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CATCHING UP IN A GLOBALISED CONTEXT: TECHNOLOGICAL CHANGE AS A DRIVER OF GROWTH

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Catching-Up in a Globalised Context: Technological Change as a Driver of Growth

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Abstract
This paper aims to understand the role that technology plays, particularly in structural change, as a driver of economic growth. Noting the exceptional few countries that succeeded in becoming a developed state and the accelerated period of globalisation (1995 – 2009), we analyse growth patterns at the product, sectoral and macroeconomic levels. Utilising trade data, we detail the type of complex products exported as a reflection of a nation's latent capabilities. At the sectoral level, technological shifts are observed through a TFP analysis to understand how countries use technological progress at varying development stages to realise economic growth. Finally, we use input-output analysis for a macroeconomic perspective on the impact of globalisation on production by sector and on demand patterns of foreign and domestic markets, both globally and regionally.

JEL: F620 Economic Impacts of Globalisation: Macroeconomic Impacts; O300 Innovation; Research and Development; Technological Change; Intellectual Property Rights: General; O470 Empirical Studies of Economic Growth; Aggregate Productivity; Cross-Country Output Convergence

Keywords: Technological Change, Development and Economic Growth, Structural change, International Trade, Convergence

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I. Intro

This paper is about the role of trade and country-level capabilities in economic development. It applies the perspective of *technology gap theory*, which is an over-arching view of how economic development is fuelled by the international diffusion of technological knowledge, and by the development of capabilities of economic actors who adopt this knowledge, and the institutions that facilitate this adoption. The technology gap theory, which is explained in more detail below, puts strong emphasis on the process of structural change that accompanies the application of technological knowledge in developing economies.

The Technology Gap Theory (TGT) of growth and structural change assigns crucial importance to international technology flows in explaining growth patterns across the globe. Pioneered by scholars such as Moses Abramovitz, Richard Nelson and Jan Fagerberg, it looks at inflows of foreign technological knowledge as a factor that potentially transforms and modernises the domestic economy. The assimilation of foreign knowledge is, however, conditional on sufficient social and other capabilities being present in the economy.

Such capabilities require a major and concerted investment in infrastructure, education, the political system, universities and other research institutes – in short institutions in a broad sense. Such investments are costly and take a high degree of state capacity. Economic policy, in particular industrial policy and innovation policy, plays a crucial role in the technology gap view of development. It is seen as a decisive factor for whether countries are able to catch-up to the global economic frontier (which, in the economic history of the last century, is an exceptional case), or will fall behind (the large majority of developing countries). Capability building facilitated by economic policy is the decisive factor. Countries that have successfully taken this route to development have therefore been characterised as developmental states (Wade, 1990). Developing these capabilities to become a developmental state is very difficult when a country starts from a low-development context. This may easily lead to a low-development trap from which only few countries are able to escape.

The most famous examples of countries that were able to follow the technology-assimilation road out of low development are the so-called Asian Tigers, and Japan. Their post-war economic history is well-documented, and shows how they actively assimilated foreign knowledge in gradual steps. Using the assimilated foreign knowledge, these countries were able to develop completely new manufacturing sectors and become competitive at a global scale. In this process, their economies transformed from largely agricultural societies to manufacturing and modern service economies.

This paper seeks to understand the role of technology in this development transformation vis-a-vis growth through three levels of analysis: i) measuring capabilities that are necessary for catching-up based growth by using product level data on trade performance of nations ii) analysing sectoral structural changes due to productivity shifts that can be attributed to technology and iii) macroeconomic inter-linkages between countries due to increased trade and demand (globalisation) by using input-output tables.

The analysis applies insights from a recent literature in which trade data are used to measure so-called latent capabilities, i.e., country-level capabilities that are not directly observed but reveal themselves through trade specialisations. We will apply a selection of methods found in this literature, and ask whether capabilities defined in this way are correlated to growth in the most recent decades.

Finding an affirmative answer, we then proceed to explore the nature of the capabilities measure in more detail. This is done by exploring so-called product space, which is loosely defined as the set of relations between the detailed product classes in the trade data, in terms of their commonalities of countries that are specialised in them.

We observe that particular groups of complex products within the product space have an impact on growth. We further explore this by understanding structural change due to technological change by looking at productivity shifts between sectors within a country and between countries. We ask, are within country sectoral shifts an important factor of growth? Is there evidence to support TGT that countries with high structural change and high technological progress tend to catch-up? Furthermore, how does technological progress look like at different stages of development? We seek to answer these questions by decomposing production factors and technological change (productivity growth rates) and analyse each factor contribution of value added to growth. To observe structural shift impact on varying levels of development, we use a locally weighted regression to map labour productivity changes as a proxy of technological progress as a function of development stages.

Finally, we conclude our analysis through a macroeconomic view by connecting structural change to globalisation and the sources (foreign or domestic) of demand across the globe. Using input-output analysis, we break down global GDP between the production location and the product's final destination and subsequently track by sector if value added is due to domestic or foreign demand. With the rise of globalisation starting in the mid-nineties, we continue our input-output analysis to see which sectors have become more global in demand, but also the changing sectoral demand patterns between regions by grouping countries by geographic proximity.

II. Catching-up and falling behind

Our analysis starts with a brief look at the post-WWII history of economic growth and development. We use Angus Maddison's database for this purpose, which documents GDP per capita trends for virtually all countries in the world (*The Maddison-Project*). We select all countries in the database with more than 1 million population in 2000, which yields 154 countries.

Some of these countries did not exist for the entire time span of 1950 – 2013. This is mostly associated with the breakup of the Eastern Bloc around 1990. Before 1990, we include Czechoslovakia, the Soviet Union, and Yugoslavia as single countries; from 1990 onwards, we use the countries that stemmed from these states. Thus, before 1990, we have 132 countries, from 1990 onwards, we have 151 countries.

We start by looking at the distribution of GDP per capita in these samples of countries, which is in Figure 1, which measures GDP per capita in 1990 international dollars in logscale on the vertical axis. The blue lines indicate borders between quintiles of the distribution at each year. Hence the bottom blue line is the minimum value and the top blue line is the maximum value. The second blue line from the bottom marks the border between the lowest 20% values and the next group of 20% observations, and similarly for the other lines. The black lines indicate the trends for GDP per capita of selected countries.

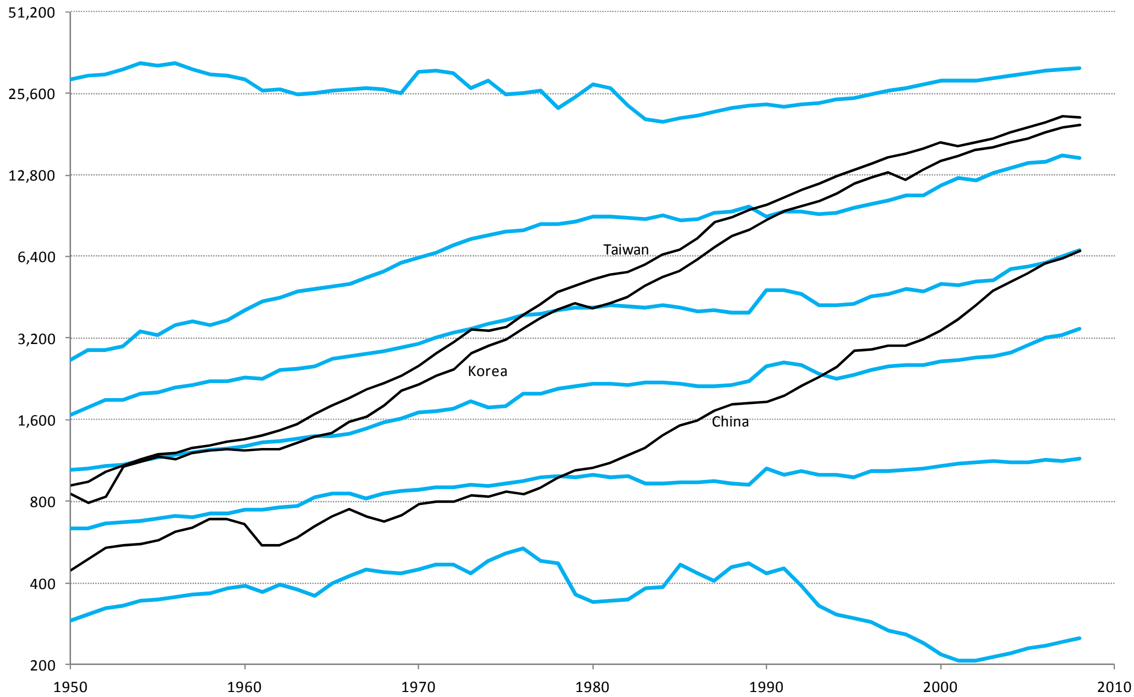


Figure 1. The distribution of GDP per capita, 1950 – 2008

The blue lines are interesting indications of trends at parts of the distribution. For example, the minimum and maximum values observed over roughly 50 years do not change much. More interestingly, the observed growth rates at the various quintiles show significant variation. This is documented in greater precision in Table 1, which tracks the growth rates for various periods at various positions of the distribution.

Table 1. Growth at various parts of the distribution

	Average annual growth rate over period:				
	1950-2008	1950-1980	1980-989	1995-2008	2000-2008
Minimum	-0.003	0.005	0.037	-0.013	0.017
20 percentile	0.010	0.016	-0.010	0.012	0.008
40 percentile	0.021	0.025	0.002	0.031	0.036
60 percentile	0.024	0.031	-0.005	0.035	0.036
80 percentile	0.030	0.042	0.009	0.034	0.030
Maximum	0.002	-0.001	-0.020	0.020	0.014

Over the long period 1950 – 2008, the (rich) countries at the 80th percentile grow at a rate of 3% per year. Each lower percentile shows a consistently lower growth rate over this period: 2.4% at the 60th percentile, 2.1% at the 40th, and only 1% at the 20th percentile. Thus, over this long period, we clearly see divergence in the distribution with the top-ranking (i.e., rich) countries growing significantly faster than the poor countries, thus making the distribution wider (in relative terms).

Looking at shorter time periods, we find that this long trend is especially associated with the period 1950 – 1980. In these 30 years, we find a magnified picture of the overall divergence trend with the growth rate declining strongly at each percentile. The 1980s show a major break with growth declining in the entire sample. Only the rich countries (80th percentile) manage to achieve some growth (close to 1%) during this decade.

We skip the period 1990 – 1995, because trends during these years are strongly influenced by the transition from 132 to 151 countries. From 1995 onwards, we see much more convergence, especially in the most recent part of this period, i.e., 2000 – 2008. During 1995 – 2008, the 40th and 60th percentile grow roughly as rapidly as the 80th percentile, and during 2000 – 2008, these two percentiles outperform the 80th percentile by about .05% per year. However, the 20th percentile continues to grow slow, in fact, roughly as slow as before 1980. Thus, since the mid-1990s, the world is slowly becoming somewhat more equal (in terms of the distribution of living standards over countries), although the poorest countries are an exception to this trend.

How about the growth experience of individual countries? In order to summarise these, we looked at which countries were able to move upward in the distribution, over the long run. Over the period 1950 – 1989, for which we have 132 countries, 65 (i.e., roughly half) countries do not change the quintile that they are in. Another 51 countries either rise 1 quintile or fall 1 quintile, and only 9 countries change 2 or 3 quintiles up or down. For the period 1990 – 2008, 109 of the 151 countries do not change quintiles, 40 countries move just 1 quintile up or down, and 2 countries jump 2 quintiles. Thus, the global distribution of countries with respect to their living standard is fairly stable over the long run. Large jumps, i.e., countries moving from the bottom of the distribution to the top are very rare.

Over the entire period 1990 – 2008, there are 4 countries that have moved 3 quintiles up. These countries, with the exception of Oman (which jumped very rapidly over the 5 years 1966 – 1970, due to oil riches), are documented in Figure 1 (black lines). They are all East-Asian countries located very closely to each other. China starts in the bottom quintile, remained there until the late 1970s, and then took off and rose to the 60th percentile over the next 40 years. Korea and Taiwan started somewhat higher in the distribution, i.e., in the second quintile, and started their rise from the early or mid-1960s onwards. In about 50 years, they rose to the top of the distribution, positioning themselves clearly in the top quintile of the distribution.

Other countries have also made impressive rises through the distribution, especially in the most recent 20 years when convergence has been documented to be stronger. We do not document these growth episodes here explicitly, but do include these countries when we investigate the link between trade, capabilities and growth below. We then group countries by geographic proximity to understand their relationships.

III. Literature Review

III.1. Capabilities for catching-up based growth

What are the necessary capabilities for countries to catch up? Economists have long searched for the right ingredients to bring about development. Classical economists pondered this fundamental question beginning with Adam Smith who asked what enriches people in *The Wealth of Nations.* For Smith, the answer was within the "productive powers of labor" (Smith ed. by Heilbroner, p.160, 1986). Today, we know there are many types of capabilities needed for development. In this section, we will review the literature that broadly identifies different subsets of capabilities necessary for development.

We may think of capabilities in terms of micro-level i) individual or human capability, meso-level ii) firm capability or in a macro-level iii) country capability. Technological capabilities usually focus only on the firm and national level, while individual capabilities are considered separate strains of literature. Yet, the two perspectives are interrelated; policies influence the daily lives and abilities of people and individuals are the foundation of the economy and firms.

III.2. Human capabilities

What one can achieve is a combination of capabilities conditioned by context. On an individual level, human capability is an individual's ability or freedom to choose the type of life they want to lead (Sen, 1992). Their capability, however, can be constrained by institutional factors of which Sen identifies five general spheres: i) political freedom, ii) economic facilities, iii) social opportunities, iv) transparency guarantees, and v) protective security (Sen, 2001). Thus, development necessarily requires a variety of capabilities or freedoms to function. Development is not only the increase of GDP as a metric of income, but it is the "integrated process of expansion of substantive freedoms that connect with one another" (Sen, pg. 8, 2001). Fundamentally, development is not only of wealth, but of well-being, too. These five factors are reiterated within the literature of technological capabilities, since human capabilities are necessary to provide the conditions for technological progress to occur.

Often, we think of this in terms of human capital, famously described by Gary Becker as the accumulation of formal education, learning-by-doing at the workplace and the creative capacity endowed within a person (Becker, 1975).Yet, capability is much more than education alone, it also requires the freedom to be creative, opportunity to apply for loans without discrimination and establish a business without coercion.

III.3. Catch-Up hypothesis

Strengthening capabilities provides a means to improve economic conditions through a process of catching up. An early proponent to understanding development as a catch-up process was Gershenkron in his comparative study of European countries and Soviet Union experience of economic growth. He saw advantages in 'economic backwardness' where countries could overcome initial obstacles and "select those paths along which they will be able to […] increase the yield in terms of human welfare and human happiness" (Gerschenkron, 1962), p.51). While there was great possibility, he also identified constraints and certain conditions, what we may call capabilities, to catch up. He noticed, "there are considerable differences, as compared with more advanced countries, not only with regard to the speed of development (the rate of industrialised growth) but also with regard to the productive and organizational structures of industry which emerged from those processes" (Gerschenkron, 1962) p.7). These productive and organisational structures include many capabilities, such as the importance of the banking structure, skills and technological knowledge.

What exactly are nations catching up to? The catch-up hypothesis views development as a process of closing a technological gap. Highly developed nations are at a frontier of technology or knowledge, while the great majority of other nations lag behind. In this way, technological gap theory sees the variety of development levels primarily due to technological differences. Therefore, countries should aim towards technological advancement, which can ignite high growth rates and place a country on a path to development. Within this tradition, there are many evolutionary and Schumpeterian scholars who have developed theoretical models and additional empirical evidence on catching up and technological gaps (Dosi, Pavitt, & Soete, 1990; Fagerberg & Godinho, 2005; Fagerberg & Verspagen, 2002; Nelson & Pack, 1999; Verspagen, 1991, among others).

Following a similar thought of Gerschenkron, Abramowitz noted that technological advancement has necessary pre-conditions, which he coined as technological congruence and social capability (Abramovitz, 1986). This requires significant effort, coordination, and investment tailored to the country's environment, internally and externally. The rate of speed to catch up also depends on the relative position to the frontier. Even though a country may be far behind, there is opportunity for rapidly growth. Abramowitz noted, "that being backward in level of productivity carries a *potential* for rapid advance" (Abramovitz, 1986, p. 386). The farther back a country is from the frontier, the larger the potential for high growth rates to catch up.

Social capability is loosely defined, but includes current processes of knowledge diffusion, conditions of the technical competence (i.e., education), labour market structure and migration, organisation of firms (i.e., business environment), political stability, macroeconomic conditions affecting investment and effective demand, and financial institutions to mobilise capital (Abramovitz, 1986; Fagerberg, Srholec, & Verspagen, 2010, p.390). These are the foundations for the catch-up process to occur.

While social capabilities are a number of factors within a country, technological congruence is a measure of relatedness between two countries in terms of matching resources, markets, consumer preferences, scale and capital intensity (Abramovitz & David, 1996). One technology may not adapt well in another setting, but also the product created must match the tastes and needs of demand. For example, the United States' agricultural production uses vast amounts of land and large-scale combines and processing facilities. This technology would not adapt well in the Netherlands where land is scarce. Alternative agricultural technologies, such as capital-intensive techniques of green-house farming are far better for a land-scarce nation. Additionally, the United States benefits from a large, homogenous market, while the Netherlands has a much smaller market and must be able to sell their products outside of their country, which may not have the same tastes. Summarised by Abramovitz, "countries have unequal abilities to pursue paths of progress that are resource-biased or scale-dependent" (1986, p.398).

III.4. Technological capabilities and learning

Innovation and technology is not a public good and does not diffuse freely and instantaneously throughout the world as was once thought in offshoots of Solow growth models. It takes skills, investment and effort to adopt or generate new technology. While knowledge can be codified in blueprints or instructions, much of it is actually tacit and embodied within a person (Lundvall & Johnson, 1994). For example, while we can read the instructions of an Ikea kitchen cabinet, the practice of actually putting together all the parts to install the cabinet securely requires previous experience using tools and usually, the first try will not result in the optimal result. There is some tacit knowledge in the process that can't be easily expressed in a manual. Technological knowledge is imperfectly imitated, tacit and requires learning (Lee, 2013, p. 223). This is why knowledge access and learning is an important part to catch up – adopting a new technology requires a different type of learning and not only human capital stock can account for this (Lee, 2013). For a firm to catch-up, learning must take place throughout an organisation in a dynamic process, where the, "Prior knowledge base and intensity of effort affect the dynamics of knowledge conversion through a spiral process that starts at the individual level and moves up to the organizational level" (Kim, 1997, p. 508, 1998).

Given the special nature of technology, there requires a certain set of capabilities, technological capabilities, that are a combination of firm level technological capabilities (FTC), and national technological capabilities (NTC), which mutually reinforce each other (Lall, 1992). A number of scholars have identified different types of technological capabilities, the mechanism of accumulation of such capabilities and their inter-linkages with consensus that there are three general aspects of technological capabilities: product capability, investment capability and innovation capability (Bell & Pavitt, 1995; Dahlman, Ross-Larson, & Westphal, 1987; Kim, 1980; Lall, 1992). Product capability refers to the efficient management and adaption during changing conditions of human resources, inputs and physical capital. Investment capability is the training, project planning and execution of building or expanding facilities. Innovation capabilities refer to knowledge generation and applied research to new products, processes or services (Kim, 1980, p.5).

III.5. National technological capabilities

A series of case studies have documented the experience of successful catch-up economies in East Asia (Dahlman et al., 1987; Hobday, 1995; Kim, 1997; Nelson & Pack, 1999; Wade, 1990) and other nations who were unsuccessful in Latin America (J. Katz, 1987; J. M. Katz, 1987; Teitel, 1981; Vera-Cruz, 2006) and India (Aggarwal, 2001; Lall, 1986). Their work has illuminated that institutions must organise, invest and facilitate capability-building processes in a series of stages, which will be summarised below.

The most influential case studies analysed the remarkable success of Korea (Kim, 1980). Kim studied Korea's dynamic technological learning as a means to understand what conditions and policies explain their catch-up process, "examining how firms learn and unlearn in response to the changes in market and technology" (p. 17, 1980). He noted three important steps for importing technology to catch-up; transfer of technology from abroad, diffusion within economy and indigenous R&D to adapt, improve and innovate their own technology (p. 23, 1980).

In a study of Latin American countries, Katz proposes that there are two phases to modernise or adopt new technologies at a national level. As a first step, there must be a period of accessing technology, an "acquisition phase" where the technology must be selected, bought, installed and used within a country (Katz, 1971). But, as we said earlier, technology is a special kind of learning and requires appropriate institutions and preconditions for a country to successfully adapt, imitate, produce, and diffuse a product of higher technological inputs or complexity in the local environment during a second phase, which he calls "assimilation and learning" (Vera-Cruz & Torres-Vargas, 2013).

Contrastingly, in a literature survey by Sanjay Lall, he doesn't identify stages, but rather highlights different capabilities at the firm or national level. At the firm level, he emphasised; i) investment capabilities, the ability to plan, acquire technology, provide human resources and establish a new project; ii) production capabilities, the skills to operate, maintain and improve process or product innovations and; iii) linkage capabilities, the ability to coordinate inputs, information, services and institutions. At the national level, Lall recognised the importance of i) physical investment, ii) human capital and iii) technological effort, which is the combination of these inputs with "efforts by productive enterprises to assimilate and improve upon the relevant technology" (1992, p. 170). Technological effort is difficult to measure, but as a proxy Lall suggests R&D, patents and technical personnel (Lall, 1992). He also notes that importing technology is necessary, but it must be done in such a way that countries can also gain the learning benefits from the innovative process. Similar to Katz's 'assimilation and learning' phase, Lall also sees the, "Central role to indigenous technological effort in mastering new technologies, adapting them to local conditions, improving upon them, diffusing them within the economy and exploiting them overseas by manufactured export growth and diversification and by exporting technologies themselves" (Lall, p.166, 1992). Capability building requires a balance and must consider the combination of economic factors and incentives between firm and national capabilities that influences the development process.

Another way to look at this adaption process for new technology is through 'absorptive capacity', which refers to the institutional environment of which a country can absorb new investments and new knowledge (Eckhaus & Rosenstein-Rodan, 1973; Rostow & Rostow, 1980). While institutional factors enable general characteristics for technology to be receptive within a country, absorptive capacity also occurs at the firm level. Cohen and Levinthal further refined absorptive capacity as the "ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends," that is largely dependent on a firms "prior related knowledge," which is their awareness of recent scientific developments (Cohen & Levinthal, 1990). This is often used interchangeably with technological capabilities, as Kim defines this as the, "Use of technological knowledge in efforts to assimilate, use, adapt, and change existing technologies. It also enables one to create new technologies and to develop new products and processes in response to changing economic environment" (1980, p.4).

Along the way, national policy must make many choices, including selectivity of industrial sectors, R&D activities for firms, and possible protection of certain domestic markets. This is one of the reasons that macroeconomic environment and context shapes the particular policies that should be implemented. While there are general capabilities necessary for development, there is no single recipe that works for every country, as Lall expressed, "The experience of NICs shows clearly that there are many roads to success" (p. 182, 1992). Development is influenced by historical, cultural, geographic, and the international environment of a particular country, in other words, "To have any chance for success, policy has to be tailored to each country's conditions and constraints" (Ocampo, Rada, & Taylor, 2009, p. 249). The mixture of capabilities needed to secure development vis-à-vis technological progress is dependent on the country, which remains a recurrent theme within the capability literature.

From the literature review, we can conclude that capabilities are multifaceted. Measuring them has often been inadequate because of the inter-linkages among them, multiple requirements at different levels and intangible organisational strength at many levels needed to maintain them. This is why we choose to understand the role of technology, broadly captured through capabilities, on development through three levels of analysis: i) product ii) sector and iii) macroeconomic.

IV. Capabilities and catching-up

IV.1. Measuring capabilities

IV.1.a. Capability Index

One way to overcome the hurdle of measuring capabilities is by aggregating proxies of varying institutions. We call this type of measurement a capability index. Fagerberg and Srholec collect data on many dimensions of capabilities and use a principal components analysis (2008). Their approach is to collect data on as many aspects of capabilities that are feasible to measure for a large set of countries, and let the method work out a weighting scheme for creating composite indicators of the main "dimensions" of country capabilities.

The leading dimension is labelled as innovation system capability. It contains indicators such as the number of patents and the number of scientific papers, but also education (human capital) and the use of ICT technology. A second dimension is called governance; this contains mostly indicators about the legal system, corruption, the banking system, and the regulatory environment. A third dimension is the political system; this includes civil rights and democracy. Finally, there is an openness dimension to capabilities, with indicators such as trade and FDI.

Table 2. Variables and loadings in principal component analysis for capability indicator

Variable and description	Source	Loading in first PC
iso – Number of ISO-9001 certificates, per capita	ISO	0.60
nsf – Science and engineering articles, per capita (2011)	NSF	0.91
uspto – Number of patents granted, per capita	USPTO	0.77
tel – Number of fixed telephone lines per 100 inhabitants	WB/WDI	0.77
mob – Number of mobile telephones per 100 inhabitants	WB/WDI	0.32
intnet – Number of internet users per 100 inhabitants	WB/WDI	0.79
prim – Gross enrolment in primary education	WB/WDI	-0.07
sec – Gross enrolment in secondary education	WB/WDI	0.61
cred – Domestic credit to private sector (% of GDP)	WB/WDI	0.82
trade – Merchandise trade (% of GDP)	WB/WDI	0.05
fdiin – Inward FDI flows (% of GDP)	WB/WDI	-0.06
va – Voice and accountability score in WGI	WB/WGI	0.86
psnv – Political stability & no violence score in WGI	WB/WGI	0.71
ge – Government effectiveness score in WGI	WB/WGI	0.92
rq – Regulatory quality score in WGI	WB/WGI	0.88
rol – Rule of law score in WGI	WB/WGI	0.93
cc – Control of corruption score in WGI	WB/WDI	0.92

All variables refer to 2013 unless otherwise indicated.

We replicate Fagerberg & Srholec (2008) by constructing a composite index of a country's capability to catch up with similar data and follow their procedure of analysing four principal components, each corresponding to one broad aspect of capabilities, but for a slightly longer time period and a larger country group. The variables entered in our analysis along with the loadings obtained in the principal components analysis, are indicated in Table 2.

Unlike Srholec and Fagerberg, our first principal component loads high on almost all variables included in the analysis, which indicates that the general development level correlates very high with almost the entire range of capability indicators used. The only exceptions to high loadings are the variables for the mobile telephones, primary education, trade and inward FDI. This also means that our indicator of capabilities in Figure 2 combines several of the dimensions found in Srholec and Fagerberg's analysis; in particular it combines the innovation systems dimension and the institutional dimension.

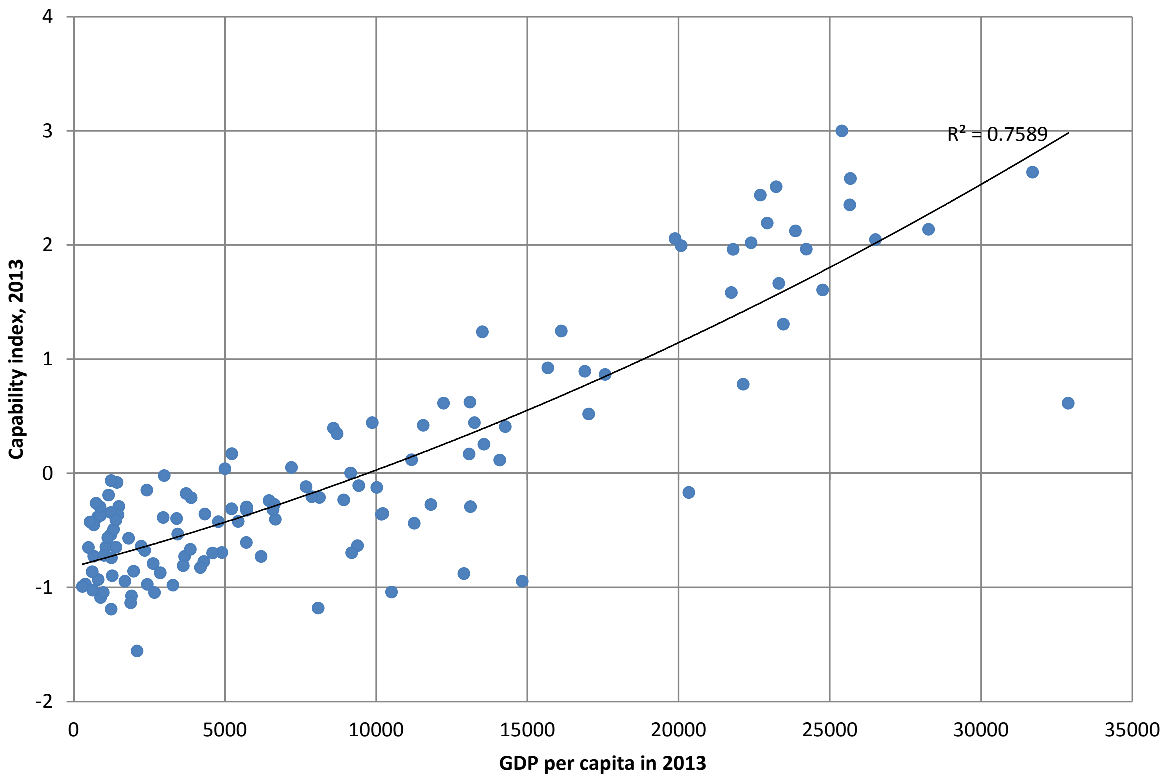


Figure 2. Index of innovation system and institutional capabilities vs. GDP per capita, 2013

Figure 3 presents a similar relationship for a single indicator related to technological capabilities, i.e., Research and development (R&D). Technological change is generated by economic actors who invest a significant amount of resources in the development of new technologies, and in accompanying assets that enable the exploitation of technological knowledge. R&D is one popular indicator of investment in the development of technology is. R&D measures investments in "hard" technology, i.e., the systematic discovery process that makes use of science and engineering methods. It is defined well so that international comparisons are quite possible.

The figure looks at the relative importance of R&D expenditures (as a fraction of GDP) and its correlation to the level of development, i.e., GDP per capita, in 1998 (the year for which R&D data are most frequently available).[3] R&D is total R&D performed in a country, including both business R&D and R&D performed in universities and public labs. Although the correlation is less tight than in Figure 2, it is clear that there is a strong positive correlation. The developed countries tend to have much higher technological capabilities, including R&D intensity, than the developing and emerging economies.

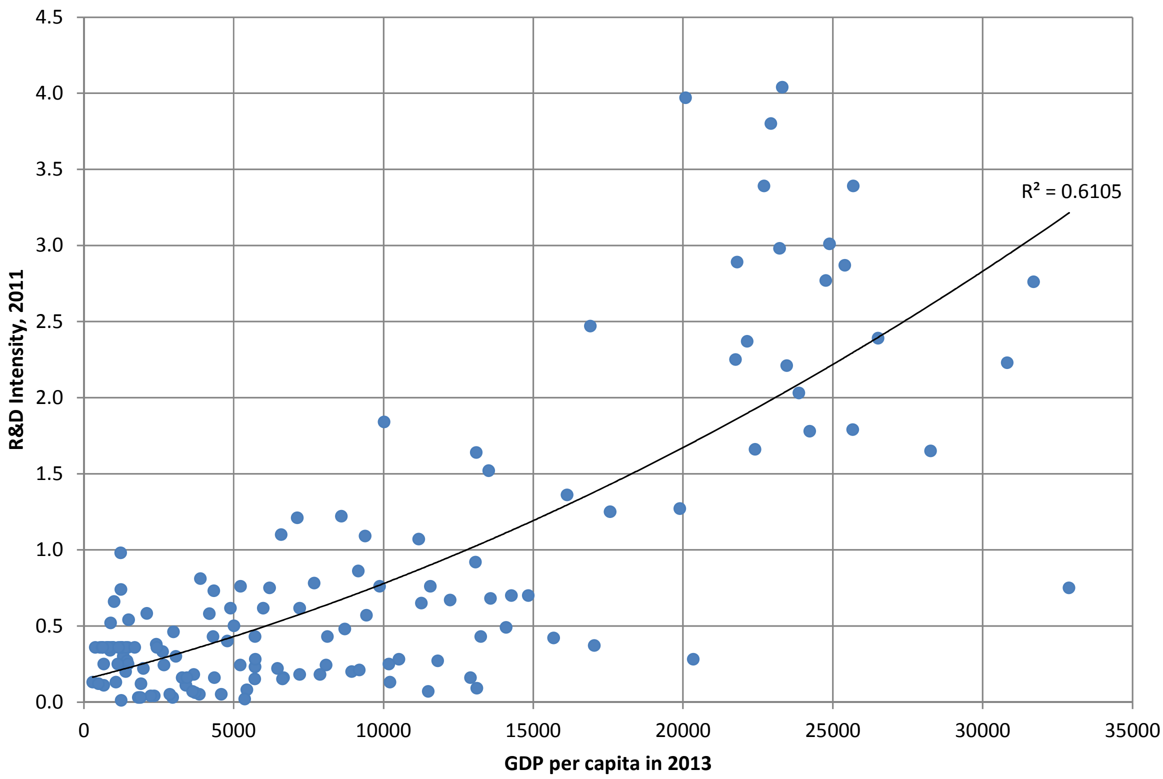


Figure 3. R&D intensity and GDP per capita, 2011/2013

Countries at low development levels need to break through the barrier of low capabilities in order to achieve a structural transformation, but the evidence in these two graphs suggests that this is hard to do. Because it is hard to develop capabilities when a country is at low levels of development, the technology gap that the country faces also represents a development trap.

[3] R&D data were taken from UNESCO. In case the value for 2011 is not available, the nearest year with available data was used. This figure and subsequent ones (unless otherwise indicated) only includes countries with >1 million population.

IV.1.b. Latent-capability measurement

Another way to measure capabilities is to utilise trade data at the product level. Recent literature on capabilities and export performance of countries suggests that the specialisation pattern of countries may hold information on what it takes to break through this barrier. The idea in this literature is that products traded in international markets require varying degrees of capabilities to produce. Some products require complex production processes, and hence only countries with high levels of capabilities can specialise in them.

Products embed many of the capability characteristics we've described earlier within itself. They hold a series of complex processes, which are necessary to realise – they are a reflection of latent capabilities, silently composed of technological, social and absorptive capabilities. Thus, the type of products that you produce is a reflection of capabilities at all levels; i) the national level, the institutional capacity and political determinism to organise, manage and implement the necessary human and physical capital investment, legal framework and financial services over a long time period; ii) the firm level, management of networks, people and processes to develop or improve upon products and processes and; iii) the individual level, freedom to create, innovate, take risk and learn. There are a number of inter-linkages between these levels that must respond, adapt and operate together to ultimately catch-up in a globalised environment.

One of the measures developed sought to understand specialisation patterns through the type of products a country produces revealing that there is a relationship with economic growth and what we call, latent capabilities (Hausmann, Hwang & Rodrik, 2007). They define

$$\text{PRODY} = \sum_j \frac{(x_{jk}/X_{j})}{\sum_j (x_{jk}/X_{j})} Y_j$$

where k is the productivity level of a product, j is the country in reference, Y is GDP per capita. This essentially provides the weighted GDP per capita for a particular product. While this provides product level information, they use the export basket of a country to produce the weighted average of the type of products a country exports.

$$\text{EXPY} = \left(\frac{x_{il}}{X_i}\right) PRODY$$

This was a great step in understanding that particular products exported by countries are related to growth. Which products contribute to growth and are there particular sectors or product categories that seem to be produced by developed or the 'caught-up' nations? This answer is much less clear when GDP per capita is included in the weights as it suggests that high income nations produce highly productive product. While this may be true, PRODY has a major flaw in that GDP is already included as a measure of highly productive products.

Realising this issue, Hausmann & Hidalgo improved upon quantifying highly productive products by removing GDP as a factor. Rather, they developed the "Method of Reflections," which takes advantage of the bipartite structure of trade data and iteratively calculates 'diversification', the variety of goods a country products and 'ubiquity', the types of goods (measuring if it is common product or a specialised product) a country produces (2009, 2010 an 2011). The method of reflections provides information about the latent-capabilities of a country. Inspired by the recent literature of economic complexity first developed by Hausmann and Hidalgo (Hausmann & Hidalgo, 2010; Hausmann & Hidalgo, 2011; Hidalgo & Hausmann, 2009) a group of Italian Physicists have methodologically expanded upon the methods of reflection (Tacchella, Cristelli, Caldarelli, Gabrielli, & Pietronero, 2012) (Cristelli, Tacchella, & Pietronero, 2015) (Caldarelli et al., 2012)

The main idea in this approach is that products are characterised by varying degrees of complexity, and that more complex products require higher capabilities to produce them. Obviously, this is an idea that is common in much of the literature that we discussed so far. The novelty of the literature we draw on here is the proposal to measure both the complexities of products, and the capabilities of countries.

These are both viewed as latent characteristics, which can be indirectly measured by their implications for observed trade patterns. Essentially, the idea is that countries with high capabilities produce complex products, which is a statement that can also be formulated reversely (complex products are produced by countries with high capabilities). Formalising, the argument, we can write $F_i = f\left(\sum_j T_{ij} Q_j\right)$ and $Q_k = q(\sum_l T_{lk} F_l)$, where F_i denotes the capability of a country i, Q_k is the complexity of product k, and T_{ij} is a binary variable that indicates whether country i is specialised in producing product j. The capability of a country is a function f of the sum of the complexities of the products it is specialised in, and the complexity of a product is a function q of the sum of capabilities of the countries that are specialised in it.

From this, it seems that we cannot measure either capabilities or complexities. However, we could start with an approximation of either capabilities or complexities, and then iterate through the formulas above to see if our measures would converge to a meaningful solution. In practical terms, we follow the proposal by Tachella et al., which starts by setting all complexities equal to the inverse of the sum of countries that are specialised in it (the more countries are specialised in a product, the less complex this product is assumed to be). Then the capability of each country is calculated as the sum of the complexities of the products it is specialised in. After this, the complexities are re-calculated in a way similar to the first stage, but now weighted by each country's capability. After this, the country capabilities are re-calculated, then the complexities again, etc. This procedure will converge to a state in which both capabilities and complexities do not change from one stage to the next. The values of capabilities and complexities are taken as measures that are indirect indicators of the latent underlying values. Full formal details of this process are provided in Tachella et al.

Are capabilities measured in this way related to economic growth and development? Can they provide an approximation of the technological and absorption capabilities that were introduced in the previous section? These are the next questions we explore.

Using export data by BACI (HS96) for the years 1998 and 1999 (the first two years for which this dataset is available), we use the iterative method to jointly measure the capabilities of 229 countries and the complexity of 4,988 products (*BACI*, 2010; Gaulier & Zignago, 2010). We use Balassa's revealed comparative advantage (RCA) to identify if a country specialises in that product.

Using a disaggregated dataset allows us to not only rank more products, but also measure the capabilities of a country more accurately. However, using export data has its caveats. Most notably, we are unable to capture services, domestic production (non-exported goods and services). Additionally, specialisations of some commodity goods such as oil, tin, copper, soy, etc., may be artificially higher due to over valuation during booms (Felipe, Kumar, Abdon, & Bacate, 2012). Nonetheless, the product variety and number of countries allows for far more comparability than other data sets.

Particularly, the number of products is important to uncover the hidden technological capabilities of a country, as it will capture a diversification in detail. For example, to produce chocolate there must be a combination of raw products and an industrial processing facility to mix, cut and package bars of chocolate. However, as we all know, not all chocolate is the same. Even within a broad product category, chocolate, there are different technologies to produce more complex and tastier chocolates like truffles or variety boxes. A more advanced set of capabilities is required to produce more varied types of chocolate. Aggregating all goods that are contain cocoa would not capture the capabilities the chocolatiers have in combining the raw materials with innovative ways to produce more complex treats. Thus, we need to distinguish the difference between the two products. In the example described, our measure can distinguish sugar confectionary products as more complex compared to chocolate bars.

IV.2. Growth and capabilities

In order to investigate the relationship between capabilities and economic development, Figure 4 presents a classic relationship between the level of GDP per capita and the subsequent growth rate, in this case for the period 1998 – 2013. This graph is a different way of specifying what was already observed in Table 1, i.e., that there is convergence as well as divergence of living standards. For low levels of (initial) GDP per capita, we observe a large variety of growth performance, while this variety becomes smaller and smaller when the level of GDP per capita increases.

If we were to draw a (regression) line for the upper layer of the data cloud, it would obviously be downward-sloping, which would indicate convergence (poor countries growing more rapidly). But this would ignore the points that lie clearly below such a line, and in fact one could draw an upward-sloping line (pointing to divergence) for the bottom part of the data cloud.

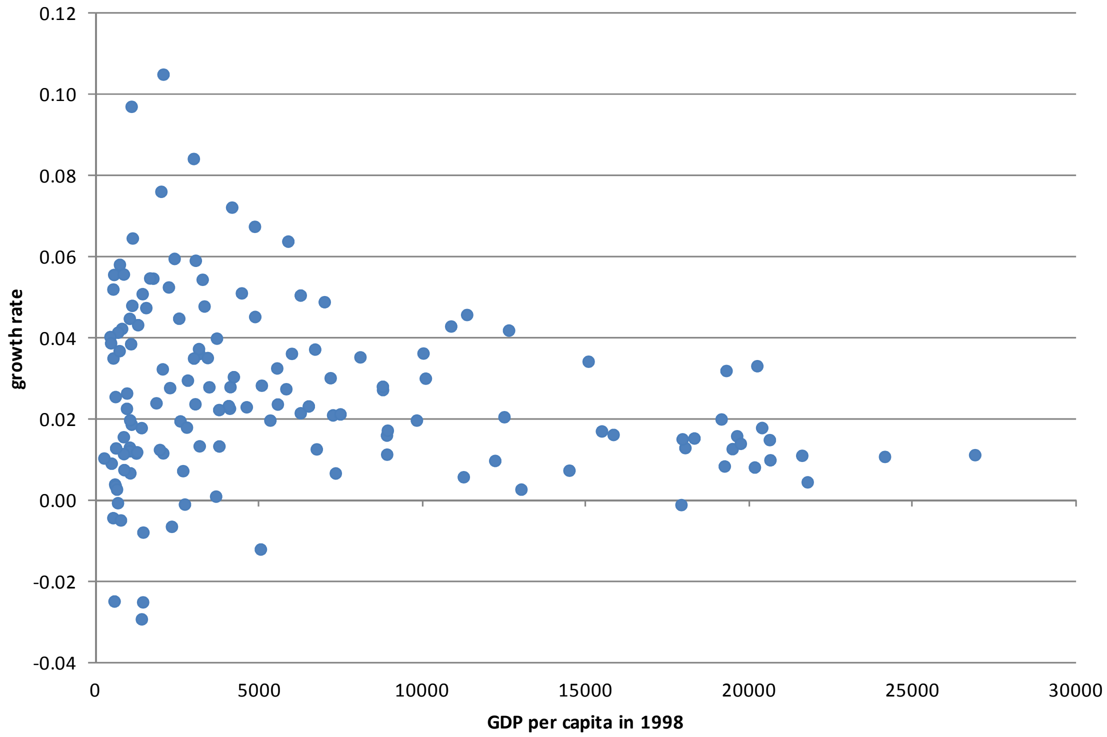


Figure 4. GDP per capita and growth rate: convergence and divergence

Technology gap theory suggests that among the countries with relatively low levels of GDP per capita, capabilities to assimilate knowledge spillovers make the difference between the rapid growers and the slow growers. This hypothesis is tested in Figure 5, which displays the same relationship as in Figure 4, but with the size (area) of the dots proportional to the country's capability level in 1998. By and large, the level of capabilities (size of the dot) seems indeed to distinguish between the slow-growers and fast-growers at levels of GDP per capita below $10,000: we find large dots in the upper-part of the data cloud and small dots in the lower part.

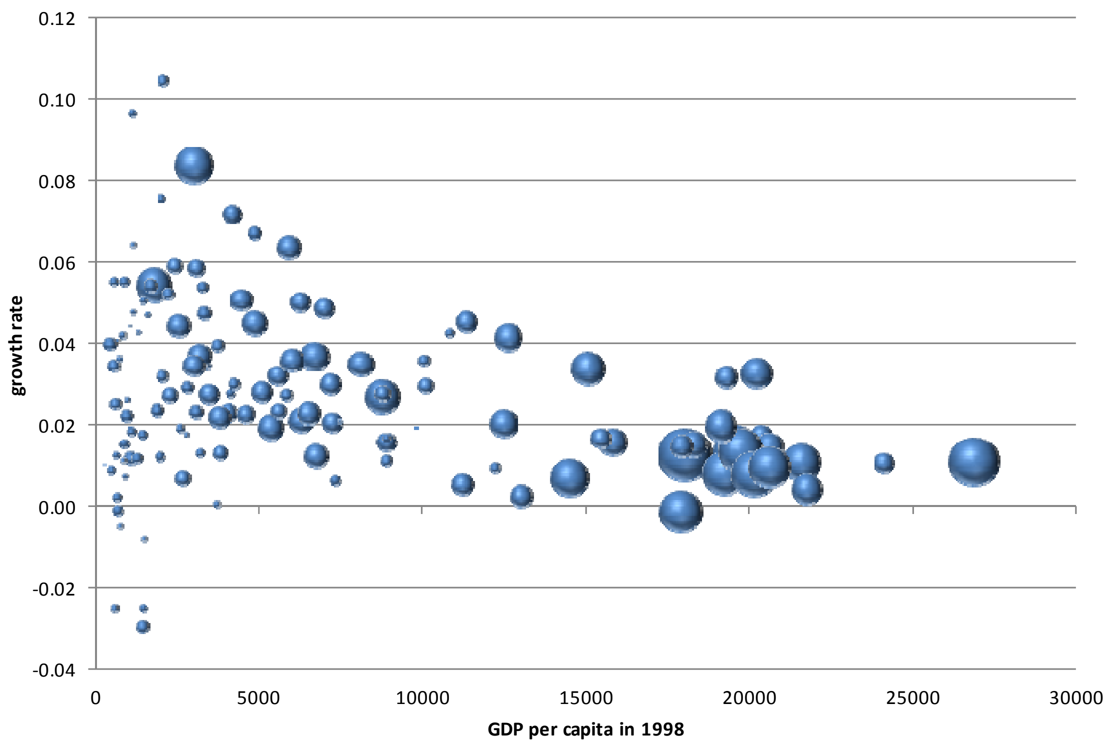


Figure 5. GDP per capita and growth conditioned on capabilities

This finding can also be illustrated with a regression:

Growth rate = -0.0060 ln(Y98) + 0.0039 ln(F) + 0.072

(2.85***) (2.95***) (4.33***)

Adj. $R^2 = 0.005$, $n = 141$.

The initial level of GDP per capita (Y98) has a significant and negative sign, indicating convergence, but this is conditional on the level of the country's capability (F), which enters with a positive and significant sign. It appears from the data that capabilities, as measured by trade performance, is indeed related to the kind of capabilities that countries need to be able to absorb foreign knowledge, and catch up. Poor countries with high (low) capabilities grow rapidly (slow).

Do these capabilities also relate to more traditional indicators of technology and innovation? Figure 6 presents the relationship between Research and Development (R&D) expenditures (expressed as a fraction of GDP) and capabilities. The size (width) of the dots is proportional to GDP per capita.

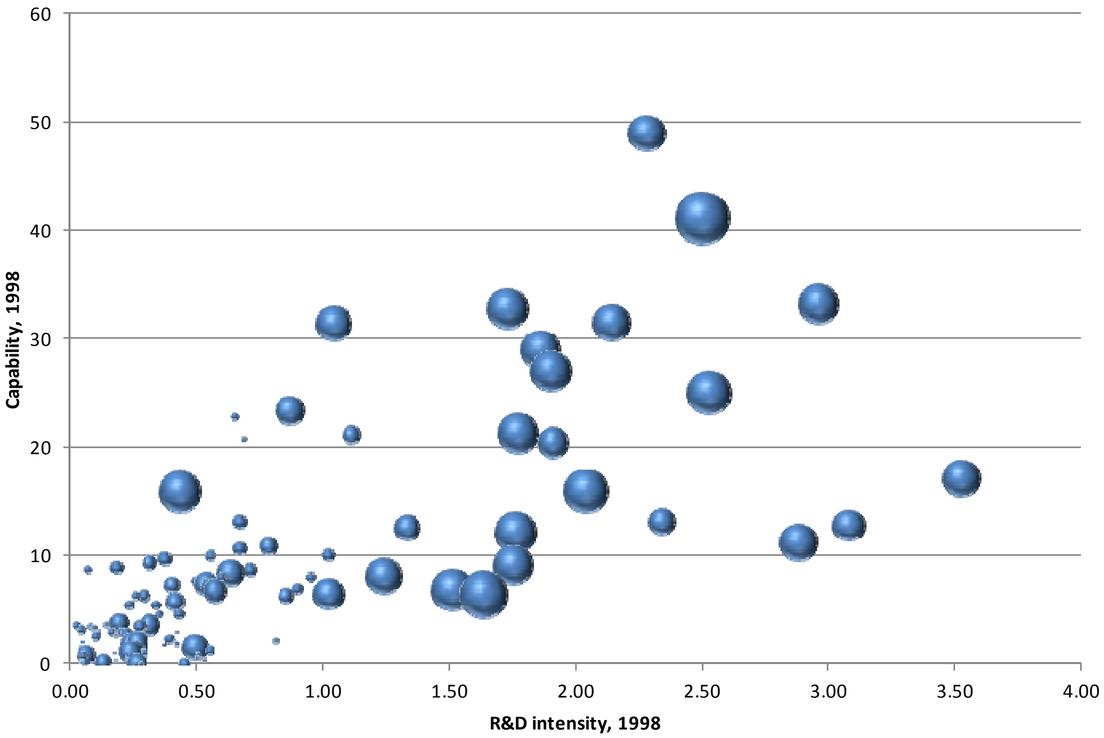


Figure 6. R&D intensity and capability (width of dots is proportional to GDP per capita), 1998

The figure shows that levels of GDP per capita, capabilities as measured by trade, and R&D are highly correlated. Wealthy countries, which have high capabilities, tend to have high levels of R&D. A distinct group of technologically advanced countries emerge while the vast majority of nations are far behind. But within the group of the advanced countries (the large dots), capabilities and R&D do not show a very tight relationship. R&D is not a perfect substitute for capabilities as measured by trade.

IV.3. Capabilities in product space

So far, we treat capabilities as a black box, i.e., we did not look at the relationship between the characteristics of products (complexity) and country capabilities. But what kind of products add to capabilities, i.e., what kind of products are considered highly complex? In order to answer this question, we introduce the notion of product space. The idea of product space is based on network theory. We start by constructing a network matrix that specifies the relatedness of each of the 4988 product classes to each other product class. Relatedness is defined here as the correlation coefficient between the specialisation profiles of the two product classes, with the specialisation profile simply equal to a vector of binary values indicating whether each of the 229 countries specialises in this product. In other words, for each combination of two product classes, we construct a correlation measure of whether the same countries tend to specialise in both classes

The resulting network matrix is graphed using a heuristic algorithm proposed by Eck & Waltman (2015). The result of this procedure is a 2-dimensional map in which product classes appear close to each other if they are strongly correlated. Before applying the graphing algorithm, we cut off the values in the product correlation matrix, maintaining only the top 3% highest values in the matrix (this value is chosen because fewer values break the network up in smaller components, and more values produce a less distinctive grouping of product classes in the graph). The algorithm also produces a clustering of the product classes, based on the idea that connections within clusters will be stronger than connections between clusters.

Figure 7 shows product space as constructed in this way, for 1998 & 1999. The labels are product class codes (Harmonized System 1996), and the colours indicate cluster membership. The clustering algorithm generates 8 clusters, of which 3 have fewer than 5 product classes (hence there are 5 clusters visible in the graph).

The 5 clusters can be clearly distinguished in terms of their content, as well as their average level of complexity. Some summary statistics and characterisations are presented in Table 3. The largest cluster (1) is mostly resource-based, with many product classes in agriculture and food, and mineral resources. This cluster has below-average complexity (although all standard deviations of complexity are large within the clusters). In the product space map of Figure 7, this is the red cluster, appearing at bottom-centre.

The second-largest cluster (2) contains mostly manufactured products, including man-made and natural fibres, electrical machinery and metal products. This cluster has average complexity level just below the average of all classes. It is the green cluster at top centre.

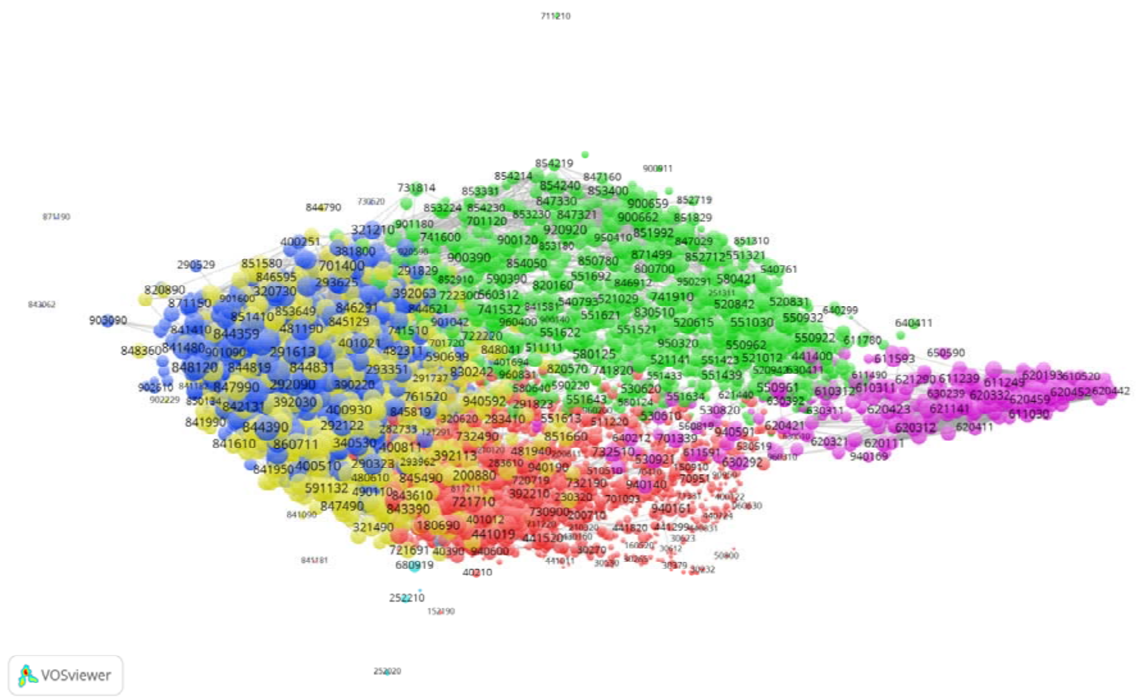


Figure 7. Product space network, 1998&1999, nodes coloured according to cluster membership

Cluster 3 is the one with highest average complexity, well above the average of all classes. This cluster contains the so-called high-tech products, such as aircraft, pharma, opticals and instruments. This cluster is about as large as the next one (4), both in terms of the number of classes and in terms of exports value. It is the blue cluster at the left of the product space map.

Table 3. Cluster characteristics

cluster	Characterisation	# classes	% global exports	Complexity Average	Complexity St dev.
1	Agriculture and food; fertilisers; mineral resources; wood; ships and boats	1849	31.6	0.13	0.59
2	Man-made and natural fibres; leather; electrical machinery; metal products	1103	22.3	0.17	0.35
3	Chemicals incl. pharma; instruments; opticals; aircraft	872	19.7	0.43	0.73
4	Paper; metals; transport equipment	826	20.8	0.22	0.37
5	Textiles	308	5.2	0.03	0.04
All classes				**0.20**	**0.53**

Cluster 4 contains a mix of resource-based industries, including paper and metals, and heavy industry, especially transport equipment. The complexity level of this cluster is about average. It is the yellow cluster on the left. The last cluster (5) is small and almost exclusively contains product classes in textiles (garments). In the product space map, this is the purple cluster, most clearly distinguished from the other clusters.

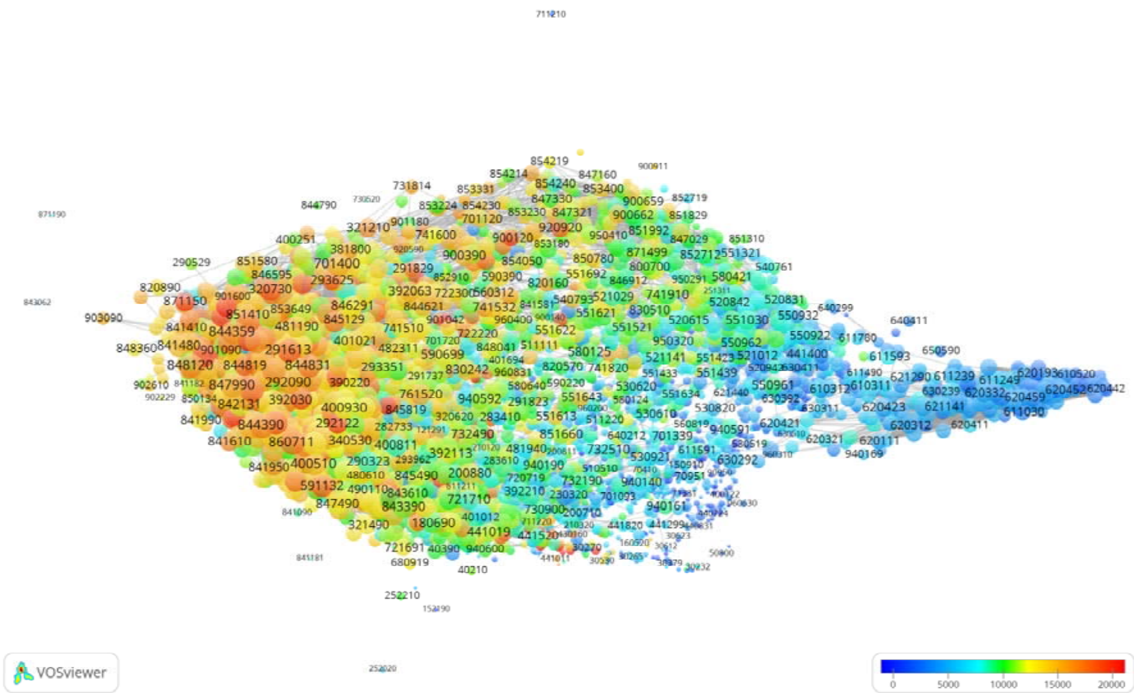


Figure 8. Product space network, 1998&1999, nodes coloured according to PRODY

Figure 8 presents a slightly different version of the product space map. The layout of the product classes is identical to the previous map, but the nodes are coloured differently. In the new map, the nodes are coloured according to the average GDP per capita level of the countries that are specialised in them. We use the so-called PRODY-measure as discussed earlier that was introduced by Hausmann, Hwang and Rodrik (2007) for this purpose. The scale for this colouring scheme runs from blue (low values) to red (high values).

We see a clear hierarchy in terms of cluster's scores on the PRODY measure. The textiles cluster (no. 5, right in the map) has almost exclusively low PRODY values. Moving to the left, i.e., closer to the other clusters, the PRODY values increase, even within the cluster. Cluster 1 (resources) also has low PRODY values. Cluster 2 (fibres, electrical, metal products) has a mix of low, intermediate and some high PRODY values. Clusters 3 and 4, which are the most complex ones, also show the highest PRODY values.

Thus, the product space map in Figure 8 provides a stylised description of how trade specialisation is related to catching-up based growth. Specialisation in low-complexity product classes (especially textiles, but also resources and simple manufactured products) is associated with low levels of development, while the complex (high-tech and others) product classes are produced by the developed and rich nations. The transition from a low development state to becoming developed that was described above, is a journey through product space, from low-complexity products to high-complexity products.

The fact that catching-up based growth is a relatively rare phenomenon, as illustrated above, suggests that such a journey through product space is not easy. Increasing capabilities is hard, and requires resources to be invested in learning and technology assimilation. The development record of countries such as Korea, Taiwan and China suggests that this is the case. Can the clusters help us to illustrate the difficulties of "travelling through product space"?

In order to answer this question, we construct a "transition matrix", as in Table 4. This table documents the average correlation coefficients between pairs of product classes of varying clusters. These are the correlation coefficients as were used to construct the maps of product space.

The table shows that especially the high-complexity Cluster 3 and the intermediate-complexity cluster 4 have high internal correlations. The fact that the off-diagonal correlations (i.e., between clusters rather than within a cluster) are generally lower, especially for these two clusters, is an indication of a certain degree of path-dependence. To see this, the correlation coefficients must be taken as indications of the ease of transition from one product class to the other. High (low) correlation coefficients indicate that this is easy (hard). Interpreted in this way, it is much easier to become specialised in a high-complexity product class in Cluster 3 if the country is already specialised in other Cluster 3 classes, compared to when it is not specialised in any Cluster 3 classes yet.

Table 4. Average correlations of product classes within clusters

Cluster	**1**	**2**	**3**	**4**	**5**
1	0.09	0.07	0.09	0.10	0.08
2	0.07	0.19	0.10	0.12	0.15
3	0.09	0.10	0.23	0.18	0.01
4	0.10	0.12	0.18	0.26	0.07
5	0.08	0.15	0.01	0.07	0.35

Looking at the off-diagonal correlations, the most “convenient” entrance to the high-complexity Cluster 3 seems to be through the intermediate-complexity Cluster 4. The correlation for this pair is twice as high as it is for Clusters 1 and 2. Cluster 5 is uncorrelated to Cluster 3, and weakly correlated to the others. This indicates that being specialised in this cluster makes it very hard to move anywhere else in product space.

Table 5. Regression results for country capabilities in 2011-12

Explanatory variables	**Regr (1)**		**Regr (2)**	
F-1998	0.855	***	0.855	***
1998 share cluster 1	14.704		11.657	***
1998 share cluster 2	25.018	**	22.468	***
1998 share cluster 3	4.137			
1998 share cluster 4	13.344		11.189	***
1998 share cluster 5	15.190		12.290	***
D share cluster 1	0.313			
D share cluster 2	6.085	*	6.019	*
D share cluster 3	4.064			
D share cluster 4	14.267	***	15.280	***
D share cluster 5	0.061			
H	0.776		0.779	*
constant	-15.589		-12.562	***
R2	0.94		0.94	

In order to obtain an idea of how the path-dependence and stickiness of product space influenced how country capabilities evolved in the most recent period, and hence to assess which countries are well-placed to grow fast in the years to come, we look at the evolution of capabilities over the period 1998 – 2012. To this end, we perform a regression with the country capability level in 2011& 2012 as the dependent variable. As explanatory variables, we include first and foremost the level of capabilities in 1998 & 1999. In addition to this, we include (i) the shares of each country's exports in 1998 & 1998 in the 5 clusters, (ii) the changes of these shares over 1998/99 to 2011/12, and (iii) a diversification (H) index for a country's 1998/99 exports in terms of the 8 clusters that were found in product space.

Table 5 presents the regression results. There are two equations, one (first column) that includes all variables, and one (second column) that excludes insignificant variables (at the 10% level), one by one, starting with the least significant variable. The results point to a convergence in country capabilities, in various ways. The capability variable at the start of the period has a value smaller than unity, which indicates that although countries that start with high capabilities also tend to have high capabilities at the end, this is not a very strong tendency.

The coefficients of the cluster share variables in 1998 can be interpreted in reference to the constant. If the trade share in any cluster was exactly one in 1998, this would add to the constant, which is negative. For example, the coefficient on the share of cluster 1 is approximately equal to the constant, which means a country that is completely specialised in this cluster would have a constant in the estimated equation equal to zero. If such a country would not change its trade shares at all, the equation predict that its capability in 2011-12 will be 0.855 times the capability in 1998-99.

Cluster 2 (fibres, electrical machinery and metal products) has the highest coefficient, slightly higher than the constant. This implies that a starting position in Cluster 2 provides the best opportunities for increasing capabilities. The other clusters have coefficients smaller than the constant, especially so the advanced (high-complexity) cluster 3. This is a further indication of convergence.

Increasing exports in Clusters 2 and especially 4 (i.e., D share variables) also adds positively to capabilities in 2011-12. These are the two clusters with intermediate complexity levels, and the regression seems to point out that they are the most relevant vehicles for increasing trade-based capabilities. Despite the fact that Cluster 3 is the cluster with most complex products, it does not show up as significant in the changing shares variables. This implies that increasing the share of exports towards Cluster 3 is not a very viable way to increase capabilities.

V. Technology and structural change

V.1. Productivity growth and structural change

Switching export patterns to more complex and technology-intensive products implies a process of structural change of the production process of a country. Therefore, we now turn to analysing structural change in the economy and its linkages to growth. As will be shown, technological change is an important source of structural change. It is difficult to measure the impact of technological change on economic production and employment, and therefore on economic development, in a direct way. In the absence of widely available data on innovation inputs (such as research and development) and outputs, economists usually resort to productivity measures as a way to quantify technological change. This is an indirect measure of technology, but it does capture the main role of innovation and technological change in the development process, i.e., increasing the economic value of production per unit of input. In this section we use the WIOD database to explore two aspects of the productivity-increasing role of technological change: its relationship to structural change, and the different roles that productivity plays in developing and emerging economies on the one hand, and developed nations on the other hand (Timmer et. al., 2015).

We will look at two forms of productivity. The simplest and most directly relevant form is labour productivity, i.e., value added per worker. The other, slightly more complicated form is so-called total factor productivity (TFP), which also takes into account the role of capital goods (such as machinery and equipment, and buildings). TFP is the amount of value added per "K&L unit", where K stands for capital and L for labour, a "K-L unit" is obtained by weighting together capital and labour by the shares of their payments in value added. This is a well-established procedure based on the economic theory of production, which we do not explain in detail here.

The main reason why technological change is an important determinant of structural change is the fact its rate differs greatly between economic sectors. Therefore, it provides a stimulus to economic growth that favours some sectors over others. This is documented in

Table 6, which gives the rates of growth of total factor productivity (TFP) and labour productivity (LP). The sectors are ranked according to the median of TFP growth.

On top of the list we find four manufacturing sub-sectors, which indicates that manufacturing is still the most important source of technological progress in the economy. These sectors are the ones that are commonly seen as high-tech, but also include the non-metallic minerals sector, which is usually seen as low-tech. This latter sector does show a lower labour productivity growth rate than the other sectors on top of the list though. Transport and telecom lists in 5th position, and together with trade (9th position), it is the only services sector in the top-10 of the list.

Table 6. The distributions of TFP and LP growth within sectors

	TFP growth		LP growth	
Sector	**average**	**median**	**average**	**median**
Electrical and Optical Equipment	0.153	0.095	0.046	0.049
Transport Equipment	0.071	0.044	0.032	0.029
Machinery, Nec	0.062	0.040	0.035	0.028
Other Non-Metallic Mineral	0.046	0.032	0.021	0.024
Transport & telecom	0.040	0.032	0.033	0.032
Rubber and Plastics	0.078	0.031	0.014	0.022
Basic Metals and Fabricated Metal	0.050	0.027	0.009	0.018
Chemicals and Chemical Products	0.031	0.025	0.025	0.025
Trade etc.	0.029	0.022	0.013	0.011
Textiles and Textile Products	0.025	0.020	0.022	0.028
Wood and Products of Wood and Cork	0.027	0.019	0.019	0.016
Other Manufacturing; Recycling	0.037	0.019	0.010	0.018
Paper , Printing and Publishing	0.019	0.017	0.026	0.025
Leather, Leather and Footwear	0.008	0.014	0.018	0.019
Agriculture	0.040	0.013	0.032	0.031
Food, Beverages and Tobacco	0.013	0.010	0.017	0.020
Finance & bus services	0.022	0.009	0.000	0.002
Utilities	0.010	0.004	0.029	0.030
Public & other services	0.008	0.001	0.010	0.003
Mining	0.012	-0.002	0.023	0.023
Construction	-0.002	-0.004	0.004	0.001
Coke, Refined Petroleum and Nuclear Fuel	0.030	-0.007	0.007	0.001

Productivity growth rates are for 1995 – 2008, TFP growth rates for a sample of 37 countries, LP growth rates for a sample of 62 countries (including the former 37).

From the point of view of structural change, the differences between the sectors are what matters most. These differences are substantial, both with a sector (between countries), and between sectors. We start to investigate what the differences in productivity growth rates imply for structural change. To this end, we apply a decomposition of an index of structural change, the Finger-Kreiner index, which is equal to the sum of the absolute differences of sectoral shares of value added between two time periods. In particular, we decompose the value of this index, for every country, into two parts: one that is related to technological change (productivity growth rates), and one that it related to changes in the allocation of the production factor(s). We use labour as the only production factor, but the method works for total factor productivity (labour and capital as production factors) as well.

The decomposition works as follows:

$$index = \left(\sum_{i=0}^{n} \left|\frac{x_i^1}{x^1} - \frac{x_i^0}{x^0}\right| = \left|\frac{x_i^0}{x^0} g_i - \frac{x_i^1}{x^1} g\right| = \left|\frac{x_i^0}{x^0}(r_i + \tau_i) - \frac{x_i^1}{x^1}(r + \tau)\right|\right)/2,$$

where x is value added in constant prices, a subscript i indicates the sector (absence of the subscript indicates an aggregate over sectors), a superscript indicates a time period, g is the growth rate of value added, r is the part of the growth rate that is due to the growth of resources, and τ is the part of the growth rate that is due to productivity growth (i.e., $r + \tau$ is the conventional split-up of the growth rate into productivity and growth of labour).

This equation starts from the simple definition of the structural change index (the sum of absolute value of the changes in shares), and then re-writes the change in sectoral share as a function of the growth rates of value added. The next step writes these growth rates, both for the aggregate economy and for the sectors as the sum of productivity growth and growth of the production factors. With this, we can re-group the terms in the following way (we have separate cases for sectors that see their share declining and those that increase their share):

$$\left|\frac{x_i^0}{x^0}(r_i + \tau_i) - \frac{x_i^1}{x^1}(r + \tau)\right| = -\left(\frac{x_i^0}{x^0} r_i - \frac{x_i^1}{x^1} r\right) - \left(\frac{x_i^0}{x^0} \tau_i - \frac{x_i^1}{x^1} \tau\right) \text{ if the share declines}$$

$$\left|\frac{x_i^0}{x^0}(r_i + \tau_i) - \frac{x_i^1}{x^1}(r + \tau)\right| = \left(\frac{x_i^0}{x^0} r_i - \frac{x_i^1}{x^1} r\right) + \left(\frac{x_i^0}{x^0} \tau_i - \frac{x_i^1}{x^1} \tau\right) \text{ if the share increases}$$

Finally, we group all terms (over all sectors, within a country) involving r, and all terms involving τ. The latter collection of terms sums the contribution of differential growth rates of productivity, or technological change, while the former (r) sums to the contribution of resource allocation to structural change.

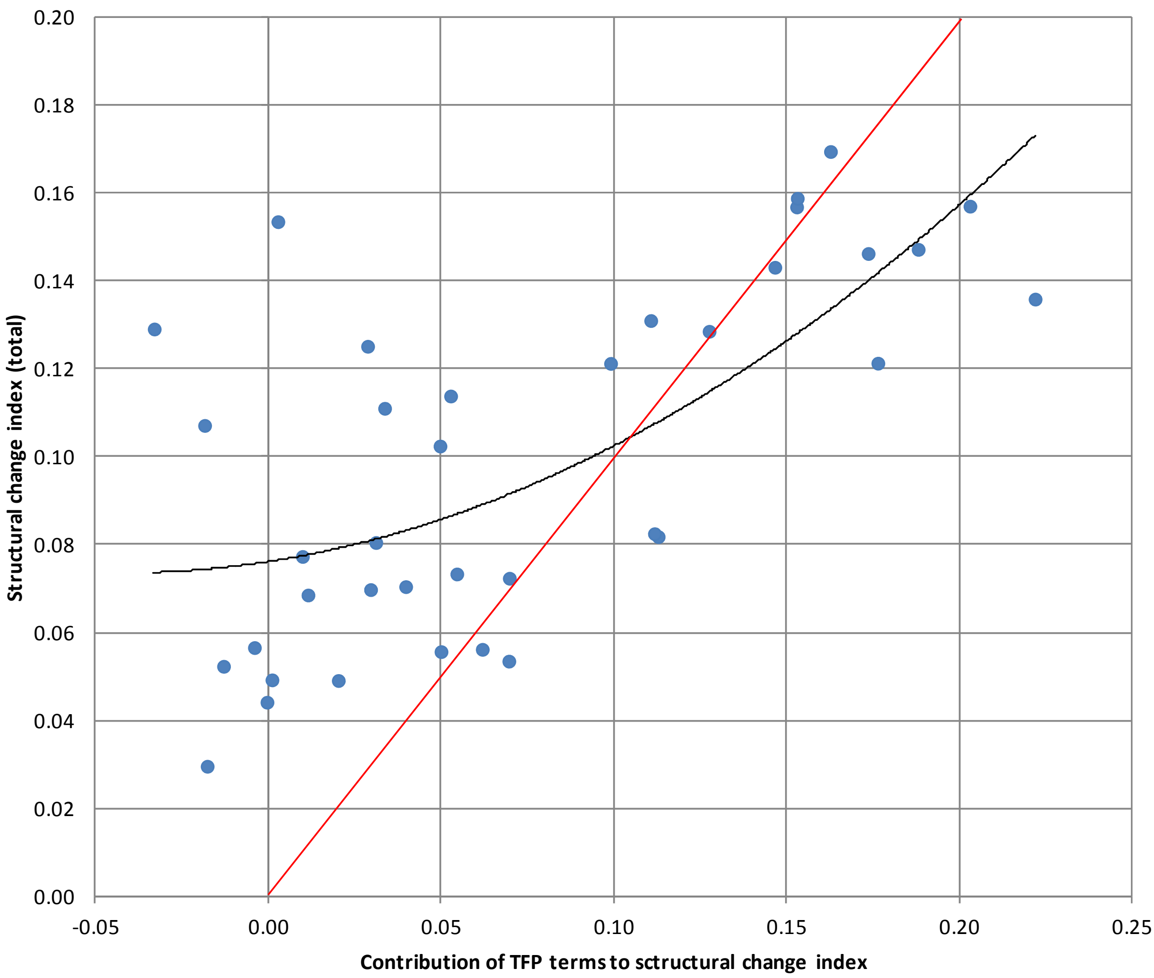


Figure 9. TFP growth as a source of structural change, 9 sector breakdown of total economy

Figure 9 (for the 9 sector breakdown of the total economy)[4] and Figure 10 (the 14-sector breakdown of manufacturing) show the relationship between the value of the structural change index and the contribution of the TFP part of the decomposition to the total value of the index. There is a clear positive relationship, which is very strong within manufacturing, and a bit weaker (but still fairly strong) in the breakdown of the total economy.

The positive relationships (regression lines) imply that we find most values in the right-upper or lower-left corners of the figure. This means that differences in TFP growth rates between sectors (within a country) are the decisive factor in accounting for structural change: high values of structural change, on the vertical axis, are mostly achieved by a large contribution of technological change, on the horizontal axis. High values of structural change achieved by high factor contributions would lie in the lower-right part of the graphs, which is in fact unpopulated.

[4] This figure excludes one outlier, Slovenia.

The countries with high structural change, and a high contribution of technological progress, are mostly Eastern European countries, such as Slovakia, Hungary and the Czech Republic. But also Sweden, Finland and Korea have high scores on both dimensions.

In Figure 9, there are some observations in the upper-left corner of the graph, above the regression line. These are Eastern European countries (i.e., Latvia, Romania, Poland), where factor movements lead to relatively fast structural change. But these countries are not sufficient to draw the regression line down, because of a large group of countries that has a low contribution of technological change, and low structural change.

The red line in the figures is the 45-degree line. Points that lie below this line have a higher contribution of technological progress than the value of the total index, which means the contribution of changes in the production factors is negative. This happens mostly as a result of production factors moving out of sectors with rapid productivity change, for example because demand is not enough to match productivity growth. We see that this happens most often when overall structural change and the contribution of technological change are high, i.e., in the right-upper corner of the figures.

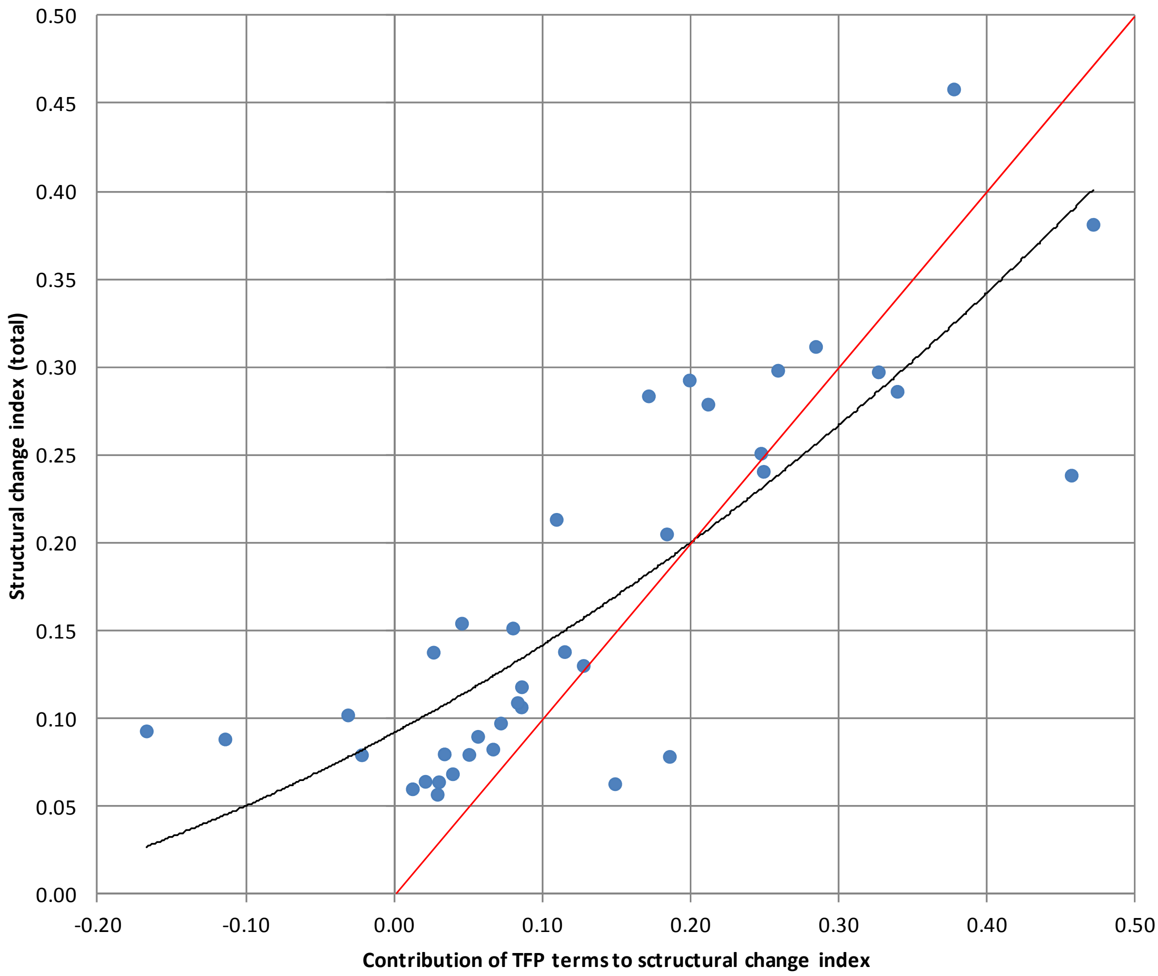


Figure 10. TFP growth as a source of structural change, 14 sector breakdown of manufacturing

V.2. The sources of growth in industries at various stages of development

So far it has been illustrated how the effective use of catch-up potential in the period after 1995 is connected to performance in export markets of “complex” products, that are generally technology-intensive, and also how technological change, in the form of productivity growth, is connected to structural change. Structural change results from differences in the rates of technological progress between sectors, and is a vehicle for realising the potential of technological progress for development.

As a result of the logic of the technology gap framework, the nature and impact of technological progress on the macro economy and structural change connected to it, will differ between countries at different stages of development. At low levels of development, the potential for rapid technological progress and growth is highest, but limits to absorptive capability will often limit the realisation of potential, so that overall growth may remain low. At increasing levels of development, potential declines, but the probability of low capability also declines. In order to see how this works out in the period under consideration, we now turn to an analysis that maps the rate of labour productivity growth, as a rough indicator of technological progress, as a function of development levels.

The method used to construct this map is smoothing by locally weighted regression (lowess smoothing), which performs regressions on moving windows of subsets of the entire WIOD dataset to construct a smooth but non-parametric plot of one variable against another. In our case, we look at the development of growth rates of value added (VA) and labour productivity (LP), over the period 1995 – 2009, against the development level of nations, as indicated by the log of GDP per capita in 1995. In this way, we will be able to see how countries at different levels of development have been able to use technological progress for realising economic growth at the sectoral level, and the associated structural change. We look at the 14 subsectors of manufacturing, and 73 countries at all levels of development. The 14 sectors are split into low-tech (ISIC rev. 3 codes 15-19), high-tech (ISIC 29-35) and medium-tech (ISIC 20-28 and 36-37).

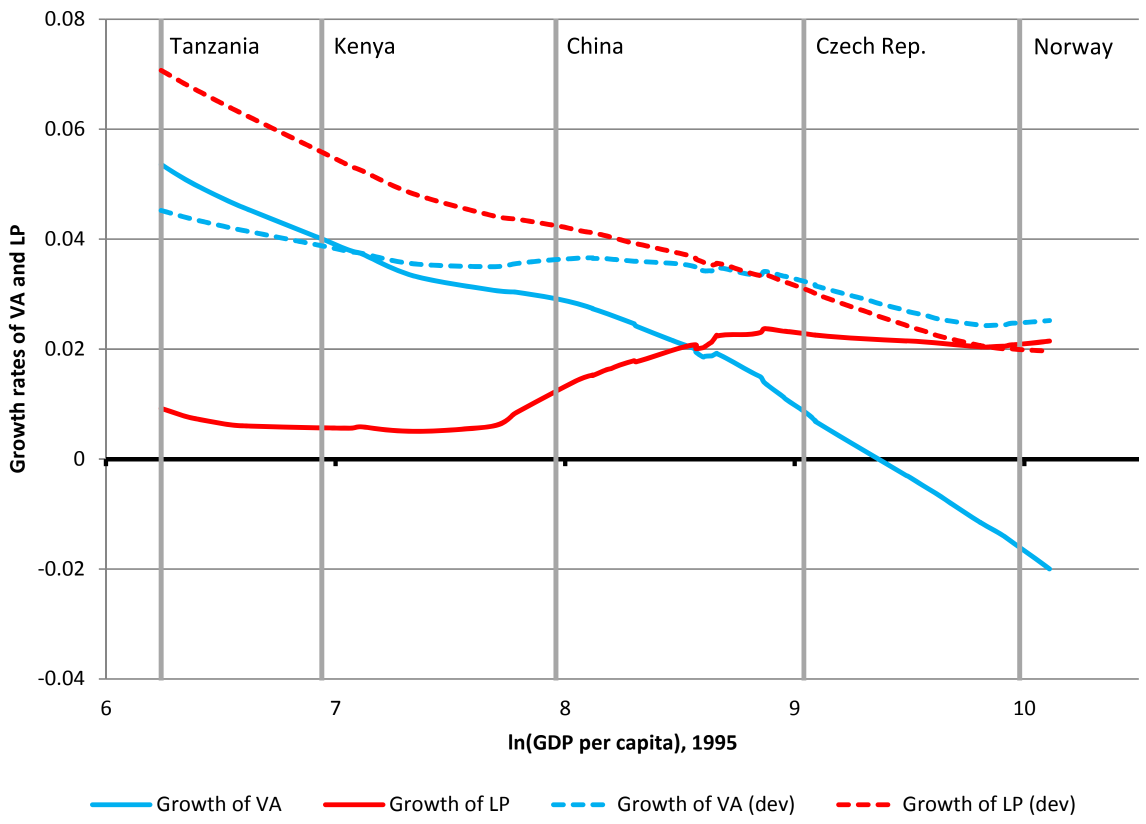


Figure 11. Rates of growth of LP and VA against level of development, 1995 - 2009, low-tech sectors in manufacturing

Figure 11 provides the results for the low-tech sectors. The solid lines show the smoothed growth rates, the dashed lines show (average) deviations from these smoothed rates, at the indicated development level. The difference between the VA growth line and the LP growth line is the growth rate of employment (factor use). The vertical grey lines indicate development levels of selected countries, which are provided as a broad reference.

In the low-tech industries, we see that at low levels of development, productivity growth rates are low, but highly variable between countries (large deviations). On the other hand, growth rates of value added are high at low development levels, which indicates that these countries are, on average, growing in a labour intensive way. Also the variability of the growth rates of value added is high at low development levels, although comparatively lower than the growth rate of LP.

For higher development levels, the LP growth curve follows an S-shaped pattern, with a strong rise starting just before China's development level, and flattening off again at the development level of the Czech Republic. The variability of LP growth rates gradually falls with the level of development. While LP growth rises with the level of development, the growth rate of value added falls, monotonically. This implies that with rising development levels, growth becomes more productivity (technology) intensive, on average, with the richest countries showing declining employment (productivity rises faster than output). The variability of output growth also falls with development, but only at a slow rate.

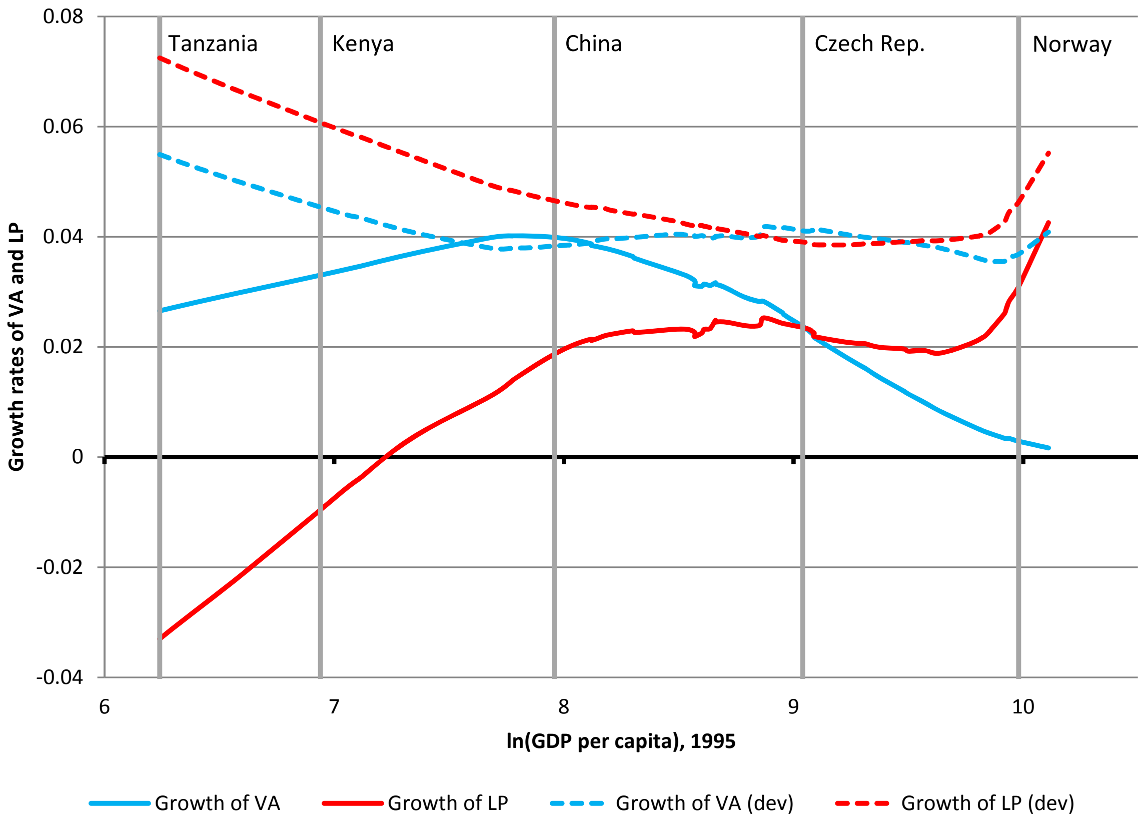


Figure 12. Rates of growth of LP and VA against level of development, 1995 - 2009, medium-tech sectors in manufacturing

Figure 12 look at the medium-tech sectors. The pattern observed is similar to low-tech, with the exception of the low and high sides of development. For low levels of development, both growth rates are lower, LP growth is even negative. This means that for the first part of the paths, growth of VA and LP are rising with development. The VA growth curve peaks just before the Chinese development level, while the LP growth curve flattens just after this level. Variability of both growth rates is still very high at low development levels, and falls gradually with development. At the high end of the development, both growth rates as well as variability, increase sharply. But this shows the results of only a few (rich) countries. As with the low-tech sectors, VA growth is combined with employment growth at low levels of development, and with employment shrinking at high development levels, on average.

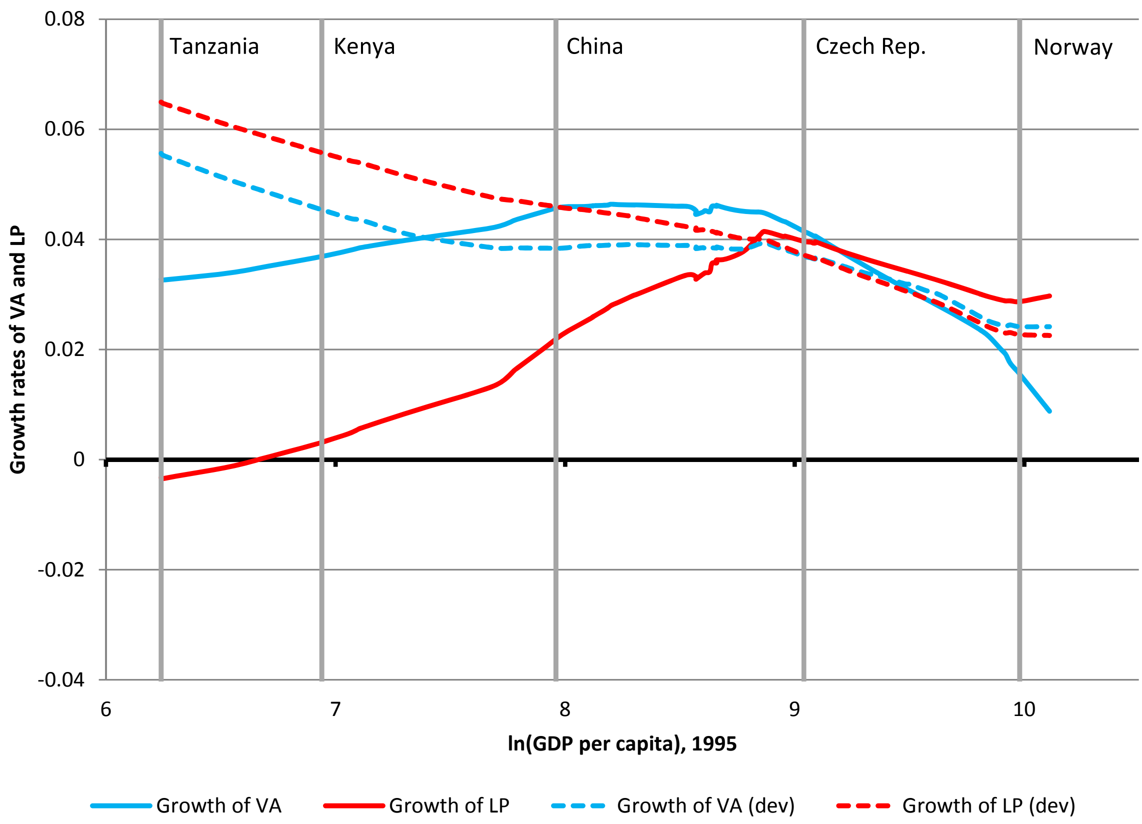


Figure 13. Rates of growth of LP and VA against level of development, 1995 - 2009, high-tech sectors in manufacturing

The high-tech sectors are displayed in Figure 13. The pattern for this group of sectors looks very similar to the medium-tech sectors, although at low levels of development, LP growth is negative for only a very short range. Also, LP growth peaks at a much higher level than either in medium- or low-tech. Also, we find that in high-tech, employment shrinkage in highly developed countries is much smaller than in the medium- or low-tech sectors.

Overall, the evidence in these figures shows that the development level is a strong determinant of the opportunities for growth, a tendency that was already associated to the existence of development traps. The low-tech industries seem to provide most opportunities for productivity growth in lowly developed countries, but on average productivity growth reaches substantial levels only at intermediate levels of development. Our results therefore confirm the importance of low-tech industries as avenues where the absorption of foreign knowledge is relatively easy (compared to other industries). But variability between countries is high, even at low development levels high productivity growth is possible, which is again a reflection of the importance of capabilities to absorb technological knowledge from abroad.

Growth rates of value added are, on average, larger in lowly developed countries, for all three groups of industries. This shows that these countries have other advantages than productivity growth, in particular low wages, that enable them to grow rapidly. Even in high- and medium-tech industries, these countries are able to find segments where this labour-intensive growth is possible, but this kind of growth does not lead to sustained productivity increases that enable the country to reach higher development levels. Again, these are average tendencies, and variability of performance, especially in productivity growth, is high, especially at the low end of development.

VI. A macroeconomic view on the impact of globalisation

We now turn to a macroeconomic perspective to investigate the role of globalisation in structural change and growth in the period since 1995. From the macro-development perspective, a crucial aspect of globalisation is that what is traditionally considered as exports, does not all represent value added to the local economy. Because value chains are increasingly becoming global, an exporting firm will likely have used intermediate inputs or services from abroad in the product that it exports, and hence the gross value of the export is not all value added for the exporting firm. The (foreign) firm that delivered the intermediate input also contributes to the value chain.

Classic cases that have been studied in the literature are electronics products such as mobile phones or music players (the iPod). These products are typically produced in Asian countries such as China or Taiwan, but much of the value added associated with the exports of these devices from the assembly locations to the final users, is produced by firms that deliver parts, or knowledge (in the form of licenses) to the assemblers. It is often argued that final assembly represents only a small fraction of total value added of the final product. This would imply that the nations that export these high-tech products do not capture much of their value, and that such high-tech exports are not a way in which the domestic production system can be upgraded, and the economy develop towards a higher living standard.

Macroeconomically, we can analyse this impact of global value chains by using input-output tables from the EORA database (Lenzen et. al. (2013). Here we suffice by explaining the general principles of the idea. Using a global input-output table, we can create a breakdown of global GDP into the producing location (where is the value created?) and the location where demand originates (where is the final product delivered?). This breakdown takes a matrix form (see Diagram 1), where the rows represent value added producing locations, and the columns represent the locations of demand. The diagram uses a simplified example with the global economy consisting of two countries, North and South.

In the diagram, if we look row-wise, we break down GDP of a country by the demand-location that it serves. In this way, GDP in North consists of value added produced for the local North market, and value added exported to South. A column breaks down total demand in a location by the source of production. The column for South sums to total final demand in South, and breaks this down between value added imports from North, and domestically produced value added.

Taking an example of an iPod, the matrix works as follows. Suppose the iPod is assembled in South, using a license that is owned by North, and using some parts (silicon chips) that are produced in North. The iPod is delivered to a final consumer in North. In this case, the sum of the demand column for North will be the value (selling price) of the iPod. Within this column, the cell for South will display the value added (wages and profits) of the firm in the South that assembled the device. The cell for North will give the value added of all North firms involved in the knowledge embodied in the license, and in the production of the silicon chip.

		Demand located in:		
Production located in:		North	South	
	North	Domestic Value Added in North	Value Added exported from North to South	GDP of the North: Yn
	South	Value Added exported from South to North	Domestic Value Added in North	GDP of the South: Ys
		Total demand of the North: TDn	Total demand of the South: TDs	

Diagram 1: Production and demand matrix, two country example

The method takes account of all indirect linkages that exist between countries. In the example of the iPod, the silicon chip could be produced using raw materials that are produced in the South. In this case, the South cell would also include the value added by the firm that mines this raw material.

Figure 14 documents the recent trends in the globalisation from a macro-development perspective.[5] The figure documents a summary of the results from the decomposition method explained above. The key indicator is the share of value added trade in global GDP (blue line). This indicator measures which share the off-diagonal cells in the decomposition matrix have in global GDP. These off-diagonal cells both include direct trade in final goods (e.g., cars produced in Japan being delivered to Germany), and all indirect value-added streams associated to global value chains (e.g., Chinese steel delivered to Japanese carmakers who sell cars on the domestic Japanese market). The other indicator (gross trade as a share of global

[5] We use input-output data from the EORA database, 26 sector version. The database has data for 189 countries. We manipulated the basic input-output table to ensure consistency. Despite these manipulations, several countries show rather strange trends, but we aggregated these countries into larger groups so that the impact of these apparent anomalies is limited.

GDP) looks at all exports, including final goods and intermediates). Because not all trade is value added, this indicator lies at a higher level than the value added trade indicator.

Globalisation is clearly on the rise: in 1995, gross trade was about 20% of global GDP, and value added trade about 15%. In 2011, these numbers had risen to about 30% and 20%, respectively. There are two discontinuities in the trend: a marked increase in the rise after 2001, and the 2009 crisis. Especially value added trade shows a different pattern before and after 2001. Before, the trend is flat, with small fluctuations. The increase occurs after 2001, and is interrupted momentarily by the crisis of 2009. In 2001, it is almost back to the 2008 level. Thus, a very substantial part of the global economy is “purely domestic”, i.e., domestic value added for domestic demand. Only about 20% of global GDP is value added that is, directly or indirectly, produced for foreign markets, but this share increased rapidly since the turn of the century.

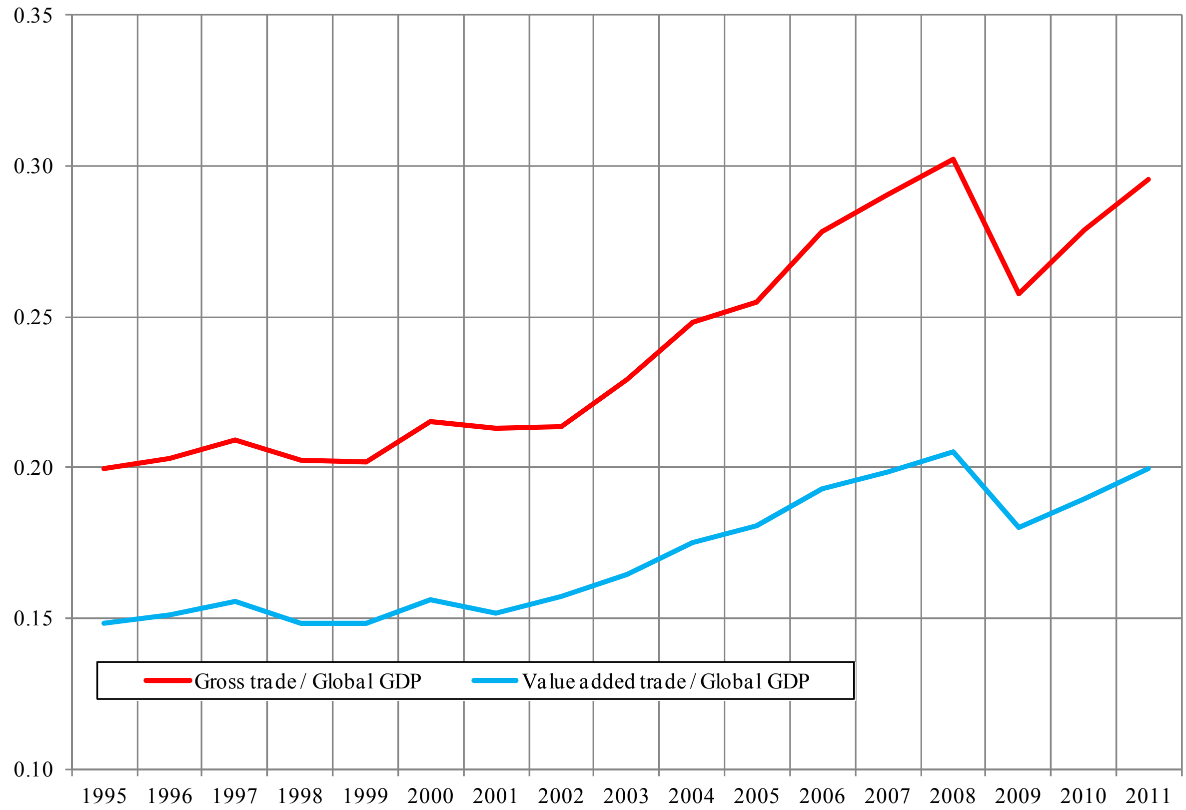


Figure 14. Recent trends in globalisation

Which sectors were responsible for this rise of globalisation since 2001? In order to keep the results presentable, we group the 9 sectors that were used to break down the total economy earlier into 4 broad sectors. These sectors are resources (agriculture, mining and utilities), manufacturing, market services (trade, hotels and restaurants; transport and telecommunications; finance and business services), and other sectors (also including re-exports, which is a separate sector in the underlying database).

Table 7 shows that, in terms of these 4 broad groups of sectors, the largest part of the increase of traded value added is produced in the market services sectors, closely followed by the manufacturing sector. Together these two sectors account for about three-quarters of the total increase. Instead of attributing the trade value added increase to the sectors where value is added, we can also look at in which sector final demand occurs, i.e., look at derived demand effects. In this case, almost half (48%) of the total increase is due to final demand for manufacturing products.

Table 7. The rise of globalisation broken down by sectors

Traded value added increases by 4.8 % points over 2001 – 2011, and of this:	
1.9 points are produced by market services sectors	2.2 points are due to final demand in manufacturing sectors
1.8 points are produced by manufacturing sectors	1.3 points are due to final demand in other sectors
0.9 points are produced by resources sectors	1.1 points are due to final demand in market services sectors
0.2 points are produces by other sectors	0.2 points are due to final demand in resources sectors
Traded value added increases by 4.8 points over 2001 – 2011, and of this:	
1.9 points are produced in the same broad group of sectors as where final demand occurs	
0.7 points are demand for market services derived from final demand in manufacturing sectors	
0.5 points are demand for resources derived from final demand in manufacturing sectors	
0.5 points are demand for manufacturing derived from final demand in "other" sectors	
0.5 points are demand for market services derived from final demand in "other" sectors	
0.7 points are other derived demand (smaller than 0.25 points per sector combination)	

The discrepancy between the demand perspective and the production perspective in Table 7 is due to the phenomenon of derived demand. Demand for manufacturing products will lead to demand for services, and for resources, and vice versa. In fact, the largest part of the rise of globalisation consists of such derived demand, which is indeed indicative of the rise of the GVC phenomenon. Only 1.9 points (of a total of the 4.8 points increase) occur in the same broad sector as where final demand occurs. The rest (2.9 points) is derived demand. The largest category within derived demand is market services production for manufacturing demand and resources production for manufacturing demand.

We must therefore conclude that the manufacturing sector plays a crucial role in the increase of globalisation. But market services also play a large role, both as a result of parts of the services sector become more tradable, and because of derived demand. Finally, resources play a substantial but limited role, clearly smaller than manufacturing and market services.

We resort to a broad geographical grouping of countries so that, the matrix that splits global GDP by source of demand and source of production can be presented with the same country groups (doing this for more groups, or even at a country level, the matrix becomes unmanageably large).

The 8 country blocks are aggregations within the total sample of 189 countries that are available in the EORA database.[6] The "developed" group includes non-communist Europe (as it stood before the 1990s), the USA, Canada, New Zealand, Australia, Japan, Korea, Singapore, Taiwan and Hong Kong (the Asian Tigers). China and India, because of their size, are kept separate. The other blocks are simple geographical groupings.

[6] The country groupings are as follows: (1) developed countries: Australia, Ireland, Canada, New Zealand, Norway, Spain, UK, USA, Switzerland, Finland, Greece, Portugal, Italy, Belgium, Sweden, Netherlands, Denmark, France, Austria, Germany, Singapore, South Korea, Hong Kong, Japan, Taiwan; (2) other Asia: Mongolia, Sri Lanka, Laos, Cambodia, Myanmar, Viet Nam, Malaysia, Nepal, Indonesia, Philippines, Pakistan, Thailand, Bangladesh; (3) Post-communist: Latvia, Lithuania, Estonia, Romania, Bulgaria, Slovakia, Czech Republic, Poland, Hungary, Slovenia, Azerbaijan, Bosnia and Herzegovina, Kazakhstan, Armenia, Turkmenistan, Russia, Belarus, Albania, Tajikistan, Georgia, Kyrgyzstan, Uzbekistan, Ukraine, TFYR Macedonia, Croatia, Serbia, Moldova; (4) Latin America: Trinidad and Tobago, Dominican Republic, Ecuador, Bolivia, Mexico, Chile, Nicaragua, Panama, Peru, Argentina, Honduras, Venezuela, Guatemala, Costa Rica, Paraguay, Haiti, Brazil, Colombia, El Salvador, Jamaica, Uruguay; (5) MENA: Iraq, Qatar, Jordan, UAE, Oman, Kuwait, Iran, Algeria, Egypt, Yemen, Bahrain, Saudi Arabia, Syria, Turkey, Lebanon, Tunisia, Morocco, Israel, Gaza Strip, Libya; (6) Sub Saharan Africa: Sudan, South Sudan, Angola, Liberia, Ethiopia, Nigeria, Mozambique, Zambia, Chad, Rwanda, Ghana, Eritrea, Botswana, Uganda, Burkina Faso, South Africa, Mauritania, Burundi, Gambia, Tanzania, Zimbabwe, Niger, Congo, Gabon, Togo, Mali, Benin, Senegal, Malawi, Cameroon, Namibia, Madagascar, Sierra Leone, Kenya, Mauritius, Swaziland, DR Congo, Lesotho, Cote d'Ivoire, Central African Republic, Guinea, Somalia; (7) Other/small countries: Former USSR, Bhutan, Afghanistan, Maldives, Suriname, Samoa, Cape Verde, Macao SAR, Montenegro, Sao Tome and Principe, Vanuatu, Guyana, Cyprus, Papua New Guinea, Brunei, North Korea, Djibouti, Belize, Andorra, Malta, New Caledonia, Bermuda, Liechtenstein, Cayman Islands, Antigua, Luxembourg, Cuba, Barbados, British Virgin Islands, Seychelles, Iceland, Aruba, Bahamas, Greenland, Monaco, Fiji, French Polynesia, Netherlands Antilles, San Marino.

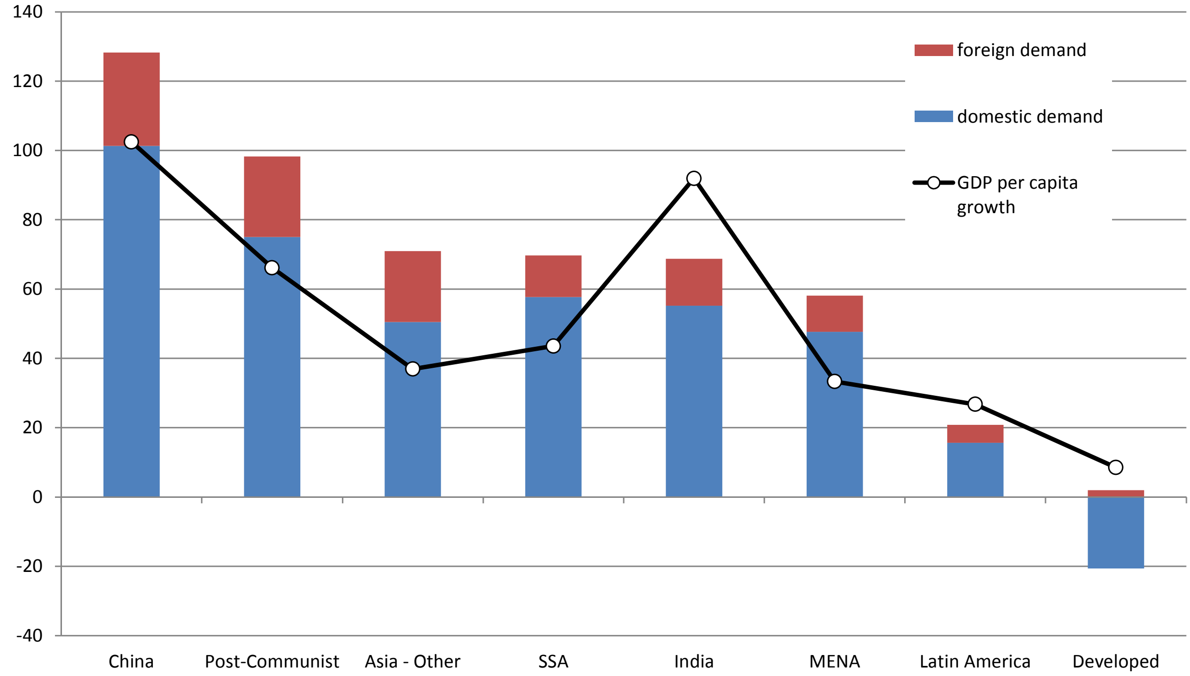


Figure 15. Growth rates of share of global GDP, and GDP per capita, by country block, 2001-2011

Figure 15 displays the growth rates of the shares of global GDP for each country block, over the period 2001 – 2011. The EORA analysis is in current dollars, hence the GDP data are not comparable with the data that are normally used for GDP per capita levels. Although we "correct" for a global inflation rate by expressing all calculations in dollars, and taking shares of global GDP, the results are not always indicative of the actual trends in "real" GDP per capita over the period, and therefore these growth rates are also included (the black line). This reaffirms and reflects our analysis of GDP growth rates in the first section.

As expected, China is the fastest grower, its share of global GDP rises from 4.2% in 2001 to 9.7% in 2001, i.e., a rise of 128%. The post-communist world's share almost doubles, which puts this block in second place. These countries are the ones that are catching-up rapidly also in terms of GDP per capita. The other country groups showed slower convergence, and this is also the case in terms of the share of GDP shares in Figure 15. India is somewhat of an exception, showing GDP per capita growth that is relatively rapid, but slower increase of the share of global GDP. Latin America is a slow grower (20%), and the developed block shows negative growth of about 20%.

The figure also shows the breakdown of the total growth rate into a part that is due to domestic demand and a part that is due to foreign demand. In all cases, the domestic part is by far largest. In these accounting terms, domestic demand is of crucial importance for growth in the entire world. However, the simple decomposition used here does not point out the role that foreign demand plays in catalysing domestic growth. This is connected to the idea of export-led growth: obtaining growth by being competitive in export markets has indirect effects in terms of domestic growth, for example because of the spending that occurs out of income earned by workers or because of investment. Hence the role of the "foreign" part of growth in Figure 15 must not be under-estimated.

China and the post-communist world are the two cases where growth is also rapid in per capita terms, i.e., where there is catching up to the global frontier of living standards. In the other country groups, this is much less the case, partly because population growth is also fairly rapid. Both China and the post-communist block have sizable parts for foreign-based growth. In relative terms, the contribution of foreign-demand-based growth is largest in the other Asian group (29%) of total growth, and lowest in sub-Saharan Africa (17%).

Table 8. The rise of globalisation broken down by country groups, demand and supply

	Developed	China	India	Asia - Other	Post-communist	Latin America	MENA	SSA	other	Total
Developed	-0.496	0.872	0.151	0.167	0.308	0.109	0.288	0.076	0.085	1.560
China	0.785	0.000	0.038	0.081	0.062	0.061	0.078	0.023	0.017	1.146
India	0.082	0.024	0.000	0.020	0.010	0.009	0.041	0.011	0.003	0.199
Asia - Other	0.178	0.120	0.021	0.044	0.015	0.013	0.027	0.007	0.004	0.429
Post-Communist	0.220	0.078	0.016	0.012	0.202	0.015	0.055	0.007	0.006	0.612
Latin America	0.074	0.046	0.006	0.007	0.012	0.122	0.013	0.006	0.036	0.323
MENA	0.140	0.057	0.025	0.019	0.029	0.014	0.058	0.010	0.004	0.356
SSA	0.038	0.030	0.007	0.004	0.007	0.006	0.006	0.022	0.002	0.122
Other	0.000	0.005	0.001	0.001	0.004	0.000	0.001	0.001	0.002	0.015
Total	1.021	1.233	0.267	0.355	0.650	0.349	0.566	0.162	0.158	*4.762*

VI.1 Globalisation and structural change

We now extend the details of analysis of the rise of globalisation since 2001 by looking at sectors and bilateral relations between the country blocks. Table 8 displays the changes in the basic matrix (Diagram 1) that underlie the calculations, over the period 2001 – 2011, i.e., it provides the bilateral view. The numbers are in percentage points, a number of +1 would indicate that the share of this cell in global GDP increases by 1% point. The sum of all cells in the matrix is 4.8% points, which is exactly the increase of the blue line in Figure 8 over the period. The diagonal of the matrix refers to international flows of GDP within the block, i.e., all (changes to) purely domestic flows have been kept out of the table.

The rise of globalisation is indicated by the fact that all but one cell show positive values. The exception is GDP produced in developed countries for markets in the same group of countries. This declines by about half a point. The largest values in the table are, as expected, associated with China. Interestingly, GDP produced in developed countries for Chinese final demand rises slightly more than GDP produced in China for demand in developed countries. The row for developed countries also attracts high values, which means that these countries take advantage of globalisation in terms of production. Post-communist countries appear to have high values with developed countries, but also within the block itself. The within-Latin America cell is also high.

In terms of production, the developed world and China take 57% of the total increase of 4.8 % points. The post-communist world and other Asian countries rank next in terms of their row-totals. The contract between India and China is large with the former country benefitting from globalisation a lot less than the latter. Sub-Saharan African countries, which have a low share of global GDP to begin with, take least advantage of globalisation in terms of production. The demand-side totals (columns) are somewhat different, but not very much. Developed countries and China take the bulk of the total. Interestingly, the developed world takes a larger share of the total in terms of production than in terms of demand, while the reverse is true for China.

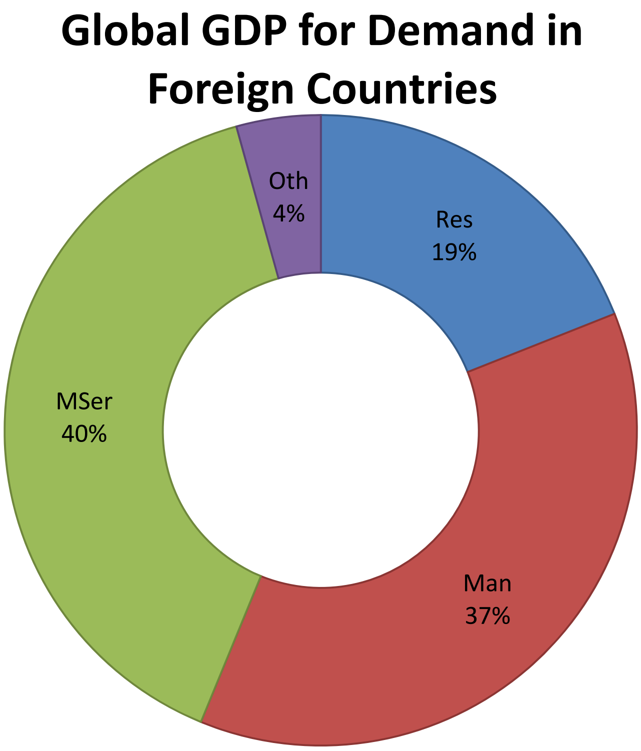
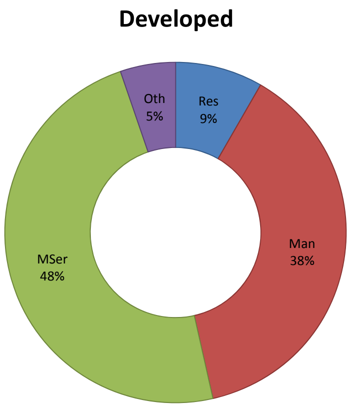


Figure 16. The rise of globalisation broken down by producing sectors

Figure 16 provides the overall sectoral breakdown of the rise of globalisation. These are the same numbers as Table 7, but expressed in terms of their sectoral share (by production). 40% of the rise of globalisation is produced in the market services sectors. Slightly less, 37%, is produced in the manufacturing sector. A much smaller share (19%) is in resources, and the small residual part (4%) in other sectors. How does this distribution compare with the distributions at the country level, or even at the level of the (inner) cells of the matrix in Table 8? This is displayed in Figure 17, which gives totals per country group for production of GDP (row totals).


Developed
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Res 9%
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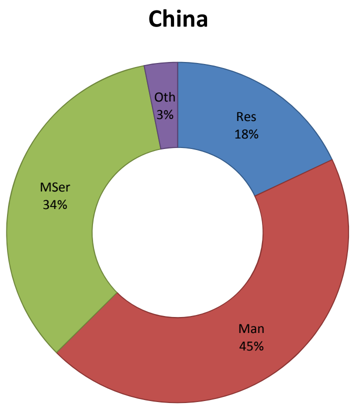
China
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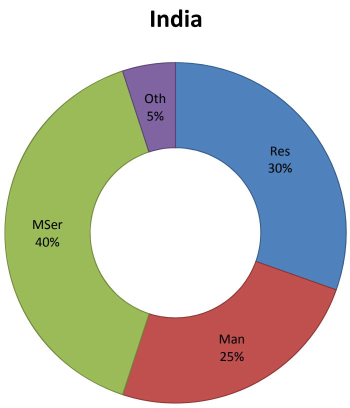
India
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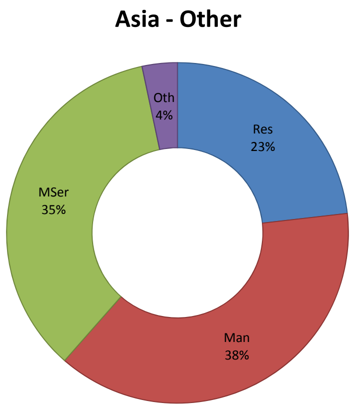
Asia - Other
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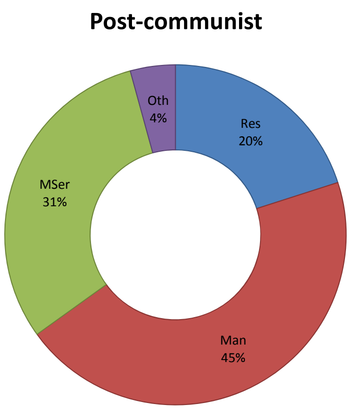
Post-communist
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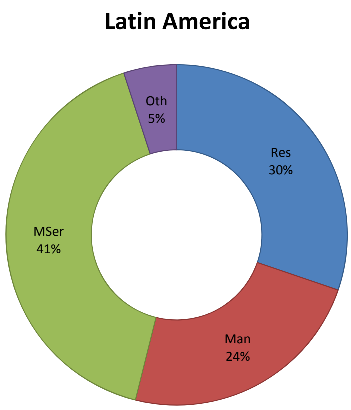
Latin America
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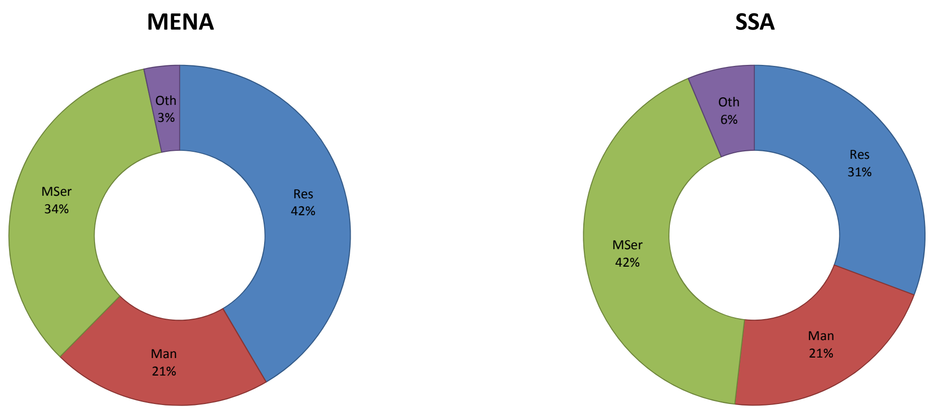

Figure 17. Growth of production for foreign markets broken down by sector, per country group

We see that within these broad country groups, the distribution differs quite a lot from the global total. The developed world has a larger share of services, and this comes at the expense of resources, not manufacturing. As expected, China has a large share of manufacturing, but this is only 7% points larger than the global average. China also has a larger share in resources, and, correspondingly, a smaller share of market services. The post-communist world also has a large share of manufacturing that is as large as China. Other Asian countries have the same share of manufacturing as the global average and all other blocks (India, Latin America, MENA and sub-Saharan Africa) have a much lower share of manufacturing.

India has a comparatively large share of market services, but also resources are high. In other Asia, besides manufacturing, resources are high. As expected, MENA has the highest share of resources (mostly crude oil), but Latin-America and sub-Saharan Africa also rank high on resources. These latter two groups also have a fairly large market services shares (although not much higher than the global average).

We also look at a few of the bilateral relationships, focusing on the ones that are responsible for the larger part of the increase in globalisation. The bilateral relationships (i.e., the off-diagonal cells in the matrix) are in fact responsible for slightly more than the 4.8% points increase, as the developed-to-developed nations cell actually declines as a share of global GDP over 2001-2011. Among the bilateral relationships, those where the developed world is involved are most important in quantitative terms. These economic relationships account for exactly 75% of the increase in globalisation, i.e., "South-to-South" relationships are only one quarter of the increase of globalisation.

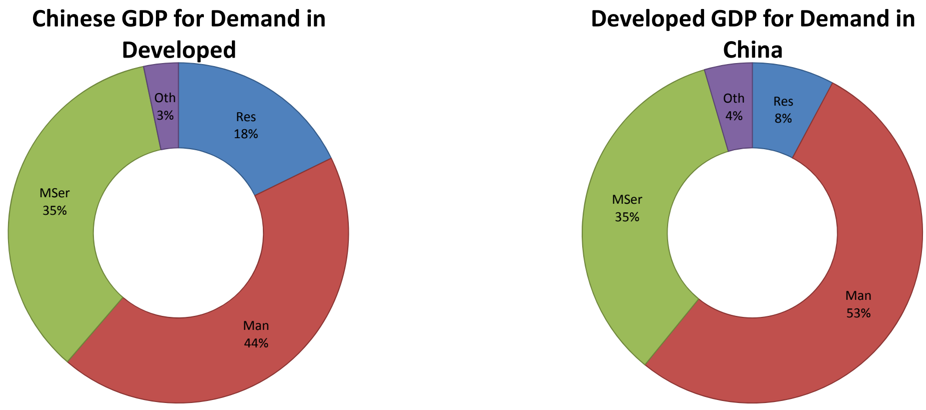

Figure 18. Growth of production for foreign markets broken down by sector, China and developed countries

The China – Developed and vice versa relationship is responsible for slightly more than one third of the increase of globalisation (1.7 of 4.8 points). The structure of these two cells is displayed in Figure 18. This particular relationship is dominated by manufacturing, in both directions. In fact, GDP produced by developing countries for demand in China has a larger share of manufacturing than the relationship in the other direction, although in both cases, the manufacturing sector is the largest. Resources are a larger part in China's production for Developed demand than vice versa.

The same structure is found for the relationship between the developed countries and the post-communist world (Figure 19). This pair of country groups is responsible for slightly over 10% of the total change. Again, the manufacturing sector is the largest in both directions, followed by market services, and the share of manufacturing for developed GDP is largest than in the other direction. We also observe that the share of resources is much larger in production in post-communist countries than vice versa. These two cases are thus indicative of the fact that in net terms, the developed world mainly imports resources from the rest of the world, but that in terms of the manufacturing sector, trade relations between the developed and other parts of the world are far more balanced than sometimes is expected.

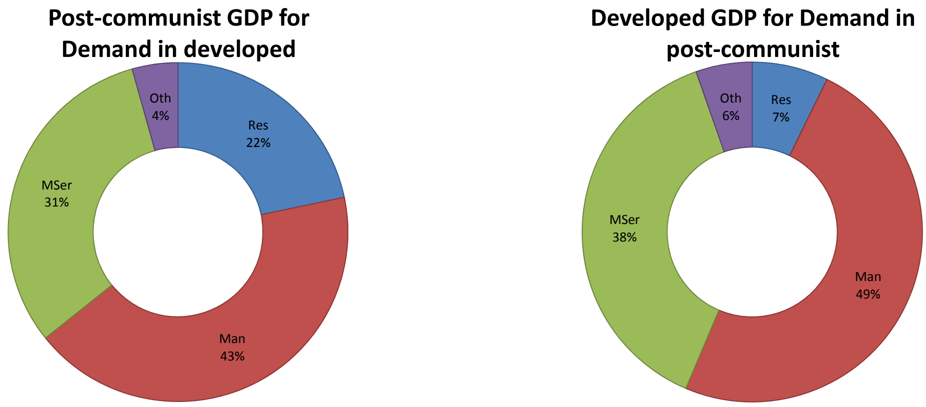

Figure 19. Growth of production for foreign markets broken down by sector, post-communist world and developed countries

Figure 20 shows a further selection of other bilateral cells. First, it looks at sub-Saharan Africa, which shows an interesting difference between the cases of Chinese demand and demand in developed countries. Overall, the share of manufacturing in sub-Saharan Africa is small, and resources is large, but this differs between Chinese and developed markets. In the Chinese case, the share of manufacturing is twice as large as in the case of developed markets. This difference comes at the expense of resources.

Other interesting cases are India, for which we document the relation to Chinese demand. India is generally a case of relatively low globalisation, and in the case of Chinese demand, it is heavily biased towards resources. This case is among the most resource-intensive bilateral pairs in the analysis. The most manufacturing-intensive case is the fourth diagram in Figure 20, GDP in post-communist countries for Chinese demand. This is heavily biased towards manufacturing, and also bit towards resources.

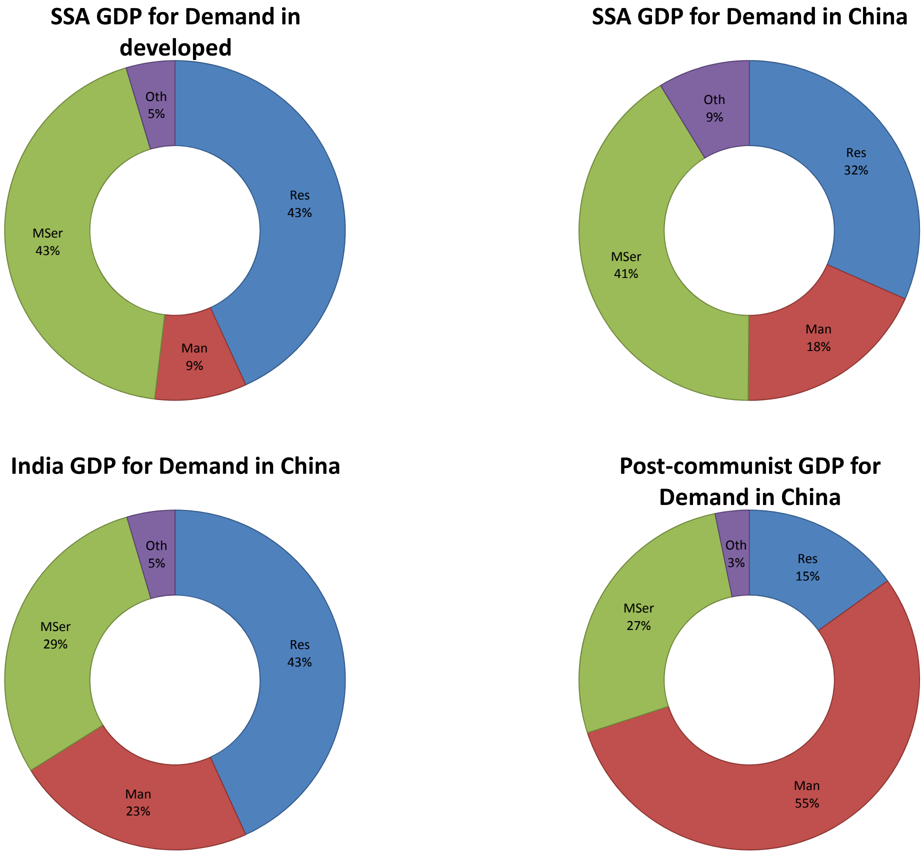

Figure 20. Growth of production for foreign markets broken down by sector, selected bilateral relationships

Overall, these results show that the increase of globalisation over the period 2001- 2011 has indeed been a process of structural change at the global level. Different parts of the world have specialised in different broad sectors of the economy. Manufacturing and market services plays the leading role in this process at a global level, but resources play a very important role in some particular parts of the world as well. Overall, resource-based growth through globalisation is an important development, especially so in sub-

Saharan Africa, India, and the Middle East. Manufacturing is very important in China but also in the developed world. The China – developed nations economic relationship is very manufacturing-intensive, in both directions.

VII. Conclusions

How do countries catch-up? In our view, international technology flows play a central role in the growth and development process of a country. We have demonstrated that moving from a low development state to high development is historically exceptional. From our perspective, this is because developing capabilities to absorb, assimilate, and adapt technology within a nation's particular context requires a great deal of effort that depends not only on investment, but also on macroeconomic conditions. Given the vast inter-linkages between capabilities, understanding the development process as a result of technological progress requires analysis on a variety levels. We chose to look at three levels of analysis: the types of products a country produces as a reflection of capabilities, the sectoral growth patterns within and between countries and the macroeconomic global and regional demand patterns.

We analysed country capabilities through two methodologies: a capability index, which weighs institutional factors through a principal component analysis and a latent capability index that measures trade specialisation at the product level. In both measures, we found that developed countries tend to have much higher technological capabilities than developing and emerging economies. Furthermore, the latent capability index supports the claim that poor countries with high (low) capabilities grow faster (slower).

At the product level, we find patterns of product clusters that are associated with low/high development. Indeed, the type of products, particularly the level of complexity/technology, reflects the development stage of a country. Specialisation in low-complexity product classes (especially textiles, but also resources and simple manufactured products) is associated with low levels of development, while the complex (high-tech) product classes are produced by the developed and rich nations. Transitioning from a one product class to another, however, is partly path dependent in that it is contingent on the type of products a country is producing now. Moving through the product space is arduous, but more easily done if one starts exporting fibres, electrical machinery and metal products; resource-based industries, including paper and metals; and heavy industry, especially transport equipment.

In the second part of the analysis, we look at structural change to see the varying rates of technological change between sectors. In our analysis of TFP, we find that sectors with higher rates of technological change contribute towards economic growth more than others and that high values of structural change are mostly achieved by a large contribution of technological change. As a country develops, growth becomes more technology intensive. Yet, at low levels of development, while some productivity growth rates are low they are also highly variable between countries. When we analysed low-tech industries, we saw higher rates of labour productivity and value added suggesting the absorption of foreign knowledge is relatively easier (compared to other industries), which confirms our findings in the product clusters (clusters 2 and 4) in our product space analysis.

In our final part of analysis, we turned to understanding the macroeconomic conditions affecting the capability building process through an input-output analysis. Specifically, we highlight the impact of globalisation, which has been rising rapidly especially since 2000. We observe that the manufacturing sector, followed by the market services contributes the most to globalisation, while resources play a substantial, but limited role. We also note that the majority of global GDP is produced for domestic markets and an important component to growth. However, this share has declined since the turn of the century and foreign demand still plays an increasing role to spark domestic growth.

Turning our attention to derived demand, we observe that almost half of the total increase in demand from globalisation is due to final demand for manufacturing products. This suggests that demand for complex products remains high and is a potential path for growth. Countries who export in this sector may have technological congruence and more ease in finding a market for their goods in the global market.

At a regional level, we find that the developed world mainly imports resources from the rest of the world, but that in terms of the manufacturing sector, trade relations between the developed and other parts of the world are far more balanced than expected. Overall, we see that globalisation has contributed to the process of structural change at the global and regional level.

We have found that at each level of analysis, technology continues to be an important force towards development. Country capabilities are reflected in the products they produce, which in turn can describe their level of development and potential pathways to achieve economic growth. We also found that sectoral rates of technological productivity drives structural changes within a country and technological intense sectors are increasingly becoming an important factor globally via demand.

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