Technological Learning Systems, Competitiveness and Development*

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1. PER CAPITA INCOME, INDUSTRIALIZATION, AND PRODUCTIVITY[1]

Contrary to the common perception, the cleavage between developed and developing economies is a relatively recent phenomenon in historical terms. Before de 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.

Two centuries of Industrial Revolution (i.e., from 1750 to 1950) brought about a 6.5 times growth in the per capita income of industrialized economies, whereas the per capita income of the developing ones remained roughly stagnated (to be precise, it increased less than 14% during two hundred years).

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

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

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).[2]

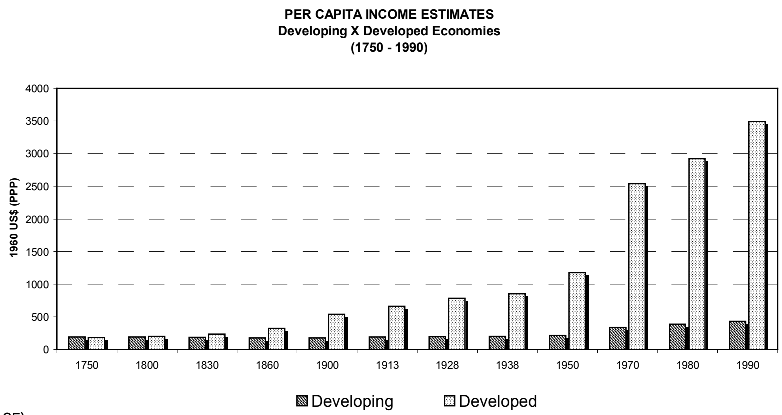
When one realizes that the cleavage amongst developed and developing economies is not an ancestral problem inherited by the modern world, a question comes almost immediately to mind: what are the reasons for such different patterns of growth? .

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. The evolution of labor productivity in this sector during 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 one, 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.

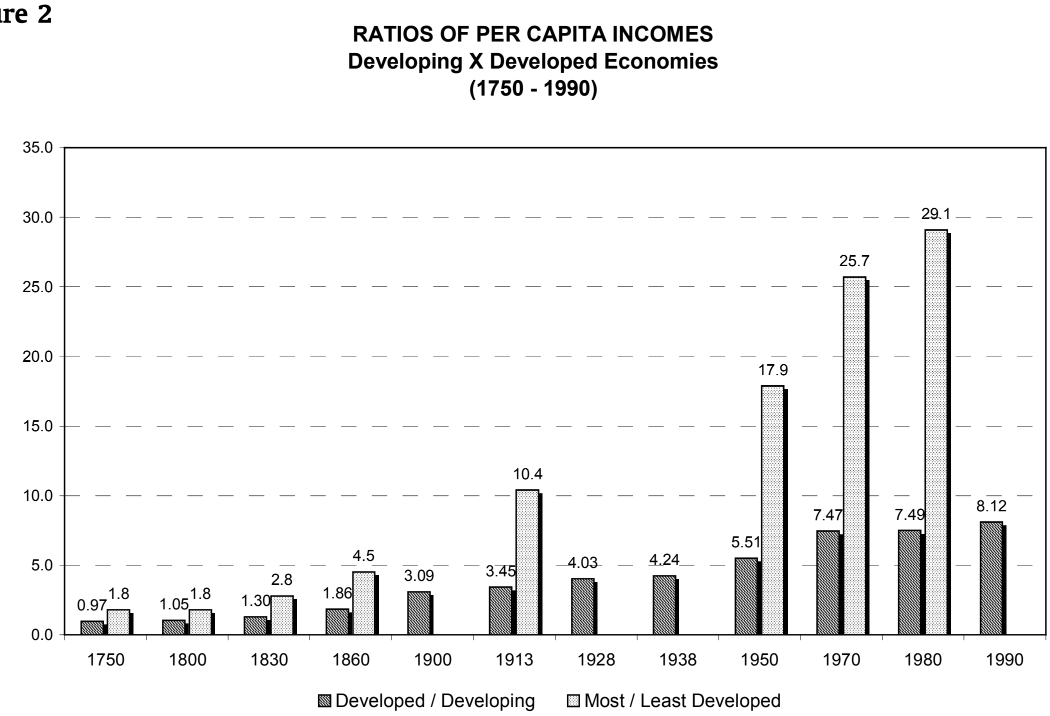
Figure 1



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.

2 Maddison (2001, p 47) expresses a harsh 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 7 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 that divergence of incomes, and for the very existence of the cleavage between developed and underdeveloped economies.

Figure 2



SOURCE: BAIROCH (1993, P. 95). THE COMPARISON BETWEEN THE LEAST AND THE MOST DEVELOPED ECONOMY COMES FROM BAIROCH AND LEVY-LEBOYER (1981, PP. 7-8), APUD FREEMAN (1999, P. 149).
NOTE: THE AUTHOR USES THE EXPRESSION "THIRD WORLD COUNTRIES" INSTEAD OF DEVELOPING ECONOMIES, AND, ACCORDINGLY, DOES NOT TAKE INTO CONSIDERATION THE ECONOMIES IN TRANSITION.

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.[3]

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 for

3 It is interesting to note that the British government prohibited exports of British textile technology (machines, expertise and skilled workers) during the First Industrial Revolution (i.e., during approximately the second half of the 18th century and part of the 19th).

the extraordinary growth of their labor productivities. There are strong 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.[4]

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[5]. 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 jump 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 investments must be much higher compared to that of early industrializations. The rate of investment that financed the First Industrial Revolution (~1750) corresponded to approximately 6% of the United Kingdom's GDP. The Second Industrial Revolution (~1850) required approximately 11% of the UK's GDP. The industrialization of Germany, Sweden and Denmark (~1860) demanded more than 15% of their GDPs. In Japan (~1970) it was approximately 30%. South Korea invested between 29 and 36% of its GDP during the 1980's and 1990's. China is investing almost 40% of its GDP in its current drive towards industrialization.[6]

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. 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.

4 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 those models lead to the conclusion that there is no need for specific development theories or policies.

5 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.

6 The estimates about the UK and Germany, Sweden and Denmark come from Bagchi (1987, p. 799).

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).[7] 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 limits and possibilities of their specific processes of technical change.

2. INNOVATORS AND LEARNERS[8]

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 process. 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.[9] This is usually the case because, at those 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.[10] 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. The curve, identified in figure 3 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,

7 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.

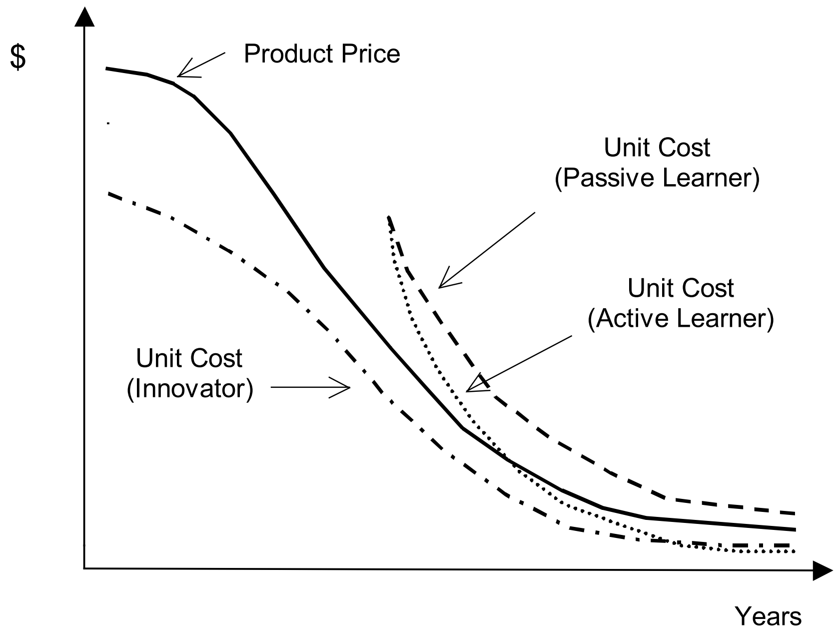
8 Learner is the firm or country whose process of technical change is limited to learning. See Box 1 on the concept of learning employed here. The word imitator will be used as synonym of learner all along this article.

9 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.

10 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.

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 a large margin of profits.

Figure 3. 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 3 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 Schumpeteriam 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.[11] Between the introduction of the product in the market and the flattening of its profit margin by the crowding out of the market by imitators, the innovator firms and their home countries enjoy the appropriation of extraordinary profits.[12]

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[13] 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 take into consideration 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 the factors of production they employ. Under those 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.

11 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.

12 Schumpeter called these profits extraordinary rent, because in the neoclassical equilibrium model they were supposed not to exist.

13 See Box 2 about the concept of authentic competitiveness.

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 obviously masters the capability to innovate, as well as the capabilities of production and improvement, with the exception of cases of innovation startups.)

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).

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.[14] The second feature refers to the fact that, besides codified knowledge that is easy to transfer, any technological transfer requires also the absorption of tacit knowledge, which demands the investment of time, resources and technological efforts by the technology recipient.[1]5 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 the tacit knowledge mastered by the innovator.

Those 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.[16] Under these circumstances, some kind of special mechanism should be in place in order to enable the imitators' entrance in the market. Such a mechanism would be required in order to compensate for that much higher cost of production.[17] 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.[18] 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.

This 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

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

15 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 whose 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, first, the continuous process of technology improvement and production in the innovator economies, and, second, the difficulties imitators face in trying to access the newest technologies, as well as to absorb tacit knowledge. If the latecomers' advantage were a decisive factor, the world would have likely witnessed more frequent processes of catching up and sneaking ahead.

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

17 The unit cost could be devised as including a margin of profit that would assure a certain rate of profit for the investment. If this is not the case, it seems reasonable to add such a profit margin in order to compute the amount of resources that mechanism would be required to provide.

18 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.

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 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 3.

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 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, in the long run, 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 the advanced economies, thus raising the productivity gap (if latecomers remain relatively stagnated in their technological capabilities).

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 graph shown in figure 3. 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 productive gap it will extend indefinitely its dependency on those spurious mechanisms to sustain its competitiveness.[19] As a consequence, the sustainability of its

19 See Box 2 about the concept of spurious competitiveness.

development process will be undermined by its addiction to those mechanisms that are inconsistent with high 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[20], characterized by Viotti (1997 e 2002). The passive learner unity cost curve of the graph shown in figure 3 represents this case.

The large majority of imitators or learners are not able to overcome the limits of passive learning. However, there are 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. Those 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).[21] The unit cost curve associated to the active learner represents this case in the graph shown in figure 3.

The reader should have already 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 science and technology (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.

In the evaluation of S&T policies of developing economies, the analysis should be focused on the role these policies play for, first, the reduction of the imitation time lag[22], and, second, 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 3, 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.

20 See Box 1 about the concept of passive learning.

21 See Box 1 on active learning.

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

Box 2. NATIONAL SYSTEMS OF TECHNICAL CHANGE AND COMPETITIVENE

PASSIVE LEARNER	ACTIVE LEARNER	INNOVATOR
SPURIOUS COMPETITIVENESS		AUTHENTIC 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.	➜	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.
Price Competition Low wages; natural resources depletion; and state subsidy or protection.		**Technological Competition** New or improved products, processes or services.

NOTE: FAJNZYLBER (1988) INTRODUCED THE CONCEPTS OF AUTHENTIC AND SPURIOUS INTERNATIONAL COMPETITIVENESS. VIOTTI (1997 AND 2002) INTRODUCED THE CONCEPTS OF ACTIVE AND PASSIVE NATIONAL LEARNING SYSTEMS, AND ESTABLISHED THEIR RELATIONSHIPS WITH AUTHENTIC AND SPURIOUS COMPETITIVENESS.

4. Selected Cases of Latecomers[23]

The data on per capita income and on labor productivity in manufacturing for Brazil, Mexico, South Korea and Taiwan, compared with the same data from the United States, make crystal it clear that South Korea and Taiwan are catching up, and Brazil and Mexico are being left behind.

The data on scientific publications and patents for those countries could be analyzed as indicators of their scientific and technological productions. The analysis of the evolution of these productions in terms of countries' shares of the total world productions gives very good clues about the nature of those countries' national systems of technical change. The size of countries' scientific production seems to have no meaningful impact on their respective technological productions. This casts serious doubt on two of the main pillars of the Linear Model: first, the belief that "basic research is the pacemaker of technological progress" (Bush 1945, p. 19); and, second, the assumption 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).

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 20 years gives basis to the hypothesis that its S&T policy could be 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

23 The present section outlines the main ideas that will be further developed and presented during the Globelics conference.

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%) in the last 20 years. An S&T policy focused largely on the expectation that support to research institutions, and especially to the development of research personnel, will be enough to catalyze technological advances in the domestic productive sector is one of the reasons for that large mismatch between the Brazilian scientific and technological productions.

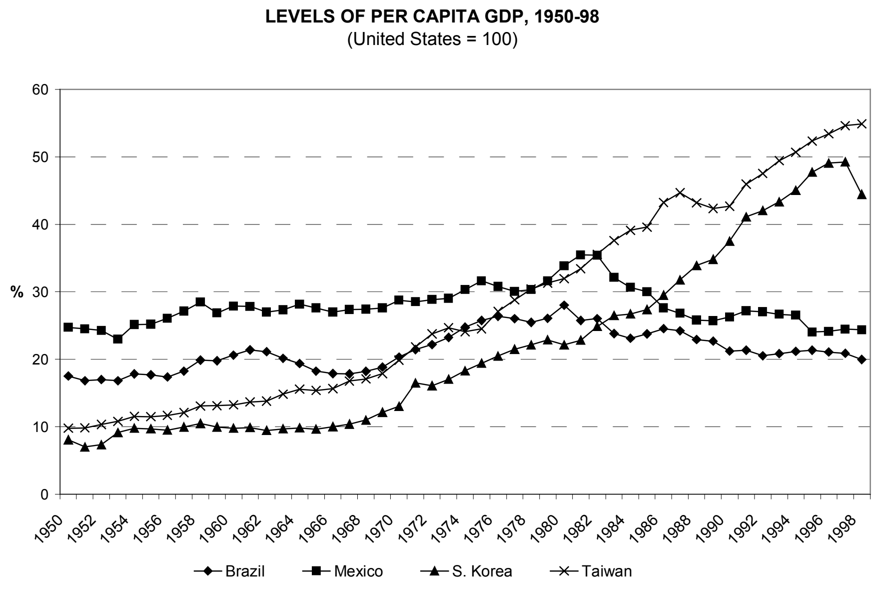
In the case of Mexico, that mismatch is smaller than in the case of Brazil, but is still very large: more than 13 times (0.67% / 0.05%). Mexico also managed to increase the number of its publications at a pace much superior to the world average, and similarly to Brazil was able to more than triple its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

The disproportion between Korea's and Taiwan's respective shares of US patents and those of Brazil and Mexico are remarkable. Those 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 increase its patent share 71 times in the last 20 years, and Taiwan almost 27 times, whereas Brazil went just slightly over its double, and Mexico reduced it.

The adequacy of conventional policies is also put into question by the data. Mexico and Brazil, have historically presented a very poor technological production, as becomes evident from the data analyzed here. This feature was not changed by the policies of the 1980's and 1990's, a period of mounting competitive pressures and strengthening of intellectual property rights in those economies, followed by a more than threefold rise in their respective shares of world scientific production.

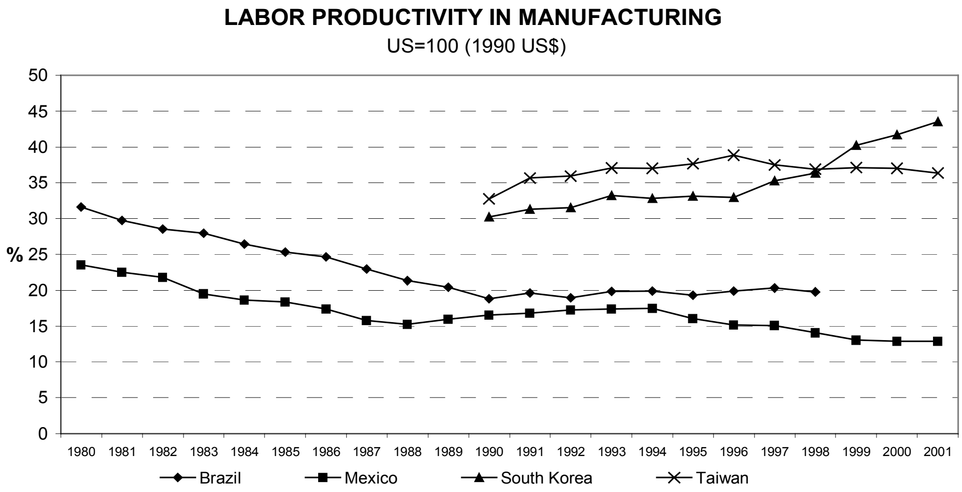
The striking differences of technological production of Brazil and Mexico, on one side, and Korea and Taiwan, on the other are related to the different (passive or active) natures of their national systems of technological learning (Viotti 2002), which are also linked to countries' processes of industrialization or catching up. Conventional S&T policies, stressing basic research, tough competition and high levels of intellectual property rights, seem to be unable to push countries through the pathway of catching up, from "passive technological learning" to "active technological learning", and possibly towards "innovation."

Figure 5



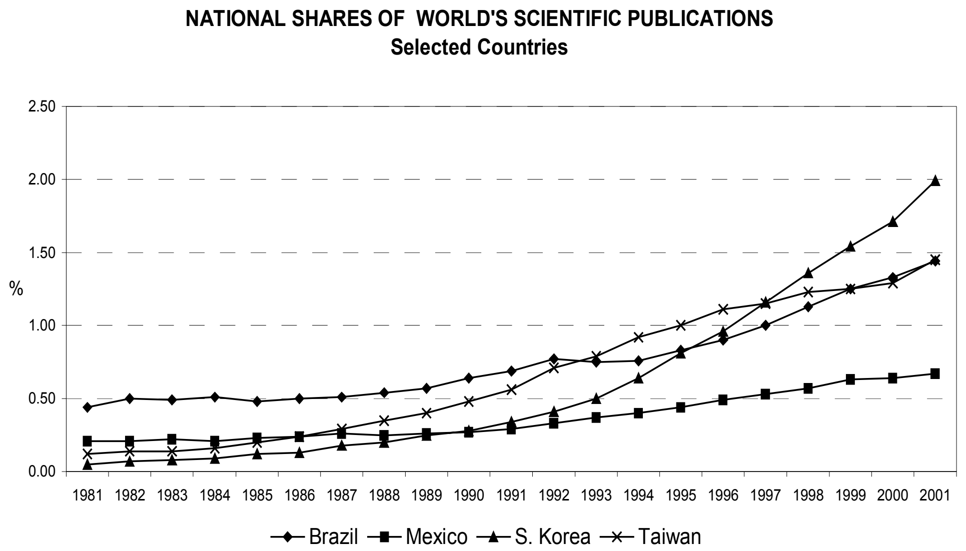
SOURCE: ANGUS MADDISON, THE WORLD ECONOMY - A MILLENNIAL PERSPECTIVE, PARIS, DEVELOPMENT CENTRE, OECD, 2001, APPENDIX C.
NOTE: ESTIMATES ARE IN 1990 INTERNATIONAL DOLLARS (GEARY-KHAMIS MULTILATERAL PPPS).

Figure 6



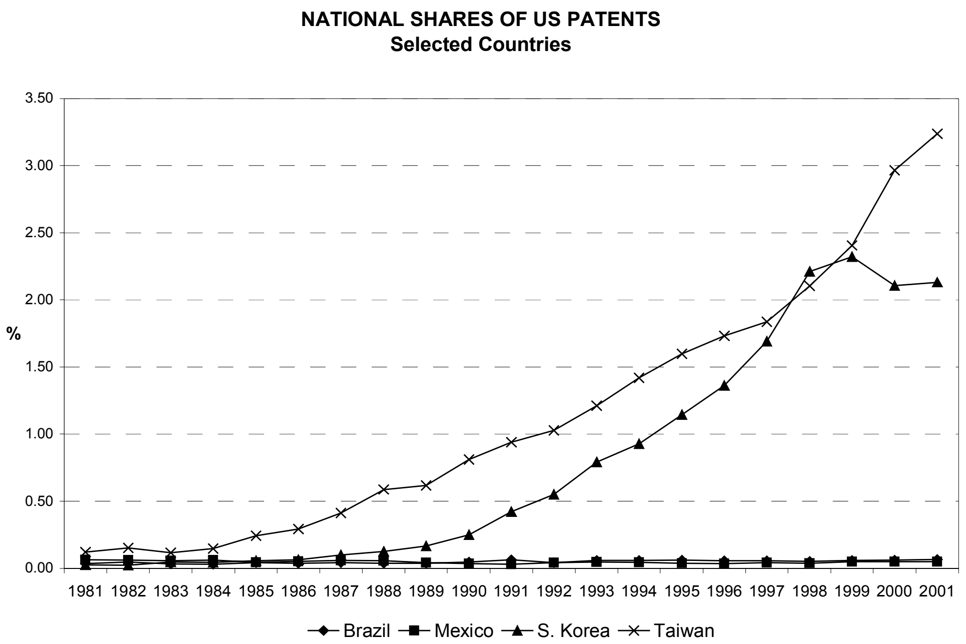
SOURCE: KEY INDICATORS OF THE LABOUR MARKET 3RD EDITION, ILO, GENEVA, 2003 (TABLE 18B-LABOUR PRODUCTIVITY AND UNITY LABOUR COSTS, MANUFACTURING)
NOTE: PRODUCTIVITY IS MEASURED AS ANNUAL OUTPUT DIVIDED BY PERSON EMPLOYED. OUTPUT IS MEASURED IN TERMS OF PURCHASING POWER PARITIES (PPPS).

Figure 7



SOURCE: ISI.

Figure 8



SOURCE: USPTO

Table 2

US PATENTS AND SCIENTIFIC PUBLICATIONS
Selected Countries
(1981-2001)

	BRAZIL				MEXICO				S. KOREA				TAIWAN			
	Patents		Publications		Patents		Publications		Patents		Publications		Patents		Publications	
Years	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
63-80	307	0.03			1033	0.09			85	0.01			236	0.02		
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	640	0.14
1984	20	0.03	2,268	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	1,088	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	1,272	0.26	84	0.10	872	0.18	343	0.41	1,440	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	3,076	0.57	39	0.04	1,413	0.26	159	0.17	1,336	0.25	591	0.62	2,134	0.40
1990	41	0.05	3,555	0.64	32	0.04	1,487	0.27	225	0.25	1,577	0.28	732	0.81	2,680	0.48
1991	62	0.06	3,926	0.69	29	0.03	1,635	0.29	405	0.42	1,944	0.34	906	0.94	3,204	0.56
1992	40	0.04	4,640	0.77	39	0.04	2,015	0.33	538	0.55	2,485	0.41	1001	1.03	4,315	0.71
1993	57	0.06	4,488	0.75	45	0.05	2,199	0.37	779	0.79	3,016	0.50	1189	1.21	4,752	0.79
1994	60	0.06	4,836	0.76	44	0.04	2,501	0.40	943	0.93	4,037	0.64	1443	1.42	5,829	0.92
1995	63	0.06	5,508	0.83	40	0.04	2,916	0.44	1161	1.14	5,405	0.81	1620	1.60	6,667	1.00
1996	63	0.06	6,053	0.90	39	0.04	3,282	0.49	1493	1.36	6,445	0.96	1897	1.73	7,497	1.11
1997	62	0.06	6,747	1.00	45	0.04	3,587	0.53	1891	1.69	7,841	1.16	2057	1.84	7,768	1.15
1998	74	0.05	7,920	1.13	57	0.04	4,031	0.57	3259	2.21	9,558	1.36	3100	2.10	8,616	1.23
1999	91	0.06	8,954	1.25	76	0.05	4,492	0.63	3562	2.32	11,058	1.54	3693	2.41	8,961	1.25
2000	98	0.06	9,516	1.33	76	0.05	4,587	0.64	3314	2.10	12,231	1.71	4667	2.96	9,224	1.29
2001	110	0.07	10,555	1.44	81	0.05	4,948	0.67	3538	2.13	14,641	1.99	5371	3.23	10,635	1.45
Total	1373	0.04			1988	0.06			21707	0.67			30017	0.92		

SOURCE: USPTO AND ISI.
NOTES: PATENTS # EQUALS TOTAL NUMBER OF INVENTION PATENTS GRANTED BY THE USPTO TO 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 PUBLICATIONS.

5. POLICY IMPLICATIONS FOR LATECOMERS[24]

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.

The broad objective should be targeting active learning, i.e., to build the institutions and the right set of incentives and disincentives in order to foster active 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 should target fields that are more promising for nurturing the development of an innovation process within the country.

Latecomers S&T policy and corporate strategy become a feasible objective for nations and firms because it does not need to replicate institutions like NSF, MIT, NIH or the old Bell's Lab. R&D for adaptation and improvement, manufacturing extension, technical assistance, demonstration and

24 The present section just outlines the main ideas that will be further developed and presented during the Globelics conference.

diffusion, networking of producers-suppliers and labs, and benchmarking becomes essential.

Firm's shop floor is essential 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.

S&T policy must be articulated with economic, industrial and educational policies.

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

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

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