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TECHNOLOGICAL LEARNING SYSTEMS, COMPETITIVENESS AND DEVELOPMENT[1]

Eduardo Baumgratz Viotti[2]

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SUMÁRIO

SINOPSE

Este artigo tem por objetivo contribuir para a compreensão das principais especificidades dos processos de desenvolvimento tecnológico das economias retardatárias. Segundo esta compreensão, são investigadas as razões pelas quais as medidas convencionais de políticas de Ciência e Tecnologia (C&T), normalmente inspiradas no chamado modelo linear e na teoria econômica neoclássica, não são geralmente apropriadas ou suficientes para os países em desenvolvimento. Isto acontece porque os retardatários competem basicamente com base na imitação e não com base em produtos ou processos inovadores. Esta característica de seus processos tecnológicos os obriga a recorrer ao uso de mão-de-obra barata, à proteção estatal ou à exploração predatória de recursos naturais como forma de compensar suas produtividades iniciais relativamente baixas. Os casos de quatro países retardatários – Brasil, México, Coréia do Sul e Taiwan – são brevemente analisados. Nas últimas duas décadas, estes quatro países elevaram grandemente suas participações na produção científica mundial. As duas economias asiáticas também foram capazes de obter elevações muito grandes em suas participações na produção tecnológica mundial, assim como reduzirem grandemente os hiatos de produtividade e renda *per capita* que as separam da economia industrial líder, os Estados Unidos. As duas economias latino-americanas, no entanto, seguiram na direção oposta. Tal fato coloca em xeque o pressuposto do modelo linear de que haveria uma relação mais ou menos direta entre o nível da produção de conhecimento científico de um país e sua produção de tecnologias ou inovações. O artigo conclui-se com apresentação de algumas implicações desta análise para as políticas de C&T de países em desenvolvimento

ABSTRACT

This paper aims to contribute to the understanding of the main specificities of latecomers' processes of technological development. Building on the basis of this understanding, it searches for the reasons why the conventional measures of Science and Technology (S&T) policies, usually inspired by the so-called linear model and by neoclassical economics, are frequently inappropriate or insufficient for developing economies. This is so because latecomers compete primarily by imitating, rather than by innovating. Such feature of their technological processes compels them to rely on cheap labor, on state protection or natural resources depletion as a way to compensate for its relatively low initial productivity. The cases of four latecomers – Brazil, Mexico, South Korea and Taiwan – are briefly analyzed. During the last two decades, all these four countries were successful in greatly increasing their shares of world scientific productions. The two Asian economies were also able to achieve very large increases in their shares of world technological productions, greatly shrinking the productivity and *per capita* income gaps that separate them from the levels of the leading industrial economy, the US. The two Latin-American economies, however, went in the opposite direction on those respects. Such fact put into question the linear model's assumption of a more or less direct connection between a country's scientific achievements and its technological production or innovation performance. The paper is concluded by presenting some implications of its analysis for S&T policies for developing economies.

1 INTRODUCTION

Late industrializing economies have a specific process of technical change that has fundamental and structural consequences for their competitiveness and development possibilities. Most of the Science and Technology (S&T) policies followed by or prescribed for those economies do not take into consideration the specificity of their processes of technical change. These policies are usually inspired by the so-called linear model and by neoclassical economics. The main emphases are typically on state support of basic research, associated to the stiffening of competition and the strengthening of intellectual property rights. The main objective of this paper is to contribute to the understanding of the main specificities of latecomers' processes of technological development. Building on the basis of this understanding, it searches for the reasons why those conventional measures of S&T policies are usually inappropriate or insufficient for latecomers. It concludes by suggesting some general guidelines for alternative policies.

The second section of this paper uses a historical series of *per capita* income of developed and developing economies to indicate the association of the industrialization process with the emergence of the cleavage between developed and underdeveloped countries. An emblematic case of labor productivity in cotton spinning is used as an example of how the uneven process of development and adoption of new technologies should be at the center of any inquiry into the reasons why the large divergence between *per capita* incomes of developed and developing economies emerged. It is argued that efforts to overcome the technological gap require latecomers to leap to steps of the technological ladder early industrializers took centuries to climb in a progressive process of technological and capital accumulation. The difficulties of such a task are highlighted by the sheer size of the rate of investment necessary for catching up. The First Industrial Revolution required investments corresponding to approximately only 6% of British's GDP, whereas the Japanese catching up required more than 30% of its GDP, and China is investing almost 40% of its Gross Domestic Product (GDP) in its current drive towards industrialization. Furthermore, latecomers usually do not compete by selling new products or old commodities produced by new processes, a feature that was a hallmark of early industrializing economies.

The *third section* of the paper develops an elementary graphic representation of unity cost variation through time in order to highlight the meaning and consequences of competing by imitating. Passive and active technological learning processes[1] are associated with different patterns of unity cost evolution. When one assumes that both innovators and imitators face the same structure of prices for inputs and factors of production, the initial unit cost of imitators is usually higher than that of the innovators. In the beginning, i.e., when the imitator sets foot in the market, its higher unit cost (lower productivity) needs to be compensated by the use of cheap labor, lower prices of raw materials, intensive use of natural resources, or some form of protection. As times go bye, the imitator could progressively reduce its dependency on this kind of spurious competitiveness advantage as long as it develops technological improvement capabilities,

1. Concepts proposed elsewhere by the author (Viotti 1997 and 2002).

i.e., as long as it becomes an active learner. If the imitator lacks these capabilities, i.e., if it is a passive learner, it remains dependent on those compensation mechanisms. The need to reduce the imitators' lag is shown to improve the opportunities for the development of technological improvement capabilities. Besides reducing the imitation time lag, it is also argued that policies and firms' strategies should aim at increasing the speed and efficacy of the process of technology absorption and improvement.

The *forth section* of the paper analyzes briefly the case of four latecomers: Brazil, Mexico, South Korea and Taiwan. The evolution of the *per capita* income and labor productivity of these economies is compared with that of the United States (US). These data are used to figure out the evolution of the technological gap that separates those latecomers from the leader industrial economy. Since 1950 until approximately 1980, all four economies reduced progressively their *per capita* income gap with the US. After 1980 the two Latin American economies lagged behind, whereas Korea and Taiwan continued in their path towards catching up.

The section also investigates if the lack of technological dynamism of Brazil and Mexico could be explained by the fragility of their scientific basis, as an analysis based on the linear model of innovation would assume. The numbers and world's shares of scientific publications and patents, from 1981 to 2001, are used for questioning the explanation inspired by the linear model. During that period, these two countries have increased more than three times their shares of world's scientific publications. This rapid advance in scientific production was accompanied by a very poor performance in patents and a strong increase in the income gap that separates them from the leading industrial economy (the *per capita* incomes of Brazil and Mexico, measured as a percentage of the US's one, declined respectively 24% and 29% between 1981 and 2001). The same data on scientific publications and patents is also used as important indications about the natures of the national systems of technological learning of the four selected latecomers, and for discussing some of the consequences of the liberalization policies in Brazil and Mexico.

The *fifth and last section* of the paper presents some implications of the analysis developed in the previous sections for the S&T policies of latecomers.

2 *PER CAPITA* INCOME, INDUSTRIALIZATION AND PRODUCTIVITY[2]

Contrary to the common perception, the cleavage between developed and developing economies is a relatively recent phenomenon in historical terms. Before the Industrial Revolution, the standard of living of the regions of the world that correspond to the current developed economies was not much different from that of the developing economies, as indicated in figure 1. In other words, before the Industrial Revolution there was no meaning in dividing the world in developed and underdeveloped or developing economies.

2. This section draws partially on section 2 of Viotti (1998) and on section 2.1 of Viotti (2001).

Two centuries of Industrial Revolution (i.e., from 1750 to 1950) brought about a 6.5 times growth in the *per capita* income of the economies that are nowadays industrialized, whereas the *per capita* income of the developing ones remained roughly stagnated.[3]

After World War II, when the industrialization processes in several developing economies took off, the standard of living of these economies started to grow. This phenomenon, however, was not strong enough to offset the growing disparity among developed and developing economies. By 1990, the *per capita* income of developed economies was more than eight times higher than that of developing countries. The disparity is yet larger when the *per capita* incomes of the single most and least developed economies are compared. At the time of the Industrial Revolution, the richest economy in the world had a *per capita* income approximately two times that of the poorest country, whereas that ratio achieved almost thirty times by 1977 (see figure 2).[4]

When one realizes that the cleavage amongst developed and developing economies is not an ancestral problem inherited by the modern world, a question comes almost immediately to mind: what are the reasons for such different patterns of growth?

The idea that the *per capita* income is to a large extent an index of the *per capita* productivity could direct that question towards the investigation about the determinants of such different patterns of productivity growth.

A good hint about the importance of the industrialization process for the explanation of productivity growth and disparity comes from the example of labor productivity in cotton spinning, which was a manufacture sector at the heart of the first Industrial Revolution.[5] The evolution of labor productivity in this sector during

3. For the sake of precision, *per capita* income of industrializing economies increased less than 14% during two hundred years.

4. Maddison (2001, p. 47) expresses a criticism of Bairoch's assessment of relative income per head that is used here. Maddison (2001, p. 46) estimates that before the Industrial Revolution, by the year 1700, for instance, rich countries (Western Europe, Western Offshoots – as he calls Australia, New Zealand, Canada and United States – and Japan) had a level of *per capita* income that was 1.65 times that of the poor countries (Latin America, Eastern Europe & former USSR, Asia, excluding Japan, and Africa). Nevertheless, his estimates support the idea that such a difference was slowly built over several centuries during which time the *per capita* income of poor countries remained roughly stable. Only after the Industrial Revolution, rich countries increased drastically the speed of their *per capita* income growth, while poor countries continued to follow the old pattern of a very slow growth for a long time. By 1998, that difference amounted to approximately seven times, according to his estimates. Therefore, besides the recognition of the existence of a certain difference between the *per capita* incomes of rich and poor countries by the beginning of the Industrial Revolution, Maddison's estimates by no means deny the importance of the industrialization processes for the explanation of this divergence of incomes, and for the very existence of the cleavage between developed and underdeveloped economies.

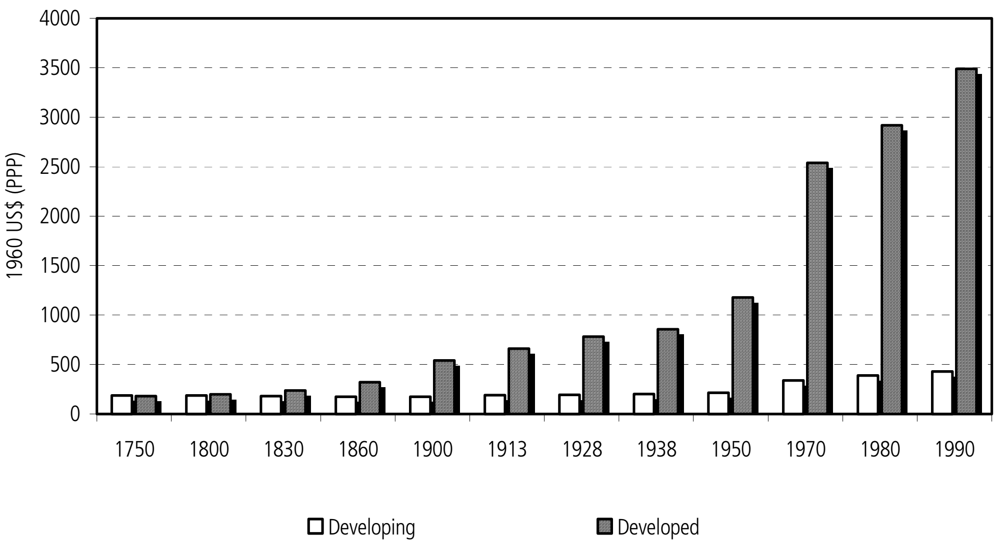
5. Maddison (2001, p. 96) indicates the importance of the textile industry for the British's advance to hegemony as follows: "From the 1760s, there was spectacular growth in the cotton textile industry. Demand for cotton clothing and household furnishings had been nurtured by a century and a half of imports from India. The prospects and profitability for domestic expansion were transformed by a wave of technological innovation. Cotton was much easier to manipulate mechanically than wool and mechanisation had a dramatic impact on labour productivity with modest levels of capital investment. Hargreaves' spinning jenny (1764-1767) permitted a 16-fold productivity gain in spinning soft weft. Arkwright's spinning frame (1768) could produce a strong warp and used water power. Crompton's 1779 "mule" could produce both weft and warp. Cartwright's 1787 power loom extended the productivity gains to weaving; and, finally, the American Eli Whitney invented the cotton gin in 1793, which substantially reduced the cost of the raw cotton which was imported from America. Between 1774 and 1820, imports of raw cotton increased more than 20-fold. Employment in cotton textiles rose from a negligible level in the 1770s to more than 6 per cent of the labour force in 1820. Cotton yarn and manufactures rose from 2 per cent of British exports in 1774 to 62 per cent in 1820 (even though the price of these exports had fallen sharply)."

two and a half centuries of industrialization, as indicated in table 1, is emblematic. Labor productivity in cotton spinning multiplied extraordinarily as a result of the introduction of new technologies. By 1990, modern machines had rendered human labor employed in the process of cotton spinning 1,250 times more productive than that applied to hand spinning, which was characteristic of the great Indian manufacture of the 18th Century.

This case is a clear example of how the process of technical change evolves in the long term in such a way as to make new technologies superior to the old ones. A technology could be considered superior when it is more efficient and more profitable than the other, regardless of the relative prices of the production factors. In such case, the modern technology makes labor so productive that the use of the old and more labor-intensive technology will not become economically feasible even though there might be workers willing to receive a fraction of the wage received by those using the modern technology. After the introduction of new spinning technologies, the Indian hand spinner would no longer be competitive, no matter how cheaper the Indian labor was, compared to the British.

FIGURE 1

Real *per capita* income estimates developing "x" developed economies (1750-1990)

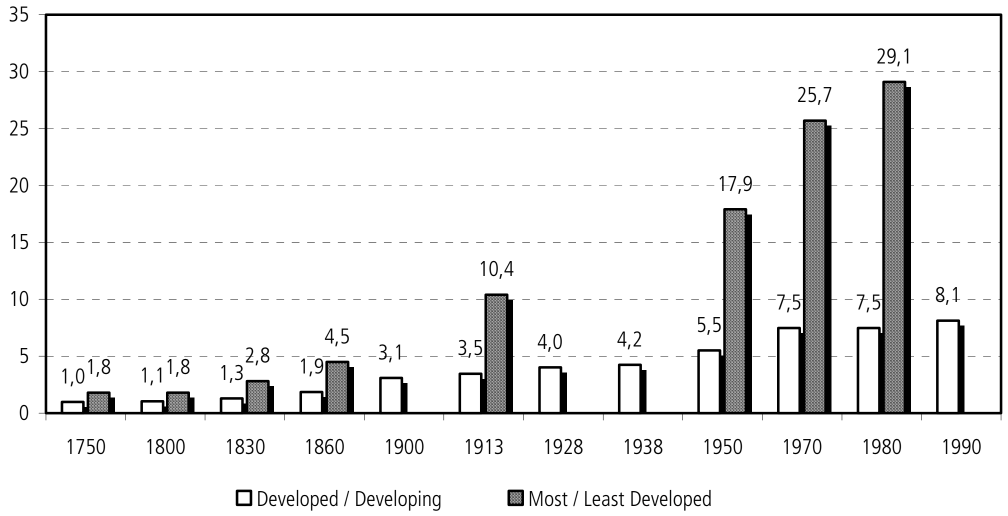


Source: Bairoch (1993, p. 95).

Note: The author uses the expression "third world countries" instead of developing economies, and, accordingly, does not take into consideration the economies in transition. Incomes are measured in terms of Purchasing Power Parity (PPP) and converted to 1960 US dollars.

FIGURE 2

Ratios of real *per capita* incomes developing "x" developed economies (1750-1990)



Source: Bairoch (1993, p. 95). The comparison between the least and the most developed economy comes from Bairoch and Levy-Leboyer (1981, p. 7-8), *apud* Freeman (1999, p. 149).

Note: The authors use the expression "third world countries" instead of developing economies, and, accordingly, do not take into consideration the economies in transition. Incomes are measured in terms of PPP and converted to 1960 US dollars.

TABLE 1

Labor productivity in cotton spinning (18th Century - 1990)

Technology	Period	Operative hours to process 100 lbs of cotton	Relative productivity
Indian hand spinners	18th Century	50,000	1
Crompton's mule	1780	2,000	25
100-spindle mule	c. 1790	1,000	50
Power-assisted mules	c. 1795	300	167
Roberts' automatic mule	c. 1825	135	370
Most efficient machines	1990	40	1.250

Source: Jenkins (1994) as quoted by Freeman (1999, p. 153).

Note: The author computed the last column.

That is the main reason why competition by British textile manufacture ruined the best textile industry of the 18th Century – the Indian one –, although the latter was able to rely on a labor supply, which was much cheaper than the British. At the same time, it is essential to realize that it was precisely the higher productivity of the British worker that made it possible for him to enjoy a much higher standard of living than that of the Indian worker.[6]

Similarly to what happened in the cotton spinning industry, the continuous process of development and adoption of new technologies in the economies that became industrialized was responsible, on the one hand, for the extraordinary growth of their labor productivities and, on the other hand, for the growing lag of productivity and loss of competitiveness of developing economies. There are strong

6. It is interesting to note that the British government adopted and enforced several measures in order to thwart exports of British textile technology during the First Industrial Revolution. It banned the emigration of skilled workers from as early as 1719 until 1825; and prohibited exports of tools, utensils and machines from 1750 until 1842 (Chang, 2002, p. 54-55).

reasons to believe that such a continuous and uneven process of development and adoption of new technologies should be at the center of any search for the reasons why the large divergence between *per capita* incomes of developed and developing economies emerged. Differences in labor productivity are the most important reason for countries' income differences and the main engine of labor productivity is technical change.[7]

Before industrialization, tradition (kept, for instance, by guilds and their masters) was the main factor determining which technology would be employed. After the industrial revolution, the push towards technical change became a staple feature of the new way of doing business and one of the most important tools of competition. The manufacturing sector became the vehicle for the systematic introduction of technical change in the economy as a whole.[8] In this sense, it could be said that the industrialization process became the main engine of technical change. Then, it is not surprising that industrialization came to be seen as the way out of underdevelopment, as suggested by almost all theories of development.

Late industrializing economies, however, are not allowed to follow the same path of gradual introduction of technologies pursued in the original industrialization process. There is no sense, for instance, in adopting the "Indian hand spinning" technology first; the "Crompton's mule" a few decades later; the "100-spindle mule" twenty years later; and so on, in order to achieve the current productivity of a British worker in cotton spinning around the middle of the 23rd Century. It would also be economically unfeasible.

Late industrialization is a process completely different from the original industrialization. Latecomers are required to leap to steps of the technological ladder that industrial economies took centuries to climb in a progressive process of technological and capital accumulation. That is the reason why latecomers' rates of investment must be much higher compared to that of early industrializations, as shown on figure 3. The rate of investment that financed the First Industrial Revolution (circa 1760) corresponded to approximately 6% of Great Britain's GDP. The Second Industrial Revolution (circa 1850) required approximately 11% of Great Britain's GDP. The industrialization of Germany, Sweden and Denmark, which occurred after 1860, demanded more than 15% of their GDPs. Japan, at the height of its effort of catching up, during the 1970's, was required to save and invest a share of its GDP (33%), which was more than two times that of the German industrialization process a century earlier. South Korea invested in average 35% of its GDP during the 1990's. China is investing an even higher share of its GDP in its current drive towards industrialization.

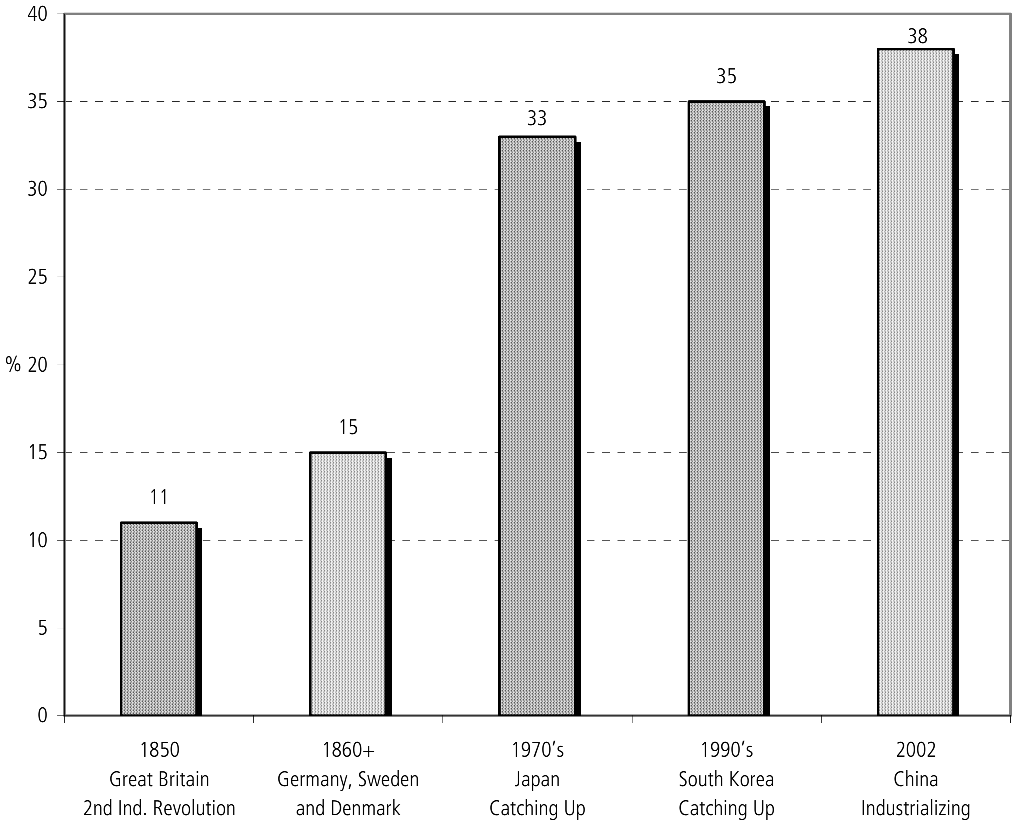
7. Orthodox (neoclassical economics') models of international trade assume that each and every country has access to the same set of technologies (i.e., have equal production functions). Such an assumption disregards or rules out the main cause for countries' unequal productivity and levels of development. Hence, it is not surprising that these models lead to the conclusion that there is no need for specific development theories or policies.

8. Even in more recent times, the industrial sector still remains very important for technical change as a whole. Scherer (1984) estimated that 93% of the technologies employed in the non-manufacturing sector came from the manufacturing sector.

Moreover, latecomers lack the naturality of the original industrialization process, and do not usually compete by selling new products or old commodities produced by new processes, a feature that was a hallmark of early industrializing economies, as pointed by Amsden (1989, p. v). Latecomers must then overcome the entrance barrier represented by the need to compete with products that already exist in international markets and are produced, in almost all cases, with the help of technologies which are more efficient than those a latecomer is able to access.

FIGURE 3

Early "x" late industrializations gross domestic investment as % of the GDP



Sources: The estimates about the period of the 1st Industrial Revolution in Great Britain come from Crafts (1983), and those about the 2nd Industrial Revolution come from Feinstein (1978, p. 91), both as quoted in Bagchi (1987, p. 799). The estimates about industrialization in Germany, Sweden and Denmark come from Bagchi (1987, p. 799). The author computed the estimates for Japan and South Korea as the averages of the GDP percentages invested as Gross Fixed Capital Formation respectively for the 1970's and 1990's. The source for these data was the Annual National Accounts of OECD Countries, online. Available in: <http://www.oecd.org>. Accessed in 10/15/2003. The data for China comes from World Development Indicators Database 2003, The World Bank, Washington, 2003, online. Available in: <http://www.worldbank.org>. Accessed on 10/13/2003.

Therefore, the dynamics of late industrialization is usually deprived of the innovation element and depends essentially on a continuous process of efficient and fast absorption and improvement of technologies, i.e., the dynamic engine of late industrialization is technological learning, not innovation (Viotti, 1997 and 2002).[9]

9. For a sum up of the concept of learning and innovation used here, see box 1. It should become clear, at this point in the paper, that the current use of the concept of innovation as something that encompasses innovation, diffusion or absorption and incremental innovation (as if it were a kind of synonym of any form of technical change) hinders the ability to understand the differences in the processes of technical changes typical of developed and developing economies.

The search for the main reason why the large majority of developing economies is left behind in their productivity and income levels whereas others are successful in their catching up processes should concentrate on the analysis of the limitations and possibilities of their specific processes of technical change.

3 INNOVATORS AND LEARNERS[10]

The knowledge of how the unity cost of a product evolves through time and, specially, how and why innovators and imitators have different cost functions, is essential to the understanding of the specificities of latecomers' technical change processes. This understanding is also a key factor in the explanation of latecomers' competitiveness and development shortcomings.

The curve that represents the unity cost of production of a certain (homogeneous) product through time, with constant factors and input prices, is a declining function. Such a function usually presents a relatively steep slope in its initial stages, i.e., the rate of unity cost reduction in the beginning of the product life is usually high.[11] This is usually the case because, at these initial stages, there are many still unexplored technological opportunities for the introduction of innovations, especially incremental innovations, as well as room for economies of scale to become effective. Ahead in the product life, the pace of unity cost reduction should become slower when the easy opportunities of cost reduction are explored. Later, product or technology maturity should mean a kind of saturation of opportunities and, then, follows a relative stability at the lowest unity cost.[12] The likely shape of the curve indicated here, describing the general tendencies of a product unity cost is, to a large extent, a consequence of the working of mechanisms of cumulativeness and path-dependency typical of the evolution of any technology, and of firms' technological capabilities as well. The curve, identified in figure 4 as representing the innovator's unity cost, presents the general features of a likely unity cost curve of any product.

Firms usually present different levels of technological capabilities even though they produce the same commodity. That is the reason why they should have different unity cost curves, although these curves should present shapes similar to those described above, they also should present unity cost declines in a not completely synchronized fashion. However, when the product is homogeneous, all firms face the same market price and, because of their different unity cost, have different rates of return. As a consequence, some firms are compelled to go out of business, while others are able to enjoy relatively large margins of profit.

10. Learner is the firm or country whose process of technical change is limited to learning. See box 1 on the concept of learning employed here. The word imitator will be used as synonym of learner all along this article.

11. The attentive reader has likely realized that the unit cost curve could also be understood as a kind of inverse function of productivity, as well as that the rate of variation (the derivative on time) of the unity cost function could be taken (with the negative sign) as a kind of a growth rate of productivity and as an indicator of the rate of technical change.

12. It is obvious that process innovations (not just incremental innovations) could happen at any moment in time and this could open new trajectories of unity cost reduction.

BOX 1

Innovation and learning
(Definitions)

Innovation is the process of technical change achieved by the introduction of (the first commercial transaction involving) a new product or process of production (new to the world, and not to the firm, country or region).

(An innovator usually masters the capability to innovate, as well as the capabilities of production and improvement. Cases of innovation startups are obvious examples of exceptions on this respect.)

Technological learning is the process of technical change achieved by:

1. the absorption of already existing techniques, i.e., the absorption (diffusion) of innovations produced elsewhere; and
2. the generation of improvements in the vicinity of acquired techniques, i.e., incremental innovation.

Passive learning is the process of technical change achieved by:

1. the forms of technological absorption that follow the pathway of minimal technological effort (the black-box approach), (e.g., turnkey projects); and
2. the type of incremental innovation achieved as an almost automatic and costless consequence of experience acquired in production (learning-by-doing).

   (A passive learner is satisfied with just the acquisition of the capabilities for production.)

Active learning is the process of technical change achieved by:

1. technological absorption accompanied by technological efforts to master the assimilated technology (e.g., reverse engineering); and,
2. the type of incremental innovation achieved as a consequence of deliberate efforts and investments in technology.

   (An active learner develops capabilities of improvement, besides the capabilities for production.)

Main technological capabilities

Innovation: knowledge, skills and other conditions required for the creation of new technologies, i.e., major changes in the design and core features of products and production processes.

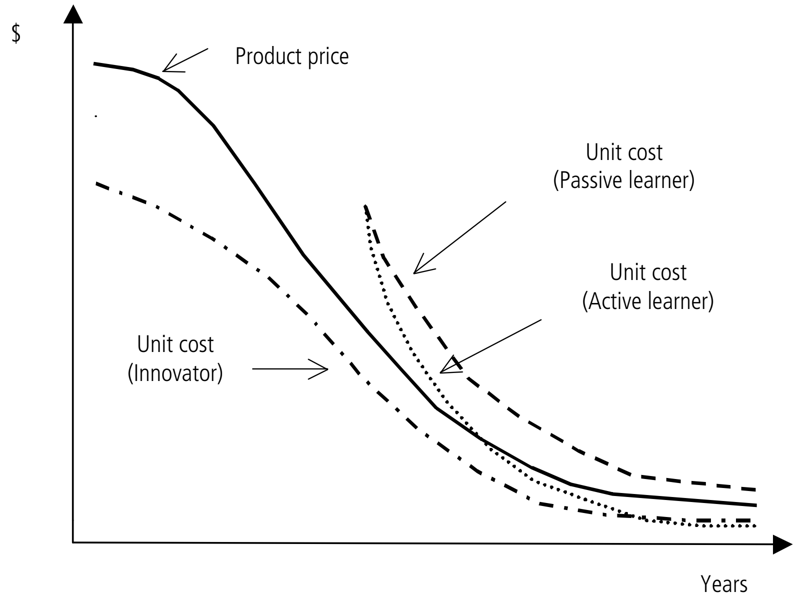
Improvement: knowledge, skills and other conditions required for the continuous and incremental upgrading of product design and performance features and of process technology.

Production: knowledge, skills and other conditions required for the process of production.

Source: Viotti (1997 and 2002).

FIGURE 4

Comparative evolution of unit costs innovator, passive and active learners



Note: The graph represents a likely evolution through time of the comparative unit costs of an undifferentiated product, assuming that the input prices are the same for innovator, passive and active learners and are constant through time.

The behavior of the product price through time, represented in figure 4 as the product price curve, should have a behavior similar to the average unity cost curve of the market, positioned slightly above that curve. The distance between the price and the cost curve should be larger in the beginning and should be smaller as time goes by and the extraordinary or Schumpeterian rent wanes. As a matter of fact, it is the average unity cost that approximately shapes the price curve in the long term. Such an understanding of price formation dynamics in the long range has, actually, a long tradition in economics. It comes from the Classical economists, who described prices as having a tendency towards gravitating around the cost of production plus a certain margin of profit.

There are good reasons to believe, as indicated before, that the distance between the unity cost curve and the price curve should be larger at the beginning, i.e., after the introduction of the product in the market. During this initial period, profit margin of the innovator firm should be higher than the average of the other firms or sectors. That distance becomes progressively smaller with the diffusion of the production technology used by the innovator, i.e., with the emergence of imitators, and the corresponding influx of new capital (attracted by the higher rates of profit) and the consequent expansion of the product supply. Thus, as times goes by, entrepreneurial profits become smaller and the profit rate of the sector defined by the product under scrutiny becomes similar to the profit rate of more mature or traditional sectors.[13] Between the introduction of the product in the market and the flattening of its profit margin by the crowding out

13. Only at this moment, when a product or technology approaches its obsolescence, some of the features of the functioning of actual markets become close to some of the assumptions of the neoclassical equilibrium model.

of the market by imitators, the innovator firms and their home countries enjoy the appropriation of extraordinary profits.[14]

These extraordinary profits could fund innovators' R&D, as well as their modernization investment and capital accumulation, creating the conditions for them to retain their innovation lead, extraordinary profits, and competitive advantages trough time.

Moreover, a share of such a Schumpeterian surplus, produced by the comparatively higher productivity of the innovator, could (under special conditions) become the object of appropriation by workers and the state, without jeopardizing a healthy process of capitalist accumulation. The mechanism described here is therefore vital for the authentic competitiveness[15] of innovators, as well as for building societies with high standards of living and relatively equitable income distributions, which characterizes developed economies.

The unity cost curve typical of a learner shows two main features that differentiate it from that of the innovator. The first is the obvious fact that imitators enter the competition late, i.e., its unity cost curve does not exist in the initial stages of the product life. So, its business is deprived of the period when profit is extraordinarily high. The second main feature is related to the fact that, at the moment when the imitator enters the market, its unity cost is usually higher than that of the innovator. It is important to consider that, in this first stage of analysis and just for the sake of comparability, both, innovators and imitators, are supposed to pay the same and constant prices for inputs and factors of production they employ. Under these assumptions, the differences in unity cost structures are almost just a direct consequence of the technological capabilities or of the technical productivities of the respective firms or countries.

Imitator's unity cost is usually higher than that of the innovator mainly because of two essential features of the process of technology transfer. First, innovators are usually the formal or informal proprietors of the technologies they employ and they are, in principle, not interested in their diffusion or, the creation of competitors that will erode their profit margin. Under such circumstances, imitators usually have access to technologies that present a certain degree of obsolescence and that either are no longer in use by the innovators, or have already undergone a process of improvement for the exclusive use of innovators. The transfer of this type of second-class or old generation technology represents a kind of safe guard for extending innovator's advantages. The access to a second-class technology compels imitators to initiate their production with comparatively lower productivity and higher unity cost.[16] The second feature refers to the fact that, besides codified knowledge that is easy to transfer, any technological transfer requires also the absorption or

14. These profits are also called extraordinary rent, because, in neoclassical economics, profits are in general supposed to fade away when markets achieve equilibrium, and any market unbalance is seen as just a short-lived phenomenon.

15. See box 2 about the concept of authentic competitiveness.

16. The willingness of innovators to transfer technologies, as well as their inability to retain their exclusive control of them, increases by the time the product or the technology becomes more mature, the profit margin decreases and the technological opportunities for improvements also become smaller.

development of tacit knowledge, which demands the investment of time, resources and technological efforts by the technology recipient. Hence, the imitator's unity cost will remain higher than that of the innovator, even if hypothetically they both use the same technology, until the imitator becomes able to absorb or develop tacit knowledge equivalent to that mastered by the innovator.[17]

These are the reasons why imitators usually face higher unity cost of production than that of those who are already positioned in the market. Imitators some times have to cope with unity cost that are even higher than the price of the product.[18] Under these circumstances, some kind of special mechanism should be in place in order to enable the imitators' entry in the market. Such a mechanism would be required in order to compensate for that much higher cost of production. Hence, the imitator is banned from the pool of extraordinary profits that is a privilege of innovators, its profit margin is squeezed by its relatively high cost, and, it some times needs to fund, at least initially, an extraordinary cost that is represented by the amount its unity cost exceeds the market price.[19] These limitations would impose a heavy initial burden on imitators and, as a consequence, hinder their prospect of competing based on productive or technological advantage. The structural difficulties described here are some of the most important reasons why latecomers have difficulties in achieving higher levels of income and equitability. Higher wages, for instance, could jeopardize one of the few sources of competitiveness of these economies. The original sin of late coming economies is this type of structural limitation, and the possible success of its development process depends of the redemption of such a sin.

That initial burden must be overcome by means of mechanisms such as low wages and state subsidy or protection. As a matter of fact, the imitator usually has such high initial cost of production in comparison to the international price of the product that it is hard to devise a way he can manage to overcome this barrier to his entrance. As suggested before, the effective introduction of the imitator's product in the market depends on some especial factors that could contribute to the overcoming of that barrier. A possibility would be the willingness of the proprietors of the factors of production to receive rates of return or payments lower than those that are normally paid in the innovator's country. This differential would have to be large enough to compensate for the gap in productivity between imitators and innovators. Such a differential could either be the consequence of the natural condition of the

17. Some authors, as Gerschenkron (1962), for instance, emphasize the advantage imitators are supposed to have, in comparison to the early industrializing economies, because of the possibility of having access to advanced technologies which cost and risk of development they had no need to pay for. In order to achieve this conclusion, these authors seem not to have taken appropriately into consideration these two features of the technology transfer process, as well as the fact that technologies are usually been incessantly improved by innovators or technology suppliers wile imitators are busy trying to master them, and the fact that imitators face large hurdles in trying to have access to the newest technologies. If the latecomers' advantage identified by Gerschenkron were a decisive factor, the world would have likely witnessed more frequent processes of catching up and sneaking ahead.

18. It should be kept in mind that we are still under the assumption of constant and equal factor and input prices.

19. The political and economic stress under which late industrialization process operate could be understood when one recalls that, in addition to the extraordinary cost of production latecomers have to overcome, they also need to invest relatively huge amounts of capital, as indicated in the previous section.

domestic market or could be induced by state policy, by means of, for instance, subsidies or protection, labor movement repression, state capital, concessions for natural resources exploitation and of pollution rights, etc. This would amount to a downward shift in the imitator's unit cost curve in the graphic representation developed before. The second possibility is an intervention in the product market in order to artificially raise the price in the domestic market by means of the imposition of tariffs, other barriers to imports, or the concession of subsidies for the consumption of the domestic product. This would amount to an upward shift in the price curve that appears in figure 4.

The potential for the natural conditions of the domestic markets of factors of production to provide enough stimuli for the imitator seems to be limited in the long term. Cheap raw materials, associated to a large supply of natural resources, seem to represent a good possibility at first sight. It could, however, play a limited role in this process. A large supply of natural resources in developing economies is generally directed towards international markets in order to generate hard currency. At the same time, there is no reason to believe that domestic raw material should naturally be supplied to the domestic industry for an inferior price to that it could receive in the world market, unless there is a natural or artificial barrier to its exportation.

The cost of capital is usually higher in developing economies than it is in the advanced countries. The relative abundance of labor in developing economies turns to be the most relevant possibility for compensating the productivity gap of latecomers. And it is true that it has historically represented an important competitive advantage in the beginning of several industrialization and development processes. However, in the long run, the very success of these processes undermines progressively the competitive advantage achieved by cheap labor, because wages are prone to rise with the advancement of industrialization and development. Moreover, it is likely that new late coming countries would try to compete on the basis of cheap labor, lowering the level of wage that would be required to remain competitive. At the same time, productivity should continue to increase in other economies, thus raising the productivity gap and undermining the competitive edge achieved by cheap labor.

If the latecomer overcomes the initial barrier by means of competitive advantages based on cheap labor or on industrial policy stimuli, the crucial question turns out to be related to the speed of technology absorption and improvement processes and their impact in the imitator's productivity. Such a speed could be inferred by the slope (the derivative) of the unity cost function represented in the graph shown in figure 4. That slope must be compared to the slope of the price curve, and more specifically, with the slope of the unity cost curve of the innovator.

If the imitator is not able to advance its process of cost reduction at a superior speed to that of its competitors in order to close the productivity gap it will extend indefinitely its dependency on those spurious mechanisms to sustain its competitiveness.[20] As a consequence, the sustainability of its development process will be undermined by its addiction to those mechanisms that are inconsistent with high

20. See box 2 about the concept of spurious competitiveness.

levels of income and equity, as well as by the difficulties to appropriate profit margins high enough to sustain an accelerated process of capital accumulation and growth. This is clearly the case of the national systems of passive technological learning[21], characterized by Viotti (1997 e 2002).[22] The passive learner unity cost curve of the graph shown in figure 4 represents this case.

The large majority of imitators or learners are not able to overcome the limits of passive learning. However, there are few cases of latecomer economies with very successful processes of continuous, fast and efficient technology absorption and improvement, economies that have shown the ability to achieve rates of productivity increase (cost reduction) much higher than that of their competitors. These are cases in which the sustainability of their development processes becomes progressively independent from the spurious mechanisms to achieve or keep their competitiveness. Because of their active process of technological learning these latecomers managed to achieve fast processes of capital accumulation and *per capita* income growth, with relatively fair patterns of income distribution. These cases could be characterized as national systems of active technological learning (Viotti, 1997 e 2002).[23] The unit cost curve associated to the active learner represents this case in the graph shown in figure 4.

At this point, the reader may have realized the potential of the conceptual and theoretical framework developed in this section as a device for assisting in the analysis of the technical change process typical of late industrializing economies and its consequence for their competitiveness and development. This framework seems to be helpful for the analysis and evaluation of policies, and, especially, of implicit and explicit policies of (S&T) in those type of economies. The main issue to be evaluated is the contribution of these policies to the redemption of what was suggested to be called the original sin of late industrializing economies, which is directly related to the productivity gap they start with in their processes of industrialization.

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21. See box 1 about the concept of passive learning.

22. The current situation of the labor-intensive industries created in the north frontier of Mexico in order to profit from the Nafta agreement constitutes a revealing example of the pitfalls and short-lived advantages achieved by means of spurious competitiveness. Forero (2003) indicates that: "More and more plants like Gicsa – so-called maquiladoras that are allowed to import components duty free so long as they are assembled for export only – are scaling back operations or closing altogether. In all, 500 of Mexico's 3,700 maquiladoras have shut down since 2001, at a cost of 218,000 jobs, the Mexican government says. (…) The slide of companies like Gicsa has prompted soul-searching here in Mexico as this nation of 100 million assesses the last decade under a landmark free trade pact with the United States and a future of intensifying competition. (…) 'Mexico has nearly lost the battle on low-skilled, labor-intensive industries, where it simply cannot compete with China on labor costs and will likely continue losing market share,' Merrill Lynch said in a recent report. (…) To compete with a country whose labor costs one-fourth of Mexico's, they [business executives] say, the government needs to reduce taxes, provide cheaper electricity, improve roads and curtail corruption. (…) The future was much rosier for Mexico in 1994 as tariffs fell after the trade pact with the United States and Canada went into effect. Mexican exports to the United States shot up and hundreds of thousands of factory jobs were created."

23. See box 1 on active learning.

BOX 2

National systems of technical change and competitiveness

PASSIVE LEARNER	ACTIVE LEARNER	INNOVATOR
Spurious Competitiveness The ability of a country to sustain and increase its share of the international markets only at the cost of jeopardizing its (present or future) population's standard of living. **Price Competition** Low wages; natural resources depletion; and state subsidy or protection.	→	**Authentic Competitiveness** The ability of a country to sustain and increase its share of international markets in the medium and long run, and, simultaneously, enhance its population's standard of living. **Technological Competition** New or improved products, processes or services.

Note: Fajnzylber (1988) introduced the concepts of authentic and spurious international competitiveness. See Viotti (1997 and 2002) on the concepts of active and passive National Learning Systems and their relationships with authentic and spurious competitiveness.

In the evaluation of S&T policies of developing economies, the analysis should be focused on the role these policies play, first, in the reduction of the imitation time lag,[24] and, second, in increasing the speed and efficacy of the process of technology absorption and improvement. Then, it is possible to say, in terms of the graphic representation shown in figure 4, that these objectives could be understood as the contribution of the policies to, first, the decreasing of the distance (measured in the time axis) between the beginning of the unity cost curve of the innovator and that of the imitator or learner, and, second, the increase in the slope (i.e., the derivative) of the unity cost curve of the imitator or learner. There is a kind of vital threshold that must be overcome in the case of this second objective: the slope of the imitator's unit cost curve needs to be steeper than that of the innovator in order to enable a progressive decrease and eventual elimination of the productivity gap which exists between the two of them.

4 SELECTED CASES OF LATECOMERS

A rough picture of the behavior of the technological gap that separates late industrializing economies and the leader industrial economy could be figured out through the analysis of the evolution of the *per capita* income and labor productivity of those economies in comparison to that of the United States. Figure 5 shows the evolution of the real *per capita* income for the United States, Brazil, Mexico, South Korea and Taiwan during the second half of the 20th Century and the initial years of the 21st. The graph shows the four latecomers following a roughly similar pattern

24. The imitation time lag is the time span between the introduction of a product or innovation by the innovator and the moment in time it is brought to the market by the imitator. (In logical terms, the reduction of the imitation time lag to zero could be seen as the transformation of the imitator in an innovator.)

of *per capita* income growth until the beginning of the 1980's, and thereafter, South Korea and Taiwan remained in their trajectories of fast growth, while Brazil and Mexico lost dynamism and presented very slow rates of growth. Figure 6 shows the evolution of the *per capita* income of these four latecomers measured as a percentage of that of the USA. This latter graph shows all four economies reducing their *per capita* income gap until the beginning of the 1980's, followed thereafter by two divergent patterns of East Asian and Latin American economies. Korea and Taiwan persisted in their clear patterns of catching up all along the period, whereas Brazil and Mexico were left behind during the last two decades of the century, after the fatigue of their processes of import substitution industrialization and the subsequent adoption of liberal policies.

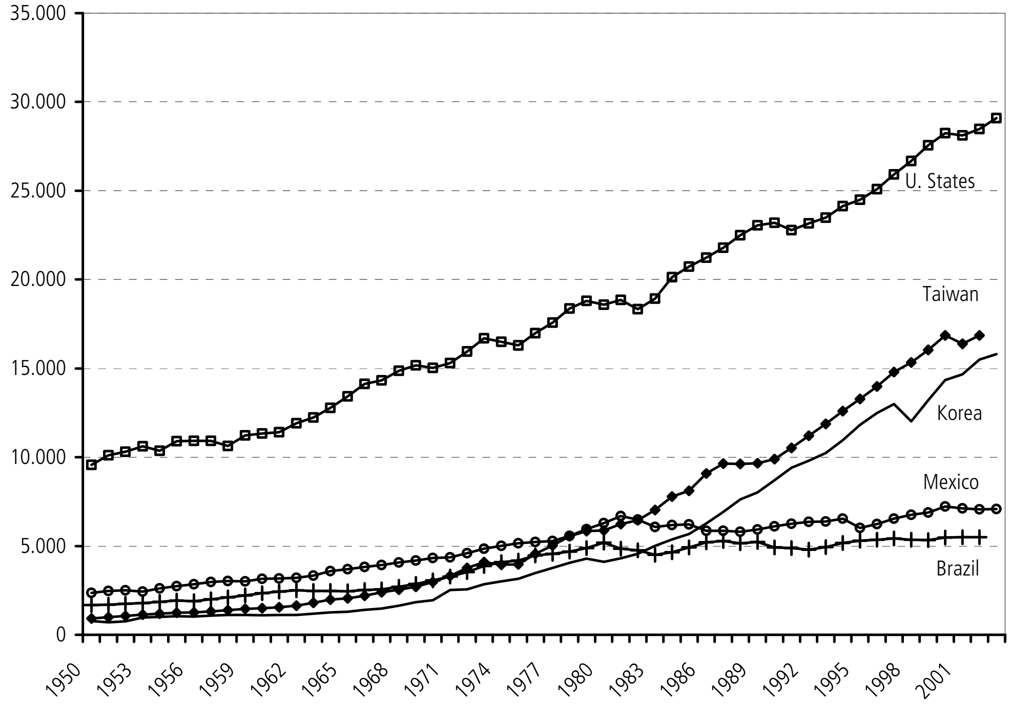
Brazilian *per capita* income, which in 1950 represented 17.5% of the US *per capita* income at that time, reached a peak of 28.0% in 1980, and fell back to 19.3% by 2002. Hence, by the beginning of the 21st Century Brazil achieved a level of *per capita* income relative to that of the leading industrial economy not much different from that of more than half a century earlier. Mexico started the period with a *per capita* income of 24.7% that of the US, achieved a peak of 35.4% in 1981, and came back to just 24.8% by 2002. Therefore, by the beginning of the 21st Century, the *per capita* income gap between Mexico and the United States became almost identical to that of the middle of the last century. South Korea and Taiwan presented a level of *per capita* income in 1950 relative to that of the US (respectively 8.0% and 9.7%) that was approximately half of those of Brazil and Mexico at that time. By the year 2002, they managed to achieve levels of *per capita* income of 54.4% (Korea) and 59.2% (Taiwan) that of the US, which correspond to levels more than six times larger than those they had by the middle of the last century. By the beginning of the new century, the Korean and Taiwanese levels of relative *per capita* income became much more than two times those of Brazil and Mexico.

A better picture of the technological gap between these latecomers and the leading industrial economy could be shown by the evolution of the labor productivity in terms of output per hour worked. As a matter of fact, labor productivity per hour worked and *per capita* income are to a certain extent bound together, but variations in the number of persons employed in the whole population, as well as in the number of hours effectively worked by employed persons, could make room for some differences in the evolution of the two variables. Unfortunately, labor productivity per hour worked is not an easily available data, especially for long periods of time. The available data, labor productivity measured in terms of annual output of all sectors of the economy (measured in PPP and 1990 US dollars) per person employed, in comparison to that of the US is presented in figure 7 and table 2. The evolution depicted by this data on labor productivity is, in general, compatible with the evolution of *per capita* income (measured as an index of the US *per capita* income) showed in figure 6.

The larger picture shown by both series is clear. South Korea and Taiwan are following a steady and sound pattern of catching up with the leading industrial economy, whereas Brazil and Mexico are being left behind since the beginning of the 1980's.

FIGURE 5

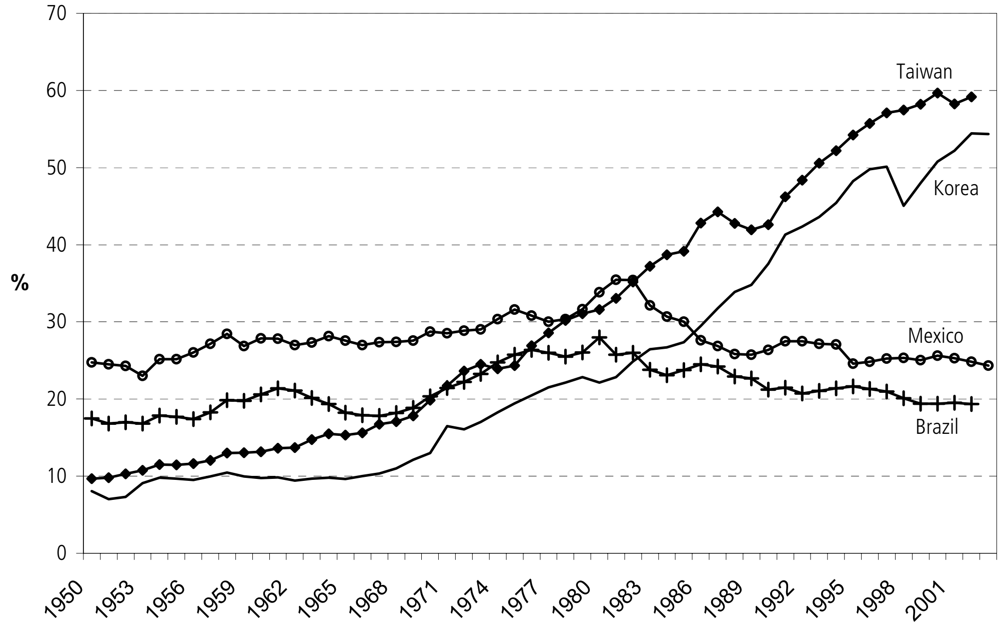
Real *per capita* income (1990 US dollars – PPP) 1950-2003



Source: Groningen Growth and Development Centre and The Conference Board, Total Economy Database, February 2004. Available in: < http://www.ggdc.net>.
Notes: Series on real Gross Domestic Product expressed in constant 1990 US dollars converted at "Geary-Khamis" PPPs.

FIGURE 6

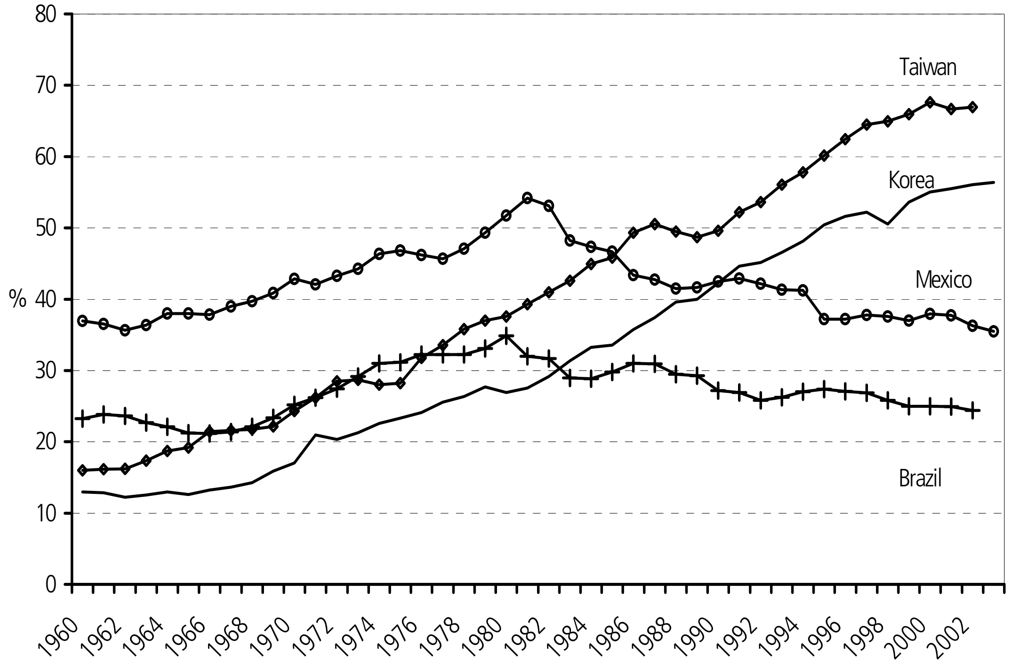
Real *per capita* income (1990 US dollars) united states = 100



Source: Groningen Growth and Development Centre and The Conference Board, Total Economy Database, February 2004. Available in: < http://www.ggdc.net>.
Notes: Series on real Gross Domestic Product expressed in constant 1990 US dollars converted at "Geary-Khamis" PPPs.

FIGURE 7

Labor productivity (United States = 100) 1960-2003



Source: Groningen Growth and Development Centre and The Conference Board, Total Economy Database, February 2004. Available in: <http://www.ggdc.net>.

Notes: Productivity is measured as annual output divided by person employed. Output is measured as real GDP expressed in constant 1990 US dollars converted at "Geary-Khamis" PPPs.

The conventional wisdom in terms of (S&T) policy, which is informed by the so called linear model, would ascribe the poor performance of Brazil and Mexico's productivity to a lack of a scientific basis upon which these countries would have been able to build their technological development. The remedy it will prescribe would be to increase state support for investments, institutions and personnel devoted to research, especially to basic research. This is so because basic research is thought to be "the pacemaker of technological progress" (Bush, 1945, p. 19), and because it assumes that "those who invest in basic science will capture its return in technology as the advances in science are converted into technological innovation" (Bush, according to Stokes 1997, p. 4).

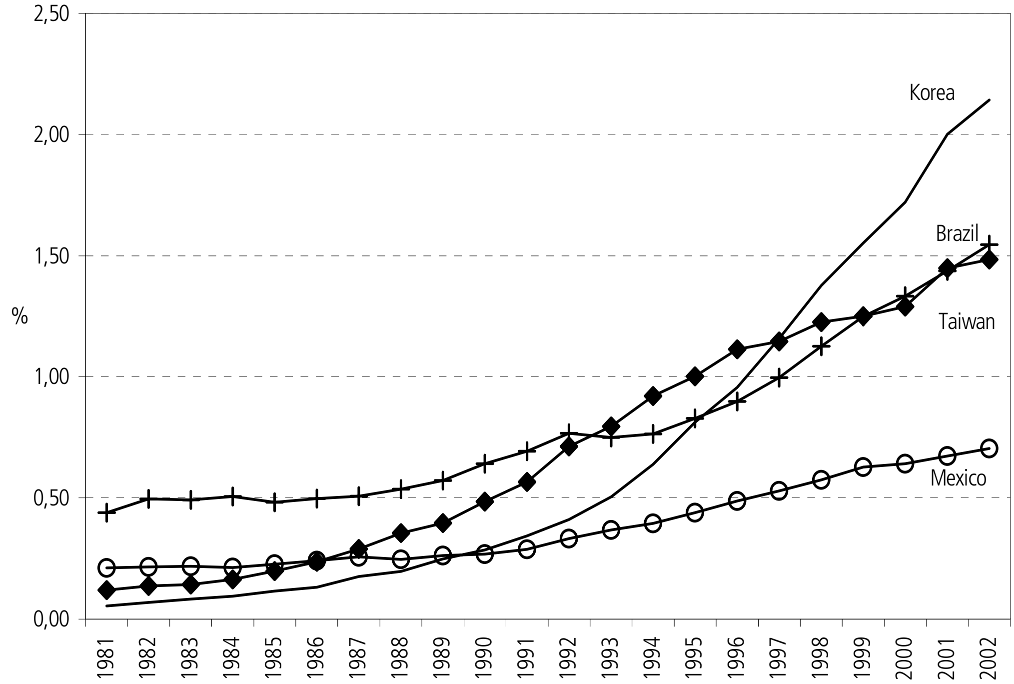
If the number of scientific publications of Brazil and Mexico, and especially their shares of world's publications, are taken as indicators of the strength of their basic research or scientific productions, those tenets of the linear model, which relate a country's advance in science with its profit in terms of technology or innovation, should be put in question.[25] Taken by the very small size of Brazil and Mexico's world's share of scientific publications in 1981, respectively 0.44% and 0.21%, the significant decrease of the technological gap of those two countries that occurred between 1950 and 1980 could hardly be ascribed meaningfully to the strengthening of their scientific basis during that period. On the other hand, the period between

25. See, on this respect, figure 8 and table 3.

1981 and 2002 was marked by the contradictory tendencies of a sharp increase of the scientific production of those two countries and, at the same time, a strong increase in their technological gap as compared to the leading economy. During that period, those two countries managed to expand their scientific production in a pace much faster than that of the world as a whole, achieving by 2002 shares of world's scientific publications that were more than 3 times larger than those they have by 1981.[26] That rapid advance in scientific production was accompanied by a labor productivity that presented a meager increase in Brazil and an actual decrease in Mexico (measured in absolute terms). The productivity gap of these two economies (i.e., the distance between their labor productivity and that of the US), increased sharply during that period.

FIGURE 8

National shares of world's scientific publications selected countries (1981-2002)

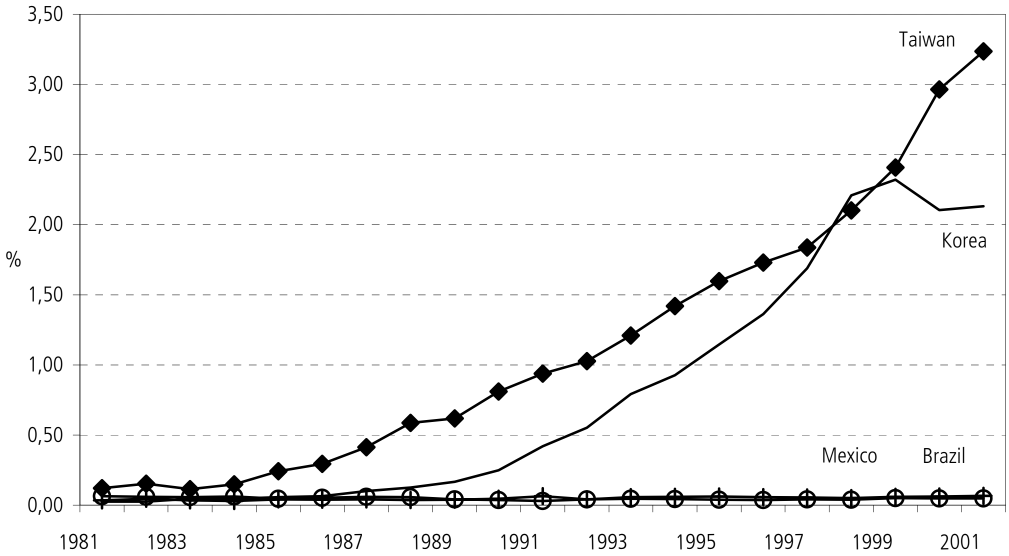


Source: Institute for Scientific Information (ISI) (table 3).

26. The contrast with the US, the country that was used here as the basis for the analysis of the evolution of *per capita* income and productivity, is in this respect sharper than that with the world as a whole. This is so because, while the world's scientific production was growing approximately 1% per year, the total number of US publications remained largely stagnated from the mid 1980's to the mid 1990's, and even declined during the latter half of the 1990s (NSB 2002, Appendix table 5-41).

FIGURE 9

National shares of world's patents selected countries (1981-2001)



Source: United States Patents and Trademarks Office (USPTO) (table 3).

If the scientific production is compared more specifically with their technological production, measured in terms of the number of patents granted by the USPTO to residents in those countries, the conclusion remains the same. The scientific production of Brazil and Mexico seems to have had no meaningful impact on their respective technological productions. The mismatch between Brazil's scientific production and its technological production is striking. This mismatch and the very fast growth of its scientific production in the last decades give grounds to the hypothesis that its S&T policy could have been inspired by a kind of linear model. Brazil's share of world's scientific publications in 2001 (1.44%) was more than 20 times greater than its share of the world's (US) patents (0.07%), and its share of the world's scientific production more than tripled (growing from 0,44 to 1.44%) between 1981 and 2001. An S&T policy focused largely on the support to research institutions, and especially on the development of research personnel, in the expectation that it would catalyze technological advances in the domestic productive sector, should be one of the reasons for that large mismatch between the Brazilian scientific and technological productions.

In the case of Mexico, that mismatch is smaller than in the case of Brazil, but is still very large. Its share of world's publications in 2001 (0.67%) was more than 13 times larger than that of patents (0.05%). Mexico also managed to increase the number of its publications at a pace much superior to that of the world average, and similarly to Brazil was able to more than triple its world's share of scientific publications, coming from 0.21% in 1981 to 0,67% in 2001 (approximately half the Brazilian share).

The disproportion between Korea and Taiwan's respective shares of US patents and those of Brazil and Mexico are remarkable. These ratios vary between 30 and 64, i.e., Korea's share of patents is more than thirty times that of Brazil, and Taiwan's share is more than 64 times greater than that of Mexico. Korea managed to achieve in 2001 a patents' share 71 times larger than that of 1981. Taiwan increased its share almost 27 times during those 20 years, whereas Brazil went just slightly over its double, and Mexico even reduced it.

The adequacy of the implicit and explicit S&T policies associated with conventional economics is also put into question by these data. Mexico and Brazil, have historically presented a very poor technological production, as became evident from the data analyzed here. The policies of the 1980's and 1990's, a period of mounting competitive pressures and strengthening of intellectual property rights in these economies, followed by an expressive and effective expansion of their pool of scientific knowledge, seems not to have contributed to the change of that historical and structural feature of the Brazilian and Mexican processes of technical change.

The correlation between the world's shares of scientific and technological productions of each country is also revealing in an additional sense. The shares of scientific productions of Brazil and Mexico in 2001 are much larger (respectively 20 and 13 times larger) than their technological productions. For Korea and Taiwan, that type of correlation goes in the opposed direction. Their shares of scientific production in 2001 (respectively 2.00 and 1.45%) are smaller than their shares of technological production (respectively 2.13 and 3.23%). The divergent and, to a certain extent, disparate trends of scientific and technological productions of those four countries put into question the linear model's assumption of a more or less direct connection between a country's scientific achievements and its technological production or innovation.

These divergent and disparate trends could be explained by the fact that the dominant process of technical change of those four economies was technological learning. This type of technical change, especially when it is restricted to its passive form, has a tenuous relationship with the scientific basis of the country. For that reason, Brazil and Mexico were able to reduce their technological gap during the 1950's, 1960's and 1970's, even though they could not rely on a relatively strong scientific and technological basis. These were decades characterized by ISI. Problems of balance of payments, together with some other reasons, led the Mexican and Brazilian governments to the adoption of industrial policies that allowed for the absorption of the technological capabilities of production of industry after industry.

However, by the end of the 1970's this process came to an end (i.e., it became unfeasible to set up new industries on an import substitution basis). Stagnation came, and this hindered the process of spasmodic bursts of absorption of new blocks of technological capabilities of production typical of import substitution industrialization. Lacking this flow of technologies and, at the same time, unable to develop significant capabilities of improvement of the absorbed technologies, Brazil and Mexico went through a period of very low productivity growth during the 1980's and 1990's. The development of technological capabilities of improvement, a requirement of active learning, would be the way out of this constraint. Active learning would be required for the progressive reduction of the productivity gap and of the associated burden of spurious competitiveness. It would be required for expanding domestic markets by means of lowering prices and or rising wages. It would also be required for the expansion of foreign markets for domestic products.

The data analyzed before seems to indicate that Brazil and Mexico were not able to develop the additional technological effort required for the development of active learning and, by consequence, were left behind during the last two decades.

Moreover, the policies followed during that period seem not to have worked in favor of active learning. The significant improvement of the scientific basis that occurred in those two Latin American economies during the last two decades of the 20th Century seems to have been largely irrelevant for the processes of technology absorption, mastery and improvement. Stricter intellectual property rights, enforced during that period, made the absorption and improvement of technologies more difficult and expensive. The hope that stronger intellectual property rights (in line with the TRIPs' agreement) would bring about an environment that would be more attractive for technology licensing or transfer does not seem to have materialized. At least the case of patents licenses in Brazil leaves no room for doubts on this respect. The number of licenses for the use of foreign patents in Brazil remained very low and even declined during the 1990's.[27] Stronger competition achieved trough the fast and sharp process of liberalization seems to be favoring a competitive specialization in natural resources' processing, and food and commodities' production of low value-added (Katz, 2000).[28] This kind of backward evolution of the Latin American industrialization processes goes in a direction that is most compatible with passive learning and spurious competitiveness.

Korea and Taiwan are considered examples of late industrializing economies that were very successful in shortening the imitation lag and, accordingly, the share of high-tech products in their exports are very high. Their capabilities of improvement on the absorbed technologies are also very good as could be inferred from the literature on case studies and indirectly from the evolution of their productivity. They were able to develop an active technological learning strategy.

The contrast between the processes of technological learning characteristic of Brazil and Mexico, which are of a passive nature, and that of Korea and Taiwan, which are active, could be easily linked to the successes or failures of these countries' processes of industrialization and catching up.

The cases analyzed here indicate how the linear model and conventional economics seem to be poor guides for both, the understanding of the processes of technical change characteristic of late industrializing economies, and the prescription of S&T policies for them. The analysis of these cases reinforces the importance of an approach that focuses on these specificities.

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27. The number of patents' licenses in Brazil declined from 134 in 1990, to 60 in 1995, and to just 39 in 2001 (Cassiolato and Elias, 2003, p. 302).

28. Sarti and Sabbatini (2003) indicated that beef, sugar, and soybean oil were the products that gave the largest contribution to the growth of Brazilian exports between 1989 and 2001. These three products were responsible for almost a quarter of the growth of Brazilian exports during those years. By the way, the authors signaled the risks of a strategy of trade that specializes in a set of products for which international markets are growing a meager 0.5% per year. They also indicated that Mexico presented a relatively good performance in exporting high-tech products during the 1990's, but these exports were mainly the result of assembly lines of multinational corporations established near the US border, using very high levels of imported parts and components and basically exploiting the local advantages of cheap labor under the NAFTA agreement. The products could be high tech, but the Mexican competitive advantage on these high-tech products seems to be reduced essentially to the low costs of Mexican labor.

TABLE 2

Labor productivity selected economies (1960-2003)

Years	U. States		Brazil		Mexico		S. Korea		Taiwan	
	Output PPE	%	Output PPE	%	Output PPE	%	Output PPE	%	Output PPE	%
1960	31.095	100,0	7.235	23,3	11.483	36,9	4.032	13,0	4.976	16,0
1961	31.835	100,0	7.587	23,8	11.628	36,5	4.088	12,8	5.145	16,2
1962	33.272	100,0	7.853	23,6	11.851	35,6	4.072	12,2	5.393	16,2
1963	34.167	100,0	7.740	22,7	12.417	36,3	4.287	12,5	5.929	17,4
1964	35.341	100,0	7.806	22,1	13.433	38,0	4.576	12,9	6.607	18,7
1965	36.653	100,0	7.768	21,2	13.919	38,0	4.611	12,6	7.029	19,2
1966	38.086	100,0	8.053	21,1	14.415	37,8	5.033	13,2	8.152	21,4
1967	38.263	100,0	8.171	21,4	14.918	39,0	5.217	13,6	8.267	21,6
1968	39.267	100,0	8.682	22,1	15.588	39,7	5.601	14,3	8.545	21,8
1969	39.466	100,0	9.209	23,3	16.128	40,9	6.273	15,9	8.746	22,2
1970	39.145	100,0	9.867	25,2	16.764	42,8	6.667	17,0	9.519	24,3
1971	40.017	100,0	10.469	26,2	16.835	42,1	8.387	21,0	10.467	26,2
1972	40.709	100,0	11.171	27,4	17.606	43,2	8.273	20,3	11.592	28,5
1973	41.549	100,0	12.111	29,1	18.399	44,3	8.846	21,3	11.924	28,7
1974	40.607	100,0	12.586	31,0	18.821	46,3	9.159	22,6	11.371	28,0
1975	40.940	100,0	12.756	31,2	19.161	46,8	9.541	23,3	11.559	28,2
1976	41.675	100,0	13.444	32,3	19.254	46,2	10.044	24,1	13.249	31,8
1977	42.017	100,0	13.557	32,3	19.200	45,7	10.735	25,5	14.091	33,5
1978	42.550	100,0	13.714	32,2	20.036	47,1	11.217	26,4	15.227	35,8
1979	42.762	100,0	14.149	33,1	21.083	49,3	11.849	27,7	15.821	37,0
1980	42.575	100,0	14.831	34,8	22.015	51,7	11.463	26,9	16.000	37,6
1981	43.162	100,0	13.810	32,0	23.387	54,2	11.879	27,5	16.970	39,3
1982	42.723	100,0	13.528	31,7	22.675	53,1	12.464	29,2	17.512	41,0
1983	43.936	100,0	12.726	29,0	21.189	48,2	13.776	31,4	18.715	42,6
1984	45.263	100,0	13.060	28,9	21.435	47,4	15.051	33,3	20.341	44,9
1985	46.077	100,0	13.730	29,8	21.510	46,7	15.457	33,5	21.120	45,8
1986	46.599	100,0	14.445	31,0	20.215	43,4	16.648	35,7	22.982	49,3
1987	47.018	100,0	14.540	30,9	20.105	42,8	17.601	37,4	23.746	50,5
1988	47.920	100,0	14.128	29,5	19.876	41,5	18.988	39,6	23.711	49,5
1989	48.574	100,0	14.211	29,3	20.222	41,6	19.405	39,9	23.651	48,7
1990	48.819	100,0	13.256	27,2	20.747	42,5	20.633	42,3	24.203	49,6
1991	48.967	100,0	13.167	26,9	20.995	42,9	21.855	44,6	25.550	52,2
1992	50.079	100,0	12.917	25,8	21.126	42,2	22.607	45,1	26.850	53,6
1993	50.601	100,0	13.281	26,2	20.913	41,3	23.570	46,6	28.362	56,0
1994	51.401	100,0	13.879	27,0	21.203	41,3	24.725	48,1	29.718	57,8
1995	51.952	100,0	14.225	27,4	19.318	37,2	26.184	50,4	31.256	60,2
1996	52.994	100,0	14.342	27,1	19.724	37,2	27.363	51,6	33.080	62,4
1997	54.096	100,0	14.541	26,9	20.449	37,8	28.245	52,2	34.873	64,5
1998	55.474	100,0	14.321	25,8	20.855	37,6	28.042	50,6	36.023	64,9
1999	56.998	100,0	14.233	25,0	21.099	37,0	30.556	53,6	37.589	65,9
2000	58.212	100,0	14.540	25,0	22.082	37,9	32.040	55,0	39.347	67,6
2001	58.405	100,0	14.547	24,9	22.019	37,7	32.400	55,5	38.930	66,7
2002	59.774	100,0	14.578	24,4	21.681	36,3	33.528	56,1	40.008	66,9
2003	61.078	100,0			21.683	35,5	34.438	56,4		

Source: Groningen Growth and Development Centre and The Conference Board, Total Economy Database, February 2004. Available in: <http://www.ggdc.net>.

Notes: Labor productivity is measured as the annual real output (GDP) divided by person employed.
GDP was computed (at market prices) in 1990 US dollars converted at "Geary-Khamis" PPPs.
"Output PPE" stands for output per person employed.
"%" stands for each country's "output PPE" measured in terms of a percentage of the US "output PPE" at the same year.

TABLE 3

Number and shares of patents and scientific publications selected countries (1981-2002)

Years	Brazil				Mexico				S. Korea				Taiwan			
	Patents		Publications		Patents		Publications		Patents		Publications		Patents		Publications	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
1981	23	0,03	1.887	0,44	42	0,06	903	0,21	17	0,03	230	0,05	80	0,12	517	0,12
1982	27	0,05	2.183	0,50	35	0,06	945	0,21	14	0,02	300	0,07	88	0,15	604	0,14
1983	19	0,03	2.205	0,49	32	0,06	980	0,22	26	0,05	374	0,08	65	0,11	638	0,14
1984	20	0,03	2.269	0,51	42	0,06	953	0,21	30	0,04	419	0,09	99	0,15	735	0,16
1985	30	0,04	2.313	0,48	32	0,04	1.090	0,23	41	0,06	557	0,12	174	0,24	954	0,20
1986	27	0,04	2.481	0,50	37	0,05	1.201	0,24	46	0,06	656	0,13	208	0,29	1.176	0,24
1987	34	0,04	2.525	0,51	49	0,06	1.274	0,26	84	0,10	872	0,18	343	0,41	1.441	0,29
1988	29	0,04	2.770	0,54	44	0,06	1.278	0,25	97	0,12	1.017	0,20	457	0,59	1.835	0,35
1989	36	0,04	3.078	0,57	39	0,04	1.414	0,26	159	0,17	1.336	0,25	591	0,62	2.133	0,40
1990	41	0,05	3.552	0,64	32	0,04	1.487	0,27	225	0,25	1.577	0,28	732	0,81	2.681	0,48
1991	62	0,06	3.925	0,69	29	0,03	1.634	0,29	405	0,42	1.944	0,34	906	0,94	3.206	0,57
1992	40	0,04	4.643	0,77	39	0,04	2.014	0,33	538	0,55	2.484	0,41	1.001	1,03	4.316	0,71
1993	57	0,06	4.487	0,75	45	0,05	2.199	0,37	779	0,79	3.016	0,50	1.189	1,21	4.752	0,79
1994	60	0,06	4.838	0,76	44	0,04	2.502	0,40	943	0,93	4.038	0,64	1.443	1,42	5.830	0,92
1995	63	0,06	5.512	0,83	40	0,04	2.917	0,44	1.161	1,14	5.405	0,81	1.620	1,60	6.670	1,00
1996	63	0,06	6.053	0,90	39	0,04	3.282	0,49	1.493	1,36	6.448	0,96	1.897	1,73	7.501	1,11
1997	62	0,06	6.749	1,00	45	0,04	3.586	0,53	1.891	1,69	7.845	1,16	2.057	1,84	7.767	1,15
1998	74	0,05	7.919	1,13	57	0,04	4.037	0,57	3.259	2,21	9.674	1,38	3.100	2,10	8.613	1,23
1999	91	0,06	8.954	1,25	76	0,05	4.492	0,63	3.562	2,32	11.132	1,55	3.693	2,41	8.964	1,25
2000	98	0,06	9.524	1,33	76	0,05	4.588	0,64	3.314	2,10	12.302	1,72	4.667	2,96	9.225	1,29
2001	110	0,07	10.557	1,44	81	0,05	4.948	0,67	3.538	2,13	14.701	2,00	5.371	3,23	10.636	1,45
2002			11.285	1,55			5.137	0,70			15.643	2,14			10.831	1,48
Total	1.066	0,05	109.709	0,85	955	0,05	52.861	0,41	21.622	1,04	101.970	0,79	29.781	1,43	101.025	0,78

Sources: United States Patent and Trademark Office (USPTO), "Patents counts by country/state and year – Utility Patents – January 1, 1963 – December 31, 2001", Washington, USPTO, February 2002. Available in: <http://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_util.pdf>. Accessed on 05/10/2003; and Institute for Scientific Information (ISI), National Science Indicators (NSI).[29]

Notes: Patents "#" equals the total number of utility patents (i.e., patents for invention) granted by the USPTO to (first-named-inventors) residents in the country. Patents "%" equals the country's percentage of the total number of invention patents granted by the USPTO. Publications "#" equals total number of scientific publications in all fields authored by residents in the country. Publications "%" equals the country's percentage of the total number of world's scientific publications.

5 POLICY IMPLICATIONS FOR LATECOMERS

The process of technical change characteristic of latecomers is different from that of earlier processes of industrialization and, consequently, their policies should take this into consideration.

Conventional S&T policies, stressing basic research, tough competition and strong protection for intellectual property rights, seem to be unable to push countries through the pathway of catching up, from passive to active technological learning, and possibly towards innovation.

Latecomers' S&T policy should be evaluated mainly in terms of its contribution to the reduction of the imitation lag and of the productivity gap.

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The immediate objective should be to foster a strong active learning process, i.e., to build the right set of institutions and incentives in order to foster active technological learning.

Building firm's technological capabilities is crucial.

Academic, basic research and R&D institutions have a fundamental role, but should be articulated with the country's learning effort and, simultaneously, should focus mainly on some scientific fields that are promising for the future development of an innovation process within the country.

When one realizes that innovation (strict sense) is not the only objective, and that active learning is also a very important target, latecomers' S&T policy and corporate strategy become more feasible and less risky.

R&D for adaptation and improvement, manufacturing extension, technical assistance, demonstration and diffusion, networking of producers-suppliers and labs, and benchmarking, all become essential elements of S&T policies and strategies.

Firm's shop floor is critical for learning. Issues like labor education and training, a cooperative environment between management and workers, few hierarchical layers and total quality management become very important.

Picking the right sector or technology becomes crucial. The less mature the technology is, the higher the technological opportunities for active learning and innovation, the higher the rates of market growth and the prospects for high profit margins. Mature technologies are largely a dead end for active learning.

Macro-economic, industrial and educational policies should be appropriate for the generation of an environment suitable for the construction of an active learning system.

For latecomers, tough competitive pressure alone, achieved by means of open and liberalized domestic markets, usually induces price competition and specialization in industries which are intensive in labor and natural resources or which employ mature technologies. As a consequence, it favors passive learning and spurious competitiveness.

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