Belize	343.6	410.7	491.6	533.5	13.4	12.6	87.5	65.0	4.5	8.7	..	1.2
Benin	28.0	41.2	3.1	3.2	7.8	9.3	..	13.4	10.8	17.1	11.8	19.2
Bhutan	11.9	23.0	..	..	8.1	10.6	55.1	..	12.5	..	1.6	..
Bolivia	137.1	155.3	79.1	91.2	17.0	16.2	56.3	55.5	8.6	11.2	0.3	28.1
Botswana	161.9	172.4	..	104.9	4.9	4.3	..	7.2	11.0	9.4	..	9.3
Brazil	913.6	865.0	159.3	221.9	22.5	18.8	75.1	76.8	51.6	54.1	40.0	51.5
Bulgaria	497.0	365.7	..	475.0	39.1	17.4	..	74.6	41.9	45.8	..	32.7
Burkina-Faso	24.4	34.3	..	2.8	15.3	12.2	..	25.3	4.7	4.6	14.0	29.2
Burundi	27.8	16.9	1.0	0.4	11.8	11.0	..	5.9	2.8	2.5	12.9	3.3
Cameroon	84.7	87.6	40.3	39.2	14.2	12.5	22.5	31.9	20.7	20.8	17.1	2.9
Canada	3 266.1	4 292.0	3 347.6	7 041.9	15.5	18.1	74.2	78.6	51.9	57.9	58.3	59.4
Cape Verde	153.6	184.0	..	21.6	8.2	6.8	..	98.8	29.1	27.6	8.7	0.2
Central African Republic	34.9	29.5	7.3	19.5	10.4	8.9	15.5	22.8	13.5	10.1	2.8	21.7
Chile	574.0	765.2	152.2	398.0	18.5	14.1	24.0	33.2	42.5	39.0	15.2	20.4
China	100.7	359.4	41.6	234.5	33.1	34.5	76.0	91.6	51.6	57.3	34.4	45.6
Colombia	437.0	313.0	64.1	125.8	19.9	13.7	33.1	42.4	34.1	32.2	20.6	37.2
Comoros	18.8	11.3	..	0.8	4.2	5.3	..	2.6	6.2	4.3	..	13.9
Congo	85.3	59.2	..	..	8.3	8.4	..	..	9.3	..	5.5	..
Costa Rica	588.1	781.0	161.5	1 005.5	19.4	20.6	33.8	71.7	23.7	29.0	27.2	65.5
Côte d'Ivoire	113.4	109.0	..	121.6	20.9	20.9	..	58.7	4.7	11.5	..	8.1
Croatia	1 688.5	1 085.0	902.2	920.2	27.7	17.5	..	94.0	40.5	44.2	..	41.9
Cyprus	1 542.1	1 297.2	606.5	352.5	14.2	9.1	72.1	77.8	17.4	21.8	13.2	30.7
Czech Republic	1 378.3	1 606.9	1473.1	2 668.5	24.6	28.3	..	94.4	59.0	56.9	..	56.2
Denmark	4 929.0	5 799.3	4 819.4	7 864.6	15.6	14.6	71.2	75.6	49.3	54.4	51.5	56.5
Djibouti	48.4	17.6	..	..	4.6	3.3	8.3	..	8.2	..	9.3	..
Dominica	184.5	172.2	244.1	431.8	5.9	5.9	32.9	61.0	12.1	12.4	72.4	59.3
Ecuador	270.0	236.2	39.2	96.1	19.4	19.9	14.8	24.4	20.3	12.7	4.4	17.1
Egypt	142.1	225.5	29.1	53.0	16.9	19.2	63.3	77.5	34.0	40.9	10.2	10.4
El Salvador	301.5	427.1	38.4	148.9	21.7	23.9	48.0	69.7	30.6	29.9	28.2	25.0
Eritrea	21.9	17.9	..	..	..	..	..	..	..	..	..	..
Estonia	763.2	650.1	..	2610.6	35.4	27.7	..	88.0	46.3	38.9	..	46.2
Ethiopia	7.6	7.2	..	..	7.3	6.2	17.0	12.4	8.2	9.6	2.5	0.5
Fiji	280.1	383.1	450.6	372.9	10.5	13.6	90.5	75.4	13.8	12.8	5.9	2.6

Table A2.1 **Six indicators of industrial performance (1990 and 2002; *continued*)**

	Manufacturing value added (MVA) per capita (1995 US$)		Manufactured exports per capita (US$)		Share of manufacturing in total output (GDP) (percent)		Share of manufacturing in total exports (percent)		Share of medium-or-high-technology production in MVA (percent)		Share of medium-or-high-technology products in manufactured exports (percent)	
	1990	2002	1990	2002	1990	2002	1990	2002	1990	2002	1990	2002
Finland	5 231.0	8 388.7	5 135.8	8 002.3	20.1	26.0	95.8	93.4	47.3	55.9	42.0	56.0
France	4 386.7	5 443.7	3 239.6	4 447.7	18.8	17.8	87.7	87.3	53.9	50.8	59.2	69.2
French Polynesia	942.2	1 192.4	208.8	215.6	5.7	6.2	54.5	21.4	12.1	12.4	..	13.1
Gabon	244.9	251.1	..	334.5	5.6	5.8	..	16.2	23.1	34.3	16.4	3.1
Gambia	20.8	17.8	..	3.1	5.5	5.0	..	25.0	6.2	10.1	..	41.9
Georgia	191.7	64.0	..	33.8	19.2	17.6	..	60.2	43.5	27.4	..	45.7
Germany	6 871.3	6 649.1	4 665.1	6 512.1	30.6	27.2	93.2	90.6	66.5	63.2	68.7	74.9
Ghana	35.4	39.2	15.2	25.6	9.8	9.4	..	50.5	26.0	27.2	10.1	6.1
Greece	1 444.9	1 434.7	592.7	720.6	14.9	13.1	74.7	77.9	34.5	33.5	16.9	26.8
Grenada	141.2	296.3	56.0	532.2	5.2	6.5	23.9	70.8	12.1	12.4	13.2	28.4
Guatemala	204.5	198.4	55.2	112.4	15.0	12.8	41.5	47.4	33.9	35.1	27.6	33.6
Guinea	27.7	26.4	..	11.3	4.5	5.0	..	18.0	21.5	19.0	2.2	6.4
Guyana	60.4	83.8	23.3	243.4	9.1	8.6	..	42.1	21.5	..	..	5.6
Haiti	50.6	19.0	21.2	5.8	15.8	5.6	85.8	77.3	5.1	4.8	14.5	4.1
Honduras	106.2	121.8	20.5	54.0	14.5	17.1	18.0	32.4	16.4	12.6	7.0	24.7
Hong Kong SAR	2 042.8	1 133.0	4 842.9	3 211.6	16.3	8.7	95.3	94.9	41.8	58.5	40.6	36.8
Hungary	841.5	1 461.2	762.6	3 101.9	24.3	35.5	82.4	89.6	53.9	52.9	40.9	73.7
Iceland	3 469.6	3 911.7	644.6	1 072.4	14.2	12.6	10.4	15.7	24.1	24.6	46.0	60.6
India	49.0	77.6	16.8	38.5	16.6	15.8	79.6	85.8	55.3	58.4	17.9	19.7
Indonesia	162.0	278.7	82.0	224.0	20.7	27.0	58.6	76.9	30.0	43.4	10.5	31.3
Iran, Islamic Republic	168.1	303.2	..	41.6	12.0	13.3	..	10.0	25.7	9.3	..	21.0
Ireland	3 141.5	8 121.0	5 575.1	20 835.0	25.3	26.5	82.4	92.1	56.5	72.2	52.2	59.1
Israel	2 145.9	2 607.7	2 354.7	4 680.6	21.1	22.7	88.2	90.0	52.7	56.1	41.9	52.8
Italy	3 740.3	4 224.1	2 804.6	4 027.1	22.5	22.1	94.1	95.0	56.9	49.4	50.5	55.9
Jamaica	399.7	287.3	122.2	161.9	19.4	13.7	26.1	32.9	21.5	19.0	7.7	11.2
Japan	9 696.9	9 850.9	2 263.9	3 595.2	26.5	25.0	97.5	93.0	66.5	68.1	83.9	86.3
Jordan	195.4	234.6	148.5	142.9	16.1	17.7	52.4	74.4	29.5	28.8	59.1	40.5
Kazakhstan	319.8	214.2	..	112.1	20.3	20.3	..	20.2	43.5	27.4	..	46.9
Kenya	28.4	26.1	22.2	19.2	10.1	10.3	51.3	37.7	24.9	22.4	27.7	14.4
Korea, Republic of	2 237.6	4 858.7	1 455.4	3 591.1	28.8	33.9	96.2	96.5	55.1	64.1	52.9	70.6
Kuwait	617.6	1 560.9	221.0	3 463.6	11.6	20.0	6.9	54.6	6.4	7.5	54.6	12.5
Latvia	1 096.1	503.2	..	735.9	33.2	19.9	..	89.5	46.3	38.9	..	16.9
Lebanon	378.0	368.6	..	177.7	13.1	9.4	..	78.4	10.5	9.3	..	30.2
Lesotho	54.3	99.4	..	129.8	10.1	12.8	..	94.5	42.2	50.3	..	12.0
Liberia	8.5	4.9	..	..	6.9	7.0	..	..	4.7	..	..	..
Libya	424.2	655.3	538.4	295.5	7.9	12.6	16.7	25.5	15.6	16.0	5.7	9.4
Lithuania	1 131.9	526.7	..	1381.4	20.9	17.8	..	91.1	46.3	38.9	..	30.5
Luxembourg	6 855.5	7 590.6	..	16 237.7	20.1	13.0	..	93.5	54.2	55.5	..	41.8
Macedonia, FYR	886.7	438.6	..	440.9	..	21.7	..	84.0	35.7	35.8	..	22.4
Madagascar	19.8	15.2	6.2	7.2	10.9	10.9	25.4	49.3	11.2	12.8	9.8	6.0
Malawi	20.5	12.8	5.6	6.2	17.4	11.1	13.1	19.1	32.3	23.3	10.6	9.1
Malaysia	757.5	1 516.5	1 286.5	4 120.5	26.5	35.9	78.0	93.3	52.3	65.1	50.6	76.2
Maldives	62.7	100.9	..	158.2	5.4	4.8	..	60.4	13.8	12.8	3.2	3.5
Mali	17.1	17.8	1.1	1.0	8.1	7.7	3.0	3.8	4.7	4.6	..	60.2
Malta	1 418.7	2 086.9	2 722.1	5 552.8	27.0	26.8	94.8	96.1	35.1	49.2	63.3	81.1
Mauritius	563.8	901.8	1 129.5	1 323.9	19.8	19.8	97.8	97.6	13.4	13.7	6.2	4.6

Table A2.1 **Six indicators of industrial performance (1990 and 2002; *continued*)**

	Manufacturing value added (MVA) per capita (1995 US$)		Manufactured exports per capita (US$)		Share of manufacturing in total output (GDP) (percent)		Share of manufacturing in total exports (percent)		Share of medium-or-high-technology production in MVA (percent)		Share of medium-or-high-technology products in manufactured exports (percent)	
	1990	2002	1990	2002	1990	2002	1990	2002	1990	2002	1990	2002
Mexico	619.1	746.0	159.4	1 450.4	19.0	20.3	50.5	86.4	40.9	42.8	64.1	77.1
Mongolia	77.1	66.2	..	56.3	29.0	5.4	..	26.4	4.7	5.8	..	3.0
Morocco	218.3	250.4	113.1	194.6	18.4	17.5	65.8	74.5	28.7	24.1	25.9	25.7
Namibia	243.4	276.2	..	111.1	11.5	9.9	..	23.4	21.5	9.4	..	19.0
Nepal	11.2	22.8	8.5	21.8	5.8	8.6	85.3	72.5	12.5	15.6	0.4	12.2
Netherlands	4 196.9	4 841.2	6 986.1	9 164.3	17.9	15.4	79.4	87.6	56.9	60.0	47.1	59.7
New Caledonia	784.8	857.7	1 571.5	1 498.1	4.4	4.3	..	61.5	13.8	12.8	..	3.2
New Zealand	2 659.0	3 000.4	1 475.7	2 191.5	17.8	15.5	54.8	65.6	35.0	44.4	13.8	18.1
Nicaragua	76.7	67.1	20.7	29.9	16.9	13.5	24.3	25.0	13.1	15.4	9.6	12.1
Niger	15.8	13.6	..	3.8	6.6	6.6	..	3.3	4.7	4.6	..	46.8
Nigeria	15.5	13.0	1.0	0.5	5.5	4.8	1.2	0.2	25.5	36.7	24.5	58.1
Norway	3 801.4	4 026.3	3 930.2	4 679.4	11.7	10.0	48.9	34.9	55.4	58.0	44.3	36.1
Oman	237.5	396.5	259.9	791.0	2.9	3.7	8.4	19.5	10.0	14.1	48.7	54.1
Pakistan	64.9	78.7	44.7	58.3	15.5	15.7	88.8	98.2	31.9	35.1	8.1	10.1
Panama	216.2	235.3	57.0	88.7	9.5	7.2	40.5	36.3	19.8	19.8	17.2	8.5
Papua New Guinea	66.9	79.1	60.2	267.3	9.0	9.4	22.0	53.4	17.4	12.8	36.9	3.8
Paraguay	297.2	247.5	31.2	50.8	17.3	15.2	13.7	30.7	10.3	11.5	8.6	7.9
Peru	289.5	343.2	58.1	73.3	14.9	26.0	37.8	35.4	36.1	26.3	7.8	10.6
Philippines	252.4	269.5	69.8	482.4	24.8	24.2	52.7	96.2	31.2	38.3	30.0	81.8
Poland	470.4	884.7	225.4	782.3	22.5	21.0	63.0	89.7	47.9	38.7	49.5	46.4
Portugal	1 985.4	2 368.4	1 556.7	2 417.9	18.7	17.9	93.8	91.7	30.7	32.9	27.3	43.4
Qatar	1 317.6	1 798.9	1 628.9	5 372.0	12.9	14.7	20.9	43.0	10.0	14.1	38.7	12.1
Romania	501.3	363.9	235.8	451.9	36.7	27.2	93.2	89.0	43.5	27.4	39.4	31.5
Russian Federation	1 164.9	644.7	..	257.0	27.8	22.2	..	53.6	46.3	61.0	..	26.7
Rwanda	26.2	27.3	..	0.2	18.3	11.5	..	2.8	6.2	4.3	..	20.0
Saint Lucia	239.7	195.4	341.3	118.9	6.8	5.0	37.2	44.2	12.1	12.4	11.1	16.2
Saint Vincent & The Grenadines	157.0	124.6	..	96.4	7.4	4.8	..	44.2	12.1	12.4	..	3.1
Samoa	262.2	221.6	17.1	322.2	2.0	1.3	34.2	79.4	13.8	..	4.1	83.9
Saudi Arabia	681.4	846.3	675.6	723.2	7.6	8.7	23.8	20.0	52.7	65.3	16.6	18.7
Senegal	73.7	91.1	65.1	32.8	13.1	14.5	61.0	59.4	18.8	34.9	..	0.1
Seychelles	724.7	..	149.5	..	10.1	15.6	75.7	47.2	4.2	4.8	12.8	21.3
Singapore	4 410.3	6 582.5	16 266.1	33 105.8	28.6	28.2	93.2	96.8	78.8	87.6	62.3	78.9
Slovakia	1 579.2	1 067.4	..	2 459.5	38.9	23.2	..	91.7	53.8	56.3	..	54.5
Slovenia	2 966.6	3 225.6	3 104.2	4 751.2	..	26.1	..	95.0	45.3	53.1	..	53.0
South Africa	788.7	753.7	287.7	336.7	21.5	18.5	25.7	65.3	46.4	51.0	28.8	47.2
Spain	2 767.2	3 152.6	1 233.2	2 533.2	22.1	17.5	87.2	87.0	49.4	50.4	54.8	63.1
Sri Lanka	71.3	134.0	56.6	177.5	13.4	17.4	51.0	78.0	11.6	19.1	5.9	8.3
Sudan	19.4	27.3	0.2	46.5	8.6	8.3	..	79.3	13.8	19.4	0.1	2.8
Suriname	309.8	251.7	31.9	37.6	12.0	7.7	2.7	3.3	21.5	19.0	0.1	24.1
Swaziland	453.7	432.8	..	866.3	29.2	27.4	..	74.6	0.4	1.4	..	17.0
Sweden	4 848.6	8 154.4	6 357.4	8 418.8	19.3	24.1	94.9	90.0	56.5	66.2	58.1	63.6
Switzerland	9 583.0	12 190.8	8 463.5	10 515.1	24.4	29.0	90.8	91.8	58.1	59.5	63.8	69.3
Syrian Arab Republic	80.6	154.8	166.2	45.6	20.4	29.4	48.9	15.6	10.5	9.3	43.3	9.4
Taiwan Province of China	2 842.1	4 397.5	3 148.7	6 563.7	32.7	28.1	95.8	98.3	52.2	58.6	51.6	71.2
Tajikistan	215.8	64.3	..	15.3	14.8	13.3	..	13.4	4.7	5.8	..	68.4

Table A2.1 **Six indicators of industrial performance (1990 and 2002; continued)**

	Manufacturing value added (MVA) per capita (1995 US$)		Manufactured exports per capita (US$)		Share of manufacturing in total output (GDP) (percent)		Share of manufacturing in total exports (percent)		Share of medium-or-high-technology production in MVA (percent)		Share of medium-or-high-technology products in manufactured exports (percent)	
	1990	2002	1990	2002	1990	2002	1990	2002	1990	2002	1990	2002
Tanzania	13.4	14.1	2.4	3.1	8.5	7.0	..	20.4	25.0	29.6	..	10.4
Thailand	520.9	999.6	338.6	869.6	27.2	33.6	80.6	87.4	23.7	42.6	33.3	60.3
Togo	36.1	38.9	14.1	16.0	9.9	12.3	18.1	37.8	10.8	17.1	6.3	12.9
Tonga	66.0	82.6	24.5	4.8	5.1	4.7	..	5.5	13.8	12.8	..	0.2
Trinidad and Tobago	332.9	555.0	1 053.2	2 819.2	8.6	10.0	61.5	85.4	12.1	12.4	14.8	14.1
Tunisia	313.9	492.5	329.7	603.7	16.9	19.0	76.9	85.4	13.4	22.0	24.0	26.8
Turkey	427.5	538.0	177.4	388.6	22.0	23.3	76.8	85.9	35.9	40.3	22.4	32.7
Turkmenistan	396.1	244.1	..	147.3	9.9	10.4	..	77.8	28.3	35.7	..	2.7
Uganda	11.4	30.2	..	2.3	5.3	8.6	..	12.5	18.4	20.5	44.6	34.4
Ukraine	846.6	332.8	..	289.7	34.7	30.2	..	79.0	45.3	47.9	..	47.2
United Arab Emirates	1 835.8	1 881.3	245.6	1 632.1	7.5	9.8	54.5	19.5	10.0	..	17.4	6.1
United Kingdom	3 807.7	3 748.7	2 655.5	3 884.8	20.6	16.3	82.4	85.5	60.0	64.3	67.3	74.4
United States	4 325.2	5 567.7	1 181.8	1 947.9	18.1	17.6	81.1	88.1	63.0	63.7	73.4	76.7
Uruguay	1 316.8	902.2	310.9	496.2	28.0	19.4	56.9	72.7	27.3	20.3	16.3	20.1
Vanuatu	96.7	48.4	18.4	27.2	5.3	2.7	19.9	23.1	13.8	..	21.6	8.1
Venezuela	569.2	480.8	127.4	474.6	20.2	18.3	13.8	37.1	28.3	35.7	35.4	12.9
Yemen	38.5	32.6	0.2	1.4	9.6	10.3	9.9	0.9	10.5	9.3	5.7	23.0
Zambia	44.6	42.6	..	30.7	12.4	14.7	..	33.0	23.1	23.7	16.1	13.6
Zimbabwe	137.2	101.7	55.3	58.4	20.5	16.0	38.6	38.4	34.9	43.5	49.2	35.5

Source: UNIDO Scoreboard database

Note: Due to data constraints, for the share of medium-or-high-technology production in MVA the year 2000 had to be chosen as the end of the period surveyed here.

Table A2.2 Industrial-cum-technological advance (1990 and 2002)

	ITA index		Industrial-advance indicator		Technological-advance indicator	
	1990	*2002*	*1990*	*2002*	*1990*	*2002*
Albania	..	0.078	..	0.494	..	0.157
Algeria	0.043	0.053	0.212	0.327	0.205	0.163
Angola	0.001	..	0.033	..	0.031	..
Antigua and Barbuda	..	0.029	..	0.435	..	0.067
Argentina	0.121	0.153	0.395	0.362	0.307	0.423
Armenia	..	0.181	..	0.431	..	0.420
Australia	0.093	0.125	0.228	0.275	0.410	0.454
Austria	0.300	0.311	0.579	0.550	0.518	0.565
Azerbaijan	..	0.052	..	0.209	..	0.248
Bahrain	0.044	0.043	0.382	0.483	0.115	0.088
Bangladesh	0.075	0.072	0.492	0.541	0.154	0.134
Barbados	0.130	0.158	0.520	0.496	0.250	0.318
Belarus	..	0.288	..	0.624	..	0.462
Belgium	0.278	0.291	0.526	0.522	0.529	0.558
Belize	..	0.019	0.505	0.388	..	0.049
Benin	..	0.021	..	0.113	0.113	0.182
Bhutan	0.022	..	0.316	..	0.071	..
Bolivia	0.016	0.070	0.367	0.359	0.045	0.197
Botswana	..	0.005	..	0.058	..	0.094
Brazil	0.224	0.252	0.488	0.478	0.458	0.528
Bulgaria	..	0.181	..	0.460	..	0.393
Burkina Faso	..	0.032	..	0.188	0.094	0.169
Burundi	..	0.002	..	0.085	0.079	0.029
Cameroon	0.035	0.026	0.184	0.222	0.189	0.119
Canada	0.247	0.284	0.449	0.484	0.551	0.587
Cape Verde	..	0.073	..	0.528	0.189	0.139
Central African Republic	0.011	0.025	0.130	0.158	0.082	0.159
Chile	0.061	0.070	0.213	0.237	0.289	0.297
China	0.235	0.324	0.546	0.631	0.430	0.515
Colombia	0.072	0.097	0.265	0.280	0.274	0.347
Comoros	..	0.004	..	0.039	..	0.091
Costa Rica	0.068	0.218	0.266	0.461	0.255	0.473
Côte d'Ivoire	..	0.039	..	0.398	..	0.098
Croatia	..	0.240	..	0.558	..	0.431
Cuba	..	0.029	..	0.400	..	0.073
Cyprus	0.066	0.114	0.432	0.435	0.153	0.263
Czech Republic	..	0.347	..	0.614	..	0.566
Denmark	0.219	0.250	0.434	0.451	0.504	0.555
Djibouti	0.006	..	0.065	..	0.088	..
Dominica	0.082	0.120	0.194	0.334	0.423	0.359
Ecuador	0.021	0.033	0.171	0.222	0.124	0.149
Egypt, Arab Rep.	0.089	0.124	0.401	0.483	0.221	0.257
El Salvador	0.102	0.129	0.349	0.468	0.294	0.275
Estonia	..	0.246	..	0.578	..	0.425
Ethiopia	0.007	0.005	0.122	0.093	0.054	0.051
Fiji	0.050	0.034	0.505	0.445	0.099	0.077
Finland	0.259	0.334	0.580	0.597	0.447	0.560
France	0.301	0.315	0.533	0.525	0.566	0.600
French Guiana	0.035	0.120	0.212	0.287	0.168	0.419
French Polynesia	..	0.018	0.301	0.138	..	0.128
Gabon	..	0.021	..	0.110	0.198	0.187
Gambia, The	..	0.039	..	0.150	..	0.260
Georgia	..	0.142	..	0.389	..	0.366
Germany	0.418	0.407	0.619	0.589	0.676	0.690
Ghana	..	0.050	..	0.299	0.181	0.166
Greece	0.115	0.137	0.448	0.455	0.257	0.302
Grenada	0.018	0.079	0.146	0.387	0.127	0.204
Guadeloupe	0.067	..	0.344	..	0.195	..
Guatemala	0.087	0.104	0.283	0.301	0.308	0.344
Guinea	..	0.015	..	0.115	0.119	0.127
Haiti	0.050	0.018	0.508	0.414	0.098	0.045
Honduras	0.019	0.046	0.163	0.247	0.117	0.187
Hong Kong SAR	0.230	0.247	0.558	0.518	0.412	0.477
Hungary	0.253	0.396	0.534	0.626	0.474	0.633
Iceland	0.043	0.060	0.123	0.141	0.351	0.426
India	0.176	0.198	0.481	0.508	0.366	0.391
Indonesia	0.080	0.194	0.397	0.519	0.203	0.374
Iran, Islamic Rep.	..	0.018	..	0.116	..	0.152
Ireland	0.293	0.389	0.539	0.593	0.544	0.657
Israel	0.258	0.307	0.547	0.564	0.473	0.545
Italy	0.313	0.308	0.583	0.586	0.537	0.527
Jamaica	0.033	0.035	0.228	0.233	0.146	0.151

Table A2.2 Industrial-cum-technological advance (1990 and 2002; continued)						
	ITA index		*Industrial-advance indicator*		*Technological-advance indicator*	
	1990	*2002*	*1990*	*2002*	*1990*	*2002*
Japan	0.466	0.456	0.620	0.590	0.752	0.772
Jordan	0.152	0.159	0.343	0.460	0.443	0.347
Kazakhstan	..	0.075	..	0.202	..	0.371
Kenya	0.081	0.044	0.307	0.240	0.263	0.184
Korea, Republic of	0.338	0.439	0.625	0.652	0.540	0.674
Kuwait	0.028	0.037	0.093	0.373	0.305	0.100
Kyrgyz Republic	..	0.042	..	0.164	..	0.254
Latvia	..	0.153	..	0.547	..	0.279
Lebanon	..	0.087	..	0.439	..	0.197
Lesotho	..	0.167	..	0.537	..	0.312
Libya	0.013	0.024	0.123	0.191	0.107	0.127
Lithuania	..	0.189	..	0.545	..	0.347
Luxembourg	..	0.259	..	0.532	..	0.487
Macao	..	0.038	..	0.539	0.061	0.071
Macedonia, FYR	..	0.154	..	0.529	..	0.291
Madagascar	0.019	0.028	0.182	0.301	0.105	0.094
Malawi	0.033	0.024	0.153	0.151	0.215	0.162
Malaysia	0.269	0.457	0.523	0.646	0.515	0.707
Maldives	..	0.119	..	0.326	..	0.365
Mali	0.002	0.002	0.056	0.058	0.040	0.041
Malta	0.300	0.400	0.609	0.614	0.492	0.652
Martinique	0.061	0.060	0.311	0.294	0.196	0.205
Mauritius	0.058	0.054	0.588	0.587	0.098	0.092
Mexico	0.182	0.320	0.348	0.533	0.525	0.599
Moldova	..	0.081	..	0.441	..	0.184
Mongolia	..	0.007	..	0.159	..	0.044
Morocco	0.115	0.115	0.421	0.460	0.273	0.249
Namibia	..	0.024	..	0.167	..	0.142
Nepal	0.029	0.056	0.456	0.405	0.065	0.139
Netherlands	0.253	0.308	0.487	0.515	0.520	0.599
New Caledonia	..	0.026	..	0.329	..	0.080
New Zealand	0.089	0.127	0.363	0.405	0.244	0.313
Nicaragua	0.023	0.026	0.206	0.193	0.114	0.138
Niger	..	0.013	..	0.049	..	0.257
Nigeria	0.008	0.012	0.034	0.025	0.250	0.474
Norway	0.151	0.106	0.303	0.225	0.499	0.471
Oman	0.017	0.040	0.057	0.116	0.294	0.341
Pakistan	0.104	0.129	0.522	0.570	0.200	0.226
Panama	0.046	0.031	0.250	0.217	0.185	0.142
Papua New Guinea	0.042	0.026	0.155	0.314	0.272	0.083
Paraguay	0.015	0.022	0.155	0.229	0.095	0.097
Peru	0.058	0.057	0.264	0.307	0.220	0.184
Philippines	0.119	0.362	0.388	0.602	0.306	0.601
Poland	0.208	0.236	0.428	0.554	0.487	0.426
Portugal	0.163	0.209	0.563	0.548	0.290	0.382
Qatar	0.041	0.038	0.169	0.289	0.244	0.131
Reunion	0.060	0.073	0.513	0.489	0.117	0.149
Romania	0.269	0.171	0.650	0.581	0.415	0.295
Russian Federation	..	0.166	..	0.379	..	0.439
Rwanda	..	0.009	..	0.072	..	0.122
Saint Lucia	0.026	0.035	0.220	0.246	0.116	0.143
Saint Vincent and the Grenadines	..	0.019	..	0.245	..	0.078
Samoa	0.016	..	0.181	0.404	0.090	..
Saudi Arabia	0.054	0.060	0.157	0.144	0.347	0.420
Senegal	0.059	0.104	0.371	0.370	0.158	0.281
Seychelles	..	0.008	0.429	0.314	..	0.025
Singapore	0.430	0.520	0.609	0.625	0.706	0.832
Slovak Republic	..	0.318	..	0.574	..	0.554
Slovenia	..	0.321	..	0.605	..	0.531
South Africa	0.089	0.206	0.236	0.419	0.376	0.491
Spain	0.285	0.297	0.547	0.522	0.521	0.568
Sri Lanka	0.028	0.065	0.322	0.477	0.088	0.137
Sudan	..	0.049	..	0.438	0.070	0.111
Suriname	0.008	0.012	0.074	0.055	0.108	0.215
Swaziland	..	0.047	..	0.510	..	0.092
Sweden	0.327	0.370	0.571	0.570	0.573	0.649
Switzerland	0.351	0.389	0.576	0.604	0.610	0.644
Syrian Arab Republic	0.093	0.021	0.347	0.225	0.269	0.094
Taiwan Province of China	0.333	0.410	0.643	0.632	0.519	0.649
Tajikistan	..	0.050	..	0.134	..	0.371
Thailand	0.154	0.311	0.539	0.605	0.285	0.514
Tanzania	..	0.027	..	0.137	..	0.200

Table A2.2 Industrial-cum-technological advance (1990 and 2002; *continued*)

	ITA index		*Industrial-advance indicator*		*Technological-advance indicator*	
	1990	*2002*	*1990*	*2002*	*1990*	*2002*
Togo	0.012	0.038	0.140	0.250	0.086	0.150
Tonga	..	0.003	..	0.051	..	0.065
Trinidad and Tobago	0.047	0.063	0.351	0.477	0.135	0.133
Tunisia	0.088	0.127	0.469	0.522	0.187	0.244
Turkey	0.144	0.199	0.494	0.546	0.292	0.365
Turkmenistan	..	0.085	..	0.441	..	0.192
Uganda	..	0.029	..	0.105	0.315	0.274
Ukraine	..	0.260	..	0.546	..	0.475
United Arab Emirates	0.042	..	0.310	0.146	0.137	..
United Kingdom	0.328	0.353	0.515	0.509	0.637	0.694
United States	0.338	0.371	0.496	0.529	0.682	0.702
Uruguay	0.093	0.093	0.425	0.461	0.218	0.202
Vanuatu	0.022	..	0.126	0.129	0.177	..
Venezuela	0.054	0.067	0.170	0.277	0.319	0.243
Yemen	0.008	0.009	0.098	0.056	0.081	0.161
Zambia	..	0.044	..	0.238	0.196	0.186
Zimbabwe	0.124	0.107	0.296	0.272	0.421	0.395

Source: UNIDO.
Note: In the data for the production component of the technological-advance indicator the year 2002 is replaced by the year 2000.

References

Abramovitz, M. (1956) "Resource and Output Trends in the United States Since 1870," *American Economic Review*, Vol. 46 (2), pp. 5–23.

_____ (1986) "Catching Up, Forging Ahead and Falling Behind," *Journal of Economic History*, Vol. 46, pp. 385–406.

_____ (1994a) "The Origins of the Post-war Catch-Up and Convergence Boom," in J. Fagerberg, B. Verspagen. and N. von Tunzelman (eds.) *The Dynamics of Technology, Trade and Growth*, Aldershot: Edward Elgar.

_____ (1994b) "Catch-up and Convergence in the Postwar Growth Boom and After," in W.J. Baumol, R.R. Nelson and E.N. Wolf (eds.) *Convergence of Productivity – Cross-National Studies and Historical Evidence*, Oxford: Oxford University Press.

Acemoglu, D., S. Johnson and A. Robinson (2001) "The Colonial Origins of Comparative Development: An Empirical Investigation," *American Economic Review*, Vol. 91, pp. 1369–1401.

Addison-Smyth, D. (2005) "Ireland's Revealed Comparative Advantage," *Central Bank of Ireland Quarterly Bulletin*, Vol. Spring, pp. 101–114.

Adelman, I. and C. T. Morris (1965) "A Factor Analysis of the Interrelationship Between Social and Political Variables and Per Capita Gross National Product," *Quarterly Journal of Economics*, Vol. 79 (4), pp. 555–578.

_____ (1967) *Society, Politics and Economic Development*, Baltimore, MD: The Johns Hopkins Press.

Adler, J. H. (1965) *Absorptive Capacity, the Concepts and its Determinants*, Washington, DC: Brookings Institution.

Aghion, P. and P. Howitt (1998) *Endogenous Growth Theory*, Cambridge, MA: MIT Press.

Alesina, A., A. Devleeschauwer, W. Easterly, S. Kurlat and R. Wacziarg (2003) "Fractionalization," *Journal of Economic Growth*, Vol. 8, pp. 155–194.

Amsden, A. H. (1984) "Taiwan in Exports of technology by Newly-Industrializing Countries," *World Development*, Vol. 12 (5/6).

_____ and W. Chu (2003) *Beyond Late Development: Taiwan's Upgrading Policies*, Cambridge, MA: MIT Press.

Angel, D. P. and M. T. Rock (2003) "Engaging Economic Development Agencies in Environmental Protection: The Case for Embedded Autonomy," *Local Environment*, Vol. 8 (1), pp. 45–59.

Archibugi, D. and A. Coco (2004) "A new indicator of technological capabilities for developed and developing countries (ArCo)," *World Development*, Vol. 32, pp. 629–654.

Arora, A. and A. Gambardella (1994) "The changing technology of technological change: general and abstract knowledge and the division of innovative labour," *Research Policy*, Vol. 23 (5), pp. 523–532.

Asheim, B. T. and M. S. Gertler (2005) "The Geography of Innovation: Regional Innovation Systems," in J. Fagerberg, D. C. Mowery and R. R. Nelson (eds.) *The Oxford Handbook of Innovation*, New York, NY: Oxford University Press.

Avnimelech, G. and M. Teubal (2005) "Evolutionary innovation and High-Tech Policy: What can we Learn from Israel's Targeting of Venture Capital?" Samuel Neaman Institute for Advanced Studies in Science and Technology Working Papers STE-WP-25, Haifa: Neaman Institute.

Barro, R. J. (1991) "Economic Growth in a Cross Section of Countries," *Quarterly Journal of Economics*, Vol. 106 (2), pp. 407–443.

_____ and J.-W. Lee (2000) "International Data on Educational Attainment: Updates and Implications," Centre for International Development Working Paper No. 42, Cambridge, MA: Harvard University.

_____ and X. Sala-i-Martin (1992) "Convergence," *Journal of Political Economy*, Vol. 100, pp. 223–251.

Barry, F. (2004) "Export-Platform Foreign Direct Investment: the Irish Experience," *EIB Papers*, Vol. 9 (2), pp. 9–37.

_____ and A. Hannan (2001) "FDI and the Predictive Powers of Revealed Comparative Advantage Indicators," Dublin: University College.

_____, J. Bradley and A. Hannan (2001) "The Single Market, the Structural Funds and Ireland's Recent Economic Growth," *Journal of Common Market Studies*, Vol. 39, pp. 537–552.

_____ and D. Curran (2004) "Enlargement and the European Geography of the IT Sector," *The World Economy*, Vol. 27, pp. 901–922.

_____, H. Gorg and E. Strobl (2003) "Foreign Direct Investment, Agglomeration and Demonstration Effects: an Empirical Investigation," *Weltwirtschaftliches Archiv*, Vol. 139, pp. 583–600.

Bartholomew, J. R. (1989) *The Formation of Science in Japan*, New Haven, CT: Yale University Press.

Beck, R. L. (1983) "The prospect theory of the patent system and unproductive competition," *Research in law and Economics*, Vol. 5, pp. 193–209.

Beck, T., G. Clarke, A. Groff, P. Keefer and P. Walsh (2001) "New Tools in Comparative Political Economy: The Database of Political Institutions," *The World Bank Economic Review*, Vol. 15 (1), pp. 165–176.

Beintema, N. M. and G.-J. Stads (2004) "Investing in Sub-Saharan African agricultural research," Issue Briefs 8, International Food Policy Research Institute, Washington, DC: IFPRI.

Bergin, A. and I. Kearney (2004) "Human Capital, the Labour Market and Productivity Growth in Ireland," ESRI Working Paper No. 158, Dublin: ESRI.

Besen, S. M. and L. J. Raskind (1991) "An introduction to the law and economics of intellectual property," *Journal of Economic Perspectives*, Vol. 5 (1), pp. 3–27.

Blind, K. (2002) "Driving Forces for Standardisation at Standardisation Development Organisations," *Applied Economics*, Vol. 34 (16), pp. 1985–1998.

_____ (ed.) (2004) *The Economics of Standards: Theory, Evidence, Policy*, Cheltenham: Edward Elgar.

_____ (2005) "Standards, Technical Change and IPRs: Lessons from Industrialized Countries for Developing Countries," Background Paper for this Report, Vienna: UNIDO.

_____ (2006-forthcoming) "Explanatory Factors for Participation in Formal Standardisation Processes: Empirical Evidence at Firm Level," *Economics of Innovation and New Technology*, Vol. 15.

_____, N. Thumm, E. Iversen, K. Hossain, R. v. Reekum, B. Rixius, R. Bierhals, J. Sillwood (eds.) (2004) "Interaction between Standardisation and Intellectual Property Rights, Joint Research Centre (European Commission); Institute for Prospective Technological Studies," Technical Report Series IPTS, Seville, Brussels: European Commission.

Bloom, D. E. and D. Canning (2003) "Geography and Poverty Traps," *Journal of Economic Growth*, Vol. 8., pp. 355–378.

Böhm, E., H. Conrad, H. Hiessl, T. Hillenbrand, V. Kühn, K. Lützner and R. Walz (1998) *Effektivität und Effizienz technischer Normen und Standards für kommunale Umweltschutzaufgaben am Beispiel der kommunalen Abwasserentsorgung. Studie im Auftrag des Umweltbundesamtes*, Bonn: UBA.

Boisot, M. (1995) *Information Space*, London: Routledge.

Broad, E., B. Choi, D. Drum and D. Lagunes (2005) "Embraer's Creation of Value for Shareholders and the Brazilian Economy," *Chazen Web Journal of International Business*, Vol. Winter.

Buchanan, R. (2002) "The Role of Quantitative Microbiological Risk Assessment in Risk Management Options Assessment," Background paper for the Joint FAO/WHO Consultation held in Kiel, Germany on March 18–22, Online http://www.foodrisk.org/Doc/qmra.pdf.

Burnside C. and D. Dollar (1997) "Aid, Policies and Growth," Policy Research Working Paper, No. 1777, Washington, DC: World Bank.

_____ (2000) "Aid, Policies and Growth," *American Economic Review*, Vol. 90, pp. 847–868.

Carlsson, B. and R. Stankiewicz (1999) "On the Nature, Function and Composition of Technological Systems," in H. Hanusch (ed.) *The Legacy of Joseph A. Schumpeter Intellectual Legacies in Modern Economics*, Cheltenham, U.K. and Northampton, MA: Elgar.

_____, S. Jacobsson and A. Bergek (2004) "Dynamics of Innovation Systems: Policy-Making in a Complex and Non-Deterministic World," Paper presented at the International Workshop on Functions of Innovation Systems, University of Utrecht, 23–24 June.

Carvalho, J. M. de (2002) *A escola de Minas de Ouro Preto: o peso da gloria, 2nd edition*, Belo Horizonte: Editora UFMG.

Cerf, V. et al. (2000) "A Brief History of the Internet," Online http://www.isoc.org/internet/history/.

Chandler, A.D., Jr. (1990) *Scale and Scope. The Dynamics of Industrial Capitalism*, Cambridge, MA: The Belknap Press.

Chang, H.-J. (2002) *Kicking Away the Ladder, Development Strategy in Historical Perspective*, London: Anthem Press.

Chen, M. X., T. Otsuki and J. S. Wilson (2004), *Standards and Technical Regulations: Do they matter to export success in Developing Countries*, Washington, DC: World Bank.

Chenery H. B. and A. M. Strout (1966) "Foreign Assistance and Economic Development," *American Economic Review*, Vol. 56 (4), pp. 679–733.

Chiesa, V., R. Manzini and G. Toletti (2002) "Standard-setting processes: evidence from two case studies," *R&D Management*, Vol. 32, pp. 431–449.

Cincera, M., B. van Pottelsberghe de la Potterie (2001) "International R&D Spillovers: A Survey," *Cahiers Economiques de Bruxelles*, Vol. 169, pp. 3–32.

Cingranelli, D. L. and D. L. Richards, (2004) "The Cingranelli-Richards (CIRI) Human Rights Dataset," *Dataset Version 1.0*.

Clague, C., P. Keefer, S. Knack and M. Olson (1999) "Contract Intensive Money: Contract Enforcement, Property Rights and Economic Performance," *Journal of Economic Growth*, Vol. 4, pp. 185–211.

Clemens, R. (2003) "Meat Tracibility in Japan," Review Paper (IAR 9:4:4–5) Center for Agricultural and Rural Development, Ames: Iowa State University.

CNET News (2005) "Ericsson sues Sendo over cell patents," 23 March 2005, Online http://news.com.com/Ericsson+sues+Sendo+over+cell+patents/2100-1039_3-5632010.html.

Coe, D. and E. Helpman (1995) "International R&D Spillovers," *European Economic Review*, Vol. 39, pp. 859–887.

Coffey, B., J. Mintert, S. Fox, T. Schroeder and L. Valentin (2005) "The Economic Impact of BSE on the US Beef Industry: Product Value Losses, Regulatory Costs and Consumer Reactions," Agricultural Experiment Station and Cooperative Extension Service, Manhattan, KS: Kansas State University.

Cohen, W. M. and D. A. Levinthal (1990) "Absorptive Capacity: A New Perspective on Learning and Innovation," *Administrative Science Quarterly*, Vol. 35 (1), pp. 128–152.

Consortium of University Research Libraries (2003) "Evidence submitted jointly by CURL (Consortium of University Research Libraries) and SCONUL (Society of College, National and University Libraries) to *House of Commons: Science and Technology Committee Inquiry into* Scientific Publications," Online http://www.sconul.ac.uk/topical/documents/STC_evidence.doc.

Conway, P., V. Janod and G. Nicoletti (2005) "Product Market Regulation in OECD Countries: 1998 to 2003," OECD Economics Department Working Papers No. 419, Paris: OECD.

Coordinadora de Industria de la Alimentación (COPAL) (2004) "Modernización del Sistema de Control de Alimentos y de SENASA. Necesidades y propuestas de COPAL," Documento preliminar (restringido), Buenos Aires, 13 December

Cornwall, J. (1976) "Diffusion, Convergence and Kaldor's Law," *Economic Journal*, Vol. 85, pp. 307–314.

Council for Scientific and Industrial Research (CSIR) (2005) "Satellite Applications Centre," Online http://www.csir.co.za/.

Cowan, R., P. A. David and D. Foray (2000) "The explicit economics of knowledge codification and tacitness," *Industrial and Corporate Change*, Vol. 9 (2).

Crafts, N. (2005) "Interpreting Ireland's Economic Growth," Background Paper for this Report, Vienna: UNIDO.

Cyranoski, D. (2005) "An irresistible force," *Nature*, Vol. 436, pp. 767–768.

Dahlman, C. J. (1984) "Foreign Technology and Indigenous Technological Capability in Brazil," in M. Fransman and K. King (eds.) *Technological Capability in the Third World*, New York, NY: St.Martin's Press.

_____ and F. Fonseca (1993) "From Technological Dependence to Technological Development: The case of the USIMAS Steel Plant in Brazil," in R. R. Nelson (ed.) *National Innovation Systems*, New York, NY: Oxford University Press.

_____ and O. Sananikone (1990) "Technology Strategy in Taiwan Province of China: exploiting foreign linkages and investing in local capability," Washington, DC: World Bank.

David, P. A. (1986) "Narrow Windows, Blind Giants and Angry Orphans: The Dynamics of Systems Rivalries and Dilemmas of Technology Policy," *CEPR Technological Innovation Project Working Paper No. 10*, Stanford, CA: Stanford University.

_____ (1993) "Intellectual Property Institutions and the Panda's Thumb," in M. B. Wallerstein, M. E. Mogee, R. A. Schoen (eds.) *Global Dimensions of Intellectual Property Rights in Science and Technology*, Washington, DC: National Academy Press.

_____ and D. Foray (1994) "Dynamics of competitive technology diffusion through local network structures," in L. Leydesdorff and P. Van den Besselaar (eds.) *Evolutionary Economics and Chaos Theory*, London: Pinter.

_____ and H. K. Monroe (1994) "Standards Development Strategies Under Incomplete Information – Isn't the 'Battle of the Sexes' Really a Revelation Game?" Paper presented at the Telecommunications Policy Research Conference, Solomon's Island, MD: TPRC.

Dhungana, B. P. (2003) *Foreign direct investment and technological capability-building in least developed countries: A case study of Nepal*, Bangkok: Social Commission for Asia and the Pacific.

Easterly, W. (2003) "National Policies and Economic Growth: A Reappraisal," Development Research Institute Working Paper No. 1, March 2003, New York, NY: New York University.

_____ and R. Levine (2001) "It's Not Factor Accumulation: Stylized Facts and Growth Models," *World Bank Economic Review*, Vo. 15 (2), pp. 177–219.

_____ and M. Sewadeh (2002) *Global Development Network Growth Database*, New York, NY: World Bank.

Economist Intelligence Unit (EIU) (2004) "Scattering the seeds of invention: The globalisation of R&D," Online http://graphics.eiu.com/files/ad_pdfs/RnD_GLOBILISATION_WHITEPAPER.pdf.

Edquist, C. (ed.) (1997) *Systems of innovation; technologies, institutions and organizations. Science, technology and the international political economy series*, London: Pinter.

_____ (2004) "Systems of Innovation: Perspectives and Challenges," in J. Fagerberg, D. C. Mowery and R. R. Nelson (eds.) *The Oxford Handbook of Innovation*, Oxford: Oxford University Press.

Eichengreen, B. and M. Uzan (1992) "The Marshall Plan: Economic Effects and Implications for Eastern Europe and the Former USSR," *Economic Policy*, Vol.14, pp. 13–76.

Einhorn, B., Carey, J. and N. Gross, (2005) "China and India – The Leap Ahead: Research, A New Lab Partner For The U.S.?" *Business Week*, Vol. 3948, Online.

European Commission (EC) (2003) "Green Paper on Entrepreneurship in Europe," COM(2003) 27 final, Brussels: EC.

_____ (2004a) *Statistics on Science and Technology in Europe*. Brussels: EC.

_____ (2004b) "Guidance On The Implementation Of Articles 11, 12, 16, 17, 18, 19 and 20 Of Regulation (Ec) N 178/2002 On General Food Law, Conclusions Of The Standing Committee On The Food Chain And Animal Health," Brussels: EC, Online http://europa.eu.int/comm/food/food/foodlaw/guidance/guidance_rev_7_en.pdf.

_____ (2005a) "Guidance Document: Key questions related to import requirements and the new rules on food hygiene and official food controls," Brussels: EC, Online http://europa.eu.int/comm/food/international/trade/interpretation_imports.pdf.

_____ (2005b) "Better Training for Safer Food Initiative," Brussels: EC, Online http://europa.eu.int/comm/food/animal/welfare/index_en.html.

Fagerberg, J. (1987) "A Technology Gap Approach to Why Growth Rates Differ," *Research Policy*, Vol. 16, pp. 87–99.

_____ (1988) "International Competitiveness," *Economic Journal*, Vol. 98, pp. 355–374.

_____ (1994) "Technology and International Differences in Growth Rates," *Journal of Economic Literature*, Vol. 32 (3), pp. 1147–1175.

_____ and M. M. Godinho (2004) "Innovation and Catching-up," in J. Fagerberg, D. C. Mowery and R. R. Nelson (eds.) *The Oxford Handbook of Innovation*, Oxford: Oxford University Press.

_____, P. Guerrieri and B. Verspagen (eds.) (1999) *The Economic Challenge for Europe. Adapting to Innovation Based Growth*, Cheltenham: Edward Elgar.

_____ and M. Srholec (2005) "Catching-up: What are the Critical Factors for Success?" Background Paper for this Report, Vienna: UNIDO.

_____ and B. Verspagen (1999) "Modern Capitalism in the 1970s and 1980s," in M. Setterfield (ed.) *Growth, Employment and Inflation*, London: Macmillan.

Fearon, J. D. (2003) "Ethnic and Cultural Diversity by Country," *Journal of Economic Growth*, Vol. 8, pp. 195–222.

_____ and D. D. Laitin (2003) "Ethnicity, Insurgency, and Civil War," *American Political Science Review*, Vol. 97(1), pp. 75–90.

Financial Gazette (2004) "African countries consider US wireless standard," Online http://www.fingaz.co.zw/fingaz/2004/June/June10/5704.shtml.

Fitzgerald, J. (2002) "Has Ireland Outgrown Its Clothes? Infrastructural and Environmental Constraints in Ireland," in V. G. Munley, R. J. Thornton and J. R. Aronson (eds.) *The Irish Economy in Transition*, Oxford: Elsevier Science.

Food and Agriculture Organisation (FAO) and World Health Organisation (WHO) (2004) "Strengthening Official Food Safety Control Services," Agenda Item 4 in Second FAO/WHO Global Forum of Food Safety Regulators, Bangkok, Thailand, 12–14 October.

Forfas (1999) *Annual Survey of Irish Economy Expenditures*, Dublin: Forfas.

_____ (2004a) *Building Ireland"s Knowledge Economy*, Dublin: Forfas.

_____ (2004b) *Enterprise Strategy Group Report*, Dublin: Forfas.

Fredebeul-Krein, M. (1997) "Veränderte Anforderungen an eine europäische Standardisierungspolitik in der Telekommunikation," *Zeitschrift für Wirtschaftspolitik*, Vol. 46, pp. 140–166.

Freeman, Ch. (2002) "The Learning Economy and International Inequality", in D. Archibugi and B.A. Lundvall (eds.) *The Globalizing Learning Economy*, Oxford, UK: Oxford Univ. Press.

Frenken, K. and A. Nuvolari (2003) "The Early Development of the Steam Engine: An evolutionary interpretation using complexity theory," Working Paper 03.15, The Netherlands: Eindhoven Centre for Innovation Studies.

Frischtak, C. (1994) "Learning and technical progress in the commuter aircraft industry: an analysis of the Embraer's experience," *Research Policy*, Vol. 23, pp. 601–612.

FX Asia (2005) "EU confirm investigation into telecom standards body," 14 June 2005.

Gallup, J. L., J. D. Sachs and A. Mellinger (1999) "Geography and Economic Development," Centre for International Development Working Paper No. 1/1999, Cambridge, MA: Harvard University.

Gandal, N. and O. Shy (2001) "Standardization Policy and International trade," *Journal of International Economics*, Vol. 53, pp. 363–383.

Gargiulo, G. (2005) "Food Safety Capacity-Building Needs: The Argentine Food Activity," Background Paper for this Report, Vienna: UNIDO.

General Accounting Office (GAO) (2001) "Overview of Federal and State Expenditures. US General Accounting Office," Report GAO-01-177, Washington, DC: GAO.

Gerschenkron, A. (1962) *Economic Backwardness in Historical Perspective*, Cambridge, MA: Harvard University Press.

Girma, S., H. Gorg and M. Pisu (2004) "The role of exporting and linkages for productivity spillovers from FDI," World Bank Research Paper, Washington, DC: World Bank.

Glaeser, E. L., R. La Porta, F. Lopez-de-Silanes and A. Schleifer (2004) "Do Institutions Cause Growth?" *Journal of Economic Growth*, Vol. 9, pp. 271–303.

Global Entrepreneurship Monitor (GEM) (2002) "Global Entrepreneurship Monitor 2002 Summary Report," Online http://www.gemconsortium.org/download.asp?fid=239.

Godin, B. (2005) *Measurement and Statistics on Science and Technology: 1920 to the Present*, London: Routledge.

Gomes, F. M. (1983) *História da Siderurgia Brasileira*, Belo Horizonte: Itatiaia and São Paulo: Editora da Universidade de São Paulo.

Gompers, P. and J. Lerner (2001) "The Venture Capital Revolution," *Journal of Economic Perspectives*, Vol. 15 (2), pp. 145–168.

Gorg, H. and F. Ruane (2001) "Multinational Companies and Linkages: Panel-Data Evidence for the Irish Electronics Sector," *International Journal of the Economics of Business*, Vol. 8, pp. 1–18.

_____ and D. Greenaway (2004) "Much ado about nothing? Do domestic firms really benefit from foreign direct investment?" *World Bank Research Observer*, Vol. 19, pp. 171–197.

_____ and E. Strobl (2004) "Foreign Direct Investment and Local Economic Development: Beyond Productivity Spillovers," mimeo, Nottingham: University of Nottingham.

Gostkowski, Z. (1986) *Integrated Approach to Indicators for Science and Technology*, Paris: UNESCO.

Grindley, P. and S. Toker (1993) "Regulators, Markets and Standards Coordination: Policy Lessons from Telepoint," *Economics of Innovation and New Technology*, Vol. 2, pp. 319–342.

Groningen Growth and Development Centre (GGDC) (2005) "Total Economy Database," Groningen Growth and Development Centre and The Conference Board, Online http://www.ggdc.net.

Gropp, R. and K. Kostial (2000) "The Disappearing Tax Base: Is FDI Eroding Corporate Income Taxes," International Monetary Fund Working Paper No. 00/173, Washington, DC:IMF.

Grossman, G. M. and E. Helpman (1991) *Innovation and Growth in the Global Economy,* Cambridge, MA: MIT Press.

Gesellschaft für Konsumforschung (GfK) (2001) "BSE crisis dramatically reduces meat consumption of German households," 17 January 2001, Press info, Online http://www.gfk.com/english/presse/pressemeldung/contentdetail.php?id=205 =en

Guillaumont, P. (1971) *L'Absorption du Capital,* Paris: Ed. Cujas.

_____ and L. Chauvet (1999) "Aid and Performance: A Reassessment," Communication ABCDE Workshop on Aid, Selectivity and Conditionality, *Washington, DC: World Bank.*

Gwartney, J. and R. Lawson (2004) *Economic Freedom of the World: 2004 Annual Report,* Vancouver: The Fraser Institute.

Haber L. F. (1971) *The Chemical Industry, 1900–1930,* Oxford: Clarendon Press.

Hausmann, R. and D. Rodrik (2003) "Discovering El Salvador's Production Potential," in *In Search of The Road Ahead: Identifying a Development Strategy for El Salvador,* Cambridge, MA: Harvard University.

_____, A. Rodriguez-Clare and D. Rodrik (2005) "Towards a strategy for economic growth in Uruguay," Inter-American Development Bank, Economic and Social Study Series, February 2005, Washington, DC: IADB.

Helbig, J. and J. Volkert (1998) "Potentiale und Grenzen freiwilliger Standards im Umweltschutz," *IAW-Mitteilungen,* Vol. 4, pp. 4–15.

Henisz, W. J. (2002) "The Institutional Environment for Infrastructure Investment," *Industrial and Corporate Change,* Vol. 11 (2) pp. 355–389.

Heston, A., R. Summers and B. Aten (2002) *Penn World Table Version 6.1,* Center for International Comparisons, Philadelphia, PA: University of Pennsylvania.

Hinloopen, J. (2003) "Innovation Performance Across Europe," *Economics of Innovation and New Technology,* Vol. 12, pp. 145–161.

Hotelling, H. (1933) "Analysis of a complex of statistical variables into principal components," *Journal of Educational Psychology,* Vol. 24, pp. 417–441.

Hsieh, S. H. (1989) "University Education and Research in Taiwan," in P.G. Altbach, et al., *Scientific Development and Higher Education. The Case of Newly Industrializing Nations,* Westport, CT: Praeger Publishers.

Huang, Y. and T. Khanna (2003) "Can India Overtake China?," *Foreign Policy,* Vol. July/August, pp. 74–81.

Huffman, W. E. and R. E. Evenson (1993) *Science for Agriculture: A Long-Term Perspective,* Ames, IOWA State Press.

Imbs, J. and R. Wacziarg (2003) "Stages of Diversification," *American Economic Review,* Vol. 93 (1), pp. 63–86.

Industrial Policy Review Group (IPRG) (1992) *A Time for Change: Industrial Policy for the 1990s, Dublin: IPRG Stationary Office.*

Industrial Technology Research Institute (ITRI) (2004) "Testing/Certification Services," Online http://www.itri.org.tw/eng/business/certification.jsp.

Industry News (2004) "Taiwan Province of China is exporting an increasing volume of electric bikes, to the tune of $700m in 2004," Issue published on 12/02/2004, Online.

Industry Updates (2005) "Food industry calls for 'cold-chain' technology," *Issue published on 23 August 2005, Online.*

Institute for Management Development (IMD) (2004) *World Competitiveness Yearbook,* Lausanne: IMD.

Instituto Argentino de Normalización y Certificación (IRAM) (2005) "Capacity-building, standarisation and conformity assessment," Background Paper for this Report, Vienna: UNIDO.

International Standardisation Organisation (ISO) (2005) "ISO/FDIS 22000: Food Safety Management Systems – Requirements for any Organization in the Food Chain (Final Draft)," Geneva: ISO.

Iversen, E. J. (2000) "Standardisation and Intellectual Property Rights: Conflicts Between Innovation and Diffusion in New Telecommunication Systems," in J. Kai (ed.) *Information Technology Standardisation: A Global Perspective,* Hershey, London: Idea Group Publishing.

_____ (2002) "Case Study: TETRA" in Blind et al. (ed.) *Study on the Interaction between Standardisation and Intellectual Property Rights,* Karlsruhe: Fraunhofer Institute of for Systems and Innovation Research.

_____, E. Øversjøen and H. Thue Lie (2004) "Standardization, Innovation and IPRs," *Telektronikk* Vol. 100 (2), pp. 65–79.

Jacobsson, S. (1986) *Electronics and Industrial Policy: The Case of Computer-Controlled Lathes,* London: Allen and Unwin.

_____ (1993) "The length of the infant industry period: evidence from the engineering industry in South Korea," *World Development,* Vol. 21, *pp. 407–419.*

_____ (2005) "Formation and growth of sectoral innovation systems – 'functional analysis' as a tool for policy makers in identifying policy issues," Background Paper for this Report, Vienna: UNIDO.

_____ and G. Alam (1994) *Liberalisation and Industrial Development in the Third World. A Comparison of the Indian and South Korean Engineering Industries,* New Delhi: Sage Publications.

Jaffee, S. and S. Henson (2004) "Standards and Agro-Food Exports from Developing Countries: Rebalancing the Debate," World Bank Policy Research Working Paper 3348, June 2004, Washington, DC: World Bank.

_____, K. van der Meer, S. Henson, C. de Haan, M. Sewadeh, L. Ignacio, J. Lamb and M. Bergovoy Lisazo (2005) "Food Safety and Agricultural Health Standards: Challenges and Opportunities for Developing Country Exports Report No. 31027," Poverty Reduction and Economic *Management Trade Unit and Agricultural and Rural Development* Department, Washington, DC: World Bank.

Johnson, C. A. (1982) *MITI and the Japanese miracle: the growth of industrial policy, 1925–1975,* Stanford, CA: Stanford University Press.

Johnson, T. (2005) "China, a low-tech powerhouse, struggles to become a major high-tech industry player," *The Miami Herald,* August 21, 2005, Online http://www.broward.com/mld/miamiherald/business/12430228.htm.

Jones, L. P. and I. S. Sakong (1980) *Government, Business and Entrepreneurship in Economic Development: The Korean Case Studies in the Modernization of the Republic of Korea: 1945–1975,* Cambridge, MA: Harvard University Press.

Katz, J. (2004) "Economic, institutional and technological forces inducing the successful inception of salmon farming in Chile," mimeo, Argentina: University of Chile and Conicet.

Kavanagh, C. (1997) "Public Capital and Private Sector Productivity in Ireland, 1958–1990," *Journal of Economic Studies,* Vol. 24, pp. 72–94.

Kim, L. (1993) "National System of Industrial Innovation: Dynamics of Capability Building in Korea," in R. R. Nelson (ed.) *National Innovation Systems. A Comparative Analysis,* Oxford: Oxford University Press, pp. 357–383.

Kirkpatrick, D. (2005) "IBM Shares Its Secrets Crunched by low-cost *competition: Big Blue is betting that giveaways of precious technol*ogy will expand the market and boost its own prospects," *Fortune 05,* August 2005, Online.

Kiszewksi, A., A. Mellinger, A. Spielman and P. Malaney (2004) "A Global Index of the Stability of Malaria Transmission," *American Journal of Tropical Medicine and Hygiene,* Vol. 70 (5), pp. 486–498.

Kitch, E. W. (1977) "The nature and function of the patent system," *Journal of Law and Economics,* Vol. 20, pp. 265–290.

Kline, P. (1994) *An easy guide to factor analysis,* London: Routledge.

Kranakis, E. (1989) "Social Determinants of Engineering Practice: A Comparative View of France and America in the Nineteenth Century," *Social Studies of Science,* Vol. 19 (1), pp. 5–70.

Lall, S. (2003) "Indicators of the Relative Importance of IPRs in Developing Countries," *Research Policy,* Vol. 32 (9), pp. 1657–1680.

Landes, D. (1998) *The Wealth and Powerty of Nations,* London: Abacus.

Langlois, R. N. (2000) "Knowledge, Consumption and Endogenous Growth," Department of Economics Working Paper 2000–2002, Hartford, CT: University of Connecticut.

_____ and D. C. Mowery (1996) "The federal government role in the development of the U.S. software industry," in D. C. Mowery (ed.) *The*

International Computer Software Industry: A Comparative Study of Industry Evolution and Structure, New York: Oxford University Press.

Lee, S. (1989) "Higher-Education and Research Environments in Korea," in P. G. Altbach et al., *Scientific Development and Higher Education. The Case of Newly Industrializing Nations,* Westport, CT: Praeger Publishers.

Lerner, J. and J. Tirole (2000) "The Simple Economics of Open Source," National Bureau of Economic Research Working Paper Series 7600, Cambridge, MA: NBER.

Levin, R., A. Klevorick, R. R. Nelson and S. Winter (1987) "Appropriating the Returns from Industrial Research and Development," *Brookings Papers on Economic Activity, Special Issue on Microeconomics,* Vol. 3, pp. 783–831.

Liebowitz, S. J. and S. E. Margolis (1999) *Winners, Losers and Microsoft. Competition and Antitrust in High Technology,* Oakland, CA: The Independent Institute.

Lim, A. (2002) "Standard Setting Processes in ICT: The Negotiations Approach," Working Paper 2.19, Faculty of Technology Management (ed.), Eindhoven: Technische Universiteit Eindhoven.

Lim, C. (1997) "Sectoral Systems of Innovation – the case of the Korean machine tool industry," D.Phil Thesis, SPRU, UK: University of Sussex.

Liphard, K. G. (1998) "Brennstoffnormen als Bausteine der Qualitätspolitik," *Glückauf,* Vol. 134, pp. 23–28.

Lucas, R. E.(2002) *Lectures on Economic Growth,* Cambridge, MA: Harvard University Press.

Lundvall, B.-A. (1988) "Innovation as an Interactive Process: From User-Producer Interaction to the National System of Innovation," in G. Dosi, C. Freeman, R. R. Nelson, G. Silverberg and L. Soete (eds.) *Technical Change and Economic Theory,* London: Pinter Publishers.

Lyman, P. and H. R. Varian (2003) "How Much Information," Online http://www.sims.berkeley.edu/how-much-info-2003.

Machlup, F. (1962) *The Production and Distribution of Knowledge in the United States,* Princeton, NJ: Princeton University Press.

MacSharry, R. and P. A. White (2000) *The Making of the Celtic Tiger,* Cork: Mercier Press.

Maddison, A. (1982) *Phases of Capitalist Development,* Oxford: Oxford University Press.

_____ (1991) *Dynamic Forces in Capitalist Development,* New York, NY: Oxford University Press.

_____ (2001) *The World Economy: A Millennial Perspective,* Paris: OECD.

_____ (2003) *The World Economy: Historical Statistics,* Paris: OECD.

Magariños, C. A. (2005) *Economic Development and UN Reform – Towards a Common Agenda for Action,* Vienna: UNIDO.

Magariños, C. and F. Sercovich (eds.) (2003) *Updating and Fleshing Out the Development Agenda,* Vienna: UNIDO.

Malerba, F. (2004) "Sectoral Systems: How and Why Innovation Differs Across Sectors" in J. Fagerberg, D. C. Mowery and R. R. Nelson (eds.) *The Oxford Handbook of Innovation,* Oxford: Oxford University Press.

Markusen, J. and A. J. Venables (1999) "Foreign Direct Investment as a Catalyst for Industrial Development," *European Economic Review,* Vol. 43, pp. 35–356.

Marshall, M. G. and K. Jaggers (2002) "Polity IV Dataset (Computer file; version p4v2002)," College Park, Center for International Development and Conflict Management, MD: University of Maryland.

Marson, I. (2005) "Telecom standards face patent ambush threat," *ZDNet UK,* 15 June 2005, Online http://news.zdnet.co.uk/business/legal/0,39020651,39203931,00.htm.

Maskus, K. E., T. Otsuki and J. S. Wilson (2004) *The Costs of Complying with Foreign Product Standards for Firms in Developing Countries: An Econometric Study,* Bolder, CD: University of Colorado.

Masters, W. A. and M. S. McMillan (2001) "Climate and Scale in Economic Growth," *Journal of Economic Growth,* Vol. 6, pp. 167–186.

Mazzoleni, R. (2003) "The Role of Universities and public research Institutes in the Catching-up Process," presented at the Globelics conference, Rio de Janeiro, Brazil.

_____ (2005) "The contribution of the *Escola de Minas* to the Development of Brazil's Iron Industry (1876–1930)," Paper presented at the 2005 EBHS Conference, High Point, NC, USA.

_____ (2005) "Historical Patterns in the Coevolution of Higher Education," Public Research, and National Industrial Capabilities," Background Paper for this Report, Vienna: UNIDO.

McGinn, N. F., et al. (1980) *Education and Development in Korea,* Cambridge, MA: Harvard University Press.

McKinsey Global Institute (2003) "Offshoring: Is It a Win-Win Game?" San Francisco, CA: McKinsey.

Midelfart-Knarvik, K. H., H. G. Overman, S. J. Redding and A. J. Venables (2000) "The Location of European Industry," *Economic Papers* No. 142, EC DG for Economic and Financial Affairs.

Millikan, M. and W. W. Rostow (1957) *A Proposal. Key to an Effective Foreign Policy,* Cambridge, MA: MIT Press.

Miselbach, R. and R. Nicholson (1994) *Intellectual Property Rights and Standardization Sec. Update,* France: Sophia Antipolis.

Mitchell, B. R. (1995) *International historical statistics: Africa, Asia and Oceania, 1750–1988 (2d rev.ed.),* Basingstoke: Stockton Press.

_____ (2003a) *International historical statistics: the Americas, 1750–2000 (5th rev.ed.),* Basingstoke: Palgrave Macmillan.

_____ (2003b) *International historical statistics: Europe, 1750–2000 (5th rev.ed.),* Basingstoke: Palgrave Macmillan.

Mokyr, J. (2003) "Long-term Economic Growth and the History of Technology," Draft chapter for P. Aghion and S. Durlauf (eds.) *Handbook of Economic Growth,* USA: Elsevier.

Momo, C. (2005) "Wireless in Africa: Insights into Mobile Market," *IT Pro,* IEE Computer Society, May–June 2005, Online.

Morgan Stanley Equity Research (2002) Online http://www.econ.ucsb.edu/tedb/Journals/morganstanley.pdf.

Mowery, D. C. (2003) "Intellectual Property, Competition Policy and Public Goods: Evidence from Policy Reform in the United States," in C. Magariños and F. Sercovich (eds.) *Updating and Fleshing Out the Development Agenda,"* Vienna: UNIDO.

_____ (2005) "The role of knowledge-based 'public goods' in economic 'catch-up': Lessons from history," Background Paper for this Report, Vienna: UNIDO.

_____ and N. Rosenberg (1993) "The U.S. National Innovation System" in R. Nelson (ed.) *National Innovation Systems: A Comparative Analysis,* New York, NY: Oxford University Press.

Murmann, J. P. (1998) "Knowledge and Competitive Advantage in the Synthetic Dye Industry, 1850–1914," unpublished Ph.D. dissertation, Columbia University, New York, NY, US.

_____ (2003a) *Knowledge and Competitive Advantage,* New York, NY: Cambridge University Press.

_____ (2003b) "The Coevolution of Industries and Academic Institutions: Theory and Evidence," presented at the Harvard Business School Business History seminar, September 24.

National Research Council (1999) *Funding a Revolution: Government Support for Computing Research,* Washingtin, DC: National Academy Press.

National Science Council (NSC) (1997) "White Paper on Science and Technology," Executive Yuan, Republic of China, Taiwan, Online http://www.stic.gov.tw/stic/policy/scimeeting/ E-whitepaper/index_e.htm.

National Science Foundation (NSF) (2004) "Science and Engineering Indicators 2004," National Science Board Division of Science Resources Statistics, Online http://www.nsf.gov/statistics/seind04/

Neary, J. P. (2004) "Rationalizing the Penn World Table: True Multilateral Indices for International Comparisons of Real Income," *American Economic Review,* Vol. 94 (2), pp. 1411–1428.

Nelson, R. R. (1984) *High-Technology Policies: A Five-Nation Comparison,* Washington, DC: American Enterprise Institute.

_____ (1990) "Capitalism as an Engine of Progress," *Research Policy,* Vol. 19, pp. 61–87.

_____ (1992) "What is 'Commercial' and What is 'Public' About Technology and What Should Be?" in N. Rosenberg, R. Landau and D. C. Mowery (eds.) *Technology and the Wealth of Nations,* Stanford, CA: Stanford University Press.

_____ (1994) "The co-evolution of technology, industrial structure and supporting structure," *Industrial and Corporate Change,* Vol. 3 (1), pp. 47–63.

_____ (2003a) "The Changing Institutional Requirements for Technological and Economic Catch Up," unpublished mimeo.

_____ (2003b) "Physical and Social Technologies and Their Evolution," *Économie Appliquée,* Vol. 56 (3), pp. 13–29.

_____ and E. Phelps (1966) "Investment in humans, technology diffusion and economic growth," *American Economic Review, Papers and Proceedings,* Vol. 56, pp. 69–75.

_____ and P. Romer (1996) "Science, Economic Growth and Public Policy," in B. Smith and C. Barfield (eds.) *Technology, R&D and the Economy,* Washington, DC: Brookings.

_____ and N. Rosenberg (1994) "American Universities and Technical Advance in Industry," *Research Policy,* Vol.23, pp. 323–348.

_____ and B. Sampat (2001) "Making sense of institutions as a factor shaping economic performance," *Journal of Economic Behavior & Organization,* Vol. 44 (1), pp. 31–54.

_____ and S. G. Winter (1982) *An Evolutionary Theory of Economic Change,* Cambridge, MA: Harvard University Press.

_____ and G. Wright (1992) "The rise and fall of American technological leadership: The postwar era in historical perspective," *Journal of Economic Literature,* Vol. 30, pp. 1931–1964.

Nicoletti, G., S. Scarpetta and O. Boylaud (2000) "Summary Indicators of Product Market Regulation with an Extension to Employment Protection Regulation," OECD Economics, Department Working Paper No. 226, Paris: OECD.

Nightingale, P. (2003) "If Nelson and Winter are only half right about tacit knowledge, which half?" *Industrial and Corporate Change,* Vol. 12 (2), pp.149–183.

_____ (2004) "Technological capabilities, invisible infrastructure and the un-social construction of predictability: the overlooked fixed costs of useful research," *Research Policy,* Vol. 33, pp. 1259–1284.

Niman, N. B. (2002) "Platform Externalities and Antirust Case Against Microsoft" *Antitrust Bulletin,* Vol. Winter, pp. 641–660.

_____ and B. Kench (2004) "Open Source and the Future of Pharmaceutical Industry," Paper presented at the DRUID Summer Conference 2004 on Industrial Dynamics, Innovation and Development, Elsinore, Denmark, 14–16 June.

North, D. (1981) *Structure and Change in Economic History,* London: W. W. Norton and Company.

O'Grada, C. and K. H. O'Rourke (1996) "Irish Economic Growth, 1945–88," in N. Crafts and G. Toniolo (eds.) *Economic Growth in Europe since 1945,* Cambridge, MA: Cambridge University Press.

O'Mahony, M. (2002) *Productivity in the EU, 1979–1999,* London: HM Treasury.

O'Malley, E. (1995) "An Analysis of Secondary Employment Associated with Manufacturing Industry," ESRI General Research Paper No. 167, Dublin: ESRI.

Odagiri, H. and A. Goto (1993) "The Japanese System of Innovation: Past, Present and Future," in R. R. Nelson (ed.) *National Innovation Systems. A Comparative Analysis,* Oxford University Press.

Ohkawa, K. and H. Rostovsky (1973) *Japanese Economic Growth,* Stanford, CA: Stanford University Press.

Olson, M. (1965) *The Logic of Collective Action: Public Goods and the Theory of Groups,* Cambridge, MA: Harvard University Press.

_____ (1996) "Big Bills Left on the Sidewalk: Why Some Nations are Rich and Others Poor," *Journal of Economic Perspectives,* Vol. 10 (2), pp. 3–24.

Organisation for Economic Co-operation and Development (OECD) (1996) "ICT Standardization in the New Global Context," *OCDE/GD* (96) 86, Paris.

_____ (2000) *Literacy in the Information Age,* Paris: OECD.

_____ (2004) "Compendium of Patent Statistics," Online http://www.oecd.org/dataoecd/60/24/8208325.pdf.

_____ (2004a) "Performance Indicators of Student Achievement, 2003," Paris: OECD.

_____ (2004b) "Revenue Statistics, 1965–2001," Paris: OECD.

Ouédraogo, L.-D. (2005) "Policies of United Nations System Organizations toward the Use of Open Source Software (OSS) – Part I: Use of OSS in the Secretariats," Joint Inspection Unit, JIU/REP/2005/XXX, Geneva: UN.

Overseas Development Institute (ODI) (2005) "Scaling up versus absorptive capacity: challenges and opportunities for reaching the MDGs in Africa," Briefing Paper, London: ODI.

Paula, J. A. de (1983) "A Siderurgia em Minas Gerais – 1809–1888," in Haydn Coutinho Pimenta (ed) *II Seminario Sobre a Economia Mineira,* Belo Horizonte: CEDEPLAR, pp. 24–31.

Polanyi, M. (1958) *Personal Knowledge: Towards a Post-Critical Philosophy,* Chicago, IL: University of Chicago Press.

Pollard, S. (1981) *Peaceful conquest. The industrialization of Europe, 1760–1970.* Oxford: Oxford University Press.

Pritchett, L. (2001) "Where Has All the Education Gone?" *World Bank Economic Review,* December 2001.

Process Engineering (2005) "All part of the process" 18 August 2005, Online http://www.processengineering.co.uk/Articles/291791/All+part+of+the+process.htm.

RAND (2002) "Can Science and Technology Capacity Capacity Be Measured?" Santa Monica, CA and Leiden, NL: RAND Corporation.

Rapp, R. T. and L. J. Stiroh (2002) "Standard Setting and Market Power, contribution to the public hearing on Competition and Intellectual Property Law and Policy in the Knowledge-Based Economy in 2001 and 2002," Online http://www.ftc.gov/opp/intellect/index.htm (3-07-2002).

Rasiah, R. (2004) *Foreign firms, Technological Capabilities and Economic Performance: Evidence from Africa, Asia and Latin America,* Cheltenham: Edward Elgar.

Redding, S. J. and A. J. Venables (2004) "Economic Geography and International Inequality," *Journal of International Economics,* Vol. 62, pp. 53–82.

Roberts, D. and L. Unnevehr (2003) "Resolving Trade Disputes Arising from Trends in Food Safety Regulation" in *International Trade and Food Safety: Economic Theory and Case Studies,* USDA/ERS AER 828, Washington, DC: USDA.

Rodríguez-Clare, A. (2003) "Innovation and Technology Adoption in Central America," mimeo Inter-American Development Bank, Online http://www.rodriguezclare.com/Papers/Innovation%20and%20Technology%20Adoption% 20in%20Central%20America.pdf.

Rodrik, D. (1999) "Institutions for High-Quality Growth: What They Are and How to Acquire Them," Paper presented at the IMF conference on Second Generation Reforms, Washington, DC, November 8–9, 1999.

_____ (2004) "Industrial policy for the twenty-first century," mimeo, John F. Kennedy School of Government, Cambridge, MA: Harvard University.

Romer, P. M. (1990) "Endogenous Technological Change," *Journal of Political Economy,* Vol. 98 (5), pp. 71–102.

Rosenstein-Rodan, P. (1961) "Notes on the theory of the big push" in H. S. Ellis and H. C. Wallich (eds.) *Economic Development for Latin America,* New York, NY: St. Martin's.

Rotherham, T. (2003) "Implementing Environmental, Health and Safety (EH&S) Standards and Technical Regulations: The Developing Country Experience," Trade Knowledge Network Thematic Paper, International Institute for Sustainable Development and International Centre for Trade and Sustainable Development, Online http://www.tradeknowledgenetwork.net/publication.aspx?id=531.

Ruane, F. and A. Uour (2002) "Foreign Direct Investment and Productivity Spillovers in Irish Manufacturing Industry: Evidence from Firm-Level

Panel Data," Trinity College Dublin Economics Paper 02/06, Dublin: Trinity College.

Sachs, J. D., J. W. McArthur, G. Schmidt-Traub, M. Kruk, C. Bahadur, M. Faye and G. McCord (2004) "Ending Africa's Poverty Trap," *Brookings Papers on Economic Activity,* No. 117–240, Washington, DC: Brookings.

Servicio Agrícola y Ganadero (SAG) (2001) *Cuenta Pública 2000. Gobierno de Chile, Servicio Agrícola y Ganadero,* Santiago de Chile.

Samuelson, P. (1955) "Diagrammatic Exposition of a Theory of Public Expenditure," *Review of Economics and Statistics,* Vol. 36, pp. 350–356.

San, G. (1990) "Enterprise training in Taiwan: results from the vocational training needs survey," *Economics of Education Review,* Vol. 9 (4), pp. 411–418.

Sánchez, G. and I. Butler (2005) "Measuring the Demand of Trade-Related Technological Public Goods in Argentina," Background Paper for this Report, Vienna: UNIDO.

Saperstein, J. and D. Rouach (eds.) (2002) *Creating Regional Wealth in The Innovation Economy,* Toronto: Financial Times and Prendice-Hall.

Saviotti, P. P. (1998) "On the dynamics of appropriability of tacit and codified knowledge," *Research Policy,* Vol. 26, pp. 834–856.

_____ (1991) "The role of variety in economic and technological development," in P. P. Saviotti and J. S. Metcalfe (eds.) *Evolutionary Theories of Economic and Technological Change,* Chur: Harwood Academy Publishers.

Schoonwinkel A. and G. W. Milne (1997) "University research and development of a microsatellite," *R&D Management,* Vol. 27 (1), pp. 37–44.

Schumpeter, J. A. (1942) *Capitalism, Socialism and Democracy,* (Harper Colophon edition, 1976), New York, NY: Harper and Brothers.

Seely, B. E. (1993) "Research, Engineering and Science in American Engineering Colleges, 1900–1960," *Technology and Culture,* Vol. 34, pp. 344–386.

Sercovich, F. C. et al. (1999) *Competition and the World Economy – Comparing Industrial Development Policies in the Developing and Transition Economies,* UNIDO, Cheltenham: Edward Elgar.

_____ and M. Dolun (2005) "The Nuances of Publicness: Implications for Catching-Up," unpublished manuscript, Vienna: UNIDO.

Servicio Nacional de Sanidad y Calidad Agroalimentaria (SENASA) (2004a) *Plan estratégico para el cambio y fortalecimiento de SENASA. Síntesis del informe de un Grupo de Expertos,* Buenos Aires, Online http://www.senasa.gov.ar.

_____ (2004b) *Cambio y fortalecimiento del SENASA. Lineamientos estratégicos,* Buenos Aires, Online http://www.senasa.gov.ar.

Sidgurdson, J. (1986) "Industry and State Partnership: The historical role of the engineering research associations in Japan," *Industry and Innovation,* Vol. 5 (2), pp. 209–241.

Slaughter, M. J. (2003) "Host Country Determinants of US Foreign Direct Investment into Europe," in H. Herrmann and R. Lipsey (eds.) *Foreign Direct Investment in the Real and Financial Sector of Industrial Countries,* Berlin: Springer.

Solow, R. M. (1956) "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics,* Vol. 70 (1), pp. 65–94.

_____ (1957) "Technical Change and the Aggregate Productio n Function," *Review of Economics and Statistics,* Vol. 39, pp. 312–330.

Spearman, C. (1904) "General intelligence: objective determined and measured," *American Journal of Psychology,* Vol. 15, pp. 201–292.

Spengel, C. and W. Wiegard (2004) "Dual Income Tax: a Pragmatic Tax Reform Alternative for Germany," CESifo DICE Report No. 3, Munich: IFO Institute.

Srinivas, S. (2005) "Technical standards and economic development: Meeting the most common denominator," Paper prepared for UNIDO, Vienna: UNIDO.

Steffensen, B. (1997) *New Technologies and Standardization: A Useful but Problematic Combination, Paper for the Interdisciplinary Workshop on Standardization Research at the University of the Federal Armed Forces,* Hamburg: Univ. der Bundeswehr.

Sutz, J. and R. Arocena (2005) "Science, technology and innovation in developing countries: some elements for defining policies and assigning resources," Background Paper for this Report, Vienna: UNIDO.

Syrquin, M. (1989) "Patterns of Structural Change," Chapter 7 in H. Chenery and T.N. Srinivasan (eds.) *Handbook of Development Economics,* Vol.1, Amsterdam: North Holland.

Tan H. W. and G. Batra (1996) "Enterprise training in developing countries. Overview of Incidence, determinants and productivity outcome," Private Sector Development Department Occasional Paper No. 9, Washington, DC: The World Bank.

Teece, D. (1986) "Profiting from technological innovation: Implication for integration, collaboration, licensing and public policy," *Research Policy,* Vol. 15, pp. 285–305.

Temple, J. and P. A. Johnson (1998) "Social Capability and Economic Growth," *Quarterly Journal of Economics,* Vol. 113 (3), pp. 965–990.

Teubal, M. (2000) "Enterprise Restructuring and Embeddedness: A Policy and Systems Perspective," *Industrial and Corporate Change,* Vol. 9(1), pp. 87–111.

_____ (2002) "What is the systems perspective to Innovation and Technology Policy (ITP) and how can we apply it to developing and newly industrialized economies?" *Journal of Evolutionary Economics,* Vol. 12 (1), pp. 233–257.

Thelen, K. (2004) *How institutions evolve: The political economy of skills in Germany, Britain, the United States and Japan,* New York, NY: Cambridge University Press.

Third Generation Partnership Project (3G), Online http://www.3gpatents.com/.

Tocqueville, A. de. (1876) *Democracy in America,* Boston, MA: John Allyn Publisher.

Uchida, H., (1980) "Western Big Business and the Adoption of New Technology in Japan: The Electrical Equipment and Chemical Industries 1890–1920," in A. Okochi and H. Uchida (eds.) *Development and Diffusion of Technology: Electrical and Chemical Industries, 6th International Conference on Business History,* Tokyo: University of Tokyo Press.

United Nations Conference on Trade and Development (UNCTAD) (2002) "Expert meeting on environment requirements and international trade," paper by Mr. Ansoumane Berete, Head of the Trade Policy and Agreement Division of the Ministry of Trade of Guinea Expert Meeting on Environmental Requirements and International Trade Geneva, 2–4 October 2002, Online http://r0.unctad.org/trade_env/test1/meetings/envreq.htm.

_____ (2004) *World Investment Report,* Geneva: UNCTAD.

United Nations Development Programme (UNDP) (2003) *Human Development Index, Human Development Report 2003,* New York, NY: UNDP.

United Nations Educational, Scientific and Cultural Organisation (UNESCO) (1972) *Statistics of Students Abroad 1962–1968,* Paris: UNESCO.

_____ Institute for Statistics (2005) "Research and Development Statistics and Indicators," Online http://www.uis.unesco.org/ev.php?ID=5182_201&ID2=DO_TOPIC.

United Nations Industrial Development Organisation (UNIDO) (1979) "The Changing Pattern of Industrial Production," Chapter II in *World Industry Since 1960: Progress and Prospects,* New York, NY: United Nations.

_____ (2003) *UNIDO in the Montreal Protocol: Impacts and lessons learned – fumigants,* Vienna: UNIDO.

_____ and World Trade Organisation (2004) "Second Joint Progress Report: Implementation of the WTO – UNIDO Memorandum of Understanding: Technical Cooperation Programme responding to the Doha Development Agenda," 8 November 2004, Vienna/Geneva: UNIDO/WTO.

van Ark, B., J. Melka, N. Mulder, M. Timmer and G. Ypma (2003) "ICT Investments and Growth Accounts in the European Union," Groningen Growth and Development Centre Research Memorandum No. GD 56, Groningen: GGDC.

Veblen, T. (1915) *Imperial Germany and the Industrial Revolution,* New York, NY: Macmillan.

Verspagen, B. (1991) "A New Empirical Approach to Catching up or Falling Behind," *Structural Change and Economic Dynamics,* Vol. 2, pp. 359–380.

von Hippel, E. (2001) "Innovation by User Communities: Learning from Open Source Software" *Sloan Management Review,* Vol. 42 (4), pp. 82–86.

von Tunzelmann, G. N. (1995) *Technology and Industrial Progress. The Foundations of Economic Growth,* Aldershot: Edward Elgar.

Wade, R. (1990) *Governing the Market,* Princeton, NJ: Princeton University Press.

Wagner, C. (2005) "The Pillars of Progress: Metrics for Science and Technology Infrastructure," Background Paper for this Report, Vienna: UNIDO.

Walsh, B. (2004) "The Transformation of the Irish Labour Market, 1980–2003," *Journal of the Statistical and Social Inquiry Society of Ireland,* Vol. 33 (forthcoming).

Walsh, V. (1988) "Technology and the Competitiveness of Small Countries," in Ch. Freeman and B.A. Lundvall (eds.) *Small countries facing technological revolution,* London: Pinter.

Wey, C. (1999) *Marktorganisation durch Standardisierung. Ein Beitrag zur neuen Institutionenökonomik des Marktes,* Wissenschaftszentrum für Sozialforschung (ed.), Berlin: Edition Sigma.

Wickham, J. and G. W. Boucher (2004) "Training Cubs for the Celtic Tiger: the Volume Production of Technical Graduates in the Irish Educational System," *Journal of Education and Work,* Vol. 17, pp. 377–395.

Willgerodt, H. and J. Molsberger (1978) "Der volkswirtschaftliche Nutzen der Normung," *Gutachten im Auftrage des Bundesministerium für Wirtschaft,* Bonn: BMWi.

Williams, G., (2002) "The Assessment of the Economic Role of Measurements and Testing in Modern Society," Final Report, Oxford, Pembrooke College: European Commission.

Wooldridge, J. M. (2002) *Econometric Analysis of Cross Section and Panel Data,* Cambridge, MA: The MIT Press.

World Bank (1993) *The East Asian miracle: Economic growth and public policy.* New York: Oxford University Press.

_____ (1999) *Knowledge for Development,* New York, NY: Oxford University Press.

_____ (2002a) *Building Institutions for Markets,* New York, NY: Oxford University Press.

_____ (2002b) *Constructing Knowledge Societies: New Challenges for Tertiary Education,* Washington, DC: World Bank.

_____ (2004) *World Development Indicators 2004,* Washington DC: World Bank.

_____ (2005) *India and the Knowledge Economy: Leveraging Strengths and Opportunities,* Washington, DC: World Bank.

World Economic Forum (2004) "Technology Index" in the *Global Competitiveness Report 2003–2004,* Geneva: WEF.

World Trade Organisation (2004) International Trade Statistics 2004 online database, http://www.wto.org/english/res_e/statis_e/statis_e.htm.

_____ (2005a) *Annual Report 2005,* Geneva: World Trade Organization.

_____ (2005b) "Review of the Operation and Implementation of the Agreement on the Application of Sanitary and Phytosanitary Measures," G/SPS/36, Report adopted by the Committee on Sanitary and Phytosanitary Measures, 11 July 2005.

_____ (2005c) "Sanitary, Phytosanitary Measures Committee: Private Standards discussed as SPS Committee adopts two reports" News Items, 29–30 June 2005, Online http://www.wto.org/english/news_e/news05_e/sps_june05_e.htm.

Yonekura, S. (1994) *The Japanese iron and steel industry, 1850–1990 : continuity and discontinuity,* New York,NY: St Martin's Press.

Zahra, S. and G. George (2002) "Absorptive capacity: a review, reconceptualization and extension," *Academy of Management Review,* Vol. 27, pp. 185–203.

Zimmerman, M. A. and G. J. f. Zeitz (2002) "Beyond survival: Achieving new venture growth by building legitimacy," *Academy of Management Review,* Vol. 27 (3), pp. 414–431.

Author Index

W

Y

Z

Subject Index

كيفية الحصول على منشورات اليونيدو

يمكن الحصول على منشورات اليونيدو من المكتبات ودور التوزيع في جميع أنحاء العالم. استعلم عنها من المكتبة التي تتعامل معها أو اكتب إلى: الأمم المتحدة، قسم البيع في نيويورك أو في جنيف.

如何购取工发组织出版物

工发组织出版物在全世界各地的书店和经售处均有发售。 请向书店询问或写信到纽约或日内瓦的联合国销售组。

HOW TO OBTAIN UNIDO PUBLICATIONS

UNIDO publications may be obtained from bookstores and distributors throughout the world. Consult your bookstore or write to: United Nations, Sales Section, New York or Geneva.

COMMENT SE PROCURER LES PUBLICATIONS DE L'ONUDI

Les publications de l'ONUDI sont en vente dans les librairies et les agences dépositaires du monde entier. Informez-vous auprès de votre libraire ou adressez-vous à: Nations Unies, Section des ventes, New York ou Genève.

КАК ПОЛУЧИТЬ ИЗДАНИЯ ЮНИДО

Издания ЮНИДО можно купить в книжных магазинах и агентствах во всех районах мира. Наводите справки об изданиях в вашем книжном магазине или пишите по адресу: Организация Объединенных Наций, Секция по продаже изданий, Нью-Йорк или Женева.

CÓMO CONSEGUIR PUBLICACIONES DE LA ONUDI

Las publicaciones de la ONUDI están en venta en librerías y casas distribuidoras en todas partes del mundo. Consulte a su librero o diríjase a: Naciones Unidas, Sección de Ventas, Nueva York o Ginebra.

Printed in Austria
by Ueberreuter – November 2005

UNIDO publication
Sales No. E.05.II.B.25

ISBN 92-1-106432-5

The Industrial Development Report 2005, UNIDO's flagship publication, addresses two key questions. First, why have most developing countries failed to narrow the gap in income and productivity with more advanced economies? Second, what strategies and policies can those countries adopt to build the capabilities that are necessary for catching-up under the current international environment?

From the perspective of domestic policy making and international cooperation, more effort – both in terms of ideas and resources – needs to be directed to structural issues so far largely neglected, where substantial degrees of freedom remain vis-à-vis the WTO rules. These issues largely relate to the building and co-evolution of domestic institutions that promote private sector development and domestic capability building. In a world increasingly driven by innovation, framework conditions that are a prerequisite of economic catch-up have been transformed so as to encompass the various dimensions of innovative development as key ingredient.

With this in mind, the Special Topic Section of the Report first takes stock of lessons learned throughout modern history. On this basis, it then provides a framework for operational policy analysis as well as a methodology for the assessment of capability building needs to help overcome clear limitations in the current understanding of economic development.

The Second Part of the Special Topic focuses on the interactions between the knowledge, business innovation and policymaking subsystems, and addresses the policy capabilities that are necessary to overcome the often intractable problem of matching demand and supply of innovative resources. Two specific areas – food safety requirements and standards – are explored to highlight these interactions and test the suggested policy analysis framework.

The Second Section of the Report reviews industrial activity worldwide including measures of technological advance following the tradition of previous Industrial Development Reports. The interaction of industrial and technological advance yields a new indicator, the industrial-cum-technological-advance index, which highlights the significant structural differences between and within regions.

About the cover illustration:
The graph on the cover, generated by means of a fractal geometry model, simulates a pattern formed by three ring vortices playing catch up with one another (also called 'chaotic leapfrogging').

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, A-1400 Vienna, Austria
Telephone: (+43 1) 26026-0, Fax: (+43 1) 26926-69
E-mail: unido@unido.org, Internet: http://www.unido.org

9 789211 064315