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741

INTERNATIONAL COMPARISON OF NATIONAL POLICY INSTRUMENTS AND INNOVATION SYSTEMS FOR TECHNOLOGY DEVELOPMENT

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ABSTRACT

Effective national systems for technology development are underpinned by educational systems that are continually restructured, with an accent on technical and vocational education providing a growing pool of skilled workers and technicians, and fostering rapid expansion of engineering, business and computer education.

Sustained efforts on strengthening the skill base can convert enclave type labour-intensive operations into horizontally integrated manufacturing, with ever increasing development of manufacturing-complimentary service activities.

Fiscal incentives like grants and tax incentives can be put into operation only after a critical mass of this technically trained human resource is developed.

In addition to the creation of a pool of technically trained personnel who would emerge as techno entrepreneurs and skilled workers in other firms for effective networking, the State should encourage positive spillovers from foreign companies through a variety of instruments.

High level of education does not necessarily mean the automatic creation of technological dynamism and productivity catch-up if institutionalized inactivity in R&D is not averted.

What is needed is the type of national innovation system that facilitates new knowledge being generated by universities, exploited by laboratories and commercialized by firms. With such an environment for technological learning and innovation occurring, the sources of dynamic growth can adequately be fostered through the combination of technological, organizational, institutional and human capabilities.

A comprehensive analysis of policy instruments across selected countries reveals the effectiveness of the public innovation policy instruments, both fiscal and non-fiscal, that each country employs to stimulate investments in R&D in the enterprise sector with varying degree of success.

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A. THE PRIMACY OF INVISIBLE FACTORS AND INTERACTIVE FRAMEWORK

At the Crystal Palace Industrial Exhibition in 1851, American goods were at the center of attraction. The surprised British industrial stakeholders, whose forefathers emerged as the pioneers of industrial revolution a century ago, went to the US to find out the reasons. They realized that the productive functional literacy rate in the US was higher than that of England. In the 1980s when Japanese goods successfully penetrated the European and North American markets, the surprised industrial magnates of the US, whose forefathers transformed a great agrarian economy into a mighty industrial power after the civil war, went to Japan to find that functional literacy rate in Japan was higher than that of the US. Productive functional literacy rate is interpreted in this paper as the percentage of literates imbued with relevant production skills and production-related service capabilities capable of turning out products to capture market niches.

The above skills and capabilities to-day stem from national innovation systems in which universities, institutions, and dynamic firms interact with each other in order to enhance skills that are capable of commercializing new knowledge. European universities were established 600 years before the evolution of industrial revolution. The system of education in those universities had little impact on economic development in general and industrial development in particular for a long time because the then system of industrial production did not demand the type of knowledge and skills required for achieving efficiency gains in productive activities. If the pattern of industrial production today does not create the demand for the type of knowledge and skills required for integrating the local value chain into the global value chain, there will be “system failures”.

Available definitions of a national system of innovation point to new knowledge being generated and disseminated by universities, exploited by relevant institutions and commercialized by dynamic industrial firms that take active part in the process of globalization and capture market niches by continually effecting improvements in processing, design and marketing.

The following definitions by eminent resource persons on the subject merit attention:

“the network of institutions in the pubic and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies.” (Freidman, 1987)

“.. The elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge and are either located within or rooted inside the borders of a nation state.” (Lundvall, 1992)

“.. That set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation processes. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artifacts which define new technologies.” (Metcalfe, 1995)

“.. The national institutions, their incentive structures and their competencies, that determine the rate and direction of technological learning (or the volume and composition of change generating activities) in a country.” (Patel and Pavitt, 1944)

“. A set of institutions whose interactions determine the innovative performance.. of national firms.” (Nelson, 1993)

Such an interactive framework for knowledge dissemination and commercialization may be called the “invisible college” (Michael Best)

"The concept of the invisible college underscores the shared creation and diffusion of knowledge within technical or occupational communities that cut across companies. Here, knowledge is created and diffused in ongoing production activities as workers address challenges and devise new methods. The informal, skill formation dimensions associated with production are rarely examined and subjected to improvement. Nevertheless, they are important to understanding economic progress.

In fact, technology diffusion and skill-formation go hand-in-hand in industrial transitions. The technology diffusion process depends upon the skill formation level and capability built into the work organization of a region's enterprises. As a region's enterprises move up the production capabilities spectrum, these communities progressively advance in skills. The diffusion of technical knowledge takes place in hundreds in ways as individuals in different firms tackle common problems, share new methods, advance their skills, and move from firm to firm".

The national systems for technology development and innovation stresses that innovation and technology development stem from a complex set of relationships among actors in the system, where knowledge and skills constitute factors of production, and the actors include universities, research institutions, and enterprises. For policy- and decision-makers, understanding of the national innovation system can help identify leverage points for enhancing the innovative performance of firms, and competitiveness of products (OECD, 1997). Failure to network among actors and institutions in an interactive learning and innovative framework may make countries bystanders at the global technological feast.

National innovation system to live with new industrial realities

The new paradigm of production points to information-, R&D- and innovation-intensive production technologies, with operating models and organizational structures based on flexible specialization and inter-firm networking. Companies are being increasingly dependent on the complementary resources of other companies and on closer integration with one another with a view to strengthening collective response to competitive pressures. The effectiveness of the new paradigm of production depends on how quickly companies, the basic structures and institutions of society adapt.

The new industrial geography is characterized by networking. The effective implementation of regional policy and networking requires the organization of local governments and institutions in order to make them think globally and act locally and thereby effectively respond to all local and global challenges.

Successful clusters in dynamic industrial locations seem to work well within well-established institutional contexts, which are formed by local institutions of education, training, research and the diffusion of technological progress. The capabilities of firms are strongly affected by local externalities. The policy approach proclaimed should therefore be in favour of the convergence of factors that make the local environment conducive to facilitate networking both at local and transnational levels.

The above process points to the fact that innovation, e.g., enhanced capabilities to commercialize new knowledge, is the new industrial theology. As competitiveness is globalised and comparative advantage localized, what is needed is a global mind-set. Such a mind-set is essential for converting local comparative advantages into competitiveness and thereby enabling local value chain participate in the global value chain, which is increasingly being driven by technology, skills and knowledge in an efficient national industrial innovation system.

B. FACETS OF INTERACTIVE FRAMEWORK FOR TECHNOLOGY DEVELOPMENT

An ideal framework for technology development entails a degree of knowledge and skill flows in an interactive framework that is designed to reduce the distance to technological frontiers and thereby helping firms to withstand competitive pressures for efficiency gains and capturing market niches in an internationally competitive environment. R&D expenditures, patents, production and trade in R&D- and innovation-induced products indicate only a rough picture of innovation systems. Core types of knowledge and skill flows in national systems for technology development encompass (OECD, 1997):

Industry Alliances
- Inter-firm research cooperation

Industry/University Interactions
- Cooperative industry/university R&D
- Industry/university co-patents
- Industry/university co-publications
- Industry use of university patents
- Industry/university information-sharing

Industry/Research Institute Interactions
- Cooperative industry/institute R&D
- Industry/institute co-patents
- Industry/institute co-publications
- Industry use of research institute patents
- Industry/institute information-sharing

Technology Diffusion
- Technology use by industry
- Embodied technology diffusion

Personnel Mobility
- Movement of technical personnel among industry, universities and research institute

Inter-firm technical and research collaboration

Taiwan's R&D consortia formed in the 1980s and increasingly in the 1990s can stand as typical example of best practice in gaining synergies from complementary human and technical assets of firms and thereby gaining economies of scale in enterprise R&D and technical collaboration.[1]

Taiwan's success in climbing the ladder of technology upgrading rests on a capacity to leverage resources and pursue a strategy of rapid catch-up. Its firms tap into advanced markets through various forms of contract manufacturing, and are able to leverage new levels of technological capability from these arrangements. This is an advanced form of "technological learning", in which the most significant players have not been giant firms (as in Japan or Korea), but small and medium-sized enterprises whose entrepreneurial flexibility and adaptability have been the key to their success in reducing the distance to technological frontiers.

[1]The information on Taiwan's R&D consortia draws on Mathew, J *Catching-up Strategies in Technology Development – With particular reference to East Asia*, background document, UNIDO Industrial Development Report 2003.

Box 1. Rapid Response of Taiwan's R&D Consortium

When IBM introduced a new PC based on its PowerPC microprocessor, in June 1995, Taiwan firms exhibited a range of computing products based on the same processor just one day later. Again this achievement rested on a carefully nurtured R&D consortium involving both IBM and Motorola, joint developers of the PowerPC, as external parties (Mathews and Poon 1995). These successes were followed up by many more such R&D alliances in digital communications and Multimedia areas. Taiwan is emerging as a potentially strong player in the automotive industry, particularly in the expanding China market, driven by its development of a 1.2 liter 4-valve engine; again, this is the product of a public-private collaborative research endeavor involving three companies, which have now jointly created a new Taiwan Engine Company to produce the product. Thus, the R&D consortium is an inter-organizational form that Taiwan has adapted to its own purposes as a vehicle for catch-up industry creation and technological upgrading. The microdynamics of the operation of these consortia, is therefore a matter of some substantial interest."

Source: Mathews, J.A. and T.S. Poon (1995). Innovation alliances in Taiwan: The case of the New PC consortium,' Industry in Free China, 84(6).

The success in technology upgrading was due largely to the efforts of public sector research and development institutes, such as Taiwan's Industrial Technology Research Institute (ITRI) which since its founding in 1973 has acted as the nerve centre and propellant of leveraging of advanced technologies from abroad, and for their rapid diffusion or dissemination to Taiwan's firms. The role of ITRI helped small firms overcome the scale disadvantages. Drawing on ITRI-induced scale advantage inter-firm R&D alliance dramatically enhanced firms' own adaptive capabilities in collaborative product development, leading the country's strong performance in communications products.

These consortia have been generally successful and some of them are more successful than others - but all seem to have learned organizational lessons from the early cases where government contributed all the funds, and research tasks were formulated in generic and overly ambitious terms for the companies to take advantage of them. The more recent R&D alliances have been more focused, more tightly organized and managed, and have involved participant firms much more directly in co-developing a core technology or new technological standard which can be incorporated by the companies, through adoption and adaptation, in their own products.

Collaboration between university/public research institute and industries serving as a source of dynamic growth

As the knowledge economy underscores the critical role in technological innovation, collaboration between universities/public research institutes and enterprises has become the center of many studies to find answers to a number of relevant questions:

- Is the linkage between universities/research institutes and industry a dynamic growth impulse across countries that emerged as first and second generations of newly industrializing countries and dynamic industrial locations?
- What have been the benefits and costs of these linkages to the universities/research institutes from the industry perspectives?
- Is there empirical evidence bearing testimony to such linkages leading to the commercialization of new knowledge?
- What policy instrument and mechanisms or institutional relationships have effectively fostered such linkages?
- What are the legal norms that effectively foster a high a degree of effective collaboration between university/research institute and industries?
- Is there consensus on best practices in industry-university/research institute cooperation?

As entrepreneurial skills do not automatically enable entrepreneurs to become scientists, the reverse is also true for scientists who cannot use their scientific skills to become dynamic entrepreneurs. An attempt to promote technology and commercialization of new knowledge should not overlook this truism. It is therefore important to establish effective linkages between scientists and entrepreneurs to commercialize research findings. For example, the Medicinal and Aromatic Plant Research Centre, Khartoum, Sudan, has collected a wealth of information from isolated villages of Sudan on the medicinal uses of rare plants that are worthy of patent rights. But related research findings of the Centre turned out to be a dead investment because of the complete absence of commercialization of those findings.

Yet another example relates to the activities of the International Institute for Tropical Agriculture in Nigeria. The Institute has done substantive research on the production of cassava-based downstream products. But one hardly finds those products in the market due to the lack of commercialization in close cooperation with enterprises.

Most of the traditional knowledge that is resident as communities of practice in developing countries is likely to be lost if the national innovation system fails to convert them into patents and thereby commercialize existing research findings. For example, neem is a tropical tree and most of its uses have been in developing countries, the patent holders are mostly from developed countries (see Table 1). Sudan and Nigeria do not figure among the patent holders listed in the following Table despite an array of research findings of relevant institutions in those countries. If there is no focused efforts research on converting traditional knowledge and uses of bio-products into intellectual property, such countries will be deprived of many opportunities. What is needed is an interactive institutional framework where research laboratories, firms and universities network in the pursuit of commercialising traditional knowledge and uses of products.

Table 1. Patents issued on products derived from neem by country, 1979-2001

Patent issuer	1979-83	1984-88	1989-93	1984-98	1999-2001	Total
Australia	-	-	9	15	-	24
Canada	-	-	5	7	-	12
China	-	-	-	3	1	4
Germany	-	2	3	5	-	10
Egypt	-	-	1	-	-	1
European Patent Office	-	-	6	14	2	22
Great Britain	4	-	1	1	-	6
Greece	-	-	-	4	-	4
Hong Kong	-	-	-	2	-	2
Ireland	-	-	-	1	-	1
Israel	-	-	1	4	-	5
India	-	1	4	3	-	8
Japan	-	-	2	2	-	4
Korea	-	-	-	1	-	1
New Zealand	-	-	3	4	-	7
African Organization	-	-	-	1	-	1
USA	-	3	6	29	8	46
WIPO	-	-	3	9	3	15
Zimbabwe	-	-	1	4	-	5
Total	**4**	**6**	**45**	**109**	**14**	**178**

Source: Bowonder, B *(2001)*, "Globalization of R&D: the Indian experience and implications for developing countries", *Interdisciplinary Science Reviews*, vol. 26, No. 3.

A long-term vision is needed to achieve such an endeavour. It is crucial for developing countries to identify promising resource-based products, benchmark best practices in processing, design and marketing of those products, and identify viable avenues of replicating best-practices in order for them to make optimal use of the natural resource endowments.

A mere increase in R&D expenditure over the years may not have significant impact on *per capita* GDP. In fact, there is evidence of negative correlation between R&D expenditure and industrial productivity in a number of countries. It would therefore be wrong to assume that there is atomicity in the relationship between increased R&D spending and productivity growth. It is crucial to conduct technology audit to see what research findings of local universities and research institutions have the prospects for commercialization by private enterprises.

When the source of R&D finance shifted gradually from public to the private sector within the framework of contractual arrangements, industrial productivity was significantly enhanced in a number of countries, e.g., Republic of Korea and Finland (Watkins and Agapitova, 2004). Designing research grant programmes to help research institutes and private enterprises forge research arrangements and technology commercialization partnerships is crucial to erase the commercial vacuum research findings. Such programmes should be based on the tenets and contours of proven best-practices across countries.

Recommending an ideal system of national innovation for Latvia for the 21st century, Watkins and Agapitova (2004) suggest: "Facilitate matchmaking services with foreign laboratories and enterprises: Latvia should establish one centralized network where potential foreign partners can go to find R&D capabilities and industrial partners. In India, for example, the Council of Scientific & Industrial Research, (CSIR or Brain Bank) links 40 government research institutes and provides a comprehensive directory listing scientists by area of expertise. In addition to maintaining a centralized database, the database managers should make a proactive effort to bring theses research capabilities to the attention of venture capital firms in the US, Europe and elsewhere. The purpose of this outreach effort would not be encourage venture capital firms to invest in Latvia, although that may be secondary benefit. Instead the objective would be to encourage their portfolio firms to consider Latvia as a potential source of low cost, high quality contract research expertise that can help solve critical technical problems."

Embodied technology diffusion

An empirical analysis of embodied technology diffusion in 10 OECD countries (Papaconstantinou, Sakurai and Wyckoff, 1996), using a methodology whereby the purchases of intermediate and capital goods act as carriers of technology across industries and countries, show that while innovations are developed mainly in a cluster of high technology manufacturing industries, a different cluster of industries in the services sector are the main acquirers of technologically sophisticated machinery and equipment. R&D performance is more concentrated than technology use.

The findings also bear testimony to less than 50 per cent of the total acquired technology for every country being channeled through capital investment. Imports are also an important method of technology acquisition, rising significantly in all countries with the single exception of Japan. In intensity terms, imported technology is more important than domestic technology for all countries, excepting the US, Germany and Japan. The US is the most important source of technology for all OECD countries, and the information technology (IT) cluster of industries is the main source of technology acquired in most countries, rising significantly over the years. It is being increasingly proved that while performed R&D and embodied R&D are important sources of productivity growth, an open trade and investment regime are important elements in technology catch-up that reduced the distance to technological frontiers.

Inter-industry knowledge and skill flows

Knowledge and skill flows are facilitated by worker mobility to industries that are more similar to their industry of origin (Saxenian, 1994), and the degree of similarity is measured by input-out flows between industries. There is a considerable literature on the subject supporting the contention that workers are the conduits through which knowledge is transferred across firms, leading to significant increase in productivity and wage gains.

It is generally believed that in a high employment and high growth environment workers with accumulated knowledge and skills could usefully deployed from declining industries to rising industries, leading to optimal allocation of labour. In contrast, in high unemployment and slow growth environment, even if workers have accumulated knowledge and skills, there may be limited labour mobility.

Empirical evidence conducted by Hollanders and Weel (1999) compares the changes in skill structure in six OECD countries between 1975 and 1995. Evidence is found that technical change is largely skill-biased, favoring high-skilled labour and that employees literally working on R&D benefited less than who supervise and use the implemented parts of the advancements of R&D and increased R&D efforts. The policy implication is crystal clear: Understanding how to invest wisely in R&D is crucial for nations with high unemployment and slow growth. In the absence of a well-functioning national industrial innovation system that facilitates R&D and innovation in the above fast–growing areas, there will be a number of missed opportunities for developing countries.

Factors that strengthen the innovativeness of Japanese electronics industry are vividly depicted in Table 2.

Table 2. Factors responsible for high innovativeness of Japanese electronics industry

Aspect	Factor
Technoware (facilities)	1. Intensive application of integrated manufacturing 2. Large investment for continuous upgrading of facilities 3. Continuous scanning of technology 4. Large investment for quality control
Humanware (skills)	1. Skill to convert ideas into innovative products 2. Transfer of engineers from research to production for skill development 3. Intensive corporate level skill development efforts 4. Operator-engineer communicative skills are well developed 5. Technology assimilation skills are highly evolved
Infoware (facts)	1. On-line information availability 2. Detailed forward looking assessments 3. Standard for products jointly derived 4. Firms holding large share of patents
Orgaware (framework)	1. Separate centers for VLSI development by corporations 2. Three-year industry plans prepared by consensus 3. Inter-industry collaboration 4. Use of diverse technology acquisition arrangements 5. Long-term technology development projects 6. MITI coordinates inter-industry aspects 7. Rigorous standardization 8. Commitment for technology upgradation 9. Incentives for technology development 10. Concern for high quality 11. Intense interaction between design/engineering/production/marketing functions 12. Intense technology development efforts 13. Risky projects are not rejected 14. Objective long-term cooperative technology development projects among firms 15. Well-developed subcontracting network

	16. Presence of large diversified but vertically integrated firms 17. Detailed planning for technology development in thrust areas
Technology climate (national supporting systems)	1. Will to succeed in the market place 2. Low cost of capital 3. Emphasis on technology in education 4. Liberal import of technology for manufacturing 5. Publication of a large number of technical journals and books 6. Operator-engineer relationship is cordial and smooth 7. Technology parks and science cities 8. Plans for developing technology-intensive cities 9. Informationalization of society as a national objective
Source: Bowonder B. and Miyake T (1988), "Measuring innovativeness of an industry: an analysis of the electronics industry in India, Japan and Korea" Science and Public Policy, October	

C. POLICY IMPLICATIONS: LESSONS FROM SINGAPORE, MALAYSIA & INDIA[2]

Sources of innovation can be ascribed to formal R&D activities by research institutes, universities, and firms and to an array of non-R&D activities, e.g., the purchase of capital goods. Developing countries are generally considered to be platforms for enclave type assembly operations or at best imitators of technologies, which are generally imported from developed countries. Firms in developing countries are not expected to commit resources to R&D for just re-inventing the wheel. The opening up of their production and trade regimes could facilitate the flow of technology. What is needed is adaptive R&D in view of imported technology being adapted to local conditions. According to Mani (2002), this familiar argument assumes much less significance in the context of a small number of developing countries becoming creators of technologies in their own right. Dwelling on lessons from Singapore, Malaysia, India, South Africa and Brazil, Mani (2002) argues that a mere fine-tuning of the financial instruments, while necessary, is not sufficient enough and that for financial instruments to succeed, non-fiscal policy instruments are required, the most important of which is the policy on human resources development.

Singapore: Sequencing of policy instruments matters

The electronics industry of Southeast Asia began in Singapore following an investment mission to the United States in 1967 to establish Singapore as an offshore enclave assembly platform. In the same year Texas Instruments set up a semiconductor assembly plant to assemble and test simple integrated circuits for re-export to the United States. Following the American influx, transnational corporations from Europe and Japan made deep inroads into the same field in Singapore. Reflecting national specialization, American transnational corporations tended to invest in electronic components (semiconductor and disk drive assembly) and industrial electronics (computer and telecommunications) and Japanese primarily in consumer electronics and electrical products. Singapore's highly responsive education system has enabled local operating units to successively develop high value-adding production activities from the home bases of transnational corporations.

Since the 1960s, the educational system has been continually restructured, with an accent on technical and vocational education below tertiary level to provide a growing pool of skilled workers and technicians; and rapid expansion of engineering, business and computer education at tertiary level. Around 40 per cent of the graduates from polytechnics and universities were trained in engineering and technical areas. The proportion of students enrolled in polytechnics and universities

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[2] This section draws largely on the research findings of Sunil Mani (2002), whose in-depth research on the changing role of governments in selected countries in respect to domestic technology development efforts, highlight the policies and instruments that worked and failed to work in strengthening national innovation systems.

is targeted to reach 60% in 2001. Formal education is supplemented by training in specialized industrial training institutes to produce qualified craftsmen and technicians. The establishment of the Skills Development Fund provides upgrading training for those already employed.

As a result of sustained efforts on strengthening the skill base, Singapore's electronics industry was strategically converted from a labor-intensive manufacturing operations platform for vertically integrated MNCs to a horizontally integrated manufacturing services cluster with ever increasing development of manufacturing-complimentary service activities such as engineering-intensive product redesign and process automation and complementary business services associated with regional coordination, procurement, development, and integration activities.

The principal objective of the innovation policy in Singapore is to enhance local development of technology through the medium of technology-based small and medium enterprises. The key to this was the creation of a pool of technically trained personnel who would emerge as techno entrepreneurs and also as skilled workers in other firms. At the same time the state encouraged positive spillovers from foreign companies operating in the country through a variety of instruments. Fiscal incentives like grants and tax incentives were put into operation only after a critical mass of this technically trained human resource was developed. In short, the country placed much emphasis on human resource development in the earlier years and subsequently on fiscal measures. This is an ideal sequencing to follow for other countries.

The main institutional structure for S&T policy in the country used to be the Singapore Science Council. This was revamped in 1991 to become the National Science and Technology Board (NSTB) under the Ministry of Industry and Trade. All major policies with respect to innovation are formulated and implemented by this agency though in the very recent past some of it has been passed on to another governmental organization, namely the Economic Development Board. The policy instruments and institutions, which the country has used in increasing its R&D intensity, can be broadly categorized into four components, namely those:

- Increasing the supply of technically trained human resource;
- Establishing and further improving physical technological infrastructure
- Assuring in various types fiscal incentives.
- Promoting techno entrepreneurship and venture capital;
- Engineering increased positive spillovers to local companies from foreign companies

As a result, today Singapore is able to produce small hardware parts with high degree of precision and participate effectively in product areas that are characterized by monopolistic and oligopolistic conditions.

Box 2. R&D and innovation advantage over comparative cost advantage in Singapore: Evidence from the experiences of selected enterprises

Many entrepreneurs find manufacturing in Singapore ideal because transnational corporations look for local producers to meet their needs and were willing to groom them. Government agencies help, by bringing the big firms in to push the small boys in the local industry to international standards.

When recession hit in 1997, many long-term customers transferred projects overseas to whoever offered them the cheapest deals. 'The logical move was to follow the customers abroad but the company Wangi moved from printing to the optics and photonics industry instead, supplying optical components to advanced display producers.

Given the high cost of manufacturing in Singapore, Wangi decided to move some low cost operations to facilities in Shanghai. However, Singapore remains the company's base for higher-end precision optics manufacturing, and will be for the next five to 10 years at least. Singapore still presents many advantages over low-cost regions in China. For one, a strong talent pool is especially important, given the constantly advancing photonics industry Wangi operates in. Linkages with research institutes was what first got the company started on more high-end production of optical components for use in the biomedical industry. Human resource is another key factor that keeps the company firmly rooted in Singapore.

Toyo Packaging Industries continued its manufacturing in Singapore despite falling demand and rising operating costs. Having moved away from low-end production altogether, the company could not shift some of its operations overseas while keeping high-end manufacturing in Singapore as companies in other industries did. The company tackled part of a shrinking market by exporting 40 per cent of its sales and continued to produce high value added products due to an enabling environment offered by the country's industrial innovation system

Source: Economic Development Board (EDP, 2004), "EDP Series on local manufacturers", The Business Times, March 24 and 30.

Malaysia: Need to fine-tune human resources

In contrast to Singapore's star performance, Malaysia's electronics industry is stranded at the bottom of the ladder of value added. It accounts for half of Malaysia's total exports and employs a quarter of the manufacturing labor force.

Box 3. Malaysia caught between lower wage and higher performance rivals

The competitive advantage of Malaysian electronics has shifted from low wage, labor-intensive manufacturing activities organized by foreign-based multinational companies (MNCs) to low cost, rapid ramp-up, high volume, increasingly automated manufacturing activities with special capabilities in assembly, testing, and packaging of semiconductors and hard disc drives. Nevertheless, the Malaysian electronics industry has reached a critical impasse: it is caught between lower-wage rivals that are imitating Malaysia's present production capabilities and higher-performance rivals with superior production and innovation capabilities. Raising per capita income depends upon developing higher value adding production activities.

Source: Best M. (2001), Globalization and Localization of Value Networks, Background Paper, UNIDO Industrial Development Report 2003, Vienna.

In terms of incentive systems and institutions, the country compares very favourably with Singapore and indeed even with developed countries such as Japan and the US. However, in terms of enrolment ratios at the tertiary level, the country does not rank high compared to Singapore, Japan and the US. However, it is not merely to increase the enrolment ratio *per se*, but enrolment in Science and Technology related subjects that matter. Until the government commits itself to a concrete strategy in this direction, mere provision of even sophisticated fiscal instruments for encouraging innovation is unlikely to bear fruits. It must be emphasized that on the demand or innovation side, enterprises in both Malaysia and Singapore are subjected to the same or very similar pressures in view of their export-oriented manufacturing sector. Another important contrast between the two countries is the fact that Malaysia does not have any specific instruments to engineer positive spillovers from the numerous transnational corporations that operate in its manufacturing sector. This is because the country does not have a strong technology-based small and medium sector that can be a stable source of supply. What Malaysia lacks is some fine-tuning in its human resources development policy.

India: Largest pool of scientists and engineers matters less

By international standards, the technological infrastructure of India is fairly sophisticated, but less than proportionate to the potential. Despite country being blessed with the largest pool of scientists and engineers, the country's innovation- and research-intensity is one of the lowest. Limited research grants for enterprise-level research is largely utilized by public sector enterprises. The network of institutions and their interactions with labs and enterprises, despite efforts to enhance it in recent years, are still not extensive due partly to low demand for innovations from the enterprise sector.

The paradox of having the largest pool of scientists and engineers and their shortage for R&D and innovation at the enterprise level will need to be addressed with an effective proactive innovation policy that spells out more attractive incentive systems for enterprise R&D.

The above overall sombre picture of enterprise R&D- and innovation-intensity should not be allowed to eclipse innovation that occurs across selected enterprises:

Box 4. Tata Indica: An innovative Indian car with 100 per cent indigenous components

The Indian market for passenger cars was dominated by two car makers for several decades. In the face of liberalization in the 1990s, there was a proliferation of Indian-made foreign cars. The process of liberalization and global connectivity enabled auto makers learn the new realities of the industry, and eventually leading to the emergence of an Indian producer as a successful producer of a 100 per cent indigenous car of world standards.

An innovative initiative of a leading automobile producer in India resulted in a 100 per cent indigenous Indian car of world standard designed around the specific needs of the Indian market:

- Easy entry and exit for passengers; this meant a higher suspension and raised back seats
- World-class standards of safety
- The economy of diesel
- Price approximating the Maruti 800
- Contemporary design.

With these as the specs, the company's designers at its Engineering Research Centre (ERC) created some renderings (see illustrations alongside) of the car which were refined and finalised in association with the famous Milan-based design house, I.D.E.A.

- Total number of engineers who worked on the Indica project: 700.
- Time taken from conception to completion: 31 months.
- Number of components specially developed for the Indica: 3,885
- Number of dies specially manufactured for the Indica: 740
- Number of production fixtures created for the Indica: 4,010

Tata Indica is on the road now, and capturing a significant share of the market, with success in external market penetration. The car is also competing against global payers who are present in the Indian market: General Motors (Opel-Astra), Ford (Escort, Ikon), Hyundai (Accent, Santro), Daewoo (Cielo, Matiz), Fiat (Uno, Sienna), DaimlerChrysler (Mercedes), Suzuki (Maruti 800, Zen, Esteem, Baleno and Alto) and Mitsibushi (Lancer). All these carmakers have introduced products in the Indian market that they have developed abroad.

Source: Ajay Kumar, Ideas that have worked: the Indian car – www.telcoindia.com.

Bowonder and Mani (2002) observe that venture capital is emerging as an effective propellant of innovation and entrepreneurial growth and that there is a strong need to enhance the availability of venture capital. Drawing on a number of case studies, Bowonder and Mani suggest that distortions in the capital market due to over regulations and multiple controls are a problem that is hindering the growth of venture-capital-induced innovation. Their observations point to the fact that venture capitalists bring the balance between business and technology so that innovation becomes a commercial success.

D. INTER-COUNTRY COMPARISON OF R&D AND INNOVATION INTENSITY AND POLICY INSTRUMENTS

By the late 1990s, Singapore had around 79 scientists and engineers per 10,000 labour force, compared to 6 in Malaysia in 1998 and 8 in India in 1996. The high R&D and innovation intensity of Singapore is due largely due to the fact that a large majority of scientists and engineers were actively involved in R&D and innovation. The educational policy of Singapore encouraged a number of well-known foreign universities to establish their branches in the country, and having completed science and technology related subjects, students were seldom encouraged to join government departments as civil servants. Rather, they were encouraged to emerge as entrepreneurs and to be engaged in R&D and innovation with the aid of proper incentive systems, both fiscal and non-fiscal. In contrast, of the 8 scientists and engineers per ten thousand labour force in India, hardly one was actively engaged in R&D and innovation. Once they join institutions and enterprises, most of them are more administrators than scientists. The situation can be called “institutionalized inactivity in R&D in innovation”, implying that they has a large number of research institutions, scientists and engineers, with little involvement in enterprise R&D and innovation. Malaysia had 6 scientists and engineers in 1998, with very limited number of them involved in R&D and innovation. The sharp contrast between Singapore and Malaysia is corroborated by Singapore winning in 1999 patents, compared to 20 by Malaysian inventors.

Performance of Singapore, Malaysia and India on the UNIDO Scoreboard of competitive industrial performance (CIP)

A number of parameters can be used to measure R&D and innovation intensity. An attempt is made in this section to see the extent to which the degree of such intensity and the findings furnished in the preceding sections are corroborated by UNIDO findings (UNIDO, 2004).

Table 3. Competitive Industrial Performance (CIP) Rankings of Singapore, Malaysia and India on UNIDO Scoreboard and Selected Performance Indicators, 2000

CIP Rank	Country	MVA per capita (dollars)	Manufactured exports per capita (dollars)	Share of medium-and high-tech activities in MVA (percent)	Share of MVA in GDP (percent)	Share of medium- and high-tech goods manufactured exports (percent)	Share of manufactured goods in total exports (percent)
1	Singapore	5 498	33 106	87.6	28.2	78.3	96.8
15	Malaysia	1 369	4 121	65.1	35.9	73.3	93.3
40	India	90	38	58.4	17.4	19.7	85.8

Source: UNIDO (2004), Industrial Development Report 2004, Industrialization, Environment and the Millennium Development Goals in Sub-Saharan Africa: The new frontier in the fight against poverty, Vienna.

Note: Four performance indicators – manufacturing value added (MVA) per capita, manufactured export per capita, industrialization intensity (the arithmetic mean of the share of MVA in GDP and the share of medium and high technology (MHT) activities in MVA, and export quality (the arithmetic mean of the share of manufactures in total exports and the share of MHT products in manufactured exports) – were chosen as the components of the CIP index. For details, see UNIDO (2004), Industrial Development Report 2004, Industrialization, Environment and the Millennium Development Goals in Sub-Saharan Africa: The new frontier in the fight against poverty, Vienna, pp. 208-209.

Of the 93 countries selected for the UNIDO scoreboard exercise, Singapore tops the list, Malaysia ranks 15, and India scores the 40^{th} rank. Gauging their performance in 2002 in terms of selected parameters merits attention. As can be seen from the following Table, both Singapore and Malaysia enjoy a high share of MHT products in manufactured exports, 78.3 per cent and 73.3 per cent respectively in 2000, compared with 19.7 per cent for India. While Singapore increased the share of value added products in its export profile of MHT products due to enhanced domestic capacity building in terms of R&D and innovation intensity, Malaysia's export profile is continued to be dominated by low valued added products that are continued to be induced by foreign direct investment (FDI) in enclave type operations. As the structure of MHT product profile differ, the reasons for achieving competitiveness in different product areas are also different.

While the share of MHT products in MVA stood at 58.4 per cent in 2000 for India, the structure of industrial production was not akin to the global reality as evidenced by 19.7 per cent of those products on the country's profile of manufactured exports.

Table 4: Structure and content of innovation policy in Singapore, Malaysia, and India

Country	Fiscal Instruments			Non- Fiscal Instruments
	Tax Incentives for R&D	Research Grants	Government backed Venture Capital	
Singapore	**Double deduction on R&D expenses for both manufacturing and services**	Research incentive schemes for companies innovation development scheme Funds for industrial cluster **Promising local Enterprises Scheme**	Techno-entrepreneurship **fund: the government launched a US$ 1 billion investment fund to attract more venture capital activities to Singapore**	Strengthening tertiary education in S&T fields at the university and polytechnic levels; Engineering positive spillovers to local small and medium enterprises from FDI **Strengthening the technological infrastructure by setting up 13 GRIs in areas of high technology**
Malaysia	**Nine different types of tax incentives for R&D**	Industry R&D Grant scheme Technology acquisition fund Intensification of research in priority areas Commercialization of R&D fund Multimedia grant scheme	**No specific policy on venture capital industry**	**No clearly articulated**
India	**A variety of direct and indirect tax incentives for R&D,but are poorly administrated**	Programme aimed at technological self-reliance Fund for technology development and application Home grown Technology programme **Technology projects on mission mode**	Government backed venture capital funds **Reasonably well articulated public policies for the development of venture capital**	

Source: Mani S (2002), Government, innovation and technology policy: An international comparative analysis, London.

E. AN AGENDA FOR ACTION

Much of the traditional wisdom about how companies compete in an internationally competitive environment needs to be overhauled. It is becoming increasingly evident that R&D at all levels is crucial, not necessarily to innovate new things but to learn, acquire, and adapt new technologies. One of the major reasons for the emergence of dynamic industrial locations across countries is ascribed to the presence of high quality academic institutions in those locations and an excellent academic culture that constantly disseminate knowledge for commercial exploitation by intermediate institutions and firms. These institutions act as nuclei for growth by the creation of talent. University- R&D institutions and linkages act as potential sources of dynamic industrial growth in those regions. The message is clear: strengthening of the national industrial innovation system comprising universities, institutions and firms is the panacea for fostering industrial progress.

Industrial R&D and innovation is one of those activities, which cannot be left entirely to either public research institutions or the private sector. The arguments for this are now fairly well known to be recounted here. Governments will need to put in place a whole host of essentially support systems and instruments. Given this state of affairs, there is no need to commit resources to R&D for just re-inventing the wheel. At best what is expected is to conduct some adaptive R&D since all technologies are location-specific and consequently any technology that is imported from abroad will have to be adapted to local conditions.

The basic issue relates to whether developing countries can stimulate investments in R&D in its enterprise sector by merely fine tuning financial instruments, such as research grants and tax incentives that generally stimulate this activity. For financial instruments to succeed and bear fruit, what is required is non-fiscal policy instruments and the most important is the policy on strengthening the industrial innovation system. It is necessary to reiterate that as evidenced by the experience of Singapore, the financial instruments for promoting industrial R&D can succeed only if the country has high density of technically trained personnel who can engage in R&D and innovation in an institutional framework that is conductive.

Enhanced capabilities are often measured by the number of patents registered by local firms with no affiliation to foreign firms. It may be worth asking where do developing countries' firms stand in this sphere? Most of the firms do not seem to undertake R&D but do engage in a number of non-R&D but technology generating activities such as purchase of capital goods, improving plant layouts, or even disembodied technologies from abroad. While this may be so in the short run, to emerge as an industrially more developed country the enterprise sector will require investments in at least R&D of the adaptive type.

Fostering R&D and Innovative Efforts

Having increased the density of scientists and engineers engaged in R&D and innovation, determined efforts should be initiated to disseminate scientific information with commercial potential, and to generate commissioned research projects. A new and strong acknowledgement of the necessity of developing appropriate linkages between basic research, applied research, industrial activities and national objectives should be encouraged among the scientists and the technical personnel, as well as among policy makers.

Facilitating Knowledge Dissemination and Industry University/Institution Linkages

Information is an important intangible resource input, and knowledge is a factor of production in modem industrial production systems. Information poverty makes entrepreneurs isolated. The lack of high quality, reliable and valid information makes entrepreneurs fail to learn right things - leading to waste of money, time, energy, income - and very often go out of business. The UK Competitiveness White Paper (1998) said: "the most dynamic economies have strong universities, which have creative partnerships with business". While all universities cannot emerge as vanguards of translating research findings into commercial orientation, insight into university research will need to come from intermediate support systems, instruments and institutions in order for university research to see the commercial marketplace. There is increasing evidence of universities across countries following the example of United States universities such as MIT, Stanford and Berkeley, which have become central to local and regional industrial dynamism by virtue of the fact that they produce people with knowledge and skills and generate new knowledge, serving as the seed bed for new industries, products, and services. They also constitute the nerve centre of effective business networks and dynamic industrial clusters. In order for university education to be relevant, the private sector should be actively empowered in curriculum development to ensure that education and training facilities adapt quickly to entrepreneurial needs.

Policy Interventions to enhance Indigenous Capabilities and Skills through Foreign Investment

Foreign investment flows to enclave-type manufacturing activities often fail to contribute to enhancement of indigenous innovative capabilities and skill development. Strategic policy intervention in terms of incentives and intermediate policy measures is needed to foster the innovative behaviour of foreign investments. A research agenda in this area should attempt to address the crucial issue of selecting appropriate criteria for allowing foreign investment. Country case studies are needed to learn lessons from the experiences of countries that have successfully enhanced their indigenous innovative capabilities and skills through foreign investment.

Acquiring Tacit Knowledge

It is important to formulate and implement policies to acquire tacit knowledge that enables firms to make effective use of such subsector-specific know-how. A quantum leap in technological capability is commonly associated with the arrival of technical people imbued with skills and up-to-date knowledge of production processes and marketing. They bring new tacit knowledge capable of enriching firms' technological base and tackling tasks that were previously beyond their competence. The mobility of experienced technical personnel is the most effective means of diffusing technology and, thereby, enriching competitiveness. For example, the aggressive recruitment of high calibre Korean-American scientists and engineers has been a major source of enhancing competitiveness. Korean firms have developed state-of-the-art products such as new automobile engines, semi-conductor memory chips, electronic switching systems, multi-media electronics, etc, due to acquisition of tacit know ledge through Korean- American scientists and engineers, who earned doctorates at America's finest universities and rose through the ranks of leading concerns in the US. Coveted jobs and attractive compensation packages were provided by the government and firms to attract such personnel, which eventually turned the brain drain into a brain gain. As most of them prefer to be associated with relevant institutions, provision should be made for accommodating such aspirations.

State-Societal Arrangements on International Competitiveness

State-societal arrangements influence competitiveness mainly through their impact on the speed of diffusion of new technologies. Labour must be receptive to the introduction of new technologies at the work place; business must be prepared to adopt new technologies in a timely manner, and state must be able to work with both business and labour to maximise the probability that new technologies will be created and diffused rapidly. The receptivity of labour to the introduction of new technologies in the workplace depends on instilling the confidence that higher wages follow productivity increases. This confidence depends on state-societal arrangements to guarantee job security through opportunities for training, to be offered by relevant institutions. In a rapidly growing technological age, when the weakness of labour is the result of a low societal commitment to raising the level of skills in the work force, there is bound to be extensive resistance to the introduction of new technologies in factories. Public institutional arrangements to ensure the means of upgrading skills in cooperation with the private sector are crucial determinants of enhancing industrial competitiveness.

Avoiding Distortions in Production and Application of Knowledge

There are many cases of systemic distortions affecting the ability to produce and apply knowledge towards enhancing competitiveness. Industrial policy initiatives attempt to address these distortions. Well-known sources of distortions relate to non-profit research institutions. Much of the innovations of these institutes is not linked to commercialisation, and consequently, they fail to appropriate the full economic benefits of accumulated knowledge or to represent their value as an asset in financial markets. An appropriate institutional framework within the perspective of public-private partnership for commercialising research findings is crucial.

Encouraging Multi-Stakeholder Partnerships

Multi-stakeholder partnerships entail involvement of government, industry associations, business groups, academics, scientists, local communities and inter- and non-governmental organisations to forge partnerships to enhance competitiveness. Such alliances with a wide range of experience and expertise contribute significantly by looking at the entire supply chain, where all stakeholders play their roles efficiently. The Geneva-based World Business Council for Sustainable Development (WBCSD) has set up a Working Group to look specially at the viability of forging such partnerships especially for "greening" the supply chain. WBCSD is currently engaged in devising innovative strategies for the future. The aim is to provide a benchmark that can help stakeholders compare the actual performance against ideal state in order to sharpen competitive tools.

Promoting Venture Capital/Private Equity

Venture capitalists are called business angels. Traditionally a large portion of the capital came from banks and other providers of risk money. But in recent years venture capitalists have been breaking through in funding innovative ideas leading to new business ventures. A good venture capitalist takes on a few carefully selected, highly promising businesses, not willing to spend time on businesses that are not going to grow big very quickly. As the new industrial realities are fast changing, venture capitalists are also emerging as portfolio managers, dealmakers and financial engineers, translating innovative ideas into promising business deeds.

Developing Internal Linkages and Networking

Interaction and interdependence among firms is one of the fundamental determinants of collective efficiency to withstand competitive pressures. When pursuing innovations, firms interact more or less closely, and interactive learning occurs in the context of established institutional framework. Institutional links and inter-firm networking are critical specifically for clusters and industrial districts since interactions are very much associated with collective learning e.g. within user-producer networks. Significant market links are also equally important at each stage of production. The Silicon Valley phenomena are beginning to diffuse to pockets of regional industrial dynamism across countries, and inter-firm networking for learning and innovation is becoming increasingly important.

In this context Regional Development Agencies (RDAs) play a crucial role. Best practices can be traced from the role being played by RDAs in dynamic industrial locations. For example, the Welsh Development Agency in Wales offers a comprehensive programme designed to meet the needs of small and medium enterprises in the region, assist technology transfer between companies, create links between academia and manufacturing companies committed to improvements in efficiency, and learn from others about the changing facets of competitiveness in general and skill development in particular. Yet another example is Scottish Enterprise. It plays a crucial role in bringing together local authorities, chambers of commerce and relevant organisations to support new business in the region. One can cite a number of similar examples of RDAs playing a crucial role in constantly injecting sources of industrial dynamism into the respective regions in developed and industrially more advanced countries. The experiences of these"-regions raise a number of issues for developing countries, which endeavour to replicate the best practices of successful RDAs in rendering an array of support services. These range from knowledge built-up in inter-ftrm collaboration and leads to advanced product and process development through global linkages, to training, advice, technical services, consultancy, testing facilities, design and quality standards, knowledge of legal stipulations, and marketing assistance.

To sum up,

Perhaps, Adam Smith (1776) was wrong in saying: “The end of production is consumption.” Today, it is being increasingly proved that the end of production is learning, and learning is continuous, serving as a constant source of innovation. The principal source of learning is “market niche,” and market niches can be captured only through enhanced adaptive capabilities that are generated by efficient national innovation systems.

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