TOWARDS A THEORETICAL APPROACH TO NATIONAL SYSTEMS OF INNOVATION

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ABSTRACT

The purpose of this paper is to formulate a theoretical framework as an alternative to the neoclassical one in order to find a more consistent explanation to the phenomenon of innovation and the proces of growth. This new frame of thought, developed on the axis of the Schumpeterian process of competition and on learning as a social phenomenon, is characterized by the systemic nature of the interactions between agents and institutions

It is posited here that such interactions can be characterized by four key processes, namely: technological absorption, human capital formation, transformation (and creation of new endogenous technology) and technological diffusion. The latter is related to informational channels which allow connecting the former three processes in the most efficient manner possible. Though some of these channels operate through the markets, the process governing most of them is characteized by the existence of strong imperfections which generates a need for public intervention and calls for the creation of institutions to solve them.

SINTESIS

El objetivo del trabajo es formular un marco teórico alternativo al neoclásico para buscar una explicación más consistente al fenómeno de la innovación y al proceso de crecimiento. Este nuevo esquema de pensamiento, que se construye sobre ejes del proceso schumpeteriano de competencia y sobre el aprendizaje como un fenómeno social, se caracteriza por la naturaleza sistémica de interacciones entre los agentes y las instituciones.

Se postula en este trabajo que dichas interacciones pueden ser caracterizadas por cuatro procesos claves, los cuales configuran la parte central del sistema; ellos son la absorción tecnológica, la acumulación de capital humano, la transformación (y creación de nueva tecnología endógena) y la difusión tecnológica. Esta última se relaciona con la existencia de canales de información que permitan la conexión de los tres primeros de la forma más eficientemente posible. Algunas de estas vías operan a través de los mercados, sin embargo, el proceso que gobierna la mayoría de ellos, se caracteriza por la existencia de fuertes imperfecciones lo cual genera una necesidad de intervención pública que exige la creación de instituciones para solucionarlas.

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1. INTRODUCTION

The neoclassical model admits that firms are the key actors in the production process as they transform inputs into final goods and services with a production technology determined by the state of 'technological knowledge', –considered as a public good– from which firms choose a particular combination enabling them to maximize their benefits under the demand conditions for the product and the factor supply[1].

The logical sequence in the neoclassical model, then, comes to define a 'technological market' where supply and demand for technology interact. The firms, that change the 'best productive practice' as soon as there is a change in the price of the factors (Salter, 1960) or in the demand for the product (Schmookler, 1966), underlie the demand for technology, while the evolution of scientific knowledge, channelled through what is known as the Science and Technology System (STS), underlies the supply of technology.

Clearly a set of important inconsistencies underlie this notion. In the first place, the vision of the firms and markets is far too stylized with no room left for managerial incompetence, capital and labor relationships or oligopolistic rivalry. On the other hand, within this approach technological progress is dealt with in a very simple manner, since it is assumed to be something 'exogenous' arising externally to firms. Where does, for instance, the empirical evidence of a close correlation between innovation, firm size and non-competitive equilibrium fit in?[2]. If it is proven that the latter is true, then innovation is 'something' arising 'inside' the production system and it is a fallacy that the STS system contains the supply of technology. If this is so, Which is such a system's role? and, Does it have any raison d'être? A third inconsistency to this approach relates to the fact that

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[1] This particular combination is called the 'best productive practice' (Salter, 1960).

[2] For a summary of empirical studies on the relationship between firm size, market structure and innovation, we suggest Cohen and Levin (1989, Chapter 18).

separability annuls the interactions between the sources of growth; they enter the growth process in a multiplicative manner rather than an additive one. That is, capital accumulation (physical and human) brings about technical change, but also innovation, by increasing capital productivity, brings about accumulation. In the fourth place, the neoclassical notion also omits the existence of institutions and their interrelationships (over and above those belonging to the STS), as are the trade unions[3], the financial system, the regulatory set-up and the educational system. In the fifth place, no allowance is made for the fact that behind the 'pseudo' demand for technology there are firms operating different productive techniques, even within the same industry, which is inconsistent with the view of innovation as a 'public good' freely offered by the STS. Finally, the neoclassical theory does not recognize the uncertain and random nature of the technological search carried out by firms, that to a great extent eventually reflects the good faith of the firm's members as well as the accumulated learning throughout the firm's lifetime.

The lack of appropriate tools within the neoclassical theory –enabling authors from different schools of thought to deal with the problem of technological change in a more satisfactory manner– is what leads them to try to 'innovate' in this field. Already in the first half of this century J.A. Schumpeter posited the need to resort to technological change as a key variable to explain both the growth process as well as the discontinuities and disequilibria in the structure of production arising from it[4]. In its most primary vision[5] technological change could be explained in terms of an innovative entrepreneur and a capitalist who provides the funds needed so that innovation may have a good result that, should it take place, results in doing away with competition and obtaining benefits beyond what is normal. It is then a process of 'creative destruction' where the structure of the previous market is destroyed to give way to a new one, led by the successful innovator[6]. Innovation, unlike neoclassical technological change taking place without having any influence on relative competitiveness, is a dynamic process where there are clearly winners and losers. The only way how the competitive process may generate winners and losers ex-post is that firms make different decisions ex-ante which are only possible by introducing the concept of imperfect information.

[3] The worker, who is the main party 'affected' by technological innovation is omitted in this 'mechanistic' conception.

[4] ..."Schumpeter insisted that the objective of the general equilibrium theory was centered on aspects which, over the long term, were less important as compared to the issue on how the capitalistic economy develops, searches and selectively adopts new and better ways to do things" (R. Nelson, 1993:66).

[5] Which corresponds to the "Theory of Economic Development" written in 1911.

[6] The Schumpeterian setting of competition has a strong evolutionary nature. A firm, only restricting itself to produce a given set of products and processes, even in the most efficient manner possible, will not be able to survive in the long run. If a firm wants to be successful, it has to innovate.

The setting surrounding the agents is characterized by an overwhelming dynamics to a degree such that it exceeds an individual agent's reasoning power, thus originating a situation where it is not possible to deal with uncertain events by assigning them a probability of occurrence simply because there are no observations available or else they are irrelevant. Under this situation, the agents have different perceptions and opinions that embody themselves in different investment decisions. The existence of these ex-ante differences is what defines the different innovative trajectories for each firm. Some succeed and others fail and the market and competition choose the survivors ex-post[7].

At the beginning of the sixties K. Arrow attempted to make the technological change endogenous by resorting to a notion of 'learning by doing'. That is, increases in productivity could be explained as the outcome of improvements in the skills acquired by the labor force through the repetition in a routine fashion of the same activity. In this primitive view of the phenomenon of learning, there is a two-way relationship having automatic characteristics between production and productivity, where learning is the unexpected and, consequently, a non-internalized result of production. It is a free good (with a null price) and therefore Arrow's initial propositions are perfectly consistent with general competitive equilibrium. Even though this approach in itself does not make it possible to explain why firms adopt voluntary and different decisions in favor of innovation, the concept of learning is a notion which, though stemming from the field of experimental psychology, is fated to become deeply rooted in the theory of innovation and production.

The process of learning within the Schumpeterian frame of competition involves that the outcomes of the investment decisions multiply themselves through the accumulation of knowledge generated by the productive activity. Consequently, Dosi (1988) states that, within a dynamic context, localized learning originates in the routines performed. Within this view, learning is not only the outcome of the mechanical repetition of an activity, but also of the deliberate search for technological solutions within a setting defined by the knowledge accumulated in the organization, at the level of both the production line and marketing. The process of learning –defined within this broader notion– is what gives stability to a technological trajectory, generating winners, losers, leaders and followers and it is what accrues the Schumpeterian rent.

The analytical pattern outlined in the foregoing paragraphs is the basis of what Nelson and Winter (1982) have defined as the Evolutionary Theory of the Firm –which, in turn, as stated by its authors themselves, was developed on the basis of the contributions of Simon (1957), Penrose (1959) and Cyert and March

[7] In this context the firm's decisions are characterized more than anything else by reflecting an act of faith of the management and aspects related to the firm's tradition. There is no a priori reason for these decisions to be in fact optimum or destructive in themselves.

(1963)– where the three neoclassical assumptions are modified: i) entrepreneurs operate with a limited rationality, ii) perfect information does not exist, but instead entrepreneurs have to operate within a context of high uncertainty and iii) the assumptions on production technology are irrelevant, because it is in a state of permanent change and there is no need to ensure that the factors account for the product, since there does not exist any competitive equilibrium within this view.

As from the mid-eighties, within the context of the economy of innovation there emerged a line of thought attempting to extend the general guidelines of evolutionary macro-economics to macroeconomic behavior; it was then when the notion of the National Systems of Innovation (NSI) was developed.

2. A SYSTEMS APPROACH TO THE INNOVATIVE PHENOMENON

The concept of the NSI is not new, as it was in the middle of the XIX[th] Century that Friederich List (1841) already explored this field concentrating his attention on the economic relationships associated with the development of the productive forces and pointed out that the State had an irrecusable obligation to provide education, training and infrastructure to support industrial development; all of them are central elements of what is nowadays defined as the NSI. More recently, Freeman (1987) characterizes a NSI by defining R&D and production subsystems, the relationships between both of them and the roles of the State and of history in their configuration, applied to the case of Japan. On the other hand, Nelson (1988) in his study on the United States, identifies the strong public and private component of technological change and the role played by private firms, the government and the universities in generating it. Porter (1990) contributes four new concepts strongly affecting national competitiveness, namely: firm strategy, factor conditions, demand conditions and supporting industries; all of them with strong local idiosyncratic components, making it possible to interpret them as integral parts of a NSI. Finally, Dahlman and Nelson (1993) point out that a central element to use a technology successfully is to have technological capability[8], deeply rooted in the country's people and institutions and requiring close interactions between them for its optimal use. In the opinion of these authors, the information network and the set of agents, policies and institutions, exerting an influence on the introduction of new technology into an economy, are precisely what make up a NSI.

From the above paragraph it follows that there are two great approaches to the concept of a NSI. A 'narrow' view focuses exclusively on the organizations

[8] Defined as the ability to search, select, use, assimilate, adapt, improve and develop any technology that is the most appropriate to changing circumstances.

and institutions specifically involved in search activities and in exploring new technological opportunities (such as R&D departments, technological institutes and universities). And another, which is 'broader' and includes all parts and aspects of the economic structure and the institutional set-up having an influence on any kind of learning (production system, financial system and markets). This paper will dwell on the latter view of the NSI as it makes it possible to gain an in-depth understanding of the interactions of production, the institutional set-up and innovation.

The point of departure to characterize the NSI in a more precise manner is to define what the innovative phenomenon is. In general terms, it can be stated that there is consensus in economic science as to what the outcomes of an innovation are: new products, new techniques, new forms of organization and new markets. However, the agreement is far more restricted as regards the forces giving rise to these results. Thus, while, on the one hand, in the neoclassical theory, innovation appears either as an autonomous event arising outside the economic system which, temporarily is drawn from its steady state by the technological shock –Solow (1957)– or otherwise, in the best of cases, as a phenomenon brought about by changes in relative prices –Salter (1960) and Habakkuk (1962).

On the other hand, within the frame of the evolutionary viewpoint, innovation is interpreted as the outcome of systematic learning, searching and exploring activities, originated in the Schumpeterian process of competition. Within this approach, the strongly competitive environment where firms operate is what forces them to undertake permanent efforts aimed at introducing new processes or products, or developing new markets. The possibility of capturing finite monopolistic rents is the prize for a successful innovation. The costs of not being able to innovate or to do it less successfully, are extremely high: to remain in a marginal role in the industry as a price-taker for a long time and eventually be driven out from it. The way how the innovative phenomenon is carried out involves finding new uses for already existing components and technological possibilities or, otherwise, creating new ones. Within the first outlook, the reliance of future innovation on past developments is generated, plotting out a particular technological trajectory in time. In this sense, innovation appears not as a single event, but rather as a continuous process emerging –though with different dimensions– in all parts of the economic system.

Though the innovative process obtains inputs from scientific research, it nurtures itself from learning activities taking place in connection with production, distribution and consumption routines; it is the everyday experience of workers, production engineers and sales representatives, that has a strong influence on the path followed by innovative efforts.

"... When bottleneck problems are met and registered in production, or in the use of a product, the agendas of producers change, and affect the direction of their innovation efforts. Everyday experience also increases technical knowledge and gives ideas about in which direction solutions should be looked for. Such activities involve learning-by-doing, increasing the efficiency of production operations, learning by using, increasing the efficiency of the use of complex systems, and learning-by-interacting, involving users and producers in an interaction resulting in product innovations....." (Lundvall, 1993:9).

Thus, it is possible to claim that the technological trajectory followed by a firm is generated primarily by the disequilibria and disturbances occurring in the production process, in the performance of the product and in the relationships of the users and suppliers. These disequilibria and disturbances are responsible for bringing on a sequence of permanent technological search, which evolves to a large measure independently from continuous fluctuations in relative prices[9]. This approach strongly contrasts with the neoclassical interpretation where relative prices are precisely the only source for endogenous change and all interrelationships are completely absent.

Following Nelson and Winter (1982), the basic conceptualization of the evolutionary model begins by assuming, in the first place, a simplified economic process with an industry where the product, price, costs, net benefits and financial constraints, reflect both the routines currently followed by the firms, as well as the interaction of those routines with the production structure, and which becomes the central source of information in the learning process. Simultaneously to this, the entrepreneur conducts a search process in order to develop new production techniques. This process can be imitative, with the firm trying to attain the best productive practice in the industry[10], or innovative, with the firm exploring a space of possible new production routines. Once the search period is over, the firm decides what routine to use; that inherited from the previous period and currently in use, or that resulting from its innovative-imitative search. If there is a change in the routine, we have what is known as 'unincorporated technological change'. At a third stage, the routine chosen and the net benefits determine the desired investment level which –along with the financial constraints affecting the firm– establish the actual investment, that sets the amount of the capital stock for the coming period and, consequently, the firm's new state. During the next period, the process is recreated in the same manner.

An important inference which follows from the preceding paragraphs is that –if the technological change reflects learning, and if the latter stems chiefly from

[9] This originates what Rosenberg (1969) defines as the 'natural trajectory'.

[10] A process known as 'benchmarking' in the management literature.

routine activities– the innovation must be, at least partially, determined by the production structure. Pursuing this analysis at an interindustry level, at any moment of time there are great differences between the possibilities of incremental learning and innovation in the different sectors, that can be described in terms of the simultaneous existence, in time, of industries that have different learning curves or have attained different stages in their life cycle. In this sense, the effects that different patterns of productive specialization have on learning and innovation are important determinants of the differences in terms both of the global competitiveness between the economies and their ability to adjust in the face of macroeconomic shocks[11].

Another important implication from the above paragraphs is that the learning process does not pertain to an individual, but is strongly interactive in nature[12]. As such, it is then a social process which can not be understood unless attention is given to its institutional and cultural context. Following the sense given by Johnson (1993), we will understand institutions to be a set of habits, routines, rules, norms and laws, that regulate the relationships between the people and also model human interaction. In a world characterized by innovative activities, uncertainty is an important aspect in economic life. Institutions, insofar as they coordinate the use of knowledge, mediate in conflicts and provide the incentive system, act as elements that reduce uncertainty and, consequently, the amount of information needed for individual and collective action. In performing these functions, institutions provide the stability needed in order to reproduce society and their inertia becomes an important vehicle for technical change. As some degree of stability is needed for the less important innovations which are carried out along some established technological trajectories, institutions make it possible to concentrate efforts on them and accelerate technological progress. In addition, even radical innovations, departing from the dominant technological trajectories, depend on institutionalized behavior. Formal and informal rules –habits of thought– in engineering and in scientific work can be interpreted as time-saving elements, leaving resources free for more creative activities which bring about radical innovations. However, and following Pérez (1985), the fact that institutions provide the stability, needed for technological change, does not mean that at any moment in time they act in favor of it. There are usually tensions in incremental technological change, along the established technological trajectories, and the ability to do radically new things. If the institutional set-up defines an

[11] According to Anderson (1993), in the face of an acute and unexpected real exchange rate appreciation, the ability to respond of a specialized economy in immature sectors (where there exist opportunities for innovation) will be very different to that of specialized economies in economic sectors which have attained a more advanced stage of maturity. In the first case, it is very likely that there arises a problem of 'transformation' in which a series of tensions and subsequent solutions are arrived at with a relative balance between the different links in the production chain. In the second case, an exchange rate appreciation will have scarcely any innovative reactions, which sooner or later will generate a forced adaptation or a 'creative destruction'. This is one example of what is known as the 'macro-micro relationships'.

[12] For instance, through the interrelationships of workers and engineers, users and producers.

incentive system which favors established trajectories, it can become a very heavy burden in terms of stagnation and loss of competitiveness in periods when a new techno-economic paradigm is rising.

Briefly stated, it can be concluded that innovation is the consequence of an interactive learning process and that both the economic structure as well as the institutional framework jointly determine it.

As learning is an interactive process, the protagonist's cultural and spatial proximity is critical. Therefore, the processes of communication and cooperation between the parties involved in originating the process, in different cultural and social systems, will always be cumbersome, especially in the case of complex and uncertain processes, as is the case of innovation[13]. This becomes then a fundamental reason why it is important to define the national dimension of the NSI. Intranational relationships are normally better than international ones as a means to transfer semiformal and informal information needed for interactive learning[14]. Creating new links of an innovative type is always easier when it involves members of a national production system.

Having defined what an innovative process is and its national characteristic, we still have to analyze the systemic scope of a NSI.

To do so, we must first formally define a system. Hall (1964) defines a 'system' as a set of objects and their relationships, and the relationships between the objects and their attributes, where the objects are simply the parts or components of a system and the attributes are their properties. In most of the systems, these parts are physical[15], though they can also include abstract objects, such as mathematical variables, equations, rules and laws, processes, etc.

The above definition can be applied to societies. Johansen (1987) posits that a social system is a set of parts coordinated to attain given objectives. These

[13] As Lundvall (1993:13) states " ... in the real world the State and the public sector are rooted in national states and their geographic sphere of influence is defined by national borders. The focus upon national systems reflects the fact that national economies differ regarding the structure of the production system and the general institutional set-up. Specifically, we assume that basic differences in historical experience, language and culture will be reflected in national idiosyncrasies regarding: internal organization of the firms, interfirm relationships, role of the public sector, institutional set-up of the financial sector and R&D intensity and R&D organization." The same author holds, by way of an example, that history and culture strongly condition the behavior of economic agents in an uncertain and changing context. Thus, it is possible to identify economies where agents have a somewhat opportunistic behavior and others where they behave in a more cooperative manner; this will strongly affect the relationships capital\work within the firms as well as the relationships user/producer, which determine product innovation.

[14] By 'better' is to be understood that this transfer undergoes less distortions when it flows through national instead of international channels.

[15] For instance, atoms, stars, mass, wire, bones, neurons, genes, muscles, gases, etc.

objectives can be classified as 'evident' and 'operational', with the term operational denoting that they can be measured.

It is of vital importance for the researcher to concentrate on the total system and not on some of the component subsystems. The above is necessary, because if we want to correctly evaluate the behavior of a system, there is the need to measure costs and benefits associated with it and which may not be considered on an overall basis, should the system not be viewed as a totality and only one of its subsystems is studied. Observing the system as a totality (and not in terms of its parts) may enable us to come up with overall solutions to the problems[16].

In terms of the above, an 'evident' objective of the NSI is to increase the socially available stock of knowledge, whereas an 'operational' objective is to generate high per capita income growth rates which are also sustainable in the long run.

It follows then that an innovation system will be made up by objects (consumers, firms, institutions), their attributes (their characteristics and forms of organization and operation) and the relationships that are at work in the processes of introducing, diffusing, using and producing new and economically valuable knowledge.

The central activities in a NSI are learning and diffusing scientific and technological knowledge to society which, in turn, also involve people in interaction. Therefore, a NSI is a social system that due to its idiosyncratic characteristics will be geographically limited by national frontiers.

3. CATEGORIZATION OF A NSI IN THE CASE OF TECHNOLOGICALLY BACKWARD COUNTRIES

The definition of a NSI, presented at the end of the preceding section, can be applied to any national economy, regardless of its degree of development. What makes the difference will be the characterization of the processes and relationships taking place inside them.

[16] It is obvious that as science and technology stand at present calls for good university professionals in the engineering-related areas in order to obtain incremental units of knowledge. The policy to be recommended by a researcher that concerns himself exclusively with the subsystem of science and technology (CONICYT Chile), would be to increase the volume of resources allocated to universities. However, a researcher, analyzing the social system in its totality (the NSI), may agree on this recommendation, yet contribute important new elements in relation to the possible distributive costs generated by this measure. If primary and secondary education are not universal and also strongly dual in quality in accordance to the income levels of the households, greater resources allocated to higher education, will help to consolidate social segmentation.

Ever since the rise of capitalism during the first industrial revolution, it is possible to perceive systematic differences in the degree of development of the countries, stemming from the different ways whereby the NSIs are able to absorb the contents of universal technical progress. This phenomenon would be surprising if technology were a freely accessible public good as is assumed in traditional textbooks on economics. However, in the real world, the capability to gain access to a new technology is conditioned by the learning processes that adjust to the productive structure prevailing in each economy and to the corresponding supporting institutional set-up.

For instance, though English firms dominated the first industrial revolution and were definite technological leaders in most sectors during the first half of the past century, they fell in a state of relative disadvantage with respect to the German and American firms in the emerging electrical and chemical industries which developed in the second half of the XIX[th] Century. A chief reason for this phenomenon was that the university systems in the United States and Germany reacted much faster than the British one, in the face of the need to generate human capital for the new disciplines in applied engineering and sciences. As an outcome of this process, the new American and German electrical and chemical firms had a greater supply of the skilled labor needed for their processes than what the British firms did. Finally, and drawing from this example, the NSIs create the competitive advantages, whereas the comparative advantages are defined by relative natural resource endowments and learning paths.

However, also ever since the rise of capitalism, we may observe the existence of different channels for technological transfer from the technological leaders to the backward countries. In the first half of the XIX[th] Century, a central channel for technological transfer was the movement of labor owing to international migrations (many of the technical principles dominant during the first industrial revolution flowed from England to the United States as an outcome of the migration of British people to the new world). In the second half of the XIX[th] Century foreign investment was the dominant channel (for instance, when England invested heavily to develop the railroad in different countries, there took place an important transfer of technological knowledge in the transport and iron and steels industries, in mechanical engineering and even other industries with products needing this means of transport). In the XX[th] Century, in addition to transnational investment, there is an increasing trade of goods (especially capital goods) which also became a vehicle of technological transfer. Finally, at the end of this century, the developments in communication technologies came to be a new channel to transfer knowledge from one country to another.

It was through these mechanisms that even countries –with low global levels of education, productivity and income– were in a position to become the recipients of enterprises resorting to leading edge technologies. However, it was the developing countries where there existed entrepôts that started and accomplished a successful catch-up and began to disseminate their advances to the rest of the economy as a whole; the latter took place when these backward nations began to perceive their relative backwardness and identified that what the foreigner knew gave him the technological leadership, and then they made all the investments needed to adapt their NSIs to the new technological reality, while conforming the latter to the idiosyncratic characteristics of their own NSIs.

In short, to characterize a NSI in a technologically backward country is consistent with an observation of both the processes of absorbing, diffusing and transforming technology and the processes of generating human resources which –as stated in the foregoing section– have an influence on the workings of the production structure and the institutional set-up.

3.1. The process of technological absorption in a developing country

Along the lines pointed out by Dahlman and Nelson (1993), to generate an innovation is highly intensive in financial and human resources, which are hardly available at the scale needed in the case of a developing country. On the other hand, the technological frontier in the world is evolving very rapidly and there is a great stock of foreign technology 'available'. To acquire foreign technology as cheaply and efficiently as possible and to then adapt it to local conditions is, therefore, a central element to a developing country's technological strategy. It is important to admit that to import foreign technology into a country is no substitute to developing new technology locally, but rather a complement to it, giving rise to local learning. The evidence both at a firm and country level suggests that the 'technological follower' strategy has high returns, at least until the technological gap with the leaders is bridged. Japan, for instance, made very quick progress by acquiring and adapting foreign technology until it was on the frontier in many industries and ever since it has had to invest more in developing genuine technology.

In general, it is possible to identify three chief channels for foreign technology absorption: direct foreign investment, technological license contracts and capital good imports.

The degree to which an economy depends on a given form of technological transfer depends on how it culturally perceives domestic versus foreign control of technology, on the availability of the latter through the different possible modes and on how effectively an economy can actually use these modes. Ultimately, the institutional set-up[17] and the production structure[18] will strongly condition the mode under which technological absorption will be carried out.

On the other hand, the degree of efficiency of the above-stated mechanisms for technological transfer is not homogeneous in what respects generating local spill-overs. According to Pietrobelli(1993:141), direct foreign investment is the technological transfer mode which is the least demanding in local technological capabilities, given that technology comes in 'packages'. Then the easiest method is to import foreign technology, but at the risk of not generating sufficient spill-overs, since the lack of local capabilities is simply solved by importing all the inputs and supporting infrastructure needed to implement it[19]. That is to say, there is a risk of inducing an excessive and permanent reliance on foreign technology. Capital good imports is the extreme opposite because it relies entirely on local engineers and technicians for its efficient use. The costs of a protracted period of suboptimal use of imported capital goods can be offset by a permanent learning acquired by local experts. Finally, licensing technology is an intermediate solution because, though implementation costs may be lower and the learning equally important, there always exists a technological reliance on the licensor who, as a rule, establishes strong conditions in order to conduct business in different markets and restrains access to other sources of technological transfer.

3.2. The process of technological transformation in backward countries

In this paper by transformation shall be meant all the processes of creation, adaptation and improvement carried out endogenously by the agents of the NSI, regardless of the institutional set-up that they belong to. Technological transfer involves ideas and designs developed in terms of the characteristics pertaining to other NSIs. In the developing countries, there exist sharp differences —with respect to the production structure and the institutional set-up— notably affecting the performance of foreign technological packages at a national level.

Three important idiosyncratic components can be perceived in the production structure: market size, density of the industrial network and market structure. In developing countries, markets are exceptionally smaller than in those countries where the technology usually originates from. Given that "physics and chemistry

[17] Through the legislation on foreign investment, the regulation of licensing foreign technology, the intellectual property regime, the acquisition of technology by the State and the infrastructure of the institutional support through the centers of technological information.

[18] Through the capability —as an outcome of local learning— to make use of each one of the channels and the sectoral specialization pattern of production.

[19] It is not unusual to observe, in the case of transnational companies based in the less developed countries, that they import from their home countries both the inputs for the production process as well as the services needed to operate their plants, which, in turn, are managed by foreign technical and skilled staff. In this way real entrepôt economies are generated.

are not linear"[20], such an initial trait leads to the need to strongly adapt knowledge to make the production process more flexible and increase the production mix, the only way to ensure an efficient scale under local conditions. The second component, leads to the absence of specialized suppliers and a system of supporting networks. The result is that many of these activities have to be carried out by the firm introducing the technology, which generates high degrees of vertical integration associated with high coordination costs[21] demanding, in turn, important organizational innovations. It is worth emphasizing that these determinants are not static, but that their relevance changes as time goes by, in association with the domestic learning process and the maturation of the production forces. This may make it possible to attain higher scales of production inasmuch as cost reductions make exports possible. Furthermore, learning allows networks of suppliers to gradually arise as an outcome of decentralization and the subsequent divestiture of sections owned by the firm in its initial stages[22].

Finally, market structure strongly governs the direction of the technological trajectory between process engineering and product engineering. When the firm operates monopolistically, the bias in adapting the production process will tend to its optimization so as to reduce production costs. On the other hand, in a context of monopolistic competition, engineering will concentrate heavily on increasing the production mix aimed at defending and controlling market niches[23].

On the other hand, the institutional set-up, reflecting the nation's history and culture, will exert a strong influence on the ratio work to capital and on the organization of work itself inside each firm. The existence of differences in labor and environmental laws between home and host countries are elements compelling the latter to make important adaptation efforts. Additionally, the existence of market regulations such as, for instance, anti-trust laws, can condition the technological trajectory followed by each firm. However, at this point, not only do the differences have a bearing on the 'regulatory' institutional set-up[24], but also the agents' behavior habits reflect the culture. For instance, a history of strong non-voluntary wealth transfers –in a context of high hostility among the agents –is bound to bias them to behaviors of an opportunistic type, consisting in the permanent violation of the implicit contracts that will lead, as Alchian, Klein and Crawford (1978) point out, to the need to either formalize contracts –generating an increase in transaction costs– or by-pass them through vertical integration. Following Lundvall (1993), a product innovation calls for an important interactive

[20] This is one of the chief characteristics of a system, which is known as "synergy", whereby the whole is not a sum of the constituent parts but that, when parts are related in some particular way, new properties arise and they can be ascribed to the system, though not to each of the parts taken separately.

[21] Which are lower than the transaction costs associated with de-verticalization.

[22] A process known as 'outsourcing' in the management literature.

[23] For instance, through product differentiation.

[24] Laws, regulations, norms, provisions, etc.

learning between producers and users and hence the existence of cooperative relationships between them. An environment of opportunistic behavior will go against these relationships and, consequently, be detrimental to product innovation. In an opportunistic setting, the diffusion rate of the new technical knowledge is likely to be lower.

3.3. Human capital generation

As defined above, technological capability consists in knowing how to efficiently select, acquire, use, adapt, improve and create technology. These actions are carried out primarily by people, not by machines and, therefore, human capital is a key input for absorption, transformation and diffusion processes. Human capital has two important sources of accumulation: formal education and 'on the job training', because there is a need to update people's skills on an on-going basis, as a consequence of the strongly changing nature of technology and competence.

The process of human capital accumulation seems to be determined, on the one hand, by the institutional set-up, since the existence of important externalities associated with learning always make private resource allocation to the educational system insufficient[25]. On the other hand, 'production technology' of education is not convex, whereby the marginal cost of training an additional individual is lower than the average cost, also leading to a private allocation of resources lower than what is socially optimum.

The method used by the State to close such gaps will condition a country's technological trajectory, with respect to not only the amount of resources, but also their allocation by discipline. For instance, if the gap between social and private involvement is closed by biasing resource allocation to disciplines that 'distribute wealth the most'[26], the NSI will depend more strongly on direct foreign investment as a technological transfer vehicle.

The second determinant of human capital accumulation is the production structure. At any moment there are industrial sectors which are positioned at different levels on their learning curves and having different degrees of maturity. Consequently, the capability of the productive sectors to accumulate human

[25] These externalities relate to the existence of critical masses at different levels of society. An investment in an engineer increases the productivity of the national product in its productivity, together with the additional productivity differential that he generates in the mass of engineers that he relates to in his productive activity. On the other hand, higher education by making access possible to better paid positions, acts positively on personal income distribution. A more equitable distribution warrants the stability of the institutional set-up to a greater extent and, furthermore, if there should be any changes in it, they are likely to be less traumatic. This, ultimately, favors the innovation activity of a country.

[26] For instance, lawyers, auditors and other kindred professions.

capital is not homogeneous and the patterns of productive specialization will strongly have an influence on the accumulation of abilities and skills. For instance, a production structure biased to the production of goods having standardized processes and corresponding to out-of-date technological paradigms[27] will also make the economy more dependent on direct foreign investment as a technological transfer mechanism. It is not surprising that it is quite frequent to observe the development of entrepôt economies in pre-capitalistic production systems.

3.4. The process of diffusing technology

In this paper by diffusion will be understood the process whereby the different agents of the NSI attain the most complete access both to technology transferred from abroad as well as to technology created, adapted and improved locally. Following Dahlman and Nelson (1993), one of the most important shortcomings of the industrial sectors in developing countries is the existence of a great diversity in economic performance of the firms belonging to the same sector. Though it is true that a part of those differences is due to natural differences between firms operating in the same sector, it is also true that there is a disparity in the levels of economic performance, even between firms resorting to the same equipment and using similar strategies. In these cases, it can be said that the differences are due to the different capabilities accumulated over time in order to efficiently use the technology available.

If there are relatively similar firms which, however, are not equally efficient in using their machinery and their work organization, it can be said that this is due to differences in the access to the technological information that they receive. In this respect, the topic of diffusion becomes relevant as a mechanism to reduce industrial dualism.

However, an effective diffusion and use of information makes it necessary to develop institutions and networks enabling massive access to the information on technological and market trends and helping firms to use this information in order to improve their performance. Consequently, these information networks are a central part of the 'social absorption capability' of an economy. Despite their importance and social returns, their development is neither fast nor automatic; their private or market development appears strongly inhibited both by problems of economies of scale as well as by the lack of complete appropriability of their results. Then an action from the government aimed at creating the institutions that are lacking or to complete imperfect markets is justified,

[27] For instance, traditional agriculture.

whenever it is possible[28]. These types of networks of institutions, necessary for absorbing and diffusing technologies, are an important part of the technological infrastructure of a NSI.

One of the most important conclusions from the discussion offered in the foregoing section was that innovation is the result of a learning process where the central component was its interactive nature that involves permanent relationships between those introducing, using and producing technology. Such relationships basically involve technological diffusion and are rooted in a country's technological infrastructure. In this sense, it can be defined as an array of technological information services to be provided either by the State or privately by the market. The suppliers of these services then coordinate the demands for 'technological needs' with the supply of 'technological solutions'.

The provision of technological services has costs and, therefore, their private existence will only be possible to the extent that the private benefits are such that they can cover such costs and at least obtain the opportunity cost of the capital. There are some services where these conditions are met. Typically, this happens when networks of subcontractors are developed where the subcontractor becomes a supplier of technological services to the contractor and vice-versa. For instance, in production backward linkages, where apart from the commercial transaction involved in purchasing inputs, the buyer of the service generally supplies the firm on contract with technological information and assistance as to the best way to produce the inputs needed. Quite often this assistance even goes further and includes financing the working capital and leasing the equipment. But also the firm providing the input will assist the purchaser as to how such an input can be used more effectively in the production process to obtain the best performance in the production of final goods. This example is enlightening in the sense that the development of subcontractors involves developing markets for technological services. Hence, the central importance assigned by developed countries to this aspect in connection with developing small and medium-size firms[29]. Another example where market mechanisms make the existence of some degree of private development possible, as in the case of some information services (networks of data bases specialized in financial, commercial, stock exchange information; yellow pages, financial periodical publications, etc.)

[28] Quite often government intervention must have continuity in time because, in the case of some institutions, market failures are permanent (this typically occurs in institutions processing and diffusing information with a high generic content). However, in other institutions, government action should aim basically at solving a 'lack of coordination' problem, that is, action should be restricted to give the initial impulse to the emergence of the institution and the market which originates from it.

[29] In Japan 65 percent of small and medium-size firms operate as subcontractors and 85 percent of them specialize in this kind of production (Dahlman and Nelson (1993:9).

However, there are many services where market incentives are simply absent. They are those where the information provided has a high generic content and is useful for a wide range of firms in specific fields. If this is so, even though social willingness to pay is important, thus reflecting the importance of such information, private willingness is practically null. As a result, there are no private suppliers of these services; this lack gives rise to networks of public institutes, extra-mural agencies and universities that provide them. An example of these services are the quality control systems; if they are to function, there is the need to create the capabilities to measure physical and chemical properties and adequately confront them to the specified standards, all of which has important costs. Apart from the existence of an agreement on the standards and a capability to measure and test them, there must be a procedure and a capability to enforce quality control. Ideally, an economy needs an array of agents who concentrate the enforcement of internationally accepted standards and serve as a basic reference to measure and document the firms. In all countries, most agents performing this function are of governmental origin, since the problem of economies of scale, public welfare problems and regulatory aspects inhibit the presence of private institutions performing these functions.

4. RECURSIVE RELATIONSHIPS

4.1. The global vision of the NSI

In this section we will analyze, within the frame of a systems approach, the relationships existing between the process defined above. The analysis will be centered on a national basis (see Graph 1)

The absorption process is the inflow to the system and consists of technological information coming from the world frontier, and its chief channels are direct foreign investment, technological licensing, capital good imports and user/producer relationships generated between national and foreign agents (for instance, patents, books and periodical publications, fairs, meetings, visits to plants, etc.).

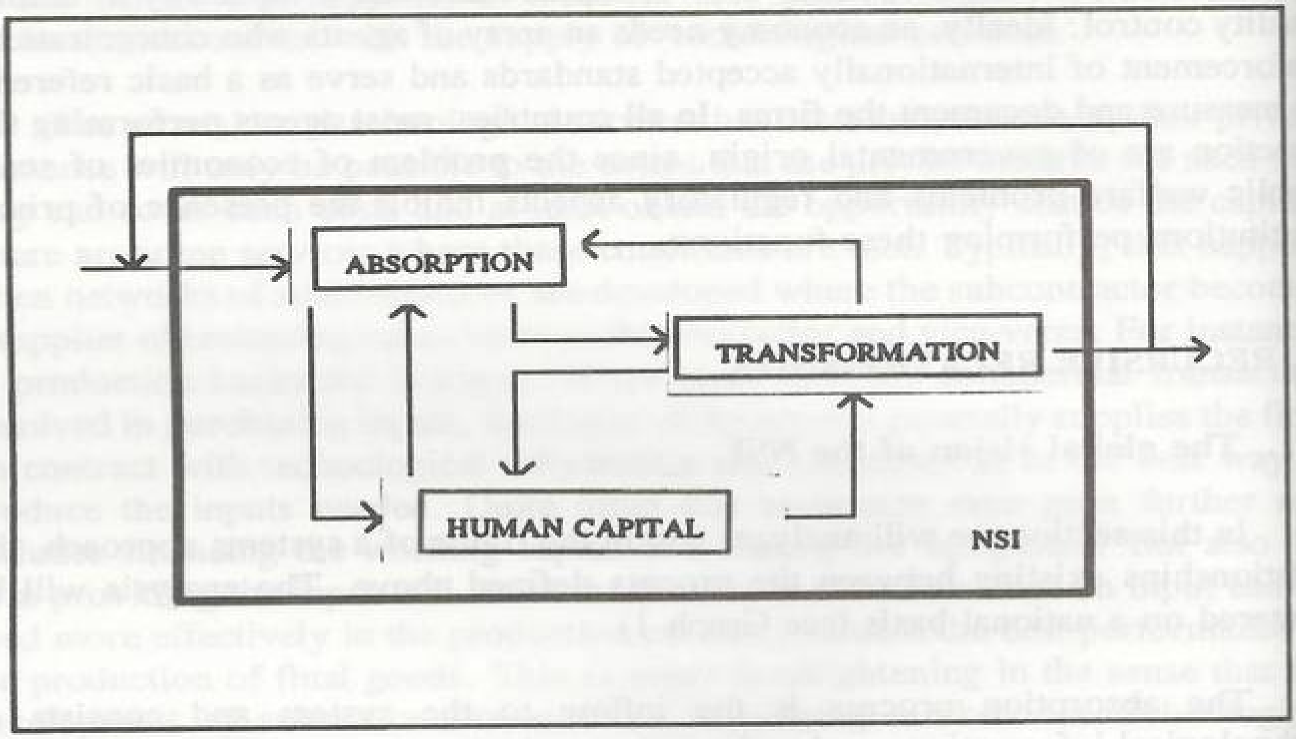
The absorption process is conducted in its entirety by people responsible for searching, selecting and purchasing foreign technology and exchanging information[30]. Hence the quality of the inflow process is determined by the quality of incoming information as well as by the quality of the human resources that carry out the above actions. On the other hand, the same inflow gives signals regarding the demand for human resources needed to efficiently carry out these actions. There are, then, interactive relationships between the processes of

[30] On quality, markets, prices, quantity, etc.

absorption and the generation of human resources. Some of these interactions are mediated by the market, for instance, through private supply and demand for skilled labor. However, an important part of them are brought about by the institutions, because market mechanisms do not have incentives enough to perform them at optimally social levels.

GRAPH 1

OVERALL VIEW OF SNI



On the other hand, the outcome of the absorption process can be summarized as a set of equipment, turnkey plants, designs and instruction manuals and a set of requirements made by the customers and foreign suppliers. All these elements define the basic guide-posts on 'how' the technology operates. However, their control makes it necessary to gain an insight as to 'why' it operates. The latter is attained to the extent that an increasing amount of adaptive engineering of imported technology takes place and illustrates the fact that to use knowledge implies the need to create knowledge in a simultaneous manner (however, taking into account the differences between the production structures and the domestic institutional set-up in relation to those of the suppliers, the initial performances of these acquired technological packages show a much lower efficiency at a local level than what was expected). This originates what is known as the transformation process. As the latter delineates learning curves, it generates an informational flow regarding the technological solutions needed to overcome any new bottle-necks. In this manner new interaction relationships are generated now between the processes of technological absorption and transformation. The mode in which these relationships structure themselves between both processes involves, in turn, a process of knowledge diffusion per se. However, the transformation process does not stop when the technology absorbed is adapted to local conditions. As the performance of the technology that was adapted reaches optimal levels[31], the firm's learning curve has become sufficiently mature to permit a leap forward leading to the redesign of the production system and even to the introduction of some degree of its own technological creation, by adding improvements to the original design.

Finally, the adaptation and improvement actions need skilled labor as a basic input due to both their formal knowledge of the technology incorporated as well as their learning on the production line. The human resources needed in order to adapt, improve and, potentially, create technology, generate demands prompting actions of the human resources formation process. Some of these demands are mediated by the market, while most are channelled by educational institutions and by 'on the job training' at the plant. In turn, on the supply side of human resources, both their number as well as their disciplinary formation determines the efficiency in implementing the transformation process.

The outflow can be characterized by a set of new production products and processes[32] interacting, in turn, with their international demanders, which is also a feedback to the absorption process[33].

4.2. Institutional recursiveness within the NSI

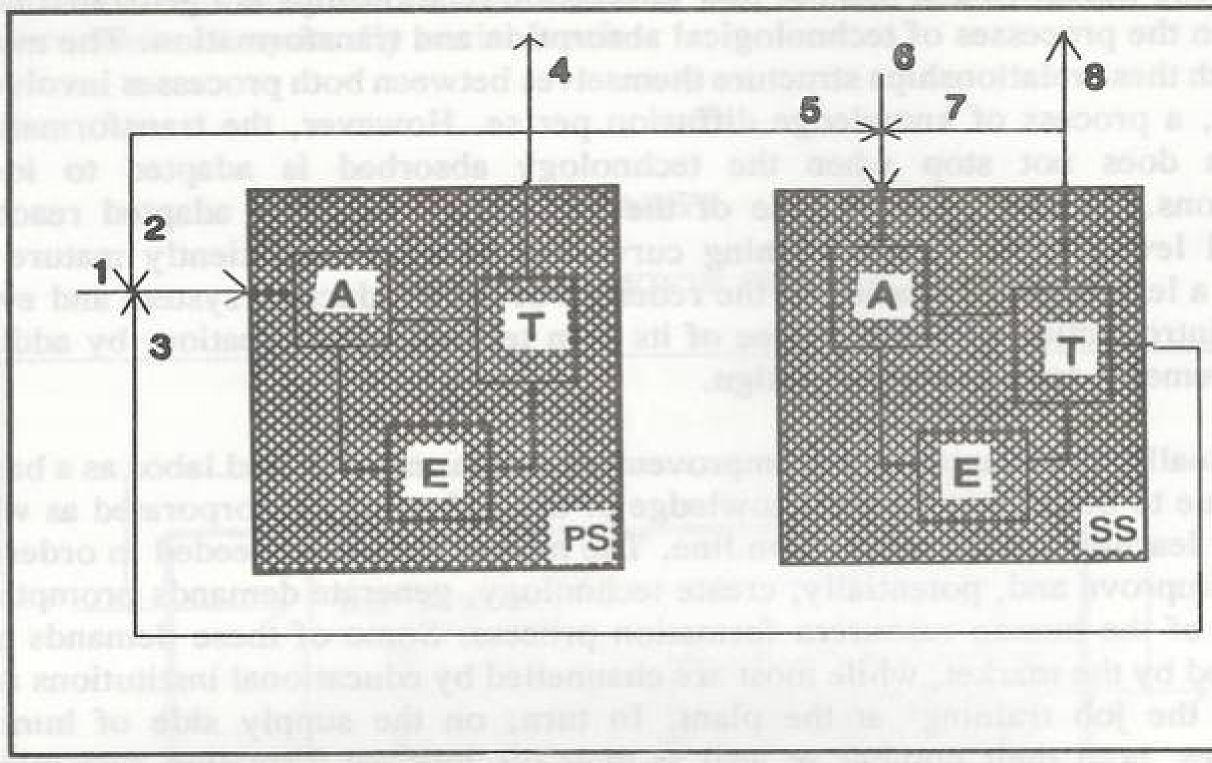
In the first place, there will be an opening of the NSI at the firm level. Two great groups are identified: on the one hand, firms devoted to the production of goods and, on the other, those oriented to provide supporting services to the former. The services that are relevant in terms of this analysis are: information, education, technology and financing.

[31] For the local conditions of demand, scale, mix, market, etc.

[32] New for local conditions only.

[33] There can also be a resale to third parties who find the adapted technology to be more in keeping with their needs and possibilities.

GRAPH 2
PRIVATE PRODUCTION AND SERVICES SYSTEMS



A: Absorption T: Transformation E: Education
PS: Production Sector SS: Services Sector

The table shows the relationships existing in both sub-systems. PS stands for the Production Sector and SS for Services Sector. Inflows and outflows are characterized as follows:

Flow 1 (inflow): It stands for the flow of technological information coming from the international technical frontier and users' needs.

Flow 2: (feedback): It stands for the flow of technological information generated by the interaction of the products of domestic firms in the international market.

Flow 3 (inflow): It stands for the flow of supporting services that the services sub-system provides the production sub-system with. These are financial, education, information and technological services[34].

Flow 4 (outflow): It is the flow of new products and processes resulting from the transformation carried out by production firms.

Flow 5 (feedback): It is the flow of needs for technological solutions and supporting services needed by firms that produce goods from firms that produce services.

Flow 6 (inflow): It relates to the flow of technological information coming from the frontier and is associated with the production of new services[35].

Flow 7 (feedback): It stands for the flow of information on services produced by domestic firms in their interaction with foreign users.

Flow 8 (outflow): It is the flow of new services arising from the transformation process carried out by service firms.

The flows of information and resources represent the diffusion processes that have taken place between these two sub-systems. They are mediated primarily by market mechanisms and user/producer relationships. However, in general terms, in all economies and especially in backward ones, the volume of these private flows does not reach the social optimum. In the first place, the market mechanisms in the four types of services feature serious shortcomings and in the case of technological and information services there usually exist appropriability problems. For educational services, problems originating from its nature as a public good and in the externalities that most of education shows due to generic contents. Finally, in the case of financial services, there are important problems of informational asymmetry between fund applicants and fund suppliers, with the results that the adjustment mode, via prices, is insufficient[36] and that there arise credit rationing mechanisms.

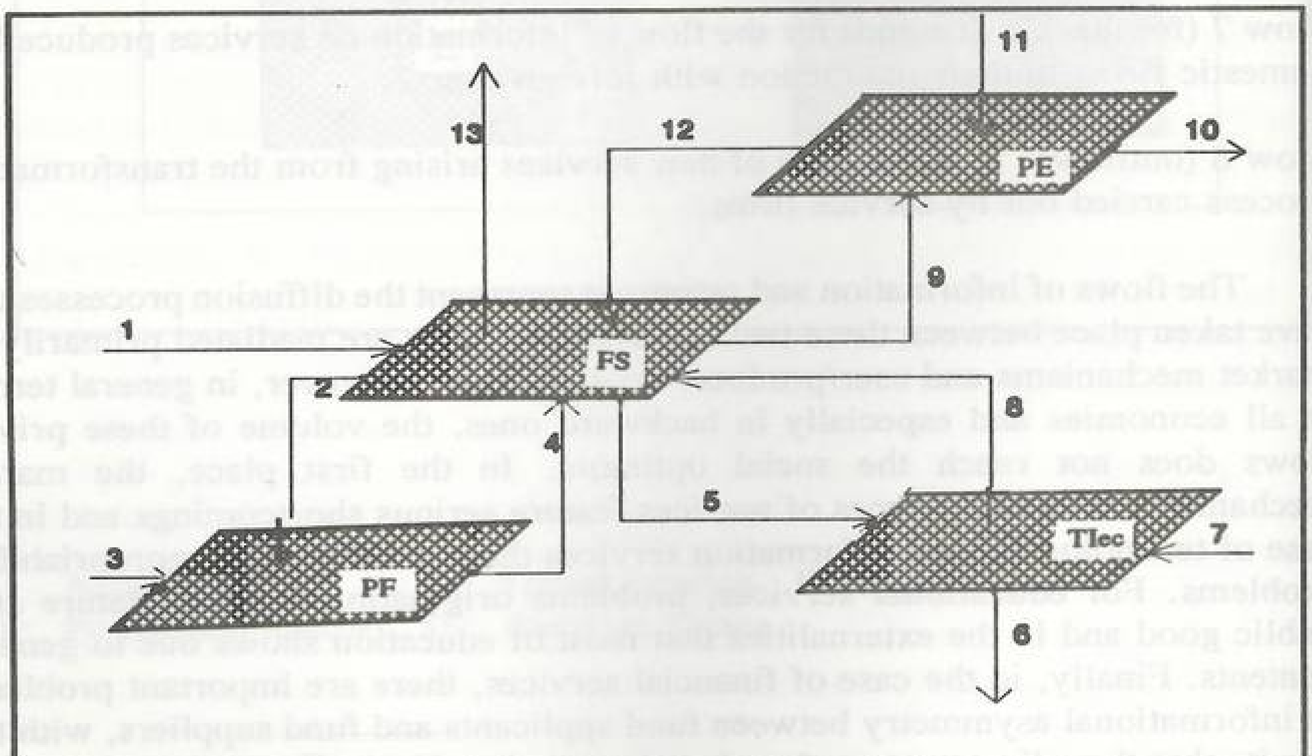
The existence of these failures generates the social need to create State-originated agents to overcome them. This makes up the institutional dimension of the NSI and presented in the Table which follows.

Graph 3 summarizes the 'devoir être' of the NSI. Before offering its description, some clarification is needed. In the first place, each one of the

[34] Among others, quality control, measurements, consulting services, etc., are important.
[35] New types of software, leasing, franchising, etc.
[36] The increase of the interest rate does not clarify the market as it generates adverse selection and moral hazard problems.

institutions in the system has its own absorption, education and transformation processes. In the second place, all inflows take place through absorption, and all outflows through transformation. In the third place, attention is focused on the relationship between the system of the firms (FS) –which includes those oriented to production and services– and the institutions. For the sake of simplicity, the diffusion relationships of public education institutions (PE), technological institutes (TI) and public financing (PF) that affect them have been omitted, as well as the feedback flows resulting from the interaction of the results of the transformation processes of each institution with the environment.

GRAPH 3
INSTITUTIONAL DIMENSION OF NSI



A description of each relationships among the institutions presented in the preceding table is offered:

Flow 1 (inflow): It stands for the flow of information coming from the technological frontier and users' needs for the firms' products and processes.

Flow 2 (outflow): It stands for R&D financing needs and the training at firms unable to satisfy them through the interaction with private financing sources.

Flow 3 (inflow): It stands for the flow of information on new sources and forms of financing which the State can implement through the learning arising from its interaction with financing agents in the rest of the world (IDB, World Bank, R&D Programs in other countries, etc.).

Flow 4 (inflow): It is the flow of financing sources provided by the State to the firms.

Flow 5 (outflow): It is the flow of needs for technological solutions and information required by firms from the technological institutes and which can not be satisfied by private suppliers.

Flow 6 (outflow): It refers to the set of technological solutions sent by institutes to the rest of the world.

Flow 7 (inflow): It is the flow of technological solutions and users' needs at the technological frontier demanded from local institutes.

Flow 8 (inflow): It refers to the flow of technological solutions from the institutes aimed at satisfying the firms' needs.

Flow 9 (outflow): It refers to the needs for skilled human resources demanded by the firms and are satisfied by the public education system in the absence of a market solution.

Flow 10 (outflow): It corresponds to the flow of skilled human resources not used by private firms.

Flow 11 (inflow): It refers to the information coming from the technological frontier and aimed at the public education system and which makes it possible to adjust skilled labor on the supply side in keeping with the needs for more advanced technology along with information on the latest scientific developments.

Flow 12 (inflow): It refers to the set of skilled human resources and scientific information flowing from the public education system to private firms.

Flow 13 (outflow): It is the flow of new products and processes originated in the firms and intended to interact on the technological frontier in international markets.

Within the frame of the above analysis, two important elements have to be highlighted. In the first place, the information flowing through each channel is not static, but it has an important dynamism generated in the interactive learning processes. That is, to the extent that the country gets closer to the technological frontier, the content of the flows is to reflect the array of needs, resources and technological solutions tending to a more efficient utilization of new information received from the frontier. In the second place, the system described above is 'ideal' and reflects the 'devoir être'; however, in the real world, there do not exist many of these institutions and not many of the flows of information either. A scientific and technological policy is not to restrict itself to structure the institutions which do not exist (public education, technological institutes, public financing funds, etc.) but it also has to generate the diffusion flows which make learning and feedback between the different institutions themselves and the public sector possible. Consequently, it is not only necessary to evaluate which institutions do not exist, but also the quality and quantity of the diffusion mechanisms interconnecting the different institutions.

Initially, the flows described in this paper operate externally to the market. However, as a more fluent exchange of information is generated between institutions and firms, new markets will be eventually generated; these new markets, however, will never be complete or perfect due to the fact that most information and resources transacted are by nature a public good.

5. THE INSTITUTIONAL DYNAMICS OF THE NSI

A chief characteristic of the processes carried out within a NSI is that they are critically governed by the phenomenon of learning. The latter, in terms of the model, can be defined as a generating process within the economies of scale. All those sub-systems of a social system where economies of scale are present, feature the shortcoming that unless a critical mass of physical, human and financial resources and a minimum volume of exchange of information is attained, the relevant processes cannot be carried out, as it is more profitable to pursue traditional production activities (without a systematic search for new knowledge) than to attempt innovative undertakings.

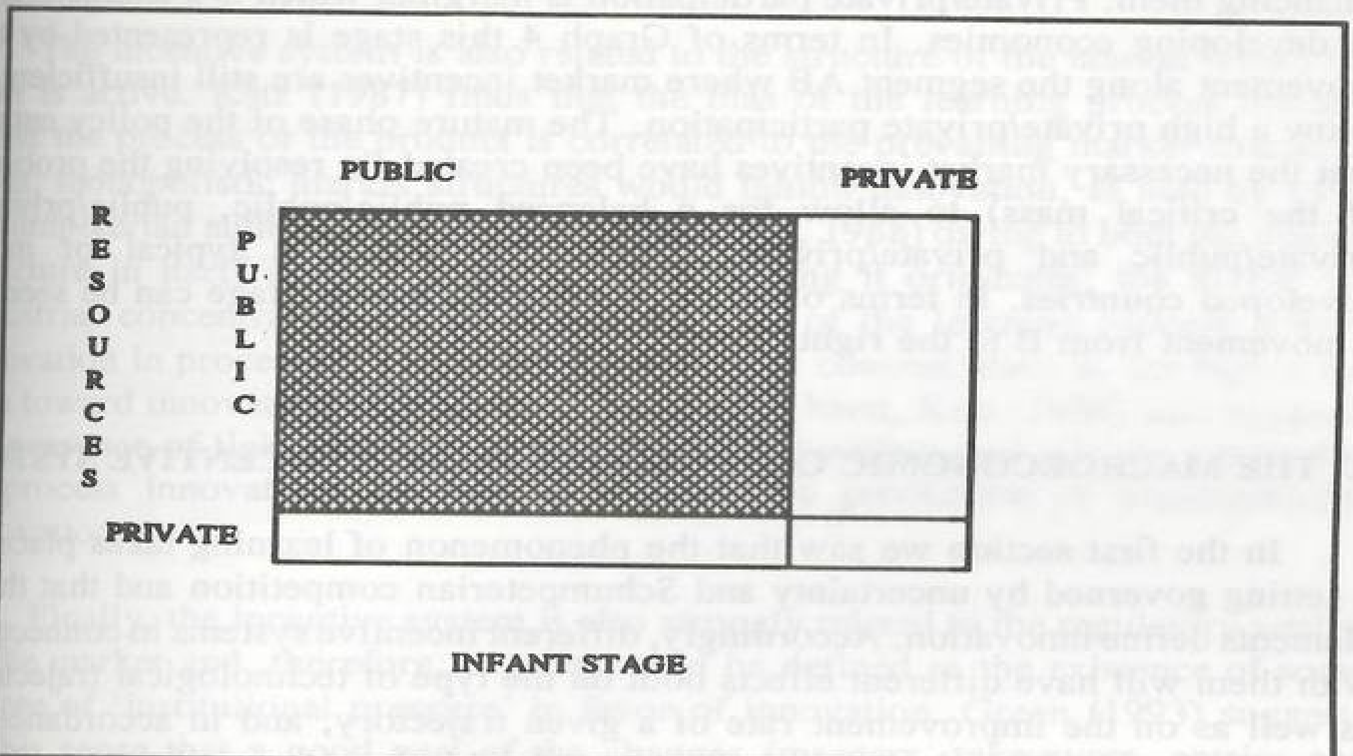
On the other hand, these processes feature the advantage that once the critical levels have been achieved, the system receives feedback in an exponential manner until the saturation effects –to be mentioned later– begin to appear.

Following Teubal (1994), it is possible to associate the problem of the absence of a critical mass with the infant stage of a NSI and the exponential situation as the 'mature' stage of this system.

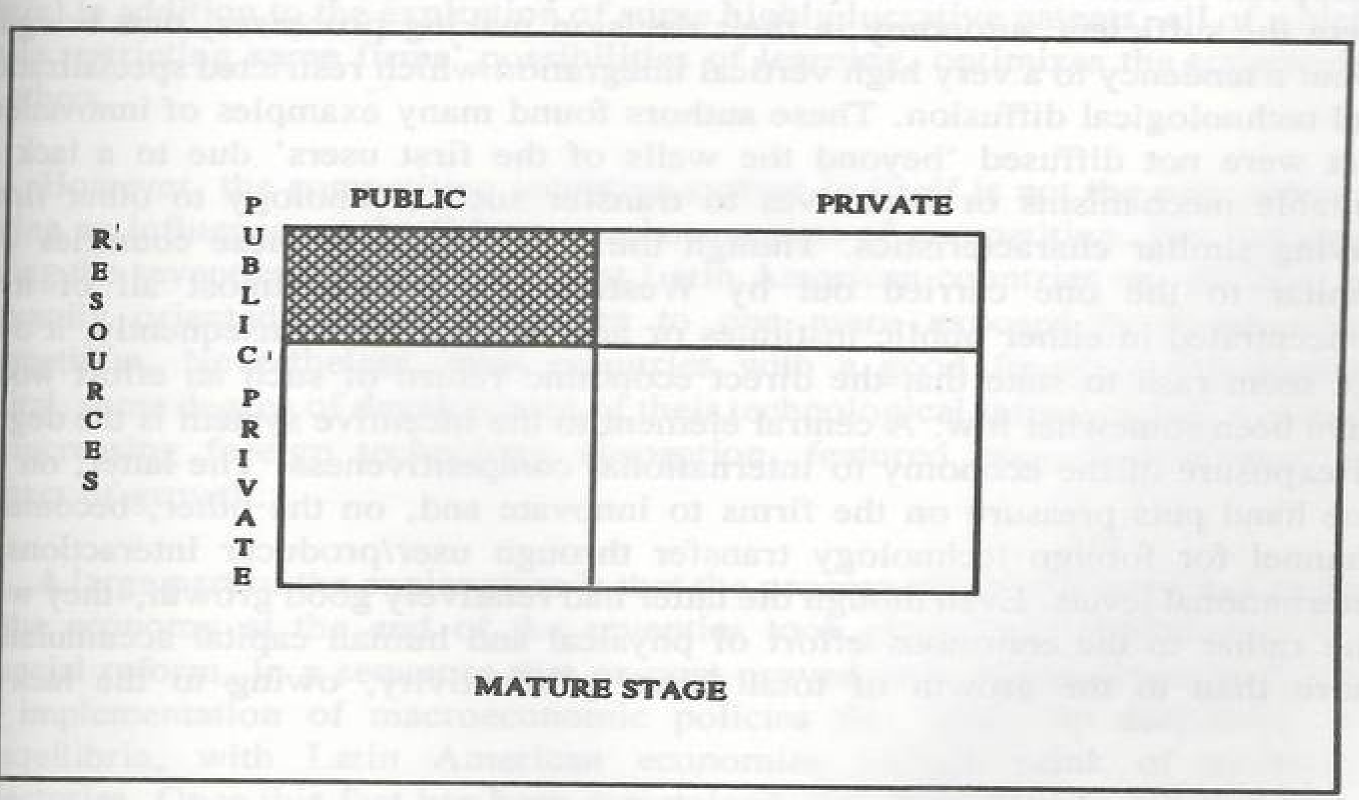
The role of scientific and technological policy, under this analytical frame, is not static but, to the contrary, it features a strong dynamism involving learning processes for policy enforcers themselves, that lead them to define different sets of intervention measures at the infant stage, the mature one and during the transition from one to the other. This is what Teubal calls the 'cycle of the technological policy'[37].

[37] For a more detailed analysis of ad hoc conditions, objectives and policies, see Teubal (1994).

GRAPH 4
PROCESSES OF NSI



GRAPH 5
PROCESSES OF NSI



Following Teubal (1994), the infant stage of the policy is characterized by a high participation of public agents in both carrying out the processes as well as financing them. Private/private participation is marginal which is a characteristic of developing economies. In terms of Graph 4 this stage is represented by the movement along the segment AB where market incentives are still insufficient to allow a high private/private participation. The mature phase of the policy entails that the necessary market incentives have been created (in resolving the problem of the critical mass) to allow for a balanced public/public, public/private, private/public and private/private participation, which is typical of more developed countries. In terms of Graph 4 the maturational stage can be seen as a movement from B to the right.

6. THE MACROECONOMIC CONSTRAINTS AND THE INCENTIVE SYSTEM

In the first section we saw that the phenomenon of learning takes place in a setting governed by uncertainty and Schumpeterian competition and that three elements define innovation. Accordingly, different incentive systems in connection with them will have different effects both on the type of technological trajectory as well as on the improvement rate of a given trajectory, and in accordance to them whether the incentives either promote or inhibit the process of competition[38] and reduce or intensify uncertainty. For instance, Dahlman and Nelson (1993) observe that the centralized planning system in the economies of Eastern European countries neither helped firms to improve their performance nor gave them the sufficient autonomy in their decision making processes, thus bringing about a tendency to a very high vertical integration which restricted specialization and technological diffusion. These authors found many examples of innovations that were not diffused 'beyond the walls of the first users' due to a lack of suitable mechanisms or incentives to transfer such technology to other firms having similar characteristics. Though the R&D effort in these countries was similar to the one carried out by Western countries[39] almost all of it is concentrated in either public institutes or academic units. Consequently, it does not seem rash to state that the direct economic return of such an effort would have been somewhat low. A central element to the incentive system is the degree of exposure of the economy to international competitiveness. The latter, on the one hand puts pressure on the firms to innovate and, on the other, becomes a channel for foreign technology transfer through user/producer interactions at international levels. Even though the latter had relatively good growth, they were due rather to the enormous effort of physical and human capital accumulation more than to the growth of total factor productivity, owing to the lack of

[38] The incentive systems are the outcome of different institutional set-ups.

[39] For instance, Hungary on average spent 2.7 percent of GDP in R&D in 1988.

competitive pressures as well as to the practically null access, over a long period, to Western technological development.

The incentive system is also related to the structure of the market where the firm is active. Katz (1987) finds that the bias of the learning process towards either the process or the product is correlated to the prevailing market structure. Thus, monopolistic market structures would inhibit innovation, as held by some Schumpeterian authors (Nelson, 1991, and Dossi, 1988) owing to both the market structure in itself as well as the type of learning it originates; the higher the industrial concentration is, the higher the bias of the learning process toward innovation in processes. The lower the industrial concentration is, the higher the bias toward innovation in products. On the other hand, Katz (1986) also suggests the presence of linkages induced by product innovations towards the generation of process innovations as well as towards the production of organizational innovations.

Finally, the incentive system is also strongly related to the regulatory setting of the market and, therefore, to what could be defined as the existence of some degree of 'institutional pressure' in favor of innovation. Green (1993) suggests in this sense that a good part of the changes (mergers, take-overs, entries and exits of firms) taking place in the international pharmaceutical market are seemingly related to a greater government regulatory pressure in developed countries (price controls in Japan and France, the Clinton Plan in the United States) in addition to the expiration of some highly lucrative patents, all of which, while restricting some firms' possibilities of learning, optimizes the trajectories of others.

However, the competitive incentive system in itself is not the only element having an influence on the Schumpeterian process of competition. For instance, during the seventies and eighties, most Latin American countries moved from an 'inwardly oriented' incentive system to one more exposed to international competition. Nevertheless, even countries with a good foundation of human capital, some degree of development of their technological infrastructure and with an increasing foreign technology absorption, featured poor performances in matters of growth.

A large part of the explanation is that the process of reform in the real sector of the economy at the end of the seventies took place in conjunction with a financial reform, in a sequence that ex-post proved to be inconsistent, and with the implementation of macroeconomic policies that ended up deepening the disequilibria, with Latin American economies on the brink of explosive trajectories. Once this fact has been ascertained, it is important to ask oneself as to the degree to which the macroeconomic instability affected the NSIs in the region.

In the first place, it is necessary to state that the high volatility of the inflation rate, relative prices and volumes transacted that followed what is known as the 'crisis of the debt', generated an important change in firms' priorities. Their ability to make decisions quickly in order hedge themselves against the transfers of wealth brought about by the situation became more relevant for them. The center of entrepreneurial interest turned to the firm's financial management rather than the technological problems associated with the 'production line'. There took place a sort of 'crowding out' of financial learning to the detriment of the productive-organization learning[40] [41].

In the second place, a central element to the above 'crowding out' and owing to which productive learning returns decreased, is the fact that long-term contracts proved to be institutions that are strongly endogenous to the system[42], to the extent that the volatility prevailing in the eighties generated the termination or the involuntary default of many of them and also exacerbated post-contract opportunistic behaviors. Agents' natural response in the face of reality was the reduction of the average duration of contracts, which not only increased economic inefficiency owing to increased transaction costs, but also led to the disappearance of a central tool of technological learning[43].

In the third place, agents' conservative attitude manifested itself through the existence of high discount rates –corrected by risk– that generated a discrimination against those investment projects with a long-term maturity. As a result, new capital good purchases are postponed, plant expansions are not made and even existing physical assets are not replaced, with which the capital formation rate is strongly cut back and, along with it, a central input to enrich the learning curves disappears.

Finally, orthodox stabilization plans implemented during the crisis of the debt, and after, placed a special emphasis on fiscal adjustment which, within a strongly recessive frame, was channelled via strong reductions in public spending which, by virtue of the fact that they were formulated in a discriminatory manner, not only deepened the crisis but also strongly weakened State institutions. Thus, for instance, budgets of the public institutes and universities for R&D budgets were cut down, human capital formation system was deteriorated at all levels and the State development banking system disappeared, just at the very moment when

[40] In an international context where it was precisely that technological-productive learning was accelerated on the international frontier.

[41] This situation was also encouraged by the diversification of the local economic groups vis à vis both the State's withdrawal from production activities as well as the globalization of financial capital.

[42] The endogeneity of contracts at a macro level was put forth by Taylor (1982).

[43] Long term contracts, either implicit or explicit, are fundamental to the development of the relationships needed for interactive learning both within the firm –the relationships capital/work– as well as between firms –the relationships capital/capital.

market mechanisms and private institutes ceased to operate or did so in highly distorting manners.

The sum of all these elements, allows us to state that, without any doubt, the slope of the learning curve in the region during the eighties was affected by a negative structural breach. Recovery will not take place overnight because it takes time to deactivate the characteristic of persistence that governs the issues mentioned above so that the learning trajectory in the region will suffer a permanent displacement.

7. SUMMARY AND CONCLUSIONS

In short, in this chapter we forwarded a theoretical framework as an alternative to the neoclassical one in order to look for a more consistent explanation of the innovation phenomenon and the growth process. This new frame of thought, built on the axis of the Schumpeterian process of competition and on learning as a social phenomenon, is characterized by the systemic nature of the interactions between agents and institutions and where the patterns of interdependence are direct.

The effort to formulate a conceptual frame for innovation more in keeping with the dependent and backward conditions of a developing country led us to determine the existence of four key processes making up the core of the system, namely, technological absorption, human capital accumulation, technological transformation (and creation of new endogenous technology) and technological diffusion. The latter is related to the existence of informational channels permitting the interconnection of the former three in the most efficient manner possible. Some such channels operate through the markets, but the process governing most of them is characterized by the existence of strong imperfections (economies of scale, characteristic of public good of most of the information, imperfect appropriability of the results of an innovation, the externalities surrounding and dominating a technically private good as is education, etc.) that generates a need for public intervention and calls for the setting up of institutions to solve them. Given the nature of these imperfections, some intervention measures will be transitory –until the markets which now do not exist arise– while others are to exist permanently.

Summing up, the theoretical model developed in this document defines the 'devoir être' of a NSI. Consequently, this study aims at determining an analytical methodology regarding the innovative phenomenon that takes place within a developing country, focusing attention on the evaluation of the processes, markets and institutions embodying what is known as that country's National System of Innovation.

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