TECHNOLOGY TRANSFER AND SUSTAINABLE DEVELOPMENT IN EMERGING ECONOMIES: THE PROBLEM OF TECHNOLOGY LOCK-IN

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Abstract
The transfer of technology from advanced countries to emerging economies constitutes one of the fundamental ways to pursue progress towards convergence between the two economies in terms of standards of living. Nevertheless, the level of R&D expenditure that developed countries can afford gives them a clear advantage in the technological field. It therefore seems logical for emerging countries, which have a more limited investment capacity, to try to exploit technological advances with the least possible expenditure.

This paper aims to show how the process of diffusion of "clean technologies" confronts a variety of forces at the macro level that create systematic, technological and institutional barriers to their adoption. There is abundant literature on the role of technology transfer in the development of emerging economies, but this perspective is clearly new. What needs to be borne in mind is the possibility that the transferred dominant technology may be subject to a techno-institutional lock-in at its source that does not allow the diffusion of environmentally superior alternative technologies. Care therefore needs to be taken when transferring the technology patterns in force in advanced countries mimetically to emerging economies, as emerging countries still have the chance to avoid the mistakes made by developed ones.

Keywords
Developing economies; sustainable development; technology transfer; techno-institutional lock-in

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Introduction

In recent years, technology transfer from advanced economies has been put forward as one of the fundamental pillars on which to base the search for alternative routes leading to economic growth in emerging economies, including those of Latin America, through sustainable development.

Experience has shown that often the technology transferred and used by transnational companies in emerging economies has caused significant negative externalities in these countries. Nevertheless, on occasion it is these very transnational companies which, given the pressure exerted upon them by the "reputation" factor in a globalized world, aim to be pioneers in the defence of the environment. The focus of this study, however, is not on whether the current path taken by technology transfer is the most appropriate one or the best suited to the interests of emerging economies. Nor do we intended to look in depth at the implications that the globalization of technology could have for these countries.

Rather, this paper aims to draw attention to an aspect of technology transfer that can shape its potential benefits in terms of the sustainable development of the economies receiving it. It is necessary to bear in mind that some technologies with a consolidated role in the production systems of developed countries are not necessarily optimal in environmental terms. The phenomenon of technology lock-in can make it difficult to give up a dominant technology, despite its demonstrated inferiority compared with other available alternative technologies. Care therefore needs to be taken when transferring the technology patterns in force in advanced countries mimetically to emerging economies, as emerging countries still have the chance to avoid the mistakes made by developed ones.

Section 2 of this paper covers some of the basic concepts regarding technology transfer in the context of emerging economies. Section 3 covers these concepts in the environmental field. Section 4 introduces the conventional approach to the problem of the diffusion of sustainable environmental technologies that are superior to the dominant ones, which traditionally centres on microeconomic factors relating to individual decision-making. However, there are other barriers to change, particularly forces at the macro level that create systematic, technological and institutional barriers to the diffusion and adoption of efficient and sustainable technologies. Section 5 demonstrates how in the context of the diffusion of production technologies in general, and of "clean technologies" in particular, there are *increasing returns from adoption* of technology, based on the aforementioned macro-level barriers to the diffusion of alternative solutions. Lastly, section 6 draws attention to one of the possible consequences of technological lock-in, namely the transfer of non-sustainable technologies from advanced countries to emerging economies, and covers, by way of a conclusion, some of the policy guidelines that can be deduced if the facts argued for in the previous sections are accepted.

An approach to the question of technological transfer from developed economies to emerging economies

The clear need for emerging economies to obtain new technologies enabling them to increase the yield obtained from their resources is an essential part of the search for an adequate development strategy. Nevertheless, to ensure that this development can be sustained over time, other factors need to be present in addition to the simple transfer of a technology from one place on the planet to another.

Numerous Latin American researchers in the social sciences (Caponi and Díaz, 1999; Busso, 1997) have maintained that the path emerging economies should follow in the quest for development is not necessarily the same one as that which was followed by today's advanced economies as they developed. It does not seem to be essential to take a mimetic approach in the field of technology and production in order to achieve a more prosperous economy.

However, it seems to be clear that there are a number of key factors in these models of development that should be reproduced, among which is knowing how to exploit the opportunities that arise and above all, recognizing a country's limitations. The level of research and development (R&D) expenditure that developed countries can afford gives them a clear advantage in the technology field. It therefore seems sensible for emerging countries, which have a more limited investment capacity, to exploit these advances with the least possible expenditure.

The technological innovation system in Latin America underwent a profound change in the nineties. Greater openness, deregulation, privatization of certain productive activities, led many state-owned companies that had set up major R&D and engineering departments during the preceding import-substitution phase in the fifties and sixties to reduce the scale of these operations after privatization (Katz, 1999). This process has led Latin American economies towards a development model that is less intensive in national R&D and is more dependent on technology "packages" from abroad.

Nevertheless, in the case of public and private companies, this technology transfer from abroad often comes up against a somewhat unfavourable environment. Among the key factors identified in various studies (Steenhuis and Bruijn, 2001; Guerin, 2001) as being able to facilitate or hinder the appropriate adoption of technologies by emerging economies, the following stand out: the availability of domestic financial resources; the degree of skills and training of the workforce; import regulations; the quality and quantity of local supplies of inputs; the delivery times of the inputs; basic infrastructure; working conditions; cultural attitudes, etc. Unfortunately, in many emerging economies the behaviour of these factors tends to limit rather than promote technological innovation.

The inefficiency of the technology transfer process is also often driven by the system of property rights over technologies, which are frequently in the hands of private companies, beyond the control of governmental or international bodies. It is difficult for such companies to share their technology unless they receive adequate financial compensation, and this price is often high for the recipient.

For this reason, in order to accelerate the process of technology transfer from its owners –mainly companies in advanced countries– to those requiring it –companies in emerging countries– the need arises to improve the current mechanisms of international trade in order to provide incentives to the private sector to take part in this transfer process. It is therefore essential to find new and flexible mechanisms of trade which make it possible to improve this flow, in which technology transfer should be seen as an important mechanism for economic globalization and international investment, and not simply from the static viewpoint of official aid to poor countries from rich ones (Forsyth, 1997)[1].

However, this defence of technological globalization should not be understood as a proposal to abolish national policies on technology, nor should it seek – in the words of Howells and Michie, 1997– to erect protectionist barriers around the base technology in each country. Instead, it demonstrates the need for sensitive policies which seek a compromise between national technological capabilities and those from abroad. The transfer of a new technology to a developing economy must therefore include an element of capacity to create technology in the recipient country, if it is to be successful (Platt and Wilson, 1999, page 396).

Moreover, the urgent need for new technologies felt by emerging economies should not lead one to think that the only valid technology is that being sold by developed countries. It is necessary to maintain and develop local technological innovation as far as possible, as it can often respond better to the reality of emerging economies. According to Da Silveira (2001, page 771), R&D in developing economies should not necessarily be based on the experience of advanced economies, rather it should be formulated taking their own contexts and specific needs into account.

Nor does it seem correct to think that the only relevant technology is that which forms part of those technologies considered to be in the vanguard or latest generation, as many such technologies are simply out of reach and cannot be implemented on an efficient scale in emerging economies. For instance, the unsuccessful attempt to transfer fermentation technologies used in the agrifoods industry to emerging economies offers a clear example of how transferring technologies for small scale installations can be much more successful than larger-scale initiatives, which are not suited to the reality, scale and needs of markets and producers in developing economies (Rolle and Satin, 2001).

Technology transfer from the environmental perspective

Technology transfer in the environmental field has sparked off one of the most intense debates between developed and less developed countries in recent years. We can find examples of the disagreements that have arisen in the negotiations that have taken place on climate change. Despite the commitment and conviction regarding the need to transfer environmentally-friendly technology from developed countries to less developed ones, the view of many observers is that the negotiations taking place at the United Nations Climate Change Convention and Agenda 21 have not lived up to expectations (WWF, 1997; CEPAL, 2001).

The transfer of clean technologies to emerging economies can provide vital support to the overall goals of reducing greenhouse gases (Ramanathan, 2002; Forsyth, 1997). Indeed, this issue occupies a prominent place in the United Nations Framework Convention on Climate Change (UNFCCC, 1998). However, past experience indicates that, in order to be successful, the transferred technologies must consider a series of factors (Parikh and Kathuria, 1997; Sathaye and Ravindranatah, 1998; UNESCAP, 1997; TERI, 1997), namely: (i) the type of needs of a developing economy and the degree to which the process of technology transfer is in harmony with the country's other development goals; (ii) the requirement for appropriate technologies able to meet these needs; (iii) the availability of the expertise necessary to ensure the transfer is effective; (iv) the factors related to the adoption, assimilation and adaptation of the imported technology.

The United States, one of the largest exporters of technology, maintains that technology transfer to less-developed countries is a lengthy process which cannot be expected to give short-term results. For this purpose, the US Agency for International Development, in collaboration with the United Nations Development Programme and the US Department of Commerce, have set up an *Environmental Technologies Network for the Americas* (ETNA2), the mission of which is to promote trade in environmentally sustainable technologies and to publicize investment opportunities in Latin America both among US and Latin American companies (Williams, 1996). To date, however, its success in protecting the environment has been limited and often debatable.

Experience has shown that often the technology transferred and used by transnational companies in emerging economies has caused significant negative externalities for the environment in the host countries. Impacts of this kind have occurred in a diverse range of areas of production, ranging from agriculture –pest control, cattle feed, weedkillers, etc.– to the high profile disasters caused by oil companies in the seventies in Latin American oil-producing countries such as Ecuador, Colombia, and Venezuela[2]. Obviously, this is not to say that all technology transferred or used by companies from advanced countries in emerging economies has had negative consequences for the environment in the latter.

On this point, authors such as Kiuchi and Shireman (2002), Lovins et al. (1999) or Starik (1995), postulate that it is precisely the transnational companies that are best suited to the role of pioneers in defence of the environment, given the pressure upon them to safeguard their "reputation" in a globalized world. Although it may be debatable whether this factor is given more weight in the decisions of private companies than the undiluted quest for profit, it is nonetheless the case that the need to conduct their business in a sustainable way is increasingly apparent to such companies. This is not only because they want to maintain their image or reputation in society, but also for economic reasons –reduced waste and costs– and the existence of ever stricter environmental legislation. Thus, the need to think in terms of sustainability, beyond being a fad or a publicity stunt to obtain new market segments, is becoming an imperative for transnational companies (Allen et al., 2002).

However, the focus of this paper is not on whether the current path taken by technology transfer is the most appropriate one or the one best suited to the interests of Latin American countries. Nor do we seek to analyse in depth the implications of technological globalization on these countries, a subject which has been addressed by authors such as Howells and Michie (1997), and Dunning (1998).

This paper aims to draw attention to an aspect of technology transfer that can shape its potential benefits in terms of the sustainable development of the economies receiving it. It is necessary to bear in mind that some technologies with a consolidated role in the production systems of developed countries are not necessarily optimal in environmental terms. The phenomenon of technology lock-in can make it difficult to give up a dominant technology, despite its demonstrated inferiority compared with other available alternative technologies.

Problems in the diffusion of environmentally sustainable technologies

It would seem to be clear that in order to achieve greater environmental quality without limiting productive activity, an effort needs to be made to promote innovation in sustainable technologies. There are numerous economic models which try to evaluate the impact that different environmental policies have on promoting *innovation* aimed at pollution control. Chapter 2 of Kemp (1997), contains an extensive review of these models.

However, there is a growing consensus on the potential for environmental improvement that may be achieved by the *diffusion* of existing sustainable technologies, in particular in terms of greater energy efficiency and the associated reduction in the emissions generated by the use of fossil fuels. Some of the conclusive empirical studies conducted in this field are included in the papers by DeCanio (1998), Krause (1996), and Lovins (1991); or the reports of the *Union of Concerned Scientists and Tellus Institute* (1998), *Interlaboratory Working Group* (1997), *Alliance to Save Energy et al.* (1997), and Sant (1979).

If we accept the validity of these studies, it could be asked what factors limit or hinder the rate of diffusion of these technologies. A second question is to what extent these factors are related to failures of the energy and associated equipment market (Jaffe and Stavins, 1994). To the extent that market failures are responsible, the effectiveness of traditional policies intended to promote the adoption of such technologies by means of economic incentives is placed in doubt. Instead, measures aimed at correcting market failures would appear to be more appropriate.

According to Jaffe *et al.* (2000), the main market failures that can affect the rate and direction of technological diffusion include, in particular: i) *problems of information* – information being a public good which is not always supplied by the markets. This is an important factor, in that the adoption of a technology by a number of users constitutes of itself an important source for the transfer of information to other participants, in the form of a positive externality; ii) *agency problems*, which are also related to imperfect information, may be internal or external to organizations; iii) *Other market imperfections*, such as the difficulty small businesses may experience in accessing the finance required to purchase new technologies, or the barriers to the import of foreign products which may be carriers of technology (Reppelin-Hill, 1999).

In addition to these factors, which may be attributed to market imperfections, Jaffe et al. (2000) also highlight other factors which may act as barriers to technological diffusion, related in this case to the decision to adopt the new technology: i) *uncertainty* is a factor which may limit the adoption of a new technology (Geroski, 2000). This uncertainty is present in both the evaluation of the efficiency of the technology (Mansfield, 1968), and in the evaluation of the saving of resources whose future price is unknown to the agent making the decision; ii) the *discount rate* used by the purchaser to evaluate the investment in the new technology. Numerous studies show that purchasers apparently use high discount rates to evaluate investments related to energy efficiency (Hausman, 1979; Ruderman *et al.*, 1987; Ross, 1990).

Increasing returns from technology adoption and lock-in

The microeconomic factors described above, which are linked to possible market failures or to characteristics of the individual decision-making processes of investing agents, have been the focus of conventional explanations of the difficulties experienced in the diffusion of technologies representing an alternative to the dominant technologies in the productive system. However, there are other barriers to change, in particular, forces at the macro level that create systematic, technological and institutional barriers to the diffusion and adoption of efficient and sustainable technologies.

The main reference in the literature on this point is Arthur (1989, 1990, 1994), according to whom –following conventional economic theory built around the assumption of diminishing returns– agents participate in perfect markets with full information, and so select the optimal technology. Agents' actions in the economic sphere lead to negative feedback, which produces an equilibrium that is predictable in terms of both prices and market share. The equilibrium signals the "best" option possible given the circumstances, the most efficient use and application of resources. However, in numerous areas of the economy these stabilizing forces do not appear to operate. Instead, positive feedback magnifies the effect of small economic changes. Diminishing returns imply a single equilibrium for the economy, but positive feedback makes numerous alternative equilibria possible. Thus, there is no guarantee that a particular economic result selected from among the many alternatives is necessarily the "best". What is more, once chance economic events have chosen a particular path, the choice may be locked in despite the advantages of the alternatives.

According to Arthur, most of those parts of the economy based on physical resources (agriculture, mining, etc.) are subject to diminishing returns. On the other hand, those parts of the economy that are knowledge based generally experience increasing returns. These areas require major investments in research, development and tools, but once sales begin, production can be increased relatively cheaply. As additional units are produced, the unit costs continue to fall and profits increase. Moreover, greater experience is acquired in their production and a better understanding is obtained as to how to produce additional units more cheaply. Furthermore, as the product gains a larger market share, people have a stronger incentive to buy the same product, insofar as they are able to exchange information with those people who are already using it. A technology that improves more quickly or is adopted by more agents has more chances of survival than its competitors (*selectional advantage*). Early superiority, however, is no guarantee of long-term suitability.

Thus we see that apparently inferior designs can be locked in to the production system in an evolutionary-dependent process (*path dependence*), in which fortuitous events can determine the winning alternative (David, 1985, 1997). One characteristic of the products or systems subject to increasing returns is that the progress of events can be critical. Whereas other markets may be explained by current supply and demand, it is not possible to fully understand markets subject to positive feedback without knowing the historical pattern of technological adoption (Jaffe *et al*., 2000, p. 42).

In practice, the individual decision to adopt one technology rather than another is taken on the basis of the information available at the time about the respective costs and benefits of the alternatives. Only with the passing of time, once the lock-in has taken place, can all the social disutilities of having made the wrong decision become apparent in all their magnitude. As we have seen, this derives to a large extent from the increasing returns that certain technologies produce during their development and commercialization (*diffusion*) phases and which can accelerate their rate of improvement with respect to the competing alternatives (Figure 1).

These returns are not constant as adoption of the technology grows: conventional economics focuses on the upper part, the important thing is the return obtained in the long-term equilibrium position. However, an incidental advantage in the initial phase of implementation may lead to the market's being dominated by a technology which in the end turns out to be less efficient than the alternatives.

The increasing returns from adoption of technology are explained mainly by the following factors, which support the process of self-reinforcement of the dominant alternative and hinder the diffusion of the remainder of the alternatives:

- **<u>Economies of scale</u>**. This is the best known and most obvious of the factors of increasing returns: the unit production costs decrease as the fixed costs are diluted by a greater volume of production.

- **<u>Learning-by-doing</u>** *and learning-by-using*. The first concept, taken from Arrow (1962) and Sheshinsky (1967), refers to the greater efficiency with which a technologically complex product is produced as experience with its manufacture accumulates, due to process rationalization, reduced waste, or the training of the workforce. The concept of learning-by-use is the counterpart of the previous idea looked at from the demand side: the learning effect is reinforced as adoption grows because users gain greater experience with the product and their productivity is enhanced. Both of these factors can consolidate the dominance of a technology that has achieved greater market share as a result of initial circumstances, such as an initial advantage in terms of costs which permitted lower market prices.

- **<u>Network externalities</u>**. Systematic relationships arise between technologies, infrastructures, interdependent industries and users. Positive externalities are produced because the physical and informational networks are more valuable to users as they grow in size (Katz and Shapiro, 1985; Farrell and Saloner, 1986).

- **<u>Increasing returns from information (adaptive expectations).</u>** As the number of people adopting a given technology grows, so the uncertainty is reduced and both the number of users and producers perceive a reduced risk. Their confidence in the quality and performance of the technology and in its likelihood of continuing to be available increases (Arthur, 1991).

In addition to these factors relating to the increasing returns from the adoption of a new technology –which are present at both industry and corporate level– formal and informal institutions can arise which are linked to the technological systems and which can have an important impact on their evolution (Nelson, 1994). Private –often non-commercial– institutions tend to arise if, as time goes on, the users of a growing technological systems recognize that they have collective needs and interests which can be met by setting up technical and professional associations. These private institutions can generate forces tending to cause technological lock-in through coalitions, voluntary associations and the emergence of social norms and customs (Unruh, 2000, 2001). Moreover, governments may create structures or lay down the "rules of the game" to which companies have to adapt their strategies (North 1981, 1990; Williamson, 1975, 1985). Once established, these governmental institutions tend to persist in their initial form over long periods of time (Williamson, 1997) and can have a powerful long-term impact on the evolution of technological systems. In the words of Nelson (1994), the institutional structures that might have been effective in one era, i.e. when they were young, can become inefficient as changes occur in the nature of the technologies and worldwide competition, and thus become rigid and antiquated.

Various authors have demonstrated empirically the phenomenon of technological lock-in in various spheres of productive activity. For example, Cowan (1990) discusses how, although it was considered inferior to other alternatives, light-water based technology dominated the nuclear reactor market, because, according to the author, of the early adoption and strong development of this technology by the US Navy as a system for the propulsion of submarines. When a civilian market emerged for this type of power, light-water technology had already achieved a considerable edge, thus blocking the diffusion of other alternative technologies that were ready to enter the market. With the same objective as the previous paper, Cowan and Gunby (1996) offer an empirical study in which they set out to explain why chemical control of agricultural pests remains the dominant technology despite the numerous claims made for the superiority of the main competing technology, namely integrated pest management.

Islas (1997) aims to show how, in a lock-in situation in the electricity generation field, a new technology can successfully overcome the lock-in and become competitive. The study seeks to demonstrate that this is possible by bringing increasing returns from adoption into play in specific production niches. Starting out from this proposition, Islas tries to draw a number of conclusions from the example of the gas turbine in comparison with Arthur's basic model.

Menanteau (2000) shows how different technologies for manufacturing photovoltaic cells compete. The paper analyses the mechanisms whereby one of these technologies –

crystalline silicon– has taken up a dominant position thanks to the fact that it shares the know-how it is based on with the electronic components industry. In the author's view, given the limited margins for improvement that this technology path presents, it is important to determine the possibilities of overcoming the lock-in so as to extend the learning process related to this system of generating electricity.

Conclusions: some policy guidelines regarding the possible transfer of non-sustainable technologies.

This paper set out to show how in the context of the diffusion of production technologies in general, and of "clean technologies" in particular, there are *increasing returns from adoption*. These are forces at the macro level that create systematic, technological and institutional barriers to the diffusion and adoption of efficient and sustainable technologies. There is abundant literature on the role of technology transfer in the development of emerging economies, but this perspective is clearly new and highlights that it is necessary to bear in mind the possibility that the dominant technology transferred is subject at source to a techno-institutional lock-in that has not allowed the diffusion of alternative technologies that are superior to it in environmental terms.

Care therefore needs to be taken when transferring the technology patterns in force in advanced countries mimetically to emerging economies, as emerging countries still have the chance to avoid the mistakes made by developed ones.

What does the foregoing analysis suggest regarding technology transfer policy? Two immediate implications emerge:

i) The first conclusion is that it is advisable to conduct *early evaluation* of the possible consequences of the adoption of a technology. From this first implication it also follows that it is necessary for the receiving country to have a system centralizing relevant information for this evaluation, and guiding the process of transfer and adoption along a sustainable path.

It is also necessary for the authorities in emerging economies to have a strategic vision of the technology, and to develop policies which include an evaluation of the technologies that is integrated with environmental policy (Davenport and Bibby, 1999, page 445). In this regard it is important to highlight that the rapid diffusion of a technology is not necessarily welfare enhancing (Stoneman and Diederen, 1994). A diffusion process can be "too fast" if the companies adopt a technology today which effectively limits the possibilities for adopting a superior technology in the future.

The adverse effects of a technology may be anticipated, avoided or mitigated (Coates 1998, p.37). As the development of the technological cycle develops, the possibilities for positive environmental management of the technology transfer are more limited. As a consequence, the focus has to be placed on the earliest stages of the project, i.e. planning, pre-development and pre-import.

According to Wicklein (1998), national and local governments, as well as private groups, make a continual effort to introduce forms of technology that are efficient and fit within their budgetary limits. This is particularly important in emerging economies. The extent of the need and the importance of choosing the most appropriate technology is magnified in these countries, where the margin of error is narrower due to the limitations on resources. Some authors (Date, 1984; Bhalla, 1979; Segal, 1992) have put forward a series of criteria on which to judge in advance whether a technology has potential for success in a developing economy –independence, image, individuality, cost, risk, multiple purpose–. In our view, sustainability should be added to this list of criteria.

Although it may look complex, this *ex ante* analysis of sustainability of the available technologies by a country's authorities is possible in practice. For example, Madu (1999) proposes a system of decision support for environmental planning in developing countries based on comparative multicriteria decision-making methods. The author illustrates the method with the case of carbon emissions. Given that environmental targets frequently conflict with these countries' social and economic development needs, it is necessary to approach the problem systematically, taking into account and prioritizing the conflicting targets and enabling the identification of all the technological options and factors that can have an impact on the alternative routes to achieving the country's goals. Along similar lines, Ramanathan (2002) outlines a way of ensuring the greater success of the process of transfer of clean technologies in an emerging economy via a model that makes it possible to take multiple criteria into account together with the viewpoints of numerous stakeholders.

ii) Secondly, if we accept and wish to exploit this "window of opportunity" for sustainable development in emerging economies, it is clear that it is necessary to have sufficient *financial resources* to permit these countries to acquire and adopt the best possible technologies from the environmental point of view[3]. Various empirical studies on the adoption of new technologies by emerging economies have identified the lack of access to credit as a critical barrier (Blackman, 1999).

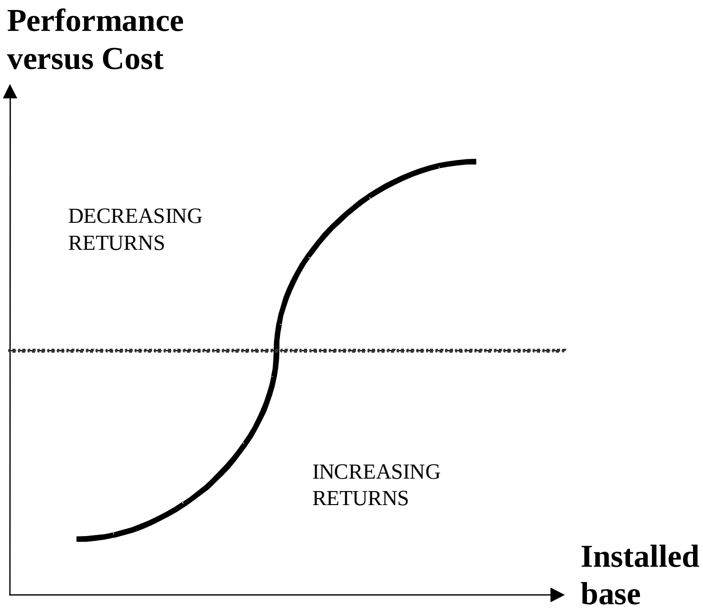
Given the inherent risk in the acquisition of a novel technology and applying it in economies of this type, these resources should probably come from official sources dedicated to financing development programmes in emerging economies. In the case of Latin American countries, we are referring here mainly to international organizations such as, in particular, the World Bank, the Inter-American Development Bank, the United Nations and CAF (Corporación Andina de Fomento). Nevertheless, it is clear that these organizations have not taken into account –at least in a clearly visible way– the need to promote the transfer of clean technologies as a path towards sustainable development for these countries[4]. Nor do they seem to have analysed in detail the environmental risks of transferring non-sustainable technologies.

Nevertheless, it is clear that these organizations have not taken into account –at least in a clearly visible way– the need to promote the transfer of clean technologies as a path towards sustainable development for these countries[4]. Nor do they seem to have analysed in detail the environmental risks of transferring non-sustainable technologies.

One of the few initiatives existing in this field is that run by the Inter-American Development Bank (2002) in the field of the development of science and technology in Latin America, which has provided finance in the form of loans and grants for pre-investment studies and technical assistance. For its part, the World Bank (2000), through its *Millennium Science Initiative*, is pursuing the enhancement of the scientific and technological capability of groups of researchers in the member countries. Nevertheless, these initiatives only tackle the technology question from a very general perspective and, of course, do not respond to the problem analysed in this article.

It is therefore necessary for international development aid organizations to set up specific instruments to support the transfer of clean technologies to emerging economies. Flexible financing routes are needed which consider the risk inherent in these operations, and which take into account the technological needs of these countries without jeopardizing their future development.

Figure 1



Source: Unruh (2000)

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Footnotes

1. Forsyth puts forward a series of mechanisms for technology transfer which permit developed countries to achieve their greenhouse gas targets while offering industrial technology to developing countries.

2. For more information on the environmental impact of agribusiness and the oil industry on emerging economies: http://home.earthlink.net; http://www.mcspolight.org

3. See UNITED NATIONS, Press Release ENV/DEV/409 (8 April 1997): "The transfer of environmentally sound technology to developing countries backed by adequate finance from private and public sources would be essential to assist them in achieving the necessary productivity (...) The number of poor people had increased and the international community had been incapable of providing financial resources and ensuring a transfer of environmentally sound technology in support of sustainable development. The increase in private financial flows should not hide the fact that such flows were directed towards certain countries and did not serve to realize sustainable development. Transfer of technology had not been achieved. Developing countries could not participate in improving the environment without appropriate assistance."

4. Indeed, according to the World Wide Fund for Nature (1997), technology transfer is a "forgotten issue" in the negotiations on climate change.