CHAPTER 4

Perspectives on Latin American Technological Innovation

Patricio Meller and Joaquín Gana

Introduction

In the global economy of the twenty-first century, technological innovation is fundamental for emerging countries to achieve three interrelated goals: to increase economic growth, to raise international competitiveness, and to generate a path toward convergence with developed economies. Yet Latin America's capability for technological innovation remains stubbornly low. This chapter analyzes why Latin American productive enterprises spend relatively little on research and development (R&D), and considers whether the region can develop an innovative and Schumpeterian entrepreneurial capacity.

Innovation and modern technology constitute a central factor in economic growth: Their contribution surpasses 50 %. This modern technology is generated mainly by multinational corporations (MNCs) of developed countries. From this it can be inferred that countries that lag behind in their level of development (i.e., emergent countries) have a great advantage: They do not need to invest resources to produce modern technology. Instead, it can be acquired from developed countries in different ways, and this generates the convergence process ("catching up") between emerging and developed countries (Gerchenkron 1962).

P. Meller (✉)
Industrial Engineering, University of Chile, Santiago, Chile

J. Gana
Corporation for Latin American Studies (CIEPLAN), Santiago, Chile

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This convergence phenomenon should be intensified in a global world. In effect, thanks to globalization and to globalization-oriented policies, there is practically free mobility in everything: free trade (of goods and services), free investments flows (foreign direct investment), free capital mobility (financial), immediate diffusion of knowledge (via the Internet), and complete access to modern technology. This has suggested the hypothesis that "the world is flat" (Friedman 2005), and that the influence of geographic distance is dramatically reduced.

Yet the empirical evidence calls into question the extent of convergence. We will examine what has happened in a period of 50 years (1950–2000) with the existing gap of per capita gross domestic product (GDP) of several emergent countries in relation to the per capita GDP of the United States (which will be used as a benchmark). The "underdevelopment gap" of the emergent country will be calculated as the relationship between two components: per capita GDP of the emergent country divided by that of the United States in 1950 and the same figures for the year 2000. The convergence hypothesis suggests that the gap should diminish. The actual results obtained show the following (see Meller and Gana 2014): (1) For most Asian countries, the convergence hypothesis is valid: Their per capita GDP in 2000 is closer to that of the United States than it was in 1950; (2) In most Latin American countries, the opposite occurred: The per capita GDP becomes increasingly distant from that of the United States.[1] Instead of convergence, there is divergence. What is the reason for such a different performance between Asian and Latin American countries? What are the factors that contribute to generate convergence in Asian countries?

The implicit assumption regarding the advantage of backwardness in emergent countries relative to the incorporation of modern technology is not generally valid (Mathews 2006). The entrance of modern technology in an emergent country does not automatically generate convergence with the development level of developed countries. Empirically, one observes that the reception of modern technology in emergent countries generates a certain technological progress, but at the same time there has also been an acceleration of the technological innovation process overall. Not all countries have the same capability to adapt to the current innovation pace.

The "flat world" hypothesis is thus overblown. As in Alice's Wonderland, it is necessary to make progress at the same speed as the average country to remain in the same place. Asian countries are advancing steadily, while Latin American countries are moving at a snail's pace and are thus lagging behind. What lessons can Latin American countries learn from Asia?

What can a Latin American country do to generate a convergent path with developed countries?

Mechanisms for Technological Transfer

There are different mechanisms associated with the promotion of technological transfer. The two main ones are trade (import of goods, machinery, capital goods, and services) and foreign direct investment (FDI).[2] Capital goods and machinery embody modern technology and incorporate R&D, which developed countries carry out to improve manufacturing products. For technological transfer to happen, emergent countries have to open up to the exterior by eliminating import barriers. In effect, imports of machinery and capital goods are an important source for the acquisition of modern technology. But this is only the first phase of the technological transference process.

The quantity of capital goods imports of a number of Latin American and Asian countries in a recent period, 1996–2011, shows the following (calculated from UNCOMTRADE):

1. In both absolute and relative terms, imports of capital goods are generally higher in Asian countries in comparison to their Latin American counterparts. In the first decade of the twenty-first century, the median value of capital goods imports for Asian countries fluctuated between 14 and 16% of GDP, whereas for Latin American countries, this median fluctuated between 4.5 and 5.5% of GDP. Therefore, Asian countries are relatively more inclined to introduce modern technology through this mechanism of capital goods imports. This would be associated with the higher investment coefficients observed in Asian countries.
2. In 2011, only four out of 15 Latin American countries displayed an import of capital goods greater than 10% of GDP: Costa Rica, Mexico, Panama, and Paraguay. In comparison, five out of eight Asian countries had capital goods imports that topped 10% of GDP. Some of them had very high percentages, such as Hong Kong (105% of GDP), Singapore (54% of GDP), and Malaysia (26% of GDP).[3]

Let us assume that we have two emergent countries: one in Latin America and one in Asia. Both countries import the same machinery in

quality and amount. The Latin American country considers imported machinery as a "black box with a plug"; the only production interest of local businesspeople is to plug in the machine. In the Asian country, by contrast, there is interest in understanding how the machine works. Thus, they dismantle "the black box" and reassemble it. This reverse engineering generates a technological learning process that is necessary to start gaining the know-how of modern technology production.

What difference does this relationship with modern technology produce in the two emergent countries? The Latin American country is a passive user. Business people there do not deem it necessary to incur the costs associated with learning modern technological know-how, as in a globally integrated world there is less cost and risk in permanently importing modern technology created by developed countries. In the Asian country, however, there is a motivation to understand modern technology in order to facilitate the process of adoption and technological adaptation. Furthermore, Asian business people have a long-term goal of producing improvements and innovations based on modern technology acquired from developed countries in order to eventually become exporters of modern technology themselves. In short, the Latin American country has a static vision of the future, which is simply a repetition of the present. The Asian country perceives the globalized world of the twenty-first century as characterized by a permanent and accelerated process of innovation. Future competitiveness requires business people to understand technology and generate technological innovations.

FDI performs a role similar to that of machinery imports in relation to the transfer of modern technology. International organizations (e.g., the International Monetary Fund, World Bank, and World Trade Organization) have argued that to stimulate development, emergent countries must implement an import liberalization process. They have also suggested that emergent countries should have a free access system for FDI without any kind of restrictions. In fact, in the 1990s, a great number of emergent countries competed with each other to attract FDI. Not only did this establish an environment of quite liberal policies, but it also provided important public subsidies (Görg and Greenaway 2003).[4] It should be noted that MNCs are the primary modern technology generators, so it seems logical that emergent countries' strategy should be oriented toward attracting MNCs (UNCTAD 2005).[5]

The implicit assumptions with regard to the benefits of FDI are: (1) For emergent countries, additional investment flows contribute to the cre-

ation of employment and growth; (2) FDI is an important mechanism of technological transfer and helps to spread modern technology in the host country, thus contributing to raising local productivity and exports; and (3) FDI increases the quality of emergent countries' capital stock because it employs the best practices of "how things are done" and incorporates modern management.[6]

In effect, MNCs are considered one of the main mechanisms for disseminating modern technology, with respect to both tangibles and intangibles. There are different ways to generate the diffusion of modern technology. One approach favors: (1) backward linkages with MNC providers; (2) forward linkages with consumers; and (3) horizontal connections between MNCs and local partners through joint ventures, licenses, and/or strategic association (Ciruelos and Wang 2005). Another approach emphasizes: (1) the demonstration effect of MNCs, or simply imitation by local companies; (2) MNC personnel who are attracted by local companies, or who leave to form their own companies; and (3) backward linkages with providers (i.e., "maquilas") (Hoeckman, Maskus, and Saggi 2004).

When comparing data on FDI in a group of Latin American and Asian countries, one sees the following: (1) In both regions, there was an important increase of FDI flows from 1990 to 2010. As a percentage of GDP, Latin America has experienced a larger relative increase of FDI incidence than Asia has. (2) If two Asian countries, Hong Kong and Singapore, are excluded, FDI was a larger share of GDP in a significant number of Latin American countries than in the Asian countries (UNCTAD 2005). In other words, FDI plays a relatively larger role in Latin American economies than in Asian ones. But what about the effect of the FDI?

Economic literature has concentrated on measuring the effects of FDI in the host country, and in particular the magnitude of the diffusion of modern technology. Once modern technology has been introduced in the emergent country, what are the mechanisms that induce the dissemination of the technology? As can be seen, this question is the same as in the case of modern technology imports. Empirical studies do not provide conclusive results. Some say that the "spillovers" from MNCs are very small or nonexistent.[7] There are even several studies that express doubts about whether FDI has positive effects on the diffusion and spread of modern technology.[8] Saggi (2002) asks, why would an MNC be interested in the diffusion of modern technology in the host country? Which objective function would it be maximizing? The rational behavior of an executive of an MNC would likely be oriented toward blocking imitation by local

companies. The advantages of MNCs are based on modern technology, management, and know-how; what incentives would an MNC have to erode this competitive advantage? In reality, this is the conduct of any business person, whether of an MNC or a local company.

If FDI does not generate "spillovers" in the host country, does this mean that MNCs have no positive impact on emergent countries? FDI performs the role of introducing modern technology in an emergent country, but who should be responsible for spreading modern technology? In the case of local companies that import modern technology, why is their very limited role in the dissemination of technology not questioned? In reality, it is the host country and the local companies that are responsible for the assimilation, adaptation, and diffusion of modern technology. If this is to happen, a capacity to absorb technology is required. This is associated with the existence of a minimum of human capital in the local country (UNCTAD 2005).

One can distinguish two types of emergent countries according to their attitudes toward FDI. One type is the totally passive emergent country, whose objective in working with MNCs is exclusively to accommodate their presence in the country. Here it would not be the responsibility of the MNC to worry about the diffusion process of modern technology. The other type is the more proactive emergent country that induces FDI to assume a dynamic role in the technological transfer process and in the diffusion of modern technology. This country encourages the constitution of joint ventures, granting licenses, and/or the use of local inputs in the production processes of MNCs.[9]

Returning to the former discussion of Latin American and Asian countries in which we considered their behavior with respect to MNCs, we would have a Latin American country acting passively when facing FDI under the assumption that in this way it will increase the probability of larger investments from MNCs in the future. On the other hand, the Asian country is more interested in learning the technological know-how of MNCs and implementing the proactive policies previously suggested. For the Asian country, the entrance of FDI is part of its technological policy (i.e., how it learns to produce modern technology). For the Asian country, the future is unpredictable and changing. What happens today may not be a good forecast of tomorrow.

In summary, confronted by both of the main mechanisms associated with technological transfer, Latin American countries have a doubly passive attitude: disdain toward modern technological imports ("what is the use of opening black boxes?") and indifference to the diffusion of MNC

technology. In contrast, Asian countries have a doubly proactive attitude: They apply reverse engineering to modern technological imports and implement specific policies to induce MNCs to generate transfer and the diffusion of modern technology.

The local existence of technological ability and entrepreneurial know-how is fundamental to generating the transfer and efficient adaptation of modern technology, and this allows the development of abilities and skills to carry out technological innovations. Which of the attitudes previously described is more prone to produce local technological capacity in an emergent country: the passivity of the Latin American country, or the proactivity of the Asian country? The answer is obvious, and the empirical evidence regarding convergence illustrates it.

Measurement of Latin American Technological Ability

In this section, we will examine several indicators traditionally employed to measure the technological ability of a country. Indicators such as R&D expenditures, human capital (number of scientists and engineers), and royalty payments reflect inputs that generate technological ability, while production generated by technological ability is measured through patents and scientific papers. By 2012, according to the World Bank (World Development Indicators, online), Latin America represented roughly 8.5% and 7.7% of world population and GDP, respectively. We will see that, concerning indicators related to technology, the relative Latin American incidence is less than 50% of their population and GDP shares.[10]

Research and Development Expenditures

R&D expenditure is considered the most representative variable of a country's level of technological capability. According to the National Science Foundation (2014), Latin America spent US$36.6 billion in 2011, which represents only 2.5% of world expenditures for R&D. The Asian region, which is much larger than Latin America, spent US$492.3 billion on R&D in 2011. This is 13.5 times what Latin America spent, a number greater than the existing gap between regions in population and GDP.[11] What is interesting is the large increase, both absolute and relative, of R&D expenditures observed in the Asian region. This region represented 24.2% of world R&D expenditures in 1996. Fifteen years later, it represented

34.3% (NSF 2014). This increase of ten percentage points illustrates the big competitive advantage attained by Asian countries.

Research and Development Expenditures

R&D expenditure as a percentage of GDP is the conventional indicator used for international comparisons of the effort and priority assigned by a country to the development of local technological capacity. Nevertheless, as we will see later, in the Latin American case, this indicator does not totally reflect the technological lag of the region.

Figures for R&D as a share of GDP for three country groups show the following (UNESCO online statistics):

1. Considering median values for 2011, Latin America is the region with the smallest R&D expenditures: 0.33% of GDP compared to 1.07% of GDP in Asia and 2.04% of GDP in the Organisation for Economic Co-operation and Development (OECD) countries.[12]
2. Observing the intertemporal evolution, one sees that R&D expenditures in Latin America vary from 0.30% to 0.33% over a period of 15 years (1996–2011), in contrast with the trends observed for Asia and the OECD, where there is an increase in R&D expenditures from 0.57% to 1.07% and from 1.63% to 2.04%, respectively.
3. R&D expenditures as a share of GDP in Asia in 1996 are 72% higher than those of Latin America in 2011. In other words, Latin America's 2011 expenditures for R&D have not even reached a level near that of Asia 15 years ago.

Contribution of the Private Sector to Research and Development Expenditures

By using total R&D expenditures as a share of GDP for international comparisons, we are implicitly assuming that the agents involved (companies, universities, and government) are similar in the different countries, but we will see that this is not the case. From the point of view of international competitiveness, it is interesting to examine what the productive sector (private and state companies) is spending on R&D. Unfortunately, the information available is incomplete.

In medium-size countries in Latin America (Argentina, Chile, Colombia, Peru, Uruguay), the productive sector contribution to R&D expenditure fluctuates between 30 and 35% of total R&D expenditure. In large countries (Brazil and Mexico), it fluctuates between 40 and 50%.

In Asian countries, the contribution of the productive sector to R&D generally exceeds 50%, and in some countries (China and South Korea), it reaches 75%. In most OECD countries, the productive sector contribution to total R&D generally fluctuates between 60 and 70% (UNESCO, online statistics). Given the total share of productive sector R&D, and since the percentages in Latin America are around half the values observed in Asia and the OECD, the figures traditionally used (total expenditures for R&D as a share of GDP) underestimate the differential between Latin America and the rest of the world.[13]

Considering private R&D as a share of total R&D also underestimates the Latin American lag. As mentioned previously, in a globally competitive world, all productive companies compete with each other "on an even playing field." So, what a company spends for R&D influences its efficiency; the more it spends for R&D per worker, the greater its competitiveness. Consequently, the best indicator to determine future competitiveness of a company will be the R&D expenditure per worker measured in US dollars per employee. In a "flat world," the competitiveness generated by R&D is not measured by the share of GDP but by employing monetary magnitudes in US dollars per worker.

In Latin America, in 2011, only Brazil spent more than US$100 per worker for R&D, followed by Mexico, which spent US$72 per worker. Most of the other Latin American countries have figures inferior to US$50 per worker. By contrast, in Asia, there are two countries, South Korea and Singapore, that spent over US$1300 per worker, while China, Hong Kong, and Malaysia spent over US$200 per worker. Similarly, there are several OECD countries (Germany, Denmark, Finland, Israel, Japan, Sweden, and the United States) that spent over US$1500 per worker.[14]

The central question suggested by these figures is the following: Why do Latin American productive companies invest relatively little in R&D? Considering that the degree of globalization will increase more and more, therefore generating a greater level of interdependence, how will Latin American companies be able to compete with Asian and European companies if the latter spend 30 times more for R&D per worker?

Licenses and Patents

Licenses

Licenses can be a substitute for FDI in the acquisition of modern technology, but MNCs can include clauses in the licenses that restrict alterations of

design for the local company. MNCs might prefer FDI in order to internalize transactional costs and to prevent losing control over technology. There is plenty of literature that examines the role of "national culture" or "degree of confidence" in the host country in relation to MNCs' preference for FDI over licenses. On the other hand, the host country may have a preference for licenses over the entrance of MNCs, since this could facilitate the acquisition of technological know-how embedded in modern technology, as is the case with South Korea (Lee 2013: Chap. 2). As previously seen, machinery imports could also be considered a substitute for FDI and licenses. In this case, local business people would have a less proactive attitude in the acquisition of technological know-how. Let us consider the amount spent on licenses as an indicator of a local business person's preferences when trying to acquire know-how embedded in modern technology. If we examine the amounts of payments for licenses (or royalties) in three geographical regions, we can conclude the following (World Bank, World Development Indicators, online):

1. In 2011, Latin America represented only 3.4% of world expenditures for licenses, while Asian countries represented 19.3%.
2. From 2006 to 2011, Latin America increased its expenditures for licenses by 51%.[15] In spite of this important increase, Latin American expenditures decreased relative to the global total. During the same period, Asia and the rest of the world increased their expenditures for licenses by 84% and 63%, respectively. This is the "Alice in Wonderland" effect regarding Latin America's relative backward trajectory.
3. The Latin American countries that stand out for paying over US$1000 for licenses are Brazil, Mexico, Chile, and Argentina.

Another indicator associated with licenses, which also gives an idea of the degree of control (or existence of adaptation and transfer) of modern technology, is the amount of royalties received by national companies. At the global level, Latin America received US$1.2 billion in royalties in 2011, which represented only 0.5% of total world payments. Asia received US$7.8 billion, which represented 3.1% of world payments (World Bank, World Development Indicators, online).

Patents

Most empirical studies consider patents a reflection of the technological change in a country, so they are supposed to be a good indicator of its degree of innovation ability (or control of modern technology). In this

section, we will present two indicators: total patenting and patents registered by country residents.

Figures of total patenting reveal Latin America's lack of importance in world patenting. In the twenty-first century, Latin America has had a total patenting level that fluctuated between 46,000 and 59,000 patents per year. This represents 2.4–3.5% of the overall global number. Asia had more than 750,000 patents in 2011, which represented 39% of world patenting. Just 15 years earlier, this region had less than 150,000 patents per year (World Bank, World Development Indicators, online). How did Asia manage to increase the number of annual patents at an average rate of 11.4% per year for 15 years?

The number of applications for patents by local residents presumably better reflects the country's own capacity for technological innovation. In this case, residents of Latin American countries received around 5000 patents a year in 2011, which is close to 0.5% of world patenting (by residents). Asia has an annual output of resident patenting which is 100 times larger. In 1996, Asia represented only 14% of resident world patenting. Fifteen years later, it represented 45% of the world total (World Bank, World Development Indicators, online). How did Asia increase its (resident) patent level from 93,000 annually to 567,000? Who is generating this enormous expansion in the number of patents? What is the incentives system that induces patenting? And what role do local universities play? All of these questions need to be answered for Latin America to increase its capacity for technological innovation.

Researchers in Private Research and Development and Scientific Papers

Private Research and Development

Assuming that the global competitiveness of companies depends mainly on R&D carried out internally, the pertinent variable would be the number of researchers involved in private R&D in a region (or country). In the first place, let us consider the total number of researchers dedicated to R&D. From this total, we will examine what percentage of them practice R&D in the private sector. In Asia and the OECD, the percentage of researchers dedicated to private sector R&D fluctuates around 45% of total researchers, while in Latin America, the equivalent percentage is generally less than 10%. In other words, contrary to what happens in Asia and the OECD, in Latin America, most of the researchers dedicated to R&D

(almost 90%) are not in productive companies (UNESCO, online statistics). Presumably, most Latin American researchers are in universities or in public agencies. What accounts for this particular distribution of Latin American researchers? Is there little demand for researchers from Latin American productive companies? Or is there a preference among Latin American researchers for primarily conducting academic research?

The effect of the pro-university bias of Latin American researchers, which consequently has negative effects on the competitiveness of productive companies, is indicated by the number of researchers involved in productive R&D expenditures per worker. In Latin America, the number of researchers involved in R&D per million workers is in the single digits, whereas in Asia and the OECD, the number of researchers involved in R&D per million workers is in the thousands. The gap between Latin America and Asia/OECD fluctuates between 20 and 30 times, which is consistent with the differentials related to expenditures for R&D in US dollars per worker.[16]

Scientific Publications

The observed bias of Latin American researchers for academic research in universities should have an effect on Latin American contributions to scientific papers in the world. The data indicates the following: (1) Latin America and Asia produced a similar percentage of the world's scientific papers in 1996: 2% and 3%, respectively. (2) In the following 15 years, Latin America increased its annual production of scientific papers by 127%, which elevated its percentage relative to the world from 2 to 3.3%. But, over the same period of time, Asia increased its annual production of scientific papers by 493%, accounting for 13.3% of global output.

The growth differential in scientific papers between these two regions is associated with the large differential of students that have completed their doctorates. For the effect of generating technological innovation, it is interesting to observe the following figures for PhDs in science and engineering who graduated in the United States from 1989 to 2009. To candidates from China, India, and South Korea, there were 57,705, 24,809, and 21,846 PhDs awarded, respectively. The only Latin American country for which there is equivalent information is Mexico, where only 3589 PhDs were awarded in science and engineering from US universities.

Summary of Results

The contrast in technological indicators between Latin America and Asia is overwhelming. Although Latin America has shown advances in absolute

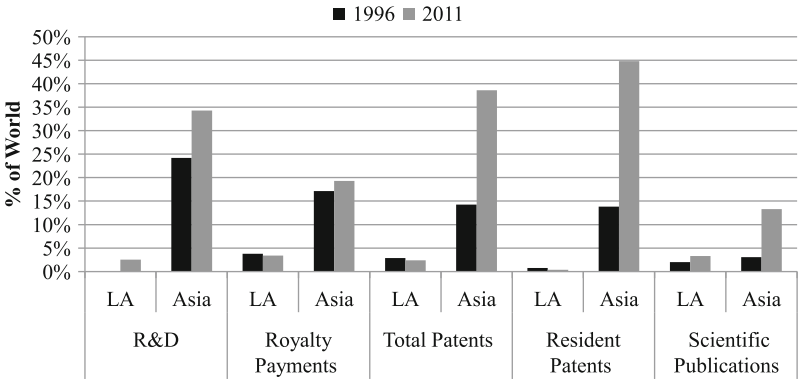

Fig. 4.1 Latin America and Asia relative technological indicators, 1996-2011. *Sources*: R&D from the National Science Foundation (2014). Other variables are from the World Bank (World Development Indicators, online). *Notes*: Asia includes Japan in R&D/Royalty Payments 1996 correspond to 2006/2011 Publications are 2009

terms in several of the indicators reviewed here, its position in relative terms has stagnated or worsened over time. In other words, the region has shown slower improvement than the rest of the world. In contrast, Asia has moved faster than the world average and staked out top positions in relative terms during the same period of time (see Fig. 4.1).

Technological Innovation in a Non-Flat World

The Role of Multinational Corporations of Developed Countries

MNCs of developed countries are the main generators of technological change at the global level. The indicators we considered in the previous section stress the importance of the private sector's share of R&D expenditures in OECD countries and, increasingly, in some Asian countries, such as South Korea and China. In this section, we will examine the importance of MNCs in technological change at the global level.

An empirical synthesis of the influence of developed countries' MNCs on world expenditures for R&D reveals the following (UNCTAD 2005): (1) The MNCs of developed countries are the dominant source of global expenditures for R&D, representing more than 50% of the total; (2)

Developed countries' MNCs represent more than 75% of private world expenditures for R&D; and (3) Many developed countries' MNCs spend more on R&D than do the majority of individual emergent countries as a whole. Relative to the two largest countries in Latin America (Brazil and Mexico), many of the 700 largest MNCs (e.g., Toyota, Roche, Microsoft) spend more for R&D than all of Mexico, and these three MNCs together spend more than all of Brazil. If the world were really homogeneous, with complete information available to all economic agents situated in any geographic site, it should be expected that technological innovation would be uniformly distributed throughout the world. Obviously, this is not the case, and this concentration of expenditures for R&D validates Latin America's interest in attracting FDI carried out by large MNCs. But, as we will see later, there is an important difference between the productive activity of an MNC in an emergent country and its expenditures on R&D.

Most MNCs that carry out R&D are located in developed countries. Only two countries, the United States (42.3%) and Japan (22%), are home to almost 65% of the MNCs that spend the most on R&D (UNCTAD 2005). In terms of industries, expenditures of the 700 MNCs that spend the most on R&D are found in the following sectors: information technology (21.7%), automobiles (18%), pharmaceutical and biotechnology (17.5%), and electronics and electrical products (10.4%). During the twentieth century, expenditures for R&D by MNCs constituted an activity that was rarely practiced outside of the home country. This is because of its strategic importance and because it requires advanced levels of knowledge, especially tacit. Eventually, MNCs started to carry out R&D away from their countries of origin, but the destination of these investments was mainly other developed countries. MNCs did invest in R&D in emergent countries, but this was oriented toward adapting products and processes to the local market. In the twenty-first century, the amount of R&D carried out by MNCs away from their home countries has been growing, and there has been an important change: Recipient countries are no longer just developed countries but also emergent countries. Formerly, the innovation dynamic consisted of MNCs generating new ideas at home and exporting them to emergent countries, especially in Asia. Today, R&D has become polycentric. On the one hand, MNCs are creating centers of R&D around the world, both in developed countries as in emergent countries.[17] On the other hand, MNCs have arisen in emergent countries that have their own centers of R&D.[18]

What are the factors that influence the location of MNCs' R&D activities in other countries? This analysis suggests the type of policies a country should adopt to attract R&D (Guimón 2009). Lee et al. (2011) state that there is a crucial difference between developed countries and emergent countries: The MNCs of developed countries locate their R&D in those developed countries where there is substantial local productive sector involvement in R&D, whereas MNCs locate their R&D in those emergent countries where there is substantial public investment for infrastructure to do R&D ("crowding-in").

The relative importance of MNC expenditures for R&D within an emergent country is very heterogeneous. There are countries like Ireland and Singapore where national expenditures for R&D are mainly carried out by MNCs (72.1% and 59.8%, respectively). Then there is a set of emergent countries, including Brazil and Mexico, where the expenditures of MNCs for R&D represent between one-half and one-third of national expenditures. Finally, countries like South Korea and Japan stand out for their low share of MNC involvement in national R&D expenditure (UNCTAD 2005).

Attraction of Multinational Corporations for Research and Development

The Latin American Evidence

Let us examine what happened in Latin America with the presence of MNC R&D centers during a recent ten-year period (2003–2013). In terms of projects and expenditures, the presence of R&D centers belonging to MNCs is highly concentrated. Table 4.1 shows that half of the projects were realized in Brazil, followed by Mexico and Chile. The situation is similar in terms of expenditures: Brazil accounted for two-thirds of total expenditures (in US dollars) for R&D, while Mexico and Chile together represented almost 20%. The same pattern appears when considering the ten largest investments: Brazil attracted eight while the other two went to Mexico and Puerto Rico. By geographical origin, practically half (47%) of the region's projects from 2003 to 2013 belonged to MNCs coming from the United States, followed by 11% from Germany. Further back were Spain, Great Britain, Switzerland, and Canada, with each accounting for close to 5% of total projects.

Table 4.1 MNC projects for R&D Centers in LA countries, 2003–2013

Countries	*Projects*		*Expenditures*	
	No. of projects	*Total (%)*	*US$ Mn*	*Total (%)*
Brazil	48	50	3,146	66
Mexico	17	18	450	9
Chile	10	10	405	9
Puerto Rico	5	5	224	5
Panama	4	4	117	2
Colombia	3	3	117	2
Peru	3	3	86	2
Costa Rica	3	3	68	1
Argentina	1	1	65	1
Uruguay	1	1	35	1
Total	95	100	4,713	100

Source: Fdimarkets.com, FDI intelligence Financial Times (2013)

Brazil

The influence of the host emergent country's policies depends on its promotion of R&D through investment promotion agencies and the strengthening of the national innovation system (UNCTAD 2005).[19] There is a broad range of available options for meeting these objectives: public R&D, technological infrastructure, human capital, financial and fiscal incentives for private R&D, intellectual property systems, formation of clusters around MNCs, achievement requisites, and post-investment service attention (Guimón 2013).[20]

What explains the great Brazilian success as compared to the rest of Latin America? Is it consistent with the factors and/or domestic policies suggested in the literature? Certainly, the Brazilian case has several of the aforementioned components, but its two main attractions are the following: It is the largest country in Latin America, with one-third of the region's GDP and population; and it presents the highest levels of expenditure for R&D (1% of GDP) in the region and in absolute terms. In line with the former and based on the 54 affiliates of the major MNCs that carry out R&D in Brazil, Galina et al. (2013) emphasize that the main attraction factors are linked to technology[21] and market size.[22] This helps to explain part of Brazil's relative success, but some researchers still question Brazil's performance.

Zanatta et al. (2008) compare Brazil with a set of successful countries, including direct competitors for R&D like China and India, and conclude that selectivity, coordination, and continuity of domestic policies help to create a favorable environment for this type of investment. Their main criticism of Brazil focuses on the lack of specific domestic policies to attract FDI, either general or R&D-intensive. The passive Brazilian attitude could be explained by the empirical fact that many centers dedicated to R&D have already entered the country. Since this is the case, why would Brazil need specific measures to attract them?

The Brazilian government has responded in part to this criticism in recent years. In 2012, the Science and Technology Department started TI Maior, a strategic plan of US$220 million over four years, in an effort to boost the software industry through several measures and incentives. Among the explicit goals was to attract MNC R&D centers that were awarded to Microsoft, Intel, EMC, and SAP. However, factors linked to the presence of MNC R&D in Brazil emphasize the size of the market and better technological capabilities in relation to the rest of Latin America, rather than a coordinated technological policy, as the reason for their appearance. This is consistent with the type of medium or low complexity R&D mainly carried out in Brazil, like the adaptation of products to new markets, among others. In short, the rest of Latin America would not be able to replicate the Brazilian experience because it lacks a similarly large market and high-quality human capital.

Costa Rica

Costa Rica provides a contrasting example to Brazil. This country managed to attract Intel in 1996, demonstrating that very small economies (3.5 million inhabitants) can also be successful in these initiatives. The arrival of Intel started a substantial transformation and productive diversification process, which was reflected in the composition of the export basket in the following years. While in 1995, technological goods exports were practically nonexistent, in 2011, they rose to US$12.4 billion, representing more than 50% of total exports (MIT Atlas of Economic Complexity, online). The primary long-term effect of Intel's arrival in Costa Rica was its demonstration that the country could be a friendly platform for FDI.[23] After the arrival of Intel, a number of MNCs followed, among them Hewlett Packard, IBM, Sykes, and Procter and Gamble, which generated a technological cluster. Other equally relevant effects include their contribution as exporters[24] and the provision of training in human capital.[25]

The arrival of Intel is due to characteristic factors typical of Costa Rica (i.e., its political and social stability), its bargaining strategy, and its specific concessions.[26] Regarding this last point, the key factor was the government's commitment to comply with the need for physical infrastructure and educational quality. Additionally, the government stipulated free commercial districts where profits were tax-free during the first eight years, and only 50% over the following four years.

In spite of its positive impact, in 2014, Intel announced the closure of its microprocessing factory in Costa Rica for reasons of efficiency. The factory will be relocated to Vietnam and Malaysia, countries with lower labor costs. Is this the end of the technology incorporation process for the Costa Rican economy? Probably not. An exogenous factor caused the departure of the most emblematic MNC in the country, but Costa Rica's technological policy that consistently favors FDI can help not only to maintain, but also to increase, the presence of other companies.[27] IBM plans to increase its investments in the country, which suggests that the space left by Intel can be an opportunity for other MNCs. It must be pointed out that Costa Rica's technological cluster is not oriented toward manufacturing but rather toward services (software and programming), giving it more flexibility in the future.

Ireland

The example par excellence of attracting FDI as a development motor, including firms intensive in R&D, is Ireland.[28] The Irish strategy consisted of promotion through low tax rates for companies and selectivity of investments coming from abroad. All of this was sustained by a national consensus about the positive effects of FDI. The objective was to convert Ireland, a small economy with few initial comparative advantages, into an export platform of services and more sophisticated goods to the European Union. This strategy has been positively evaluated.[29]

A relevant part of Ireland's success is due to the role played by the Industrial Development Agency, founded in 1949. In addition to attracting MNCs, it also operates a number of support instruments for when they arrive. This role has evolved according to the development stages of the country. At first, the challenge was to generate jobs, but later it changed to promoting Ireland's innovation and insertion into more sophisticated segments of international value chains.

In short, greater selectivity of investments is not a new policy, but rather has deepened since 1970, with a clear bias toward more complex goods such

as electronic and pharmaceutical articles, and biotechnology. Attracting Intel, Microsoft, and later Hewlett-Packard in the early 1990s turned out to be a pivotal moment, after which Ireland began to strengthen the electronics cluster, which was constantly supported by the government by way of forming human capital and other necessary inputs. Incentives evolved as the country developed: While fiscal exemptions were previously used for the installation period, at present cash grants are available exclusively for training in R&D. When comparing Ireland with Latin American countries, we observe that the former's budget for promotion and incentive efforts is 15 times larger than those of Latin American countries (Gligo 2007).

Buckley and Ruane (2006) provide a synthesis of the main lessons of the Irish case for emergent countries: (1) Recipient countries must never stop being proactive; (2) Recipient countries should adopt an MNC-centered approach; (3) Sector priorities require a selectivity of projects; (4) Selectivity of projects requires a cost–benefit analysis, strategic negotiations, and strong structures of governance to avoid corruption; (5) Incentives based on both fiscal and financial results should operate correctly; and (6) There are limits to potential local linkages due to the progressive creation of more global value chains.

Role of Intermediate Institutions in Technological Transfer

Multiple actors are linked to the technological transference and innovation process, all of whom have difficulties interacting with each other: universities and companies, business people and the state, big businesses and small and medium enterprises, providers, and so on. Intermediate institutions were created in developed countries to connect the different sectors. Brazil is among the three main exporters of orange juice, soya, and pork meat. Chile is one of the two main exporters of salmon and special varieties of fresh fruit. In both countries, intermediate institutions played an important role, focusing on adaptation and technological transfer: Brazil's EMBRAPA (Brazilian Corporation for Agricultural Research) and Fundación Chile (Andreoni and Chang 2014).[30] These institutions connect different actors to promote technological transfer and innovation, but both institutions also generate comparative dynamic advantages. Let us examine two concrete cases.

The "miracle of the Cerrado" is a great MNC success story. The Cerrado was a large zone of the Brazilian pampa where it was thought nothing could be produced. EMBRAPA's strategy to transform the Cerrado into

productive land had several stages (Andreoni and Chang 2014): (1) In the 1990s, the barrenness of the Cerrado was reduced by spraying limestone, while at the same time, EMBRAPA generated a bacterium that reduced the need for fertilizers for this very dry land; (2) EMBRAPA transformed the soya that was harvested in temperate climates to a soya that could be harvested in tropical climates through a genetic modification of the soya seed. This variety of Brazilian soya accelerates the productive cycle, allowing for two annual harvests. This is how Brazil became the top global soya producer in 2013, producing 88 million tons of soya (a high percentage in the "nonproductive Cerrado") and displacing the United States.

The main success of Fundación Chile is salmon production for export. Fundación Chile created a pilot company dedicated to salmon cultivation and looked for the best available technology in the world to solve the technological problems of foreign companies that had previously failed in Chile. Fundación Chile built a fresh water pisciculture operation in the south of Chile (Coyhaique), opened sea cultivations of roe, and started a "cages to feed salmon" program. After an experimental process, Fundación Chile managed to create an efficient productive company able to export salmon at a competitive price in the world market. Since Fundación Chile is a nonprofit (public/private) institution, it began a pedagogical program to spread the technology of salmon production among Chilean business people. Fundación Chile's pilot company was a showcase for local business people that verified the profitability of the business and taught the know-how of salmon production. At present, Chile is the second largest salmon producer in the world, with exports exceeding US$3 billion in 2013.

From these two cases, one can infer that EMBRAPA and Fundación Chile have been key factors in the creation of new export markets for Brazil and Chile. This implies that these institutions have generated dynamic comparative advantages. To this effect, EMBRAPA and Fundación Chile have carried out the following functions: (1) promoting technological transfer through the identification, adaptation, and development of productive techniques to geographic (natural) local conditions, which includes different and complex processes of experimentation (laboratories, etc.); (2) spreading, disseminating, and transferring technology and the resulting productive techniques to private domestic companies (Andreoni and Chang 2014).

The fact that both EMBRAPA and Fundación Chile are nonprofit institutions and that the public sector plays an important role solves the incentive problem resulting from failure to internalize the acquired tech-

nological know-how. On the contrary, EMBRAPA and Fundación Chile consider that a fundamental part of their work is to contribute to the expansion and diversification of the national export basket. To achieve this goal, the involvement of national private companies is fundamental.

Final Observations

Although Latin America showed advances in absolute terms in many of the technological indicators reviewed between 1996 and 2011, its global position in relative terms has remained the same or worsened. The region has improved more slowly than the rest of the world. In comparison, Asia has improved its position more quickly than the world average over the same period of time. In summary, Latin America maintains a relatively low technological position and has been at a standstill in the last 15 years, while Asia has shown notable technological improvement.

The central question related to this phenomenon is the following: Why do Latin American productive companies invest relatively little in R&D? One possible answer is linked to the shortage of Latin American Schumpeterian business people. The Latin American business person is a passive user of technology. He or she does not deem it necessary to incur the costs associated with learning modern technological know-how. In an integrated global world, there is less cost and risk associated with dedicating oneself to permanently importing modern technology designed by developed countries. On the other hand, the Asian business person is motivated to understand modern technology in order to make adopting technological processes easier. Besides, he or she has the long-term goal of improving and innovating modern technology, and eventually exporting it.

In terms of policy suggestions for generating technological transfer, disseminating modern technology at a local level, and increasing innovation, there is no single prescription. Given the existing delay, Latin American countries should apply a number of measures in different areas. On the public policy level, there must be a strengthening of the national innovation system and priority given to the promotion of and investment in R&D centered on productive activities. This implies investment for technological infrastructure and human capital. Additionally, countries should establish financial and fiscal incentives, such as tax exemptions, to stimulate private R&D, and strengthen intellectual property laws. Countries should also stimulate the formation of clusters around MNCs, which includes

strengthening the links between MNCs and other economic agents, and boosting the capabilities of national agents in order to increase their capacity to absorb technology.

The policy of attracting MNCs and foreign investments should become a central component of local technological policy, similar to that present in some Asian countries. In this sense, the local priority given to MNCs would center on maximizing the transfer of know-how from these companies instead of concentrating on maximizing tax revenues. To maximize technological transfer from MNCs, countries should encourage the constitution of joint ventures, promote the use of licenses, and establish human capital training programs in foreign investment agreements.

Latin American universities must review their engineering curricula and introduce courses related to the reverse engineering of an extensive range of modern technologies. In addition, they must get out of their academic bubble and increase their links with productive companies. Local rankings of Latin American universities should use the number of patents as the main indicator of achievement. In our opinion, the "conversion rate" of patents and articles published in top-ranked (ISI) international journals should be one to two (i.e., one patent equivalent to two ISI papers). The number of patents should also influence the promotion system in academic careers at least for faculty in science and engineering. Finally, emergent countries should always be proactive. This includes having a national development strategy with a specific role for MNCs.

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Notes

1. In this chapter, unless otherwise indicated, Latin American countries include Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Mexico, Panama, Paraguay, Peru, Trinidad and

Tobago, Uruguay, and Venezuela. Asia includes China, Hong Kong, India, Indonesia, Malaysia, Singapore, South Korea, and Thailand.

2. Other mechanisms suggested for technological transfer are the role of exports (Hausmann et al. 2007), the import of know-how, and migration (Hoeckman et al. 2004). Later on in the article, licenses and royalties as well as joint ventures will be examined.
3. Note that the very high values for Hong Kong and Singapore reflect their role as entrepôts, which handle a large volume of re-exports.
4. These public subsidies fluctuated between US$30,000 and US$150,000 for employment generated by FDI (Görg and Greenaway 2003).
5. In this chapter, FDI and MNC will be used as equivalent concepts.
6. See Saggi (2002), Görg and Greenaway (2003), and Hoeckman et al. (2004).
7. See references in Saggi (2002).
8. Görg and Greenaway (2003) go through several econometric studies and conclude that "there is no effect (statistic) of MNC on the productivity of local firms."
9. Saggi (2002) suggests in this regard that a "pure policy" (no restrictions) for FDI is not feasible in the real world.
10. It is relevant to point out that the data must be considered as estimates of the corresponding year and not as exact figures.
11. By 2010, Asia represents around one-fourth of the world GDP and had almost 60% of the population.
12. For the comparisons with the OECD, the OECD does not include Chile, South Korea, and Mexico, which are assigned to their respective geographic region. Asia includes South Korea, Hong Kong, and Singapore.
13. The differentials previously mentioned should be multiplied by two.
14. UNESCO (online statistics) for R&D and World Bank (World Development Indicators, online) for labor force.
15. The calculations were made with current US dollars; this was a period of low world inflation.
16. UNESCO (online statistics) for R&D, World Bank (World Development Indicators, online) for labor force.
17. The Microsoft laboratory in Beijing has developed very sophisticated software that permits computers to recognize handwriting.
18. "The world turned upside down" (*The Economist*, April 15, 2010). Huawei, the large Chinese telecommunications company, is already one of the companies that is at the forefront of world patenting.
19. This includes both strengthening links between MNCs and other agents and boosting the capacities of domestic agents in order to increase their absorption capacity.

20. Guimón (2013) provides a review of domestic policies used to attract R&D-intensive FDI in the case of emergent countries.
21. The main variable emphasized was availability of qualified human capital, followed very distantly by academic excellence and favorable incentives.
22. Proximity, size, growth, presence of the company's manufacturing unit, and strategic business interest.
23. World Bank (2006) provides a synthesis of Intel's effect on Costa Rica nine years after its arrival.
24. In 2012, they represented almost 20% of Costa Rican exports; in 2005–2012, they represented almost 6% of the GDP of the country.
25. See Monge-González and González-Alvarado (2007).
26. Spar (1998) provides a detailed study of the negotiation process with Intel.
27. Intel will keep its Center of Global Services in Costa Rica.
28. This country increased its income from US$10,855 (PPP) to US$34,157 (PPP) during the period 1970–2000 in what is known as the "Irish miracle."
29. In addition to the great per capita income increase, today more than half of the manufacturing jobs correspond to MNCs, and Ireland exports several products of great complexity such as medical drugs. Likewise, the contribution of MNCs as a proportion of expenditures for R&D is one of the highest of the world.
30. See also Recart and Kuznetzov (2005) and Alves (2010).

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