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Creating the Capacity to Benefit from Technological Change in Developing Countries

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Creating the Capacity to Benefit from Technological Change in Developing Countries

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Abstract

What really makes an economy competitive? This paper reviews and discusses how the capacity to generate, exploit and diffuse new knowledge is key in enabling countries to capitalise on challenges brought about by rapid technology-driven transformations rather than succumb to their adverse effects. In particular, we look at the importance of new knowledge emanating from both domestic and foreign sources in the innovation process in view of the contention that "international technology transfer" is critical for growth in developing countries. We find that there is a tight link between high rates of technology acquisition and high investment ratios, and that the absorptive capacity is a *sine qua non* of foreign technology benefits.

Keywords: absorptive capacity, knowledge, developing countries, systems of innovation

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I. Introduction

Creation of knowledge is rooted in various sources including formal education, vocational training, in-firm training, specialised employee training outside the firm, and learning on the job, Lall (2000). We note, however, that the nature of formal education and vocational training, which constitute the "initial" knowledge in an economy, determines the level of sophistication in the technologies employed. In recent times, technology production increasingly requires fairly high levels and broad coverage of formal education and training. In-firm training and specialised employee training outside the firm is calibrated on the base of formal education and training available in the economy.

Firms tend to adjust the technology they employ to the level of skill capacity produced by the existing formal system. If the formal system produces a low skill capacity, firms will use low technology equipment and the in-firm and specialised employee training will be geared towards the low technology equipment. Needless to say, the learning on the job will also be of a low level. Moreover, learning by doing does not increase labour productivity infinitely in the absence of innovation that leads to generation of new knowledge, Young (1993). For a clearer understanding of the mechanisms behind knowledge generation it is useful to first outline the two different facets of knowledge as well as the aspects that guide its production.

In the national systems of innovation (NSI) approach innovative activities result in knowledge production, which may be separated into two major outcomes: technical innovations and technological knowledge. A technical innovation is made concrete in the form of a design or blue print that is used in the production sector to produce intermediate or final goods that are more efficient than previous products, and which are usually protected by patents. Technological knowledge as a product of the innovation process results in enhanced competences for use in the innovation process. Indeed, one of the most important characteristics of innovation is that it is knowledge intensive and the use of knowledge leads to further knowledge enhancement. Thus, technological competences take a central position in the innovation process that leads to growth in a rapidly changing environment. However, the *tacit nature of technological knowledge* (technological competences) poses a major challenge: technological competence are becoming increasingly dominant in mastering new technologies because they are private rather than public goods, and their acquisition is non-linear.

An interesting point to note is that the distinction between the two outcomes of innovative activities, technical innovations and technological knowledge, clearly show that an analysis of technological knowledge as a by-product of the production sector and, hence, the view that technological knowledge production takes place in a separate sector (as is explicitly or implicitly the case in a number of models inspired by the neoclassical theory) may be flawed. Learning or the production of technological knowledge within the context of an innovation process consists of an interactive process that reflects the strength of interrelationships across and within different sectors, institutions and agents, including firms, training institutes, universities, customers, suppliers etc. Indeed, it is the interconnectedness among sectors, institutions and agents that facilitates creation, use and spread of knowledge.

Interconnectedness may be viewed as organisation or aspects that are wider and more durable than the particular technologies and core capabilities employed at any moment, and in addition these wider and more durable aspects guide the internal evolution of the particular technologies and core capabilities, Nelson (1996). Improvements in organisation, by providing a more propitious environment for technical change, lead to economic progress. As argued by Nelson (1996) '… *one needs to understand organizational change as usually a handmaiden to technological advance, and not a separate force behind economic progress.'* Organisational change at an economy level involves reorganisation and creation of new institutions, infrastructure, research institutes, education systems etc.

Another aspect that guides the evolution of technologies is often referred to as social capital. Learning or creation and up-grading of competences and its efficient use that leads to growth fundamentally depend of social capital, which refers to networks of trust and association that are crucial for sustainable growth. It has been argued that the creation of a competitive advantage increasingly depends on social networks in which knowledge (particularly tacit knowledge) is embodied, Landry et al (2002). Social capital plays a central role in shaping specific trajectories of specialisation and learning particularly due to its collaboration enhancing nature, Maskell & Malmberg (1999). However, rapid technological transformations may undermine social capital resulting in an adverse impact on growth: rapid introduction of change may weaken the interconnectedness of the social networks, which invariably face upheavals. In other words, rapid change introduces elements of imperfect information, imperfect enforcement, etc that may overwhelm the social capital that is intended to palliate coordination failure, Durlauf and Fafchamps (2004). Since social capital in not a commodity that can be readily acquired in the market, introduction of new knowledge may put agents of the same network at different wavelengths because adjustment to change does not take place instantaneously and uniformly across a network. Institutional reorganizations and redesigns may be used to mitigate such coordination failure by influencing social structures to induce solutions to cultural and institutional factors that facilitate adjustment to change.

The paper is organised as follows: section one defines the framework of analysis after considering the innovation context in developing countries and examining how the international environment influences technology acquisition. Section three outlines the methodology that is used to discern elements of innovation-led growth, while section four presents the results. The last section concludes.

II. Inducing domestic innovation in developing countries

We now turn to the question of inducing domestic innovation. In our discussion, opportunities for innovation or generation of new knowledge are created by undertaking investment, and we consider that investment opportunities confronting a firm are continuously renewed by changes resulting from its investment as well as the investments of other firms. The fundamental assumption of the NSI approach that *routine activities* form a milieu for interactive learning that determines innovation, appears to be particularly interesting in the case of developing countries since investment in research and development (R&D) activities geared to cutting edge technology is rather constrained. The bulk of technological knowledge production in developing countries that emanates from *routine activities* involves incremental change directed towards dealing with particular challenges in the environment rather than with advancing the technology frontier.

While it is clear that developing countries face various challenges that can be addressed by minor technological modifications, the question of market demand may be raised. It is often argued that innovation is hindered by local market demand due to limited purchasing power. We note, however, that a clear consensus with regard to the impact of both market demand and the availability of technological opportunities on innovation has not been reached. For example, Schmookler (1966) argues that demand influences the market size of particular technologies and, hence, the allocation of resources, and consequently the demand for particular technologies. Mowery & Rosenberg (1979), however, assert that market demand is not dominant in motivating innovative activity, and a successful innovation requires both demand and supply incentives. In our view, innovative activity depends on the simultaneous existence of both market demand and technological opportunities.

We observe that no clear evidence supporting the contention that local market demand in developing countries hinders innovation exists. However, it is evident that technological opportunities are present. Furthermore, the argument that local demand is as an obstacle may hamper useful insight into the complexities of the innovation process. In fact, studies tend to suggest that the relationship between performance in technological innovation and size of the market is weak. Pavitt (1971) carried out an empirical study and concluded that: *"there is in fact a weak relationship between the size and sophistication of national markets, and performance in technological innovation … much higher correlations with national innovative performance exist for 'supply' rather than 'demand' factors…"* Indeed, the argument of local market demand as an obstacle for innovation in developing countries fails to encompass minor changes and modifications in the production of technological knowledge. Market demand plays a role in the innovation process, but the fundamental role of supply-side mechanisms in the innovation process must be given due consideration.

The possibility of engaging in incremental changes is critical in driving technological change. It has been shown that, although innovation is not limited to cost reduction, incremental changes or subsequent improvements in a major innovation lead to far greater cost reductions than their initial introduction, Enos (1958). Other studies that view minor improvements and modifications of innovations as playing a significant role in technological growth, and within the context of cumulative knowledge include Gilfillan (1935) in his book *'Inventing the Ship'*. Schumpeter, in his analysis of business cycles, refers to innovations as *new combination* thus underlining the fact that 'existing elements' provide technological opportunities, and are used to produce 'change' in the innovation process. Hence, opportunities for technological innovation, and consequently technical change, are created by undertaking investment in innovation. It is noteworthy that innovation investment is much broader than R&D. R&D activity is therefore not the sole determinant of technical change. Schumpeter links his interpretation of innovation to his view of entrepreneurs as drivers of technical change in explaining the dynamism of economic systems. Indeed, there is a clear connection between and innovation.

Schumpeter's discussion on why entrepreneurs appear in clusters is an attempt to shed some light on the process of innovation as involving interactive learning in production activities, but it is also an attempt to place emphasis on the importance of the resulting favourable investment environment in facilitating innovation activity. Clusters act as a lever for technical progress - that leads to improved economic performance - because they create linkages and synergies that induce investment amongst economic agents.*"[T]he carrying out of new combinations is difficult and only accessible to people with certain qualities…However, if one or a few have advanced with success many of the difficulties disappear. Others can then follow these pioneers, as they will clearly do under this stimulus of the success now attainable. Their success again makes it easier, through the increasingly complete removal of the obstacles…for more people to follow suit, until finally innovation becomes familiar and the acceptance of it a matter of free choice…But pioneers remove the obstacles for the others not only in the branch of production in which they first appear, but, owing to the nature of* *these obstacles, ipso facto, in other branches as well…Hence, the first leaders are effective beyond their immediate sphere of action and so the group of entrepreneurs increases still further and the economic system is drawn more rapidly and more completely than would otherwise be the case in the process of technological and commercial reorganization which constitutes the meaning of periods of boom.”*

In all evidence linkages and synergies amongst economic agents go a long way in facilitating the generation and use of knowledge as well as its diffusion at the economy level. The removal of obstacles refers to the establishment and strengthening of economic structures and competences, thereby minimising rigidities and failures that constitute uncertainty. The second part of this section undertakes a detailed analysis of the creation of investment opportunities geared towards innovation. An interesting observation is that knowledge diffusion and use are important for knowledge generation because the latter requires familiarisation with technology that is acquired through diffusion, use and exploitation. In order to adequately tackle the various challenges they face, developing countries would have to fully embrace domestic innovation as a corner stone for growth. First, however, we begin by investigating how the international environment influences foreign knowledge acquisition in the following sub-section.

a. How does the international environment affect technology acquisition?

Innovation systems, which refer to structures and institutions with networks (linkages and synergies), provide a framework that determines the ease and speed with which knowledge is created, diffused and used in an innovation process that is driven by competitive advantage. We argue that the ease and speed with which imported knowledge is absorbed and diffused within an economy depends on the innovation systems. In this section, we shall direct out attention to the international market with the aim of acquiring insight into how technology in the international market impacts on the acquisition of technology in an economy. In particular, we explore mechanisms through which foreign knowledge is introduced into the economy, and the importance of domestic innovation in determining the capacity to use and exploit foreign knowledge. We attempt to establish whether international technology does indeed "diffuse" to developing countries.

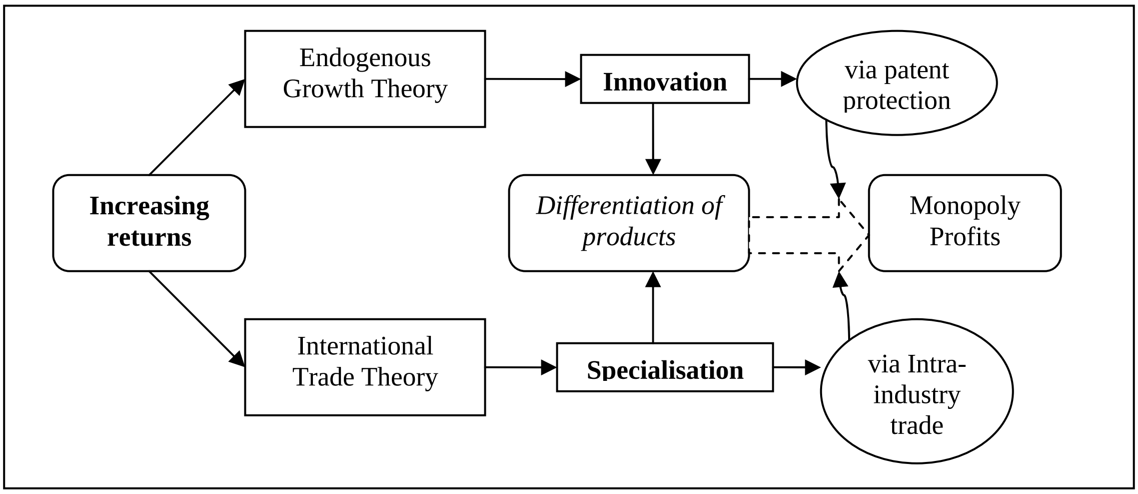
Innovation and trade flows

Specialisation that leads to trade, and specialisation that leads to innovation of new products and process through industrial activities occur within the framework referred to as a system of innovation. The efficiency/inefficiency of the systems of innovation enhances/deters interrelationships amongst economic agents, which in turn affect the ease and speed with which new knowledge is produced. Put simply, trade specialisation and innovation of new products and process are highly interconnected and the strength of interconnectedness is influenced by systems of innovation.

Innovation systems provide a cadre that influences the dynamism of knowledge producing activities by promoting domestic innovation and connecting it to foreign technology. As pointed out earlier, introduction of new knowledge into the local innovative process promotes technological knowledge production or skill upgrading. New knowledge may emanate from domestic knowledge and/or foreign knowledge (knowledge emanating from innovation activities abroad).

Both domestic and international environments affect the levels and rates of technical progress in an economy, and a vast endogenous growth literature argues that since developing economies hardly invest in the production of new technologies because of limited resources, "international technology transfer" – particularly via trade and foreign direct investment - is a viable means of strengthening their technology bases, Coe et al (1997), Temple (1998), Saggi (2002). For example, Coe et al (1997) argue that the R&D of industrial trade partners as well as imports of machinery and equipment provide direct benefits to developing countries. With regard to FDI, Saggi (2002) – based on the mere observation that foreign firms choose to locate in developing countries - asserts that FDI is a prominent channel of 'technology transfer'. Before critically analysing the so-called *mechanisms* of "international technology transfer", it may be useful to identify the link between innovation and trade in endogenous growth literature for a better understanding of the argument.

The diagram below shows that the presence of increasing returns is the motivation behind product differentiation through innovation and specialisation of goods that leads to knowledge production and, hence, the possibility of gaining profits at the firm level or technology fuelled growth at the economy level.



Source: author

Figure 1: Link between international trade theory and endogenous growth theory

Within this framework innovation gains are secured through patent protection while specialisation gains through intra-industry trade. Differentiation of products through specialisation or focus on core competences is at the heart of endogenous growth theory. However, it is important to note that specialisation reflects advantages that have been created by a cumulative process of learning and cannot be assumed to have resulted from a “natural” comparative advantage. The economic structure and pattern of specialisation reflect accumulated learning, which is a major factor in determining the direction of future learning and innovation. This reflects the fundamental assumption behind the system of innovation approach: interactive learning in rooted in *routine activities* and that most search activities will be closely oriented toward problems emanating from the existing set of economic activities, Andersen et al (2002).

Mechanisms of acquiring foreign technology

Trade, Foreign Direct Investment (FDI) and licensing are the three mechanisms that are most frequently identified by economic literature as the most feasible for technology acquisition in developing countries. We look at these three mechanisms in turn.

- *Trade and acquisition of foreign technology*

Three channels of foreign technology acquisition through trade have been identified:

(i) use of intermediate imports for the production of a final good embodying a higher technology content because the knowledge that is embodied in the intermediated good is not available to the importing country, but some doubt may be cast on the viability of this channel since the efficient use of intermediate goods presupposes the existence of a sufficient capacity to assimilate and exploit the knowledge,

(ii) copying/imitation of intermediated or final goods through reverse engineering, although with the implementation of patents these methods will no longer be possible, and

(iii) enhanced transfer of information and especially non-codified knowledge. We focus our attention on the first channel given that, as we shall see, international laws against imitation render the second channel inapplicable, while the last channel is not in practice feasible as there are no particular incentives for investors to part with knowledge that gives them a competitive advantage, and in addition this type of superior knowledge is particularly tacit in nature.

One point of view regarding foreign technology acquisition is based on the embodiment hypothesis first articulated by Solow (1958). The underlying argument is that since technological innovations are incorporated in capital equipment, investment in high technology capital equipment (capital formation) will not only increase capital intensity, which matters little for growth, more importantly they result in acquisition of technology, the dominant growth driving factor. Hence, between two countries that have "access to the same pool of technology", the country that invests more in capital formation will grow faster. Solow set about developing the so-called vintage model in order to prove this point. A study by Coe, Helpman & Hoiffmaister (1996) empirically examines the extent to which developing countries, which hardly investment in their own R&D benefit from R&D performed in industrialised countries through trade, and conclude that spillovers from the north to the south are substantial. Temple (1998) relates equipment investment to growth, and finds that the rates of return to equipment investment in developing countries are very high. These conclusions, however, are drawn on the limitation discussed earlier with regard to the linearity assumption. In addition, the level of foreign technology acquisition through trade depends on the type of trade. Inter-industry trade refers to one way trade in a sector and is typical of trade from a high-income country and a low income country, where transfer of technology is assumed to take place from the former to the latter, while intra-industry trade implies imports and exports in a given production sector; intra-industry trade plays a more significant role than inter-industry trade in “transferring” technology.

Hakura & Jaumotte (1999) in a study using data from 87 countries for the period 1970 to 1993 came to the conclusion that while inter-industry trade contributed more to foreign technology acquisition in developing countries than intra-industry trade. With regard to this study, Saggi (2002) noted that *"since intra-industry trade is more pervasive among developed countries than it is between developed and developing countries, an immediate implication of their findings is that developing countries will enjoy relatively less technology transfer from trade than developed countries.”* Other empirical studies indicating that technology diffusion from industrialised countries has stronger effects in relatively rich countries than in poorer ones reinforce this point, Eaton & Kortum (1996), Xu (2000) and Keller (2001d). The main reason behind these findings is that domestic knowledge plays a major role in facilitating assimilation and exploitation of foreign knowledge.

- *Foreign direct investment & acquisition of technology*

Foreign technology acquisition through FDI essentially takes place through the interaction of international firms with domestic firms. This occurs through (i) backward and forward linkages where local suppliers receive incentives to produce high technology inputs or services at competitive prices, (ii) demonstration effects where local firms adopt higher technology through imitation of goods, services and skills, (iii) competition effects where local firms are forced to upgrade their technologies to produce competitive goods and services in order to remain in the market, and (iv) learning by doing where foreign affiliates train workers to adapt to higher technologies and thus increase the skill level of the human capital. Different types of foreign direct investment (FDI) depending on their technology content (low, medium or high) have varying effects on different developing countries depending on the particular countries' capacity to assimilate and exploit the foreign knowledge. In addition, we note that although high technology FDI may offer a potentially great source of technology to the host country, effective diffusion of the technology will depend of the technology gap between the foreign technology and the domestic technology.

The type of FDI is also divided along the lines of vertical FDI in which there is fragmented production of the stages in the chain, and where a country serves as an export platform, and horizontal FDI also referred to as market-seeking FDI where a product is produced for the market and in which backward and forward linkages are strongest. Whereas vertical FDI is mainly from industrialised countries to developing countries, horizontal FDI tends to take place among industrialised countries because of the level of integration in terms of technology intensity as well as market and labour integration. Over 80% of the world's value of high technology production is concentrated in 10 industrialised countries. The extent of integration between the foreign firms and local firms will determine the type of technology a country will attract. The level of integration is improved through domestic innovation.

From the point view of a firm, the factors that will determine delocalisation are (i) ownership where a firm owns a particular product and has comparative advantage in producing it (ii) localisation where the host market is able to provide resources at competitive prices such as human capital (iii) internalisation where a firm has an advantage in producing the product rather than licensing

Challenges facing developing countries with regard to foreign technology acquisition are based on level of integration of foreign firms in the domestic economy of the host country, such as the unavailability of adequate resources including technological competences. A high technology firm is skill-intensive and would only begin to consider locating in a developing country if high-skilled human resources are available and at a competitive price. In addition, it has been established the FDI has a positive effect only in an economy that predisposes of sufficient technological competences. The results of a study carried out by Borensztein et al (1998) showed that the impact of FDI on growth was positive only for countries that had attained a certain minimum level of human capital.

The question of availability of specialised technology suppliers or even the probability that the specialised technology would be transferred and absorbed in developing countries is of central importance to a firm. A dense network of specialised technology suppliers provide high technology firms with high quality inputs and services that are cheaper and more easily available because of the competition within these supplier firms, resulting in strong backward and forward linkages within the domestic economy. However, the specialised suppliers are available only in economies that provide them with resources at the most competitive rate. For the most part, these resources are comprised of highly skilled human capital, Arora et al (2000). This is a major challenge for developing countries.

From a general point of view, FDI usually takes place to curb the problem of *free* technology imitation (*free riding*) in the absence of adequate property rights. This implies that technology acquisition through FDI may not be as feasible as it appears on the surface. The main incentive that a foreign firm has in locating in a host country is the assurance that imitation, a major channel of technology acquisition, will not occur so that it does not face competition that may eventually drive it out of the market. Implementation of patents is expected to check the problem of free riding.

- *Intellectual property rights & acquiring foreign technology*

It is argued that although stronger patents may reduce the flow of foreign direct investment because patent owners may opt to license their technologies, licensing facilitates foreign technology acquisition. The underlying idea is that licensing leads to a higher degree of foreign technology acquisition than FDI since in addition to using all the channels of FDI technology diffusion – backward and forward linkages, demonstration effects, competition effect and learning by doing – full information of technologies is passed on to the licensee resulting in higher technology spillovers. In addition, the patent holder has the responsibility to ensure that the technology is effectively assimilated and exploited by the licensee. However, this form of foreign technology acquisition emanating from licensing as a result of strong patents is mainly relevant to industrialised countries because of the integration factor, particularly with regard to two factors: First, the technology intensity/congruency – integration factor -whose improvement depends on domestic innovation, Abramovitz (1986 and 1994), Eaton & Kortum (1996), Xu (2000) and Keller (2001*d*) and Lall (2003). Second the non-linearity of knowledge acquisition, Mansfield (1961), Metcalfe (1982), Rosenberg (1993) and Gosi (1996).

Methods formerly used by industrialised countries to acquire foreign technology during the phases when they were net importer of technology are no longer available with the implementation of intellectual property rights. For example, in the period 1790 and 1836 when the US was a net importer of technology, it restricted the issues of patents to its own citizens and later patent fees for foreigners were ten times higher the rate for citizens. Other countries have exempted invention in certain sectors from patent protection such as chemicals in Switzerland, Taiwan and South Korea. The idea behind these attitudes is that imitation and reverse engineering constituted an important element in developing domestic technological capacities.

The development of a domestic technological capacity determines the extent to which a country is able to assimilate and exploit foreign technology. Many studies have concluded that the most distinct single factor determining the success of foreign technology acquisition is the emergence of a domestic technological capacity, Rosenberg (1982), Mowery & Rosenberg (1989) for example. However, patents now limit foreign technology acquisition although the main conclusion seems to be that acquisition of foreign technology is associated with weak intellectual property rights. Developing countries may increasingly be forced to contend with the situation and perhaps resort to utility models or petty patents, a method in line with intellectual property rights.

Utility models involve combining minor incremental innovations with registration rather than examination, and shorter periods of protection. The advantage with utility models in developing countries lies in the easier access they provide to domestic agents compared to patents in terms of both cost and congruency with existing domestic technological competences. Indeed, studies in Brazil, Turkey and even Japan show that weak protection based on petty patents facilitates incremental innovation by local agents and contributes to the creation of domestic technological knowledge through diffusion and exploitation.

While petty patents may appear to provide a feasible leeway for developing countries to develop a domestic technological capacity that would facilitate the acquisition of foreign knowledge, they remain within the general framework of patents, which is restrictive in that it stamps out rivalry in the innovation process. The argument put forward in advocating patents is that monopoly rather than competition presents larger social gains from innovation. In other words, protection encourages innovation due to the high costs of research and development as opposed to imitation, and patents provide an incentive to investors because they are sure to be able to recoup their costs. While this may be the case for some industries, other industries nonetheless face high imitation costs and there is a definite time lag that provides sufficient protection. In addition, patents result in a race for patents and may lead to sub-optimal innovation gains by directing innovation in fields that provide maximum gains at firm level but sub-optimal social gains at economy level. Moreover, a certain form of rivalry that to some extent may be thought of as wasteful still persists, while the spur of competition as opposed to monopoly may be wiped out. Nelson (1996) argues that both empirical and theoretical evidence that competition rather than control is socially more beneficial within the context of invention and innovation is well grounded.

Since innovations create various outlets for further research and development, competition rather than control may lead to higher social benefits. Although licensing is seen as an option to this constraint, it is worth noting that licences may not be particularly appealing to a licensee because the definition of the scope of patents is often hazy and often goes beyond what may be considered as obvious simple modifications. The licensee may therefore be vulnerable with regard to control rights over further finding depending on the power of the licensor. Petty patents are also confronted with this problem. Furthermore, the ability to produce incremental knowledge requires mastery of the existing knowledge with regard to the innovation in question.

The main conclusion that we can draw from the above sections is that developing countries have hardly anything to gain from patent protection given that they are net importers of technology, and that technology acquisition through direct purchase is not a feasible solution due to the high costs. In addition, neither high technology content imports nor FDI may be expected to boost technology acquisition opportunities in developing countries that do not engage in domestic knowledge production. Foreign technology acquisition is possible only if the capacity to assimilate and exploit foreign knowledge exists. However, this capacity is developed through creation of a domestic knowledge that depends to a large extent on the national systems of innovation, but also on the opportunities of accessing new knowledge including foreign knowledge.

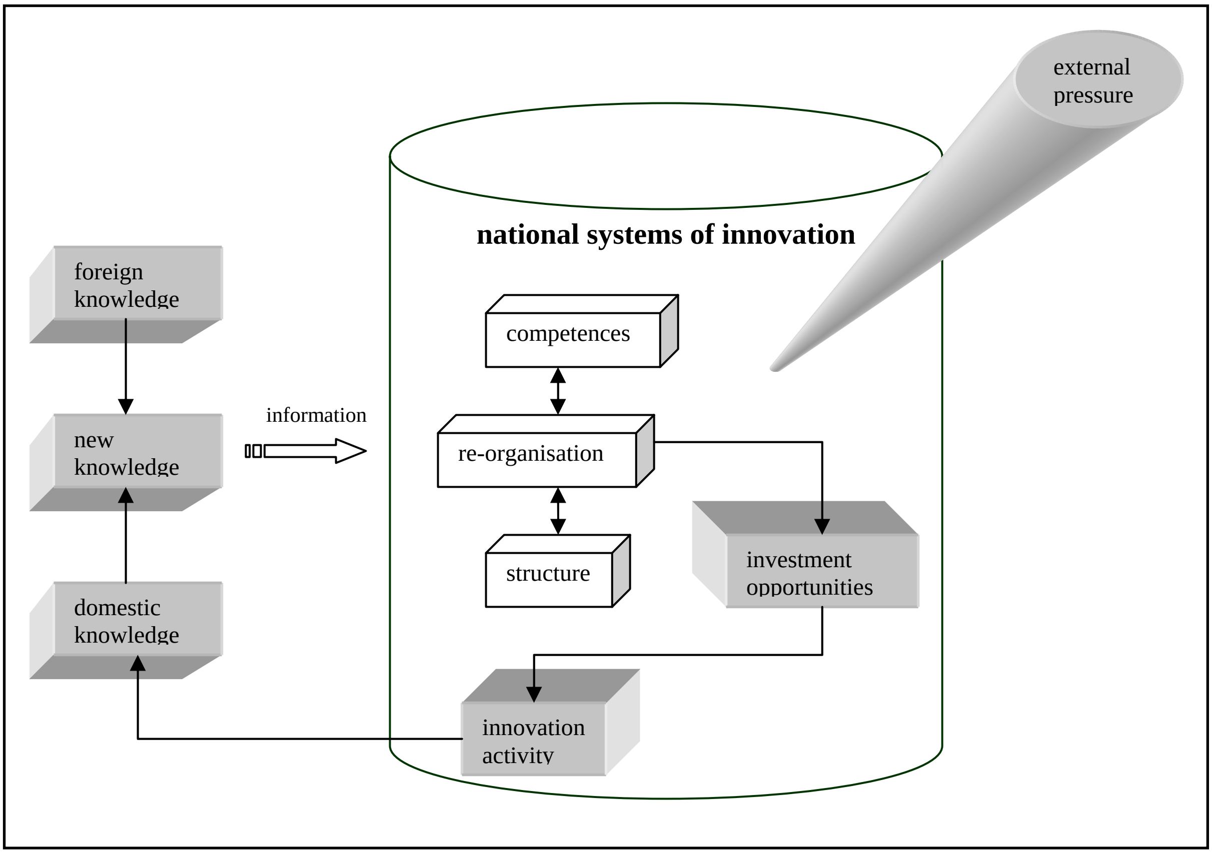
b. Framework of analysis

We have argued that the generation, exploitation and diffusion of knowledge is at the root of differences in economic performances across countries. The feedback mechanisms existing between the re-organisation of productive activities in an economy, and the generation of knowledge provoke the change that constantly takes place in an economy and results in externalities. The re-organisation of productive activities in an economy, triggered by the generation of knowledge and supported by information flows provokes the change that constantly takes place in an economy, and results in externalities. While the change is external to individual firms it is internal to the industry and is thus responsible for spillovers, the driving factor of entrepreneurial behaviour. If the industry and the economy at large have the capacity to control the change, opportunities for investment are created and may consequently lead to improved economic performance. Conversely, if the economy is unable to cope with change due to non-responsive structures, competences or poor strategies, economic performance is threatened.

Our real challenge is to understand how countries create the capacity to harness change in a manner that is suitable to their economic set-up, and thereby create investment opportunities that are responsible for the dynamism of an economy. Put simply, what factors enable an economy to undergo smooth structural shifts into an increasingly strong knowledge based economy? While common factors responsible for technical change across countries may be identified caution must be taken with regard to the specificities involved in fostering the common factors. As Rosenberg (1993) pointed out, technical progress faces extreme variability across time and place: *"One of the most compelling facts of history is that there have been enormous differences in the capacity of different societies to generate technical innovations that are suitable to their economic needs. Moreover, there has been extreme variability in the willingness and ease with which societies have adopted and utilised technological innovations developed elsewhere. And, in addition, individual societies have themselves changed markedly over the course of their own separate histories in the extent and intensity of their technological dynamism. Clearly, the reasons for these differences, which are not yet well understood, are tied in numerous complex and subtle ways to the functioning of the larger social systems, their institutions, values, and incentive structures."*

The ability or inability of economies to shift to a knowledge-based economy, and continuously adjust to both internally and externally generated change leads to the differences in growth performance. Investment ratios seem to be one of the most important indicators of the ability of an economy to take advantage of change to produce economic gains. Indeed, a robust correlation exists between investment and growth, and much work has gone into analysing for example investment in physical, although capital accumulation is contingent upon investment ratios. It may be the case that the most important link between policy and growth is investment, and that factors leading to investment play significant roles in economic performance. In the diagram below we attempt to highlight the main elements of an innovation process.

In figure *2* below, innovation activity – represented by the bottom brick in the cylinder - leads to the creation of new knowledge that is available in the form of technical innovations (blue prints) and technological knowledge (competences). The innovation process hinges on investment opportunities, and it is supported by the national systems of innovation in which the government and research institutes among other economic agents play important roles. The strength of the national systems of innovation therefore, provides an important framework for both forms of knowledge permitting innovation activity that generates new knowledge whose diffusion across the economy is part and parcel of a successful innovation process.



Source: author

Figure 2: Elements of an innovation process

However, knowledge diffusion is not an automatic process due to asymmetries that arise partly from the transmission process. For example, new knowledge undergoes codification for transmission purposes and is diffused as information, which must be subsequently translated back to knowledge for integration into the innovation process of firms.[2] The presence of technological knowledge (competences) is a necessary though not a sufficient condition for knowledge diffusion within an economy. A permeable systems of innovation, that promotes the development of a domestic capacity of knowledge generation and exploitation, a *sine qua non* of identification, assimilation and use of foreign knowledge because it provides an appropriate interface, is also necessary.

[2] As we saw earlier, there is a clear distinction between information (which is codified data that is more or less easily accessible) and knowledge. Knowledge or competences is much more complex because it requires that a person detain it and be capable of applying it appropriately to different contexts or translating blue prints into exploitable knowledge

While the constant reorganisation of firms in response to new knowledge leading to changing information and information flows influences the continuous adaptations in the economy, we note that reorganisation also impacts on information and information flows. A feedback mechanism operates between changes in organisation of firms and changes in information and information flows, leading to constant pressure to continuously upgrade structures and core competences in the economy. On the whole, firms are increasingly forced to focus on core competences and structural changes in order to remain competitive (such phenomenon as increased out-sourcing may be observed as a result), and this may lead to increased stimulus for innovation through the creation of investment opportunities or the ability to exploit and generate knowledge. Once a sufficient capacity to identify, use and diffuse knowledge has been developed an economy is able to reap maximum benefits from foreign knowledge as well as control external pressure. This brings us to the central concept to our analysis; the absorptive capacity.

The absorptive capacity is the element of technology acquisition process that is responsible for creating an interface between domestic and foreign knowledge, and consequently facilitating domestic knowledge generation as well as assimilation and exploitation of foreign knowledge. Our next section elucidates this concept.

The interface between domestic and foreign knowledge

- *The concept of absorptive capacity*

Imported knowledge has been recognised as crucial in providing firms with new ideas for integration into domestic innovative processes as it enhances the competitive advantage of economic agents. The ability of local firms to identify and assimilate foreign knowledge that increases their competitive advantage refers to the *concept of absorptive capacity*. Cohen and Levinthal (1990) introduced term and defined it as: *"the ability of a firm to recognise the value of new, external information, assimilate it, and apply it to commercial ends"*.

An absorptive capacity presupposes the existence of an innovative process that produces local knowledge and it is determined by the availability of certain skills, infrastructure and other complementary factors to foreign knowledge: the degree to which the local capability complements foreign knowledge reflects the degree of the economy's absorptive capacity. Put simply, the ability of local firms to manage external relationships for beneficial selection and assimilation of new ideas is vital for their innovative capabilities (it provides them with the ability to control change and remain competitive). One of the underlying factor may be seen as the competences involved in this process of exploiting new ideas, and the strategic goals of firms therefore, involve upgrading the skills of its workers.

We noted above that one of the ways of upgrading skills is through use of skills in the innovation process. In other words the skills of workers improve with work experience resulting in an experience-based knowledge that is tacit in nature and, hence, the central role of tacit knowledge in keeping firms competitive in a rapidly changing environment. Experience-based knowledge works in conjunction with organisational knowledge, which appears to be rather determinant in strengthening external relationships is the organisational set-up: it enhances the agility of workers in a fast paced economy. Essentially the organisational set-up creates fluidity in both internal information flows and external connections. The external connections are developed into tight relationships that increase trust and, hence, reduce uncertainty through transmission of reliable information as well as improvement of the possibility to harness it for creation of new knowledge.

To sum up, we note that the effectiveness and efficiency of learning depends on the ability to produce and use knowledge. Thus, general knowledge that is acquired through formal education and training systems has to be complemented with firm-specific knowledge (work experience, in-firm training and specialised training outside the firm) in order to be productive. Most importantly, however, the resulting knowledge must be highly malleable and porous so as to incorporate changes, and this is made possible to some extent by the organisational knowledge.

Organisational knowledge creates a structure that enhances development and upgrading of competences by building tight relationships amongst internal workers and with external actors (such as local institutions - knowledge, financial, legal etc - and local firms), particularly vertically related actors. Tight relationships, however, are embedded in social capital (networks of association and trust), which therefore plays a special role in fostering competence building and upgrading perhaps because of its influence on the overall technical efficiency of the economy, through its impact on the ability to identify, evaluate and assimilate foreign knowledge. However, as pointed out by Temple (1998) measurement of social capital poses a problem.

- *How is the absorptive capacity created?*

We have observed that engaging in innovative activities is at the root of creating technological knowledge and improving competences while at the same time inducing opportunities for further invention and innovation. It is also important to note that the diffusion process is critical in terms of the economic impact. *"… the productivity increasing effect of superior technologies depends upon their utilization in the appropriate places"*, Rosenberg (1993). Both the existence and strength of domestic knowledge generation and diffusion determine the creation and development of the capacity to absorb foreign knowledge. In other words, the absorptive capacity of an economy is to a large extent dependent on the existing domestic innovation (knowledge generation and diffusion) in the economy.

Feedback mechanisms exist between knowledge generation and diffusion on one hand, and competences on the other hand. Competence development plays a significant role in inducing knowledge creation and diffusion implying skill-biased technical change, which in turn implies that investment in innovation oriented skills *inter alia* science and engineering training is responsible for creation of an absorptive capacity and consequently, improvements that lead to greater economic performance. Creation of competences begins with investment in education and training within a schooling system, is complemented by learning on the job as well as explicit skill upgrading by firms, and enhanced by organisational set ups. These three elements, general knowledge, firm-specific knowledge and organisational knowledge are key contributors in providing a dynamic environment for investment and, hence, an absorptive capacity. However, the absorptive capacity - identification and assimilation of external knowledge - presupposes access to external knowledge as well as the existence of prior knowledge. Access to external knowledge hinges on the accessibility of foreign knowledge, which may be restricted (for example, by international laws), while prior knowledge on formal education systems and domestic innovation.

All in all, the ability of firms to benefit from new ideas determines whether they are able to remain competitive or exit the market: the ability of firms to remain in the market is often an indication of their competitiveness or profitability. This brings us back to the issue of our main concern, which consists in identifying the factors that make economies competitive. These factors are undoubtedly behind high investment ratios in an economy. We analyse this question in the following section, but first a brief look at investment ratio may provide some indication of the tight link between investment and economic performance.

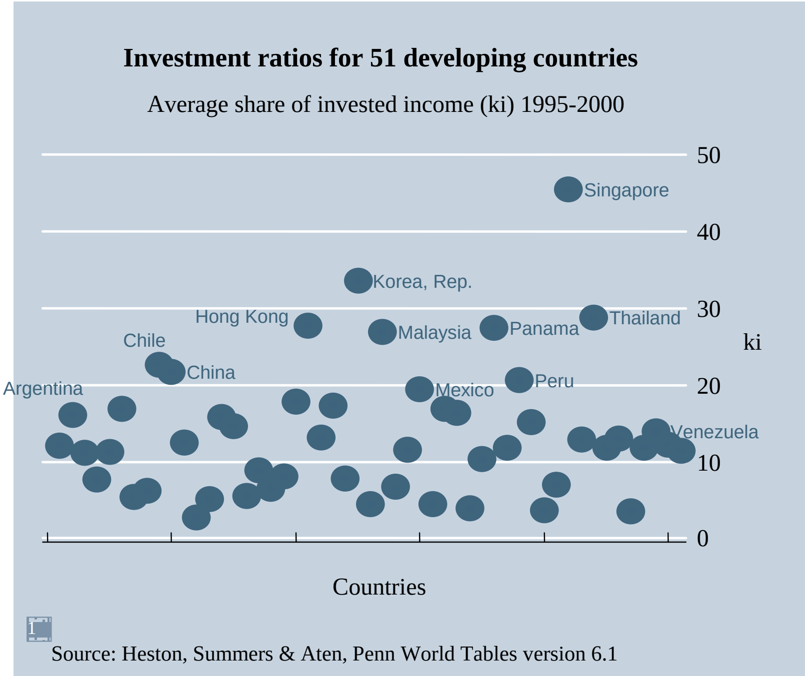


Figure 3: Investment ratios

Figure *3* above shows the investment ratio of our sample of 51 developing countries specified.[3] A parallel may be drawn between higher investment ratios and higher incomes.

III. Methodology

Technology other than that incorporated in inputs (capital) has been found to have a fundamental role in the growth of economies. In his estimates on productivity growth in the US economy, Solow (1956) found that technical change accounted for 80% of per capita

[3] See appendix for list of country sample.

growth while capital accumulation accounted for the remaining 20%. In a similar vein, Young (1994) and Easterly & Levine (2001) for example argue that there is that "something else" that determines growth.

We note that, while that "something else" is perhaps closely linked to technology, there is reason to believe that it includes various distinct factors that are responsible for driving an economy. One of the main challenges consists in identifying these factors so as to break down that "something else" into its basic elements. Abramotivtz (1986) provided a lead for this identification by observing that technological take-off is mainly prevented by "tenacious societal characteristics". This implies that country specific characteristics may enhance or hamper technology-led growth.

Economic literature is currently exploring the "tenacious societal characteristics" in an attempt to identify the factors that constitute that "something else" because they are regarded as critical in determining the success of economies. For example, Fagerberg et al (2005) in a study using 129 countries identify four aspects that are crucial in determining the competitiveness of economies (technology competitiveness, capacity competitiveness, price competitiveness and demand competitiveness). We borrow from their analysis in an attempt to identify the factors that influence the abilities of economies to confront change i.e. factors that develop the capacity to assimilate, exploit and generate new knowledge. However, we differ in that our focus is based exclusively on developing economies. Our main aim consists in trying to capture the diversity amongst developing countries, particularly with regard to differences amongst and between the group that has not succeeded in taking off and the group that is said to be catching up.

Following Fagerberg and Srholec (2004) we use factor analysis, which is a data reduction technique, to study patterns and relationships of dependent variables with the aim of discovering the nature of the underlying independent variables. The independent variables are a much smaller set of composite variables called factors or dimensions. One advantage of this method is that it does not require prior knowledge regarding the correlation of variables entering the analysis for an effective reduction of a complex data set into uncorrelated factors or dimensions.[4] The underpinning idea is that variables that are correlated cluster together in manner that allows the extraction of uncorrelated dimensions.

Our first step will consist in identifying a large number of technology related indicators in an attempt to capture as comprehensibly as possible the factors that enhance technology-led growth. The use of a large set of indicators is important from the point of view that technology-led growth is influenced by a numerous factors, and selection of a limited number would be difficult. In all evidence, a regression analysis approach would not be suitable due to the multicollinearity problem that is bound to arise from our variables that are expected to reflect different aspects of technology. The task at hand consists in reducing the variables into a few uncorrelated composite indicators that can be used to obtain a meaningful interpretation of the factors underlying economic growth. This is equivalent to breaking down that "something else" into its basic components in an attempt to gain an understanding of the particular factors that drive the growth of an economy.

Despite the fact that factor analysis does not require prior weighting of original variables for the construction composite indicators, there is one drawback: it uses factors scores to weight original indicators in producing the composite indicators that are uncorrelated. However,

[4] In the construction of composite indicators, variables have to be first weighted to avoid bias. This requires prior knowledge of the relative importance of each variable to a composite indicator.

factor scores are linear combinations of all the original variables, which may cast doubt on interpretations. To palliate this problem, we retain only the original variables that load highly on particular factors. A factor loading is considered to be high if it is above 0.6 and moderately high if it is above 0.3, Kline (2002). We also verify the loadings against the 1 per cent significance level ($p<0.01$). In addition, we attach each original variable to only one factor, which will have the added advantage of facilitating interpretation.[5]

In order to make comparisons among original indicators, and thus, the resulting composite indicators comparable, we standardise the variables. This will prevent extreme values from dominating, and in addition, correct for data quality problems. We use the standard deviation approach, which consists in deducting the mean from the indicator and dividing by the standard deviation. This converts all the variables into a common scale and assumes a normal distribution that will help to avoid a split sample. To strengthen the normal distribution property, we use logarithmic transformations to reduce skewness in the sample distribution and to deal with outliers.[6] One further problem with our analysis is that we use statistical techniques, but no hypothesis testing is carried out. Although this may result to scepticism towards our results, we note that our aim is to get a mere glimpse of the underlying factors. Data construction and sources are discussed in the appendix.

[5] This, nonetheless, implies rotation that will undermine the quality of uncorrelatedness, although the total variance remains unaffected.
[6] We use the simple rule employed by Fagerberg and Srholec (2004) to avoid zeros or negative values before carrying out the log transformations. The minimum observed value in the sample that allows us to obtain positive values is added to all the observations.

IV. Results

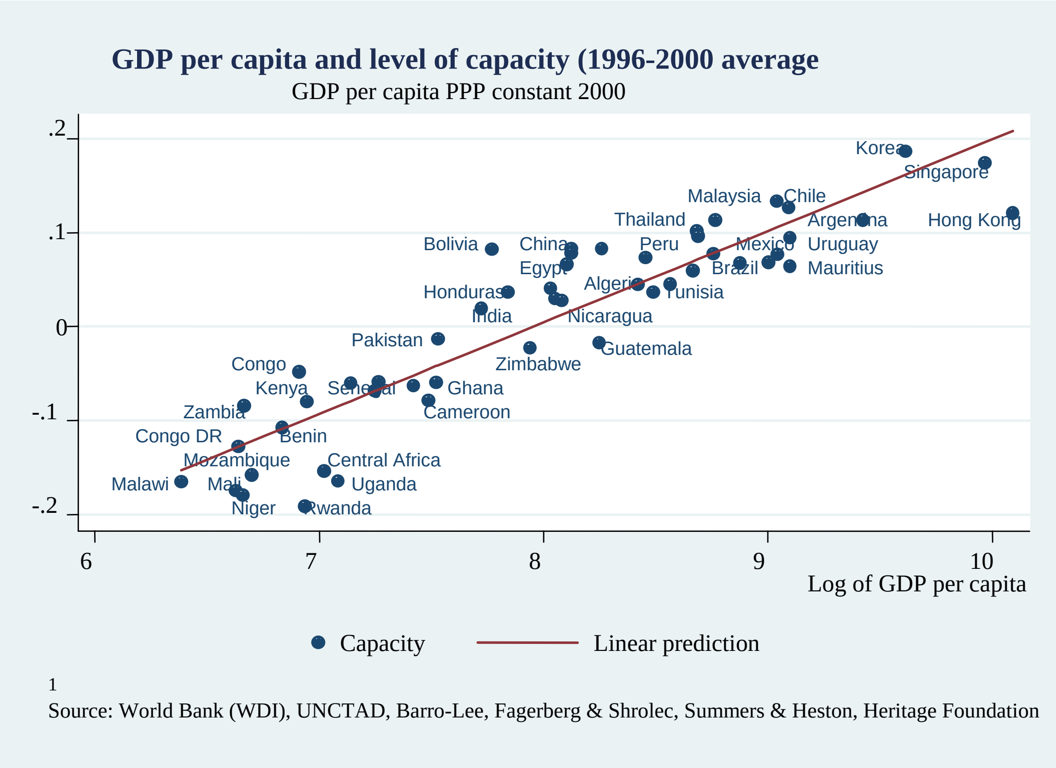
24 variables averaged over 1996-2000 period	Factor loadings				Factor score coefficients			
	capacity	technology	institutions	liberalisation	capacity	technology	institutions	liberalisation
School enrollment, tertiary (% gross)	0,78	0,28	0,36	0,20	0,27	-0,04	0,04	-0,11
Life expectancy at birth, total (years)	0,75	0,16	0,20	0,22	0,14	-0,06	-0,03	0,00
Industry, value added (% of GDP)	0,72	0,06	-0,10	-0,03	0,12	-0,01	-0,06	-0,03
Average educational attainment of the total population Aged 25+	0,71	0,25	0,31	0,30	0,15	-0,06	0,00	0,01
School enrollment, secondary (% gross)	0,68	0,40	0,31	0,42	0,25	-0,01	-0,07	0,05
Investment Share of real GDP	0,65	0,32	0,23	0,40	0,12	-0,03	-0,05	0,05
CO2 emissions (kg per 2000 US$ of GDP)	0,62	-0,13	-0,23	-0,17	0,11	-0,03	-0,06	-0,02
Fixed line and mobile phone subscribers (per 1,000 people)	0,59	0,41	0,51	0,40	0,23	-0,03	0,25	-0,06
Domestic credit to private sector (% of GDP)	0,58	0,26	0,23	0,49	0,08	-0,07	-0,04	0,09
Radios (per 1,000 people)	0,50	0,37	0,43	0,22	0,04	0,02	0,05	-0,05
Scientific and technical journal articles	0,38	0,75	0,02	-0,09	0,03	0,35	-0,10	-0,24
Total patents	0,07	0,68	0,07	-0,02	-0,03	0,17	-0,03	-0,10
Research & Development expenditure (% of GDP)	0,47	0,57	0,29	0,09	0,03	0,15	0,00	-0,12
Internet users (per 1,000 people)	0,29	0,59	0,38	0,56	-0,09	0,21	-0,01	0,11
Personal computers (per 1,000 people)	0,12	0,64	0,35	0,63	-0,48	0,61	-0,08	0,40
Banking	0,02	0,02	0,87	0,10	-0,10	-0,14	0,41	-0,08
Property Rights	-0,04	0,18	0,80	-0,01	-0,09	0,01	0,28	-0,13
Regulation	0,08	0,15	0,75	0,19	-0,05	-0,04	0,20	-0,04
Informal Market	0,15	0,05	0,68	0,17	-0,02	-0,06	0,14	-0,02
Services, etc., value added (% of GDP)	0,27	0,10	0,64	0,21	0,00	-0,06	0,12	-0,01
Trade (% of GDP)	0,10	-0,21	0,03	0,82	0,01	-0,34	-0,08	0,42
Population density (people per sq km)	-0,11	0,48	0,07	0,68	-0,11	0,07	-0,10	0,18
Inward FDI stock as a percentage of GDP	0,16	-0,19	0,27	0,55	0,01	-0,14	0,02	0,12
Money and quasi money (M2) as % of GDP	0,45	0,26	0,16	0,54	0,04	-0,04	-0,05	0,09
Explained percentage of total variance	0,72	0,73	0,62	0,66	..	..	..	..

Observations: 51 developing countries

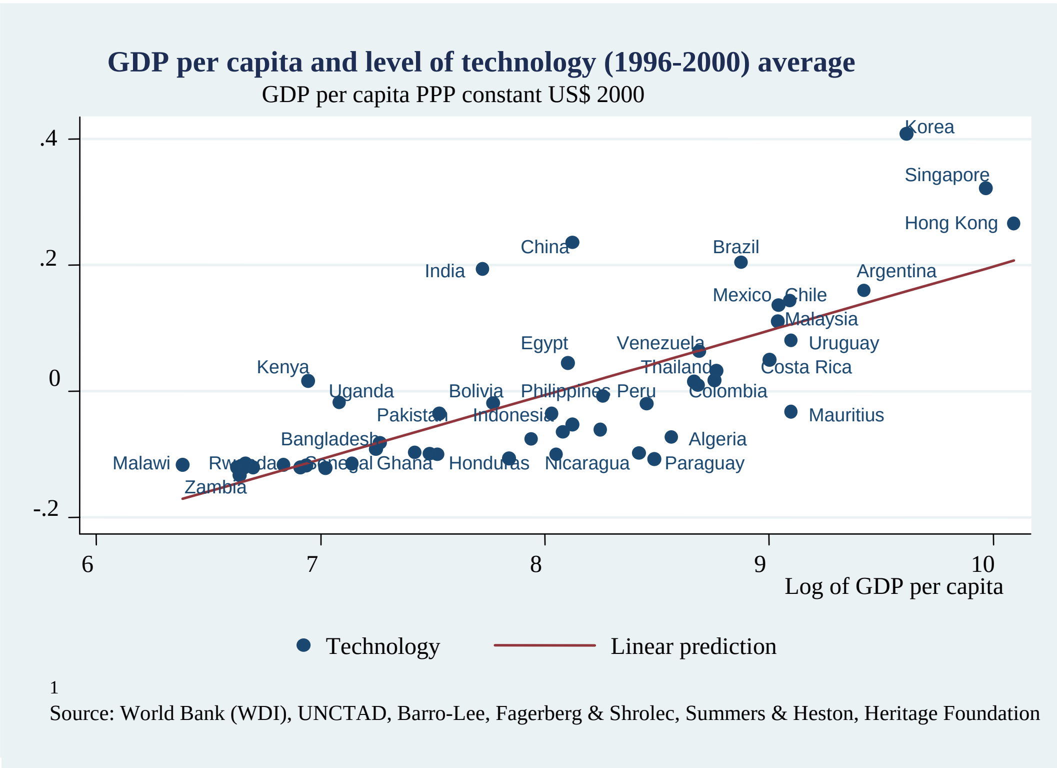
Extraction method: principal factors

Rotation: varimax normalised   Scores: Bartlett

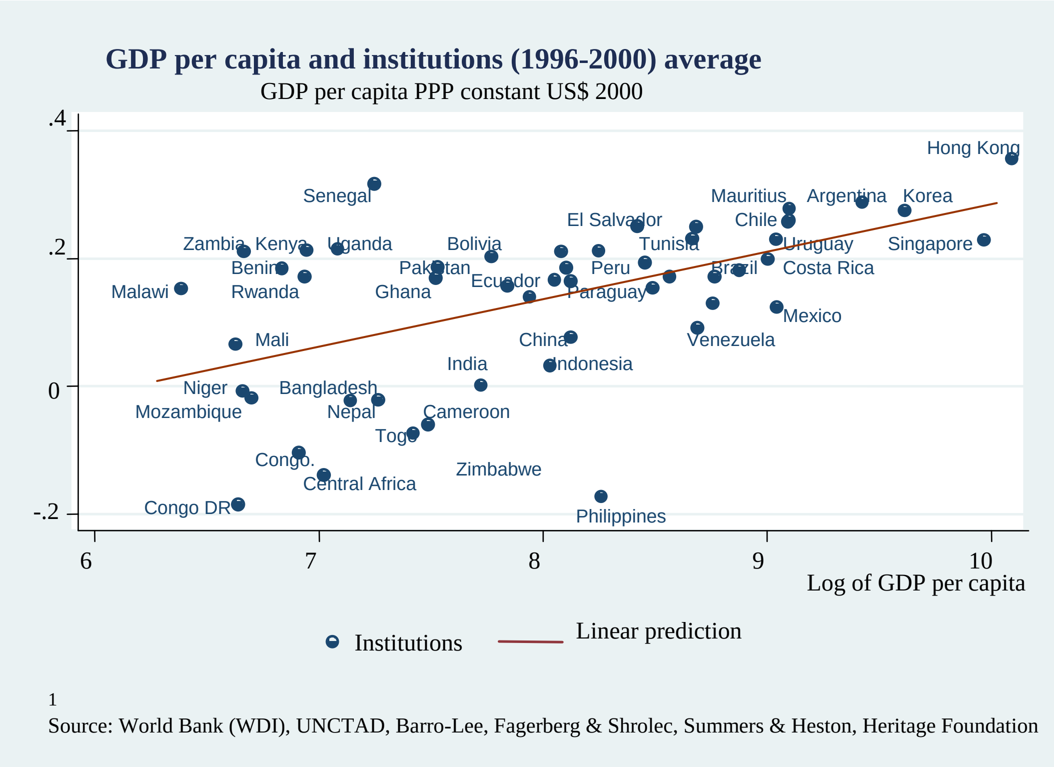
Table 1: Results of factor analysis



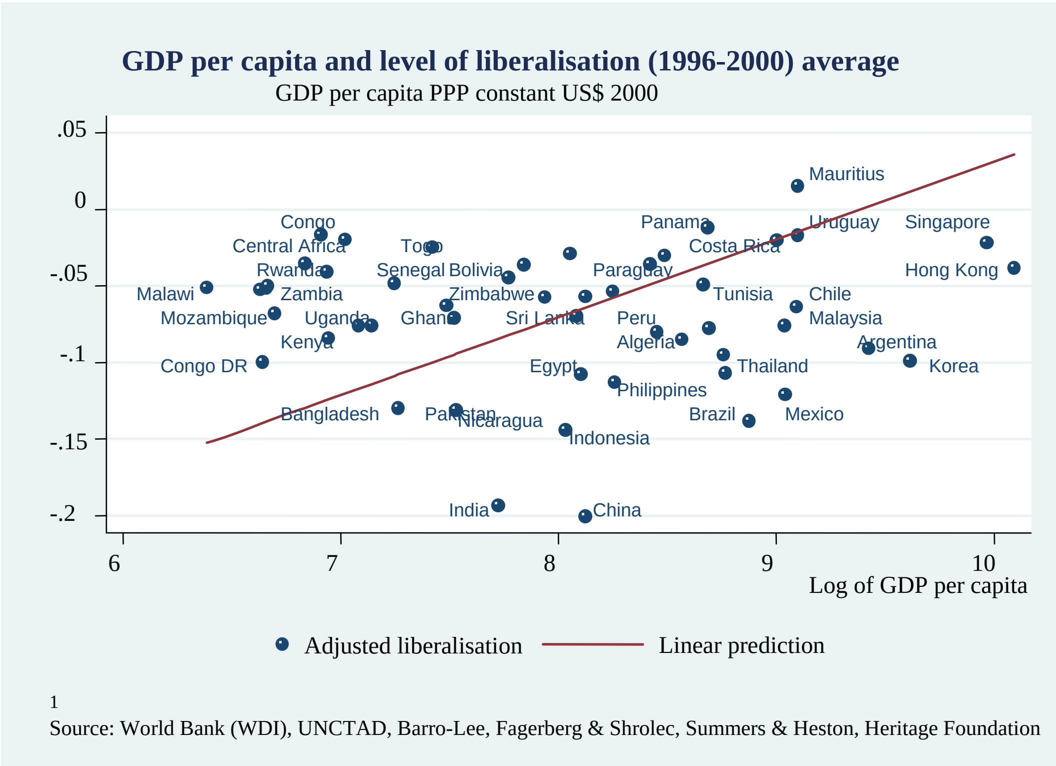
Graph 1: GDP per capita and level of capacity



Graph 2: GDP per capita and level of technology



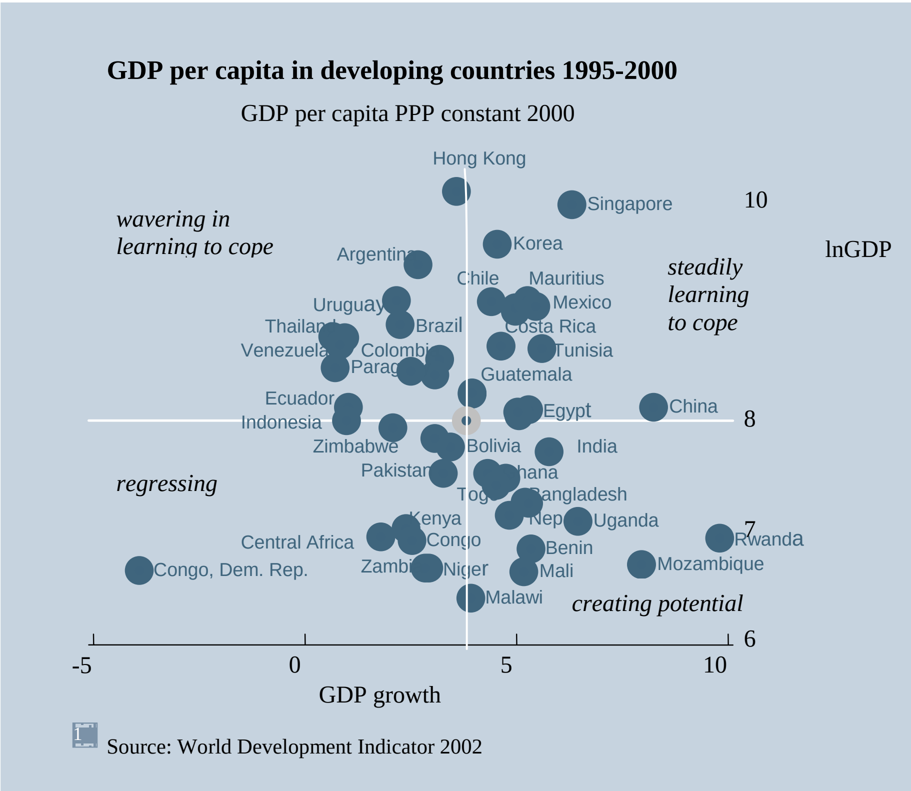
Graph 3: GDP per capita and level of institutions



Graph 4: GDP per capita and level of liberalisation

The dimensions labelled *capacity* and *technology* in graphs *2.1* and *2.2* indicate that an unambiguous positive correlation exists between them and income per capita. The weaker the dimensions the lower the income per capita and *vice versa*. In our view, these two dimensions are critical for innovation-led growth. The dimension *capacity* primarily reflects the ability to create a foundation for an absorptive capacity. Investment in competences takes place via both development of the learning capability in learning institutions as well as in the domestic industries. We note that although graph *2.2,* which represents the *technology* dimension, suggests that a non-linear fit is more appropriate the interpretation of the results is not altered: there is a positive correlation between per capita income and technology. The dimension, *institutions,* in graph *2.3* provides mixed results. For example, Senegal is only second to Hong Kong in terms of strong *institutions* whereas its income per capita falls way below that of a large number of economies with weaker *institutions*. Another set of low income countries (Zambia, Kenya, Uganda, Rwanda) have institutions that out perform a relatively large number of economies with much higher income per capita. While we admit that strong institutions contribute to growth, it appears that strong institutions evolve with strong economic performance. Prior or *ad hoc* creation of strong institutions may not drive growth. Finally, the dimension labelled *liberalisation* in graph *2.4,* which has been adjusted for size since smaller economies tend to be more open than larger ones, reveals that *liberalisation* does not matter for growth. Withdrawal of outliers from the sample does not alter the results. In fact, it is our view that *liberalisation* of fragile economies does not favour income per capita growth. However, once an economy has developed a relatively strong/competitive base, *liberalisation* may be beneficial, particularly because the economy is in a position to control foreign infiltration into its economy and at the same time to capitalise on foreign economies.

The growth performance matrix in graph *2.5*, which provides a summary of economic performance in our sample of developing countries, appears to confirm the results of our factor analysis. We plot the growth of GPD against the log of income per capita (averaged for 1995-2000) and identify two main categories. The first category lies beneath the average income per capita of the sample and has a majority of African countries. In the first sub-category the economies have both weak incomes and income growth rates. These are the economies that tend to fall further into marginalisation. In the second sub-category, we observe economies that are weak, but are able to make some headway in terms of developing the required prior capacity that is necessary for breaking away from marginalisation.



Graph 5: Growth performance matrix

In the second category, the group of economies displays an income per capita that is above the sample average. The first sub-category consists of economies with substantial potential for a definitive break-off from marginalisation, and which are on a positive growth performance.

However, this sub-category reveals hesitant performance perhaps mainly due to policy coordination. The second sub-category is made up of economies with the most promising growth performance. On the whole, we observe that while creation of technological competences and knowledge is beneficial for growth, policy coordination plays an important role.

V. Conclusion

Observations in this paper may be summarised as follows: knowledge creation, which leads to a technical innovation as well as competence building (acquisition and upgrading of skills), depends on investment that is driven by both internal effects related to, for example government policy, and external effects including investment related mimicry and international policy. However, strong feedback effects exist between knowledge generation and investment. We note that while entrepreneurial demands drive physical capital accumulation contingent upon business savings, which in turn depend upon the rate of investment, competence building responds to changes in the environment, and entrepreneurs then seek competences that best allow them to remain competitive. In other words, both the entrepreneur and the skilled individual may be viewed as investors who take decisions with regard to an environment that faces rapidly changing technological transformations. Hence, the skilled individual invests in skills that make her competent in the environment of rapid transformations, while the entrepreneurs invests in the industry that responds best to rapid changes, i.e. a high growth performing industry, and in order to be competitive seeks competences that are able to rapidly respond to change. The rising skill-premium in tandem with upgrading of skill is evidence of the importance of competence building in a changing environment because it strengthens the capacity to become or remain competitive.

One of the main points made in this paper is that in a business environment that allows for a significant profit margin it is the speed and ease with which competences are able to keep up with demands of a rapidly changing environment that matters rather than the stock of competences *per se*. Put bluntly, it is the ease and speed with which inputs, and particularly competences (which are prone to rigidities that competence up-grading a very costly and lengthy process), adjust to changes and therefore provide entrepreneurs with the ability to remain competitive.

The paper has also made an attempt to emphasize that domestic investment in innovation is central to improving the ease and speed with which an economy is able to compete because it complements competences: improved competences must be matched with a corresponding innovation environment. Indeed, insufficient innovation investment is likely to thwart competence up-grading. In addition, the importance of the feedback mechanisms existing between competences and domestic innovation cannot be ignored. Both competences and domestic innovation are critical for the development of an absorptive capacity, a *sine qua non* of sustainable growth.

Notwithstanding the limitations facing the statistical tools that were employed, the paper was intended to give an indication of factors that may contribute significantly to creating the capacity to manage technological change developing countries. In addition, it was aimed at capturing the diversity amongst developing countries particularly with regard to their potential to cope with technological transformations; the importance of creating the capacity to drive the rate of technology acquisition was a major concern of the paper.

An in-depth discuss of domestic innovation as a corner stone for technical progress as well as on diffusion as an innovation process, would have been useful in highlighting the feedback mechanism that operates between innovation and diffusion. However, these discussions lie beyond the scope of this paper.

Appendix

Country sample

Country list of 51 developing countries used in the analysis
(definition of developing countries is that of the WTO)

Africa (21 countries)	*Latin America (17 countries)*	*Asia (13 countries)*
Algeria	Argentina	Bangladesh
Benin	Bolivia	China
Cameroon	Brazil	Hong Kong
Central African Republic	Chile	India
Congo, Dem. Rep.	Colombia	Indonesia
Congo, Republic of	Costa Rica	Korea, Republic of
Egypt	Ecuador	Malaysia
Ghana	El Salvador	Nepal
Kenya	Guatemala	Pakistan
Malawi	Honduras	Philippines
Mali	Mexico	Singapore
Mauritius	Nicaragua	Sri Lanka
Mozambique	Panama	Thailand
Niger	Paraguay	
Rwanda	Peru	
Senegal	Uruguay	
Togo	Venezuela	
Tunisia		
Uganda		
Zambia		
Zimbabwe		

Database construction

Data from the above sources is averaged over a period of 5 years (1996-2000). The period 1996 to 2000 was chosen mainly due to the availability of data which was fairly comprehensive. Selection of the variables was also highly influenced by data availability. Most of the variables had full coverage, and missing values for variables with incomplete coverage did not exceed 10 percent of the total entries of 255 (51 observations x 5 years). Although the primary reason for taking data averages over a 5 year period was to care of shocks, averages were also used to fill in for missing value in some cases.

Data for both R&D and patents was obtained directly from the database constructed by Fagerberg and Srholec (2004). We note that R&D data is generally not available for most developing countries and a word on how Fagerberg and Srholec (2004) put it together is necessary. They assume that a country with zero patents jointly with zero scientific articles has zero R&D expenditure. Missing R&D values were estimated using the *impute* procedure in Stata 8.2. Estimated data was checked against observed values in countries with similar characteristics, and where necessary data was truncated.

With regard to patent data Fagerberg and Srholec (2004) took care to suppress the "home country advantage" of the United States in the USPTO patent counts indicator. The propensity of American residents to register inventions in their own national patent office is higher than that of none residents, and this was adjusted downwards based on a comparison between Japanese and American patents registered at the European Patent Office (EPO). They used the estimation method proposed by Archibugi and Coco (2004).

Most of our variables are those used by Fagerberg and Srholec (2004) and are obtained from the same sources. The methodology used in putting the data together is also taken from Fagerberg and Srholec (2004). In particular, we also reverse the scale for the Heritage Foundation indicators, but this does not influence the data. Low values signify weakness of an indicator while high values indicate strength in order to simplify interpretation of loadings in factor analysis.

Data sources and definitions

Variable	*Definition*	*Source*
FDI inward stock as a percentage of GDP	Aggregate inward FDI stocks as a percentage of GDP. FDI stock is the value of the share of their capital and reserves (including retained profits) attributable to the parent enterprise, plus the net indebtedness of affiliates to the parent enterprises.	UNCTAD Foreign Direct Investment Database (2004)
Educational attainment of the total population aged 25 and over	The data set provides the number of years of schooling achieved by the average person for the age group over age 25 for the years 1960-2000.	Barro-Lee data set (2000)
Investment share of RGDPL	Investment share of real GDP where "real" means "PPP converted" instead of "in constant price".	Alan Heston, Robert Summers and Bettina Aten, Penn World Table Version 6.1, Center for International Comparisons at the University of Pennsylvania (CICUP), Oct 2002.
Research and Development expenditure (% of GDP)	Total (public and private) intramural expenditure on research and experimental development (R&D) performed on the national territory. R&D comprises creative work undertaken on a systematic basis in order to increase the stock of knowledge and the use of this stock of knowledge to devise new applications.	*Fagerberg and Srholec (2004)* Based on World Bank (World Development Indicators), OECD (MSTI database), RICYT and national sources?

Patents	The number of patents granted by the US Patent and Trademark Office (USPTO). A patent is assigned to a country according to the investor's country of residence. When a patent is invented by several inventors from different countries, the respective contributions of each country is taken into account.	*Fagerberg and Srholec (2004)* Based on OECD Patent Database (based on the USPTO)
Banking and Finance	Measures the relative openness of a country's banking and financial system by determining whether foreign banks and financial services firms are able to operate freely, how difficult it is to open domestic banks and other financial services firms, how heavily regulated the financial system is, how great the presence of state-owned banks is, whether the government influences the allocation of credit, and whether banks are free to provide customers with insurance and invest in securities (and vice versa). It is an indication of the country's financial climate.	*Heritage Foundation – Index f Economic Freedom Database (scale 1 to 5)* Based primarily on data from Economist Intelligence Unit, *Country Commerce*, *Country Profile*, and *Country Report*, and official government publications of each country.
Informal markets	Measures the extent to which informal market activities occur. The higher the level of informal market activity, the lower the level of overall economic freedom and the higher a country's score.	*Heritage Foundation – Index of Economic Freedom Database (scale 1 to 5)* Based on Transparency International's Corruption Perceptions Index (CPI)
Property rights	measures the extent to which the government protects private property by enforcing the laws and how safe private property is from expropriation. In addition, it analyzes the independence of the judiciary, the existence of corruption within the judiciary, and the ability of individuals and businesses to enforce contracts. The less protection private property receives, the lower a country's level of economic freedom & the higher its score.	*Heritage Foundation – Index of Economic Freedom Database (scale 1 to 5)* Based primarily on data from the Economist Intelligence Unit, Country Commerce and Country Reports

Regulation	measures how easy or difficult it is to open and operate a business. The more regulations are imposed on business, the harder it is to establish one. The factor also examines the degree of corruption in government and whether regulations are applied uniformly to all businesses. Another consideration is whether the country has state planning agencies that set production limits and quotas.	*Heritage Foundation – Index of Economic Freedom Database (scale 1 to 5)* Based primarily on data from the Economist Intelligence Unit, Country Commerce and Country Reports
CO2 emissions (kg per 2000 US$ of GDP)	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include contributions to the carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	*World Bank - World Development Indicators Database (2004)* Based on Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, in the U.S. state of Tennessee.
Domestic credit to private sector (% of GDP)	Domestic credit to private sector refers to financial resources provided to the private sector, such as through loans, purchases of non-equity securities, and trade credits and other accounts receivable, that establish a claim for repayment. For some countries these claims include credit to public enterprises.	*World Bank - World Development Indicators Database (2004)* Based on International Monetary Fund, International Financial Statistics and data files, and World Bank and OECD GDP estimates.
Fixed line and mobile phone subscribers (per 1,000 people)	Fixed lines are telephone mainlines connecting a customer's equipment to the public switched telephone network. Mobile phone subscribers refer to users of portable telephones subscribing to an automatic public mobile telephone service using cellular technology that provides access to the public switched telephone network.	*World Bank - World Devpt Indicators Database (2004)* Based on International Telecommunication Union, World Telecommunication Development Report and database.

Industry, value added (% of GDP)	Industry corresponds to ISIC divisions 10-45 and includes manufacturing (ISIC divisions 15-37). It comprises value added in mining, manufacturing (also reported as a separate subgroup), construction, electricity, water, and gas. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3.	*World Bank - World Development Indicators Database (2004)* Based on World Bank national accounts data, and OECD National Accounts data files.
Internet users (per 1,000 people)	Internet users are people with access to the worldwide network.	*World Bank - World Development Indicators Database (2004)* Based on International Telecommunication Union, World Telecommunication Development Report and database.
Life expectancy at birth, total (years)	Life expectancy at birth indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life.	*World Bank - World Development Indicators Database (2004)* Based on World Bank staff estimates from various sources including census reports, the United Nations Statistics Division's Population and Vital Statistics Report, country statistical offices, and Demographic and Health Surveys from national sources and Macro International.

Money and quasi money (M2) as % of GDP	Money and quasi money comprise the sum of currency outside banks, demand deposits other than those of the central government, and the time, savings, and foreign currency deposits of resident sectors other than the central government. This definition of money supply is frequently called M2; it corresponds to lines 34 and 35 in the International Monetary Fund's (IMF) International Financial Statistics (IFS).	*World Bank - World Development Indicators Database (2004)* Based on International Monetary Fund, International Financial Statistics and data files, and World Bank and OECD GDP estimates.
Personal computers (per 1,000 people)	Personal computers are self-contained computers designed to be used by a single individual, per 1,000 people.	*World Bank - World Development Indicators Database (2004)* Based on International Telecommunication Union, World Telecommunication Development Report and database.
Population density (people per sq km)	Population density is midyear population divided by land area in square kilometres. Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship--except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin. Land area is a country's total area, excluding area under inland water bodies, national claims to continental shelf, and exclusive economic zones. In most cases the definition of inland water bodies includes major rivers and lakes.	*World Bank - World Development Indicators Database (2004)* Based on Food and Agriculture Organization and World Bank population estimates.

Radios (per 1,000 people)	Radios refer to radio receivers in use for broadcasts to the general public, per 1,000 people.	*World Bank - World Development Indicators Database (2004)* Based on United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics.
School enrolment, secondary (% gross)	Gross enrolment ratio is the ratio of total enrolment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Secondary education completes the provision of basic education that began at the primary level, and aims at laying the foundations for lifelong learning and human development, by offering more subject- or skill-oriented instruction using more specialized teachers.	*World Bank - World Development Indicators Database (2004)* Based on United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics.
School enrolment, tertiary (% gross)	Gross enrolment ratio is the ratio of total enrolment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Tertiary education, whether or not to an advanced research qualification, normally requires, as a minimum condition of admission, the successful completion of education at the secondary level.	*World Bank - World Development Indicators Database (2004)* Based on United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics.
Scientific and technical journal articles	Scientific and technical journal articles refer to the number of scientific and engineering articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences.	*World Bank - World Development Indicators Database (2004)* Based on National Science Foundation, Science and Engineering Indicators.

Services, etc., value added (% of GDP)	Services correspond to ISIC divisions 50-99 and they include value added in wholesale and retail trade (including hotels and restaurants), transport, and government, financial, professional, and personal services such as education, health care, and real estate services. Also included are imputed bank service charges, import duties, and any statistical discrepancies noted by national compilers as well as discrepancies arising from rescaling. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The industrial origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3.	*World Bank - World Development Indicators Database (2004)* Based on World Bank national accounts data, and OECD National Accounts data files.
Trade (% of GDP)	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product.	*World Bank - World Development Indicators Database (2004)* Based on World Bank national accounts data, and OECD National Accounts data files.

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