

International Technology Gap and Technology Transmission: The Policy Implications

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1. Introduction

In an important historical contribution, Maddison (2001) stressed that productivity growth jumps in the aftermath of the first industrial revolution and that its accelerating pace continues, even though this astonishing growth has not been uniform worldwide. In addition, several empirical works¹ have shown that income per capita differences have increased dramatically over the last fifty years, highlighting a trend for richer countries to converge toward parallel growth paths. Evidence of this income polarization process has been well documented by Quah (1993; 1997) and Durlauf (1996) who reported that the time evolution of cross-country income is converging toward a two-peaked distribution. Although it is incontestable that the rate of factors accumulation is important in explaining the development process of capitalist economies, economists stress that physical and human capital accumulation do not completely account for both cross-country productivity level and income per capita disparities². As Easterly - Lavine (2001) point out:

...when comparing growth experiences across many countries, «something else» – besides factor accumulation – plays a prominent role in explaining differences in economic performance. [...] ... this «something else» accounts for the majority of the cross country differences in both the level of Gross Domestic Product (GDP) per capita and the growth rate of GDP.

Thus, there is an additional source of divergence for disparities in productivity and income per capita, and many economists seem to recognize

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¹ For a review of this huge literature see in particular Caselli (2005).

² In particular, see Prescott (1998).

knowledge differences as the main factor in this worldwide economic performance divergence. But knowledge cannot easily be bought like an ordinary commodity, so the ability of each developing country to acquire and then to absorb know-how depends on the development of local capacity and on the development and efficiency of appropriate institutions. Consequently, knowledge is a key production input and each factor regarding its acquisition cost has the effect of shifting the bargaining power toward producers of knowledge and away from users. All these considerations have policy implications and raise the question of what is the best way of stimulating both innovation activities and technology transfer³.

During the 90s, there was a heated debate about how a knowledge-based firm's intangible assets could be protected in order to avoid both misappropriations and intellectual theft. One example of such a debate is the Uruguay Round of GATT, whose Final Act created the World Trade Organization (WTO) and the Agreement on Trade-Related Aspects of Intellectual Property rights (TRIPS)⁴ with the aim of providing new and more effective transnational institutions capable of managing the transition toward a globalized economy.

However, since technology is mostly in private hands, tight regulations, such as TRIPS, may deter rather than enhance technology transfer. Indeed, there is undeniable evidence⁵ that developing countries suffer significantly from lagging labour productivity and managerial efficiency, related in part to the failure to adopt the latest technology or to update their labour force. This determines the extent to which these countries can assimilate and apply foreign technology and to favour technology transfer from abroad. In Europe and the US, for instance, a democratic intellectual property (IP) rights protection system has been crucial in ensuring that returns to individual investments in creativity accrue to society as a whole. However, IP rights have always been assessed in a broader policy context including trade and anti-trust policies, as well as more general industrial policies (see Braga - Fink - Sepulveda, 1999; Maskus, 2000; and Khan, 2002).

In light of that, do international institutions, in particular WTO and WIPO, provide adequate advice and analysis for understanding the particular needs of developing countries and poor people? In their bilateral relations with developing countries, do developed countries take sufficient account of the needs of developing countries and, in particular, of poor people in them? And moreover, are developing countries themselves sufficiently aware

³ For theoretical studies on innovation and technology transfer see, among others, Helpman, 1993; Lai, 1998; and Glass - Saggi (1998; 2002).

⁴ With TRIPS, every WTO member has strengthened the global protection offered to suppliers of technology, defining what rights an inventor is entitled to and what institutions should be available to punish any infringing behaviour.

⁵ See in particular Baumol - Blackman - Wolff (1992); and Trefler (1995).

of where their own interests lie and do they have the capacity to secure those interests in bilateral and multilateral negotiations?

In this paper we will illustrate some possible strategies that policy-makers can develop in order to reduce their knowledge disadvantage, acquire technological knowledge from abroad, and solve all the problems connected with knowledge acquisition. The paper is organized as follows. In section 2 we start describing what the economic literature refers to as knowledge, define what a knowledge gap is, and discuss which policies are more likely to reduce it. In sections 3, 4 and 5, we treat the question of technology transfer in greater depth and discuss the policies concerning knowledge *acquisition*, knowledge *absorption*, and knowledge *implementation*. Finally, section 6 concludes.

2. Knowledge as a Production Input

It is common practice among growth theorists to consider technological knowledge as the main ingredient of sustained economic development. Although technology is often highlighted and emphasized as a source of economic disparities, there is no agreement in the profession about the way knowledge affects cross-country economic performances. Indeed, beside the common view that technological knowledge could be thought of as a *quasi-public good* able to generate technological spillover affecting a country's total factor productivity (TFP)⁶, there is an alternative view that looks at technology as a common pool of knowledge available to firms and individuals in all countries⁷.

The first approach is based on the belief that technological knowledge is non-rival, partially excludable and can be accumulated without bound. When technological change improves the stock of knowledge, the discoverer of a new method or good needs some form of protection that safeguards the discovery from any possible attempt to copy or imitate it, and that gives the inventor the right to exclude other persons from the use of his ideas for commercial purposes. However, this characteristic of excludability is only partial and becomes the source of technological spillover that allows the same people to use ideas in different ways at the same time. In Romer's (1990) words:

...treating knowledge as a non-rival good makes it possible to talk sensibly about knowledge spillover, that is, incomplete excludability. [...] The example of non rival input [...] is a design for a new good. The vast majority of designs results from the

⁶ The seminal paper on this approach is Romer (1990). For further extensions and developments of such an approach see Grossman - Helpman (1991); Aghion - Howitt (1992, 1998); Barro - Sala-i-Martin (1995, ch.7 and 8).

⁷ On this approach see Parente - Prescott (1994, 1999); and Acemoglu (1998) for the extension of this approach to the case of skill-biased technological progress.

research and development activities of private, profit-maximizing firms. A design is, nonetheless, non-rival. Once the design is created, it can be used as often as desired, in as many productive activities as desired.

In contrast, the alternative view looks at technology as worldwide common knowledge available to all countries, though access to it differs from country to country due to specifically domestic barriers to adopting leading-edge technology. More specifically, Parente - Prescott (1994, 1999) state that the actual cross-country divergence in income per capita is the consequence of policy differences among countries that, in turn, are the outcome of different political economy equilibria. Differences in TFP are linked to several social-political variables that make each country's cost of adopting leading-edge technology differ in time and space. In particular, Parente - Prescott (1994) say

...these barriers take different forms such as regulatory and legal constraints, bribes that must be paid, violence or threat of violence, outright sabotage, and worker strikes. Whatever their form, each has the effect of increasing the cost of technology adoption.

According to this approach, the diverse growth experiences of countries like South Korea and Philippines can be explained by a sort of unmeasured technology adoption investment and by an increase in trade openness that worked in the direction of weakening the social-political impediments to technology adoption⁸, which indicated that there is a high correlation between cross-country differences in per capita income and TFP.

Although conceptually different, both approaches share an important feature: the presence of an institutional mechanism that prevents knowledge from flowing freely among people. In particular, the relationship between knowledge gap and knowledge transmission problems raises the question of how international institutions and developing country governments can act best in order to improve people's life and to stimulate growth.⁹ However, it is not easy to narrow the knowledge gap. Developing countries are pursuing a moving target as the knowledge frontier is constantly being pushed forward by advanced countries.

In order to reach the knowledge frontier, developing countries have the option of acquiring and adapting the knowledge already available or repro-

⁸ For the sake of exposition, it is important to bear in mind that this approach has been criticized by several empirical papers. See, among others, the works of Hall - Jones (1999); Easterly - Lavine (2001).

⁹ The question of the measurement of cross countries knowledge gap is one of most debated issues in the applied economic literature. This is mainly due to the lack of detailed indicators of technological capabilities as well as to the lack of data for a large number of developing countries. For a more detailed discussion, see in particular Archibugi - Coco (2004, 2005).

ducing/copying existing knowledge. This means policy makers have to take three critical steps in order to move closer to the technological frontier:

Knowledge acquisition, which involves tapping and adapting existing knowledge as well as creating knowledge locally through R&D;

Knowledge absorption, which concerns the creation of an efficient educational system able to ensure universal basic education, opportunities for life-long learning, and the support of tertiary education;

Knowledge implementation, which involves the creation of institutions capable of taking advantage of the latest information about technological knowledge and making it available to every individual in society.

Although it is quite easy to distinguish three steps conceptually and discuss each of them separately, there exists a sort of complementarity in acquiring, absorbing, and implementing knowledge that makes it hard to separate a step from the other, and government strategies to narrow the knowledge gap are more effective when they exploit such synergies. This implies that the temporary advantage of one country in certain lines of production can no longer be seen statically in terms of unchanging tangible factors; rather, once knowledge is taken into account, dynamic comparative advantage is what matters for long run growth and prosperity. The pursuit of a dynamic comparative advantage then suggests that developing countries should remain importers rather than producers of technical knowledge for some time, in such a way as to create the potential to improve their knowledge. Obviously, the speed with which they do this will vary according to the country, depending on its capacities, incentives and policy strategies.

3. The Knowledge Acquisition Policies

In order to promote the acquisition of knowledge from abroad, a developing country's policy makers have to take into account the fact that technology moves from one country to another thanks to direct learning about foreign technological knowledge (DL), the use of the leading-edge technology embodied in the more recent generation of intermediate products (IIP), and processes of reverse engineering activity (RE).

DL stems from the fact that each technological improvement is based on a new blueprint which increases the international cumulative stock of codified information on new ideas and production processes. This new information spills over from the country where it was initially created into others even in the absence of international trade, allowing the foreign blueprint to increase the international stock of knowledge (see Howitt, 2000). Instead, when one considers IIP as source of technology diffusion, it is worthwhile to think of it as a sort of passive spillover, in the sense that employing foreign intermediate goods involve an indirect access to the results of foreign R&D. Strictly related with IIP is the concept of RE, which refers to those activities where importer countries copy the technology embodied in the intermediate products just by reverse-engineering it.

Many economists have stressed that developing countries can acquire technology by opening-up their economies to knowledge from abroad and/or by creating knowledge not already available elsewhere. In that light, there are three possible ways of approaching the technological frontier, by opening up the economy either to international trade, foreign direct investment (FDI), and incentive technology licensing. In the next subsections we will discuss the role policy-making institutions may play in the transmission of knowledge through each of these channels

3.1. *Trade as a Channel of Technology Transmission*

Whenever transportation costs and tariffs are low compared to the cost of FDI and licensing, trade can be thought of as a way to acquire knowledge. But is trade really useful to a developing country's policy makers for generating technological inflow?

Even if many theorists state that trade flows into developing countries enhance technology transfer, things are far from being clear on the empirical ground. In two hotly debated papers, Coe - Helpman (1995) and Coe - Helpman - Hoffmaister (1997) investigate the linkage between trade and technology transmission inside OECD countries and between industrial countries and developing ones, showing that significant R&D spillover are not confined to the group of industrial economies but are also important for less developed economies. This study provides a quantitative estimate of the effect of the acquisition of information through international trade on 77 developing countries' TFP. In doing so, they introduce the concept of «*foreign R&D capital stock*» as the weighted average of the domestic R&D capital stock of the industrial countries with which the developing countries trade using bilateral import share as weights. They also find that the elasticity of TFP with respect to foreign R&D capital stock and import share are positive and significant and therefore conclude that international R&D spillover are related to the composition of imports: the more a developing country's trade is biased toward industrial countries with a large cumulative experience in R&D, the higher its productivity.

Although these results are confirmed by Braga - Fink (1997) and Braga - Fink - Sepulveda (1999), Keller (1998; 2000) vehemently criticized these outcomes, finding similar high coefficients and similar predictions when a random instead of the actual import share is used. Extending the Montecarlo analysis to a two and three digit industry-data level, Keller (1998) finds that countries benefit more from domestic R&D than from the R&D of the average foreign country, and that the import composition of a country might matter for technology diffusion depending on how strongly biased it is towards (or away from) a country that is a technology leader, implying that Coe and Helpman's claim that import composition is strongly related to technology diffusion cannot be upheld. In their response to Keller's cri-

tiques, Coe - Hoffmaister (1999) show that Keller's random shares of import were not random because the probability distribution (of the import shares) concentrates around the inverse of the number of trading partners making the variance across different simulations rather small; they also demonstrate that there exist three alternative sets of random weights in which regression results lead to the conclusion that randomly created trade patterns could explain productivity growth.

In order to extend such a result to a micro-level analysis, Keller (1997) uses industry-data on international transaction in such a way as to reduce the loss of information from the use of aggregate data and to integrate the more recent theoretical works on open-economy relations with the early works on the importance of the input-output transmission of technology¹⁰. Using data from 13 manufacturing industries of eight OECD countries over the period 1970-1991, he found that the benefit derived from foreign R&D in an industry is in the order of 50-95% of the productivity effect of domestic R&D, confirming earlier findings that cumulative investment in research is positively related to the productivity level. In particular, he estimated an elasticity of TFP of between 7-17% for domestic-industry R&D, and of between 20-50% for foreign-industry R&D, showing that the impact of foreign research investment on rising productivity is higher than from domestic research investment in other industries. Moreover, if the same analysis is made for more technology-intensive industry he finds that the gain of productivity from foreign research investment in the same industry is less than from domestic other-industry research investment. This outcome suggests that the less technology-intensive industries tend to be technology users to a larger extent, while high technology-intensive industries benefit to less from outside research investment. These lower intra-industry spillover could be the result of a different market structure since high technology-intensive industries tend to be monopolistically competitive.

But what are the necessary ingredients to enable developing countries' policy makers to attract technology through trade? Trade liberalization is one of these, even though its concrete application cannot disregard other important institutional aspects such the IP rights legislation and its enforcement. In a theoretical contribution, for instance, Qiu - Lai (2003) point out that, when IP rights protection is weak, tariff protection in innovation-intensive sectors in developing countries is more detrimental to world welfare than in developed countries.

¹⁰ See particularly Scherer (1984); and Evenson - Westphal (1995).

3.2. *Know-how Transmission through FDI and Licensing Contracts*

Whenever transportation costs and tariffs are binding, FDI and licensing contract are likely to supplant trade as channels for technology transmission. FDI offers considerable opportunities for improving efficiency and growth, particularly, wherever the domestic production frontier is far from the state-of-the-art owing to a lack of managerial and entrepreneurial skills. However, as Archibugi - Iammarino (1999) stress, the debate on where multinational enterprises (MNEs) do actually locate their research and innovation activities has not reached definite results and the empirical evidence on the share of innovation generated outside the home country of the MNE is still controversial. Through FDI, MNEs can provide access to either technological knowledge or managerial assets, which provides both a direct spur to productivity and significant spillover benefits throughout the economy. Of course, a correct approach to the problem suggests that the importance of many institutional aspects (such as, for instance, the education system, the antitrust regulation and/or the strength of property rights protection) in encouraging FDI varies according to the sectors. For instance, investment in lower-technology industries such as textiles, distribution, or hotels, is probably more closely linked to some specific factor such as inputs cost and market opportunity, whereas in the presence of complex technology and a highly differentiated product, firms are more likely to undertake FDI when local human capital is particularly abundant and cheap¹¹.

According to the *ownership-localization internalization* (OLI) theory (see Dunning, 1981 and Markusen - Maskus, 2001), a firm has the incentive to become a MNE when it has an *ownership* advantage as well as a *location advantage* over indigenous firms. Obviously, the economic advantages must be such that they outweigh the disadvantages it faces in international management, cultural barriers and the geographical difficulties of monitoring local operations.

The economic advantages can be divided into *ownership advantage* and *location advantage*. As regards the former, many MNEs are characterized by some *ownership advantage* that gives them market power and cost efficiencies. Such advantages could be embodied in tangible assets – such as a property claim in facilities producing key natural resources – or in intangible assets – such as a trademark or a reputation for quality. The existence of intangible assets is often strongly associated with technology development and tends to be important in industries with high R&D intensities, where intangible knowledge-based assets specific to each firm are significant. Moreover, the fact that technological knowledge is a quasi-public good enables MNEs to enjoy *economies of scope*, in the sense that a MNE can produce its tech-

¹¹ On this point see in particular Teece (1986); Davidson - McFetridge (1984, 1985) and Parello (2007).

nological knowledge elsewhere and use it in several different locations, thus spreading the investment cost of technology development across numerous facilities (see Markusen, 1995, on this point). Note that this argument is particularly important for *horizontal FDI*¹², in which a subsidiary produces goods and services that are similar to those produced at home and firms base their strategies for penetrating markets on the economic value of their intangible knowledge-based assets. In this situation, IP rights become particularly important in the fostering of FDI in industries in which the development of transferable knowledge is a key focus of strategies. The intangible nature of their *ownership advantage* means that firms operating in such industries are strongly encouraged to engage FDI wherever IP right regimes are particularly rigid and wherever an adequate supply of high-skilled labour is present.

On the other hand, even given some *ownership advantage*, many MNEs' decisions to invest in a certain country could depend on *location advantages* (market size, local demand pattern, lower wage costs in relation to labour productivity, and so forth). Transport costs and distance from markets can be considered to be the main factors which may induce many firms to substitute export with FDI. Notice that a location advantage matters for both vertical and horizontal FDI, but it turns out to be particularly relevant for the former, especially when a subsidiary produces inputs or assembles components and when the construction of a vertically integrated network is crucial for the development of MNEs¹³. Such forms of outsourcing or delocalization are typical of a rapid expansion of intrafirm trade between developed and developing countries and for a huge knowledge transmission between MNEs' headquarter and subsidiaries.

So, when local human capital is abundant and cheap, production incentives, investment regulations and/or competition rules are important components of a general regulatory system to attract vertical FDI as well as to facilitate the setting-up of foreign R&D laboratories. On the contrary, whenever cost-reducing policies (such as infrastructure investments) are at the top of a government's agenda, technological transfer is likely to occur through outsourcing rather than through horizontal FDI. However, as soon as wages rise sufficiently so that the economies lose their cost advantages in outsourcing, vertical FDI falls off and horizontal FDI displaces outsourcing by making developing countries attractive locations for producing high-quality differentiated products (Markusen, 1995).

Obviously, policy makers must take into account that the positive impacts of inward FDI and technology transfer do not come without costs. The negative effects can be principally recognized in a trend toward wage inequality,

¹² On this topic, see the pioneering paper of Markusen (1984), and the latter developments by Horstmann - Markusen (1987; 1992); Brainard (1993); and Markusen - Venables (1998; 2000).

¹³ For an analysis of this approach, see particularly Helpman (1984, 1985); Helpman - Krugman (1985).

and in a loss of market competition. If there are few links with other economic sectors, FDI may operate with limited spillovers into the technology adopted and pay higher than average wages to their own workers without ensuring that these wage impacts and technological spillover spread to other parts of the economy. Such a situation is aggravated if MNEs engage in an abusive practice of their dominant market positions.

In the OLI framework, MNEs could decide to undertake FDI independently of *ownership* and *location advantages*. Indeed, whenever advantages of internal organization or particular human assets are strong, MNEs are more likely to decide to acquire a subsidiary rather to license an asset with an independent foreign firm.

If the costs of transferring technology through arm's-length transactions are high, and such costs are closely linked to the firm's human capital, management or corporate culture, firms can be expected to prefer the acquisition of a subsidiary rather than to undertake a licence-relationship with an independent firm. Thus, technology licensing in complex products and processes is more likely to emerge wherever the human capital base of the country is not able to receive technological advances. That is the result of the fact that transfer costs also depend on the developing country's aptitude to absorb technology efficiently, and how the phase of knowledge acquisition is carefully combined with knowledge absorption.

However, such a decision could also depend on the strength with which licensing contracts are enforced. Indeed, most of these decisions are related to the difficulties of developing a satisfactory and enforceable contract between independent firms as well as to the presence of asymmetric information between licensors and licensees (Teese, 1986). For instance, there may be problems in adopting license contracts as a channel of technology transmission in those industries where licensees try to shirk their marketing or distribution responsibilities, to degrade the products' quality or to sign contracts with competing firms, and show more interest in their products. These kinds of problems are particularly significant in those industries in which a firm's knowledge-based asset is a reputation for high quality and where the supply of technologies and products to licensees is highly competitive. If this is the case, a strong enforcement of the regulations against infringing firms could help the policy maker to compensate for the existence of imperfect information and to reduce the cost of monitoring licensees' behaviour, but alone it cannot guarantee that the policy-making institution will be able to protect the market from unfair behaviors. In this sense, the creation of information centres for domestic firms, where they can learn the ins and outs of foreign technology markets, could reduce their disadvantage in licensing negotiations and make licensing more effective in attracting technology.

The 80s and 90s saw an increasing number of national and international agreements between firms for the communal development of specific R&D activities (Hagedoorn - Schakenraad, 1993). These forms of collaboration for technological advances have promoted a variety of mechanisms for the divi-

sion of costs and the exploitation of results. In a way, the necessity to reduce innovation costs has created new forms of industrial organization and new ownership structures that are expanding beyond the simple technological sphere (Mytelka, 1991; and Dodgson, 1993).

4. Absorbing Knowledge Policies

Once a country succeeds in acquiring knowledge from abroad, the next step is to absorb it in order to construct a base for the future creation of an indigenous knowledge-based production system. In doing so, the focus of policymaking institutions must move towards higher education and technical training rather than IP rights, since it has been proved that the latter have just a marginal effect in this field. More specifically, what is needed is the creation of a flexible labour force that can keep up with a constant flow of technological advances, access to abundant financial resources and sophisticated human skill with the business acumen to proceed at the same pace as the more innovative countries. But, when they face the question of improving their national education systems, a developing country's policy makers should pay attention to both the way they design education policies and implement them, since the provision of education creates three sets of stakeholders: citizens, educators and teachers, and the government itself. Together, these stakeholders must establish a system which ensures that private and public investment in education is well spent, as well as guaranteeing teachers and educators the professional autonomy necessary for excellence. Cross-country evidences have found public spending on education to be unrelated to long run economic performances, showing that it is the quality of spending, not the amount, that matters.

As each level of education plays a crucial role in the absorption of knowledge, policy makers need to provide for all ages and start thinking of education as a lifelong process. This means that the role played by education does not stop with basic education¹⁴ but continues throughout life, especially in tertiary education and on-the-job learning. Of particular importance are the tertiary education and the learning-by-doing activity, because the increased use of information-based technologies as a country moves ahead towards a knowledge-based society raises the demand for skills in diffusing, interpreting and applying new knowledge. This is why, over the last three decades, many countries have made enormous strides in expanding school enrolment at all levels and in rendering education accessible to all members of society.

As public measures are the most effective, governments must deal with the question of the failures which characterize the education market, and the

¹⁴ For basic education we mean primary and secondary education, even though many other authors include the preschool programs in this category.

distributional problems which arise from public intervention on education. As regards the first, the market failure associated with education are mainly due to the existence of imperfect information about the quality of education, and to the existence of spillover benefits in acquiring education. Instead, the distributional problems concern the accessibility of education for all members of society which, in turn, warrant higher wages for educated people¹⁵. Thus, policy can address these questions:

- empowering informed stakeholders;
- helping poor people to pay for education.

4.1. *Empowering Informed Stakeholders: from Providing Training to Providing Information*

For many international institutions (notably the World Bank) the efficiency of education systems is crucial in helping developing countries to expand their national attitude to absorb complex technology. To build an efficient education system, however, policy makers have to deal with some informational problems which cannot be solved easily. For instance, inadequate levels of Information and Communications Technology literacy is one of the major problems facing many African countries such as Ghana and Nigeria (Oduwale, 2005 and Amekuedee, 2005) as well as big countries such as China (Zhou, 2005) as they move into the 21st century.

Education quality is a continuing source of concern for all stakeholders, especially if no adequate assessment is available. Indeed, as with all knowledge-based products, people also have a difficult time judging education quality so that there could be temptation to exploit people's ignorance. For instance, when parents have to take decisions about the education of their children, they may be uninformed about the relative benefits of competing educational opportunities, or about the value of education altogether.

But the perception of educational quality varies among stakeholders and in space, therefore the decentralization of education would give more power to those with the most information about educational needs and could therefore be a viable measure to contrast information problems. Several forms of decentralization, such as decentralizing administration, increasing school autonomy and relying on a mix of private and public providers, can help governments in offering information about specific educational institutions. For instance, moving from a «top-down» to a «client-driven» model would help institutions to mitigate the problems of an information imbalance and

¹⁵ Indeed, as empirical studies of labour markets in Ghana, Tanzania, South Africa and Pakistan point out (see World Bank, 1999), one of education's powerful effects is on wages. It has been documented that such association between higher wages and basic schooling can be partly attributed to the knowledge learned at school, and partly to the fact that acquiring education signals a worker's capacity and motivation for learning.

limited accountability due to over centralization, and to move responsibilities to smaller jurisdictional units. It would also help to improve the coordination and enforcement of education standards, because local authorities are assumed to have an advantage in identifying cheaper, more appropriate ways of providing services to fit local preferences and in better monitoring the performance of providers.

But decentralization alone cannot solve all problems. For programs to be effective and suppliers to be held accountable, all stakeholders must be well-informed in order to make decisions about a particular program of curricula. There may be high social payoffs from policies that improve the collection and dissemination of information about education and the opportunities open to more educated people. One way to match formal training programs with the evolving skill needs of employers is to move from direct provision to government intermediation between trainee and provider by means of a planning and coordinating activity¹⁶. This creates the incentive for developing countries to continuously update and upgrade their education-system, in order to ensure their labour force is able to adopt future advances in technology. For this reasons, government plays a prominent role in adapting and developing new curricula and programs and in promoting a variety of government-supported in-service training opportunities aimed at fostering and reinforcing global integration, especially in the continuously evolving fields of science and technology.

Moreover, an additional goal, in a sense complementary to the former, is to encourage the use of new technologies in the classroom, specially the new information-technology that can potentially increase access to education and reduce its unit cost. Increased access to computer-based teaching, especially after the rapid decline in the costs of hardware and software, can undoubtedly constitute a practical way of improving the quality of education. Such a quality improvement would be particularly significant for tertiary education, especially in the middle-income economies that have already experienced a rise in the secondary school graduation rate.

4.2. Poor Relief to Pay for Education

Education requires considerable private resources which often constrain a person's decision to enrol in training or education even when no fees are required. When individuals have to decide whether to become a student or a trainee, not only the formal fees but also the additional costs of education play a prominent role in the evaluation of the opportunities that education

¹⁶ For instance, in many countries governments are doing more to provide information about test score improvements and placement records for students in particular schooling and training programs. For a survey of national experiences see Middleton - Zideman - Van Adams (1993).

may open to people. The time an individual spends in taking classes or in a training program is time not spent on other more remunerative tasks, such as working for a wage or in a family enterprise.

For this reason, many surveys have shown that low income is the major constraint on people's willingness to undertake education¹⁷ and such a constraint turns out to be particularly binding wherever capital markets are far from being perfect¹⁸. If credit markets for human resource investments are imperfect, households may not be able to finance investments in education, despite high expected rates of return¹⁹. In such circumstances a poor household will find it difficult to mobilize the requisite funds, regardless of how bright the prospects are. This underlies an information problem because lenders cannot properly assess either the returns on investing in human capital or the ability level of people before undertaking an educational program. Such a situation deprives society of a large pool of people who could benefit from learning and, worse still, exacerbates income inequality among different classes. Moreover, credit constraints might also adversely affect the composition of educational, especially where the educational sector is very competitive²⁰ and where the provision of education generates externalities. Wherever private enterprise is particularly present, private schools can specialize in areas where the demand is strong, thus neglecting areas where market competition makes education not profitable. This could create a lack of supply in particular areas without a specific occupational goal such as mathematics and natural sciences, and an oversupply of educated people in more popular areas such as business. This is not necessarily a bad outcome since it frees public resources to offer education in areas where the externalities are greater.

The best solution to credit market failures is to relieve the credit constraint by means of student loan programs covering tuition, living expenses, or both. But even when the credit constraint is removed, there may still be under investment in education and it may have to be subsidized. Many developing countries subsidize both schooling and training, but often their efforts are misplaced and biased, and many times they fail to provide subsidies

¹⁷ See among others Psacharopoulos (1994) and World Bank (1995).

¹⁸ On this issue, in the 90s a vast branch of economic literature studied the effect of capital market imperfection on growth and inequality without, however, emphasizing what happens to the rate of technology transfer. For the most important paper on the effect of capital market imperfection on growth and income inequality see among others Galor - Zeira (1993); Benabou (1996). For a rich survey on all the major studies see particularly Cozzi (1998).

¹⁹ In an empirical study, Psacharopoulos (1994) estimated that the private rates of return on education in developed countries are more than 30 percent a year for primary schooling and about 20 percent a year for secondary and tertiary schooling.

²⁰ For instance, the Philippines are a clear example of a competitive environment for education, where private universities provide 80 percent of tertiary education. The need to cover the operating costs force university to offer courses with a specific occupational goal, thus neglecting to offer education wherever there are high fixed costs for lab equipment. For details see James (1991).

to all members of society²¹. The basic problem that arises when subsidies are active instruments of policy intervention, is that they are seldom targeted to those who deserve them or to the fields of study that warrant subsidization for efficiency and distributional reasons. Such subsidies must be redirected to those who, because of their talent or their choice of discipline, are likely to generate positive externalities.

5. Knowledge Implementation

Much of our dissertation so far has been focused on the ways to facilitate the flow of knowledge from those who have much of it to those who have less. But to be effective, technological knowledge must be communicated to final users in an efficient as possible way. This is essentially a problem of information disclosure, which can also be interpreted as a problem of creating the best national R&D incentive system. This question turns out to be particularly important for developing countries, where the use of new technology is still limited and foreign competition is such to discourage the setup of a local, efficient R&D system.

According to Stern - Porter - Furman (2001) a national innovation system²² can be defined as the capability of a country to produce and commercialize a flow of innovative technology over the long-term. In this sense, they point out that the most relevant factors to national innovative capacity are: *a)* the existence of a common innovation structure (investments that support innovative activity and that operate across all the R&D-orientated industries of the economy), and *b)* the presence of a cluster-specific innovation environment (investments that support the firm-specific innovative capacity that depends on the microeconomic environment).

It is worth pointing out that the matter of creating a national innovation system is substantially a matter of creating an all-encompassing institutional environment as well as an efficient incentive scheme able to promote R&D at minimum social cost. To accomplish such objectives, governments can pursue two different, though complementary, ways:

- Set up the most efficient incentive scheme to promote private R&D;
- Construct an efficient and autonomous *public R&D system*.

Each of these two issues will be treated in the following two subsections.

²¹ On this issue, see the empirical analysis of Albrecht - Ziderman (1991); and World Bank (1995).

²² On the concept of national innovation system see among others Nelson (1993).

5.1. *Providing the Best Incentive Scheme*

Following Arrow (1962), economists made a great effort to demonstrate that competitive markets are not able to direct innovation. Some form of incentive scheme is needed in order to warrant the existence of a domestic R&D environment. Over time, however, economists have proposed many different incentive mechanisms, so that the main argument that makes a government prefer one scheme rather than another is often linked to the amount of information it has on the expected value of the R&D output as well as on the efficiency level of firms (Gallini - Scotchmer, 2003). In this section we focus on three of these mechanisms, notably: IPR design, Prizes and Procurement contracts.

IP rights

When both the value and the cost of an invention are not observable without incurring cost, one way to solve this provision problem is to grant the producer of the invention a property right on it. IP rights protection has both merits and shortcomings. When the social value of the invention is not observable, IP rights can be justified as a screening mechanism to encourage investment in high-value/high cost projects. Indeed, since firms have this information advantage over government, they will use their private information to screen investment projects, otherwise the market would punish them by acting as a self-discipline device for surviving.

The second big merit is that IP rights can be seen as an efficient mechanism for increasing the rate at which firms invest in R&D as well as generating technological knowledge. As the value of the patent value increases with the value of the innovation, the existence of a well enforced patent system gives the patent-holder the economic incentive to spend more resources to create inventions of greater value.

As regards shortcomings, IP rights have the great defect of generating deadweight loss due to monopoly pricing. Optimal resource allocation requires that all goods be sold at marginal cost, which in the case of new knowledge is assumed to be practically zero. Optimization thus demands that new knowledge be made available at marginal cost or for free to all those who can use it. Moreover, it is assumed that others, if not legally prevented, can easily imitate new knowledge at little or no cost. Thus, under perfect competition conditions, there would be no incentive on the part of private agents to invest in the creation of new productive knowledge. As a result, IP rights can be taken as a second best solution to a failure in the markets for knowledge and information. Moreover, it is quite a common opinion that setting up a very tight IP rights regime could reduce the information spillover from the original discoverer to possible users by preventing people from having access to crucial technical information.

To escape these drawbacks and as an alternative to traditional IP rights protection, developing countries may opt to protect inventions by *utility models*²³ and *industrial designs*. Nowadays, only a small but significant number of countries provide the option of utility model protection, but in the past this weaker form of IP rights protection represented the backbone of the IP system of almost all the actual industrial economies. The conditions for the registration of utility models are usually less stringent than traditional IP rights since no inventive steps or only a less significant inventive step is required. Moreover, because novelty and inventive step are usually not examined prior to registration, the procedure for registration is faster and acquisition and maintenance fees are generally lower than those applicable to patents. Utility models are considered particularly suited for those innovations that make «minor» improvements to existing products. More specifically, a utility model is an exclusive right granted for an invention, which allows the right holder to prevent others from commercially using the protected invention without his authorization, for a limited period of time. In its basic definition, which may vary from one country (where such protection is available) to another, a utility model is similar to a patent. The main differences are:

The requirements for acquiring a utility model are less stringent than for patents, in the sense that, in contrast to patents, the size of the «*inventive step*» or «*non-obviousness*» may be much lower or absent altogether. In practice, protection for utility models is often sought for innovations of a rather incremental character which may not meet the patentability criteria;

The term of protection for utility models is shorter than for patents and varies from country to country (usually between 7 and 10 years without the possibility of extension or renewal);

Patent offices do not examine applications as to substance prior to registration, with the result that the process of registration is often significantly simpler and faster, taking, on average, six months;

In some countries, utility model protection can only be obtained for certain fields of technology and only for products but not for processes.

All these differences can move in favour of a more competitive environment, since, unlike patents, utility models can raise the costs of imitation without materially delaying competing product introduction. For instance, as Kumar (2002) explains, in East Asia a combination of relatively weak IP rights protection and the availability of second-tier IP rights like utility models has encouraged technological learning through a high degree of market competition.

²³ In the literature the Utility Models are also known as «petty patents» or «utility innovations».

If the innovation's expected value is known *ex-ante*, the government can screen the project itself and other incentive mechanisms, such as prizes and procurements, can replace IP rights in promoting local R&D. The reason why they may be preferred is that they avoid deadweight loss without incurring in a fall in the R&D effort provision.

If there is a single firm qualified for carrying out the research program (i.e., the cost of the innovation is freely observable *ex-ante*), a prize is the optimal incentive mechanism. Technically, the prize consists of a fixed payment financed out of public resources conditional on delivering a specific invention. The amount of the prize can be adapted individually to firms but in general it is set equal to the social value of the invention. This makes the objective function of the firm equal to that of society and aligns the private interests of the firm with those of the community.

Examples of how this incentive scheme can be extended to cases in which the value of the invention is unverifiable *ex-ante* are provided by Kremer (1998) and DeLaat (1996), where the incentive schemes proposed are hybrid mechanisms combining IP rights and prizes.

For more complicated research sectors in which more than one firm is qualified for the research program (i.e., the cost of the innovation turns out to be the firms' private information), prizes, as well as IP rights, fail to be the best incentive schemes. In such a situation, the government knows that the social value of the project exceeds its production costs but it does not know which firms are the most cost-efficient among all the competitors. A problem of optimal delegation then arises, concerning how to pick up the more efficient firms and motivate them to invest at efficient rates. If the market had room for just one firm, then there would be no reason to suppose that the lower cost firm will be the entrant when the relative efficiency of the firm is not observable and prizes would again be the best incentive mechanism. But when the market has room for more than one firm, then procurement contracts perform better than prizes in efficiently delegating the right to invent.

A procurement contract is a mechanism through which the government is allowed to acquire an invention at minimum cost. It was first introduced by Laffont - Tirole (1986, 1987) and consists of an auction for the right to be paid when the invention is delivered as well as a fixed-price contract. The idea of the contract is to pay costs as they accrue in such a way as to make future grants contingent on previous research success. Fixed-price contracts then look like prizes with the peculiarity that researchers must convince the government in advance that their research results are worthy of a prize. In general, the procurement contracts would typically not be offered to all candidates. A preliminary negotiation phase is needed so that the government can sort out which firms are more efficient and deserving of the prize.

According to Gandal - Scotchmer (1993) though, there are many research fields in which even an auction would not ensure that only the most efficient

firms invest. As a remedy, they propose an incentive scheme in which the government should offer a menu of options with both fixed fees and firm-specific prizes. The aim of such a policy is twofold. On the one hand, it encourages firms to reveal their truly efficiencies. On the other, it encourages firms to invest as efficiently as possible.

5.2. *Providing Basic Research*

Basic research is a fundamental ingredient for applied, business-orientated research. Many countries have tried to encourage basic research either directly through public R&D or indirectly through incentives to firms. Clear examples of direct government R&D are university financing, government research institutes, science parks and research-orientated graduate schools. Indirect R&D includes preferential finance, tax concessions, matching grants, commercialization and the promotion of national R&D projects. Developing countries, in fact, cannot take advantage of a vast stock of knowledge unless they develop the competence to adapt it to their domestic needs. In many cases knowledge produced elsewhere must be adapted to local conditions and consumers' tastes and the availability of basic knowledge is crucial in order to lay the *foundations* for developing an efficient national innovation system.

In general, the target of basic research may differ according to which policy instrument is used by the government. Two instruments are typically used:

- Public (government or university) performed research;
- Economic incentives for private (non-government) research institutes.

As is well known, basic research is mainly driven by scientists' *curiosity* or a particular interest in a scientific question. The main motivation is to *expand man's knowledge*, not to create or invent something. As a result, there is no obvious commercial value to the discoveries that result from basic research, so that it is carried out in public laboratories or universities and is funded essentially by government.

But even in the case that there is a clear value in various types of scientific research, it is likely that private firms will prefer those industries in which the wedge between private and social returns is likely to be highest. Thus, basic research in non-business areas (such as defence) would be underprovided in the presence of a pure private R&D system, with the result of a significant loss of technology spillover on society for business applications. Classic examples of positive spillover from basic to applied research are the Internet and later the Web browsers, which were both conceived and developed with government expenditure for non-business R&D and are now providing an entirely new realm of business opportunities. In this respect, Stern - Porter - Furman (2001) find that those OECD countries which have located a higher share of their R&D performance in the educational sector have been able to achieve more efficient national innovation systems.

The second policy instrument is the indirect support of research performed by non-government research institutes. Following the *Frascati Manual*, developing countries can account for two categories of government funding: (1) grants or subsidies; and (2) fiscal incentives. In both cases, public resources are targeted to specific goals chosen by the government. For instance, they might fund research projects that have a potentially high social return (e.g. «*generic technologies*» or «*pre-competitive research*») or that are useful to the government's own specific objectives (e.g. health, defence). If these policies are effective, public and private funding may be complementary and increasing the former will enhance the latter.

However, each of these economic incentives has its own shortcomings. In using R&D subsidies, governments must take into account that they may crowd out private spending by increasing the demand for R&D and hence its price. As David - Hall (2000) argue, the major effect of government funding is to raise the wage of researchers, so, when faced with higher research costs, firms will shift their funding to alternative investments. This implies that, even if the total amount of R&D is higher as a result of government funding, the real amount of R&D will be lower. Moreover, even though government subsidies to R&D are much better than other incentive mechanisms in terms of monopoly distortions, there remains the asymmetric information problem and the risk of inefficient subsidization. An inefficient public policy may generate distortions in the allocation of resources between fields of research and it may also distort competition between firms by supporting some at the expense of others. As regards fiscal incentives, they do not make the government discriminate much, implying that firms can use public money for any goal, whatever its social rate of return. In addition, tax incentives also have some discriminatory features, as they are not accessible to firms that are not taxable, e.g. new firms with investment higher than sales, no profit institutions, and so forth. Such companies may be among the most innovative and may also be the most in need of funds.

6. Final Remarks

In this paper we addressed the question of technology transfer from a policy standpoint. In doing so, we recognized a knowledge gap as the main source of cross-countries productivity disparity. What emerged from the paper is that a successful trade liberalization (both in terms of lower trade barriers and less FDI impediments) ought to be part of a broader set of policy-measures including competition and industrial policies, and education.

We also stressed that IP rights are more effective in attracting knowledge in the absence of private information, while other incentive schemes, such as prizes and procurement contracts, appear to be more appropriate for more complicated industrial environments.

Stimulating information transmission turns out to be fundamental also

for the creation of an indigenous R&D. Governments can pursue this goal by both creating the right incentive scheme and by developing an efficient and autonomous public-founded R&D system. But after a country succeeds in building local R&D, the next goal of the government must be an industrial policy aimed at protecting the most technologically active firms and industries from external misappropriation and at enhancing international collaboration. In such cases, an industrial policy aimed at protecting the most technologically active firms and industries must pay attention to MNEs' acquisition strategies as well as their merger activities, especially when organizational issues could lead MNEs' management to generate positive knowledge spillovers.

The recent development of India and China seem to confirm our analysis. In the case of India, its brilliant growth performance has mainly been the result of a human capital-based acquisition policy aimed at attracting inward FDI in some value added industries such as IT, chemical and pharmaceutical. Together with the success of many economic reforms, this has resulted in rapid export growth in skill-intensive manufacturing sectors such as apparel and textiles, automotive components, and electronics assembly, which includes hi-tech areas such as information technology and biotechnology.

For China, on the other hand, things are different and reflect in part the country's ability to attract inward FDI through a low production cost policy for manufacturing and, in part, the capability of its workforce to reverse engineer low value-added imported-products.

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Summary: International Technology Gap and Technology Transmission: The Policy Implications
(J.E.L. F4, K2, O2, O3)

Income per capita differences have increased dramatically over the last fifty years. Many economists seem to recognize knowledge differences as the main factor in this worldwide economic performance divergence. Developing countries suffer significantly from lagging labour productivity and managerial efficiency related in part to the failure to adopt the latest technology or to update their labour force, and such an evidence has recently led to a huge debate about which channel is most effective in stimulating technology transfer and acquisition. In this paper we will review the policy tools that have been effective in reducing the international knowledge-gap between Developed and Developing countries, and the role played by institutional factors in accomplishing such an issue.

