THE CHILEAN NATIONAL SYSTEM OF INNOVATION

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ABSTRACT

It may be stated that there exists, within the field of the economy, a growing consensus regarding the fact that together with capital accumulation, technological progress and its associated innovations are the central forces of the process of economic growth and increase in welfare of the countries. There does not exist any country at a world level that has experienced important increases in its level of development without consistently exhibiting a sustained increase in its endowment of machinery and equipment per worker, as well as continuous improvements in the efficiency and quality of both such capital goods and the human resources responsible for their operation. Based on the above, this research is aimed at characterizing both the processes that are determinant of the fundamental interrelationships as well as the agents responsible for the innovative phenomenon in the case of Chile.

SINTESIS

Es posible afirmar que, dentro del campo de la economía, existe un creciente consenso de que, además de la acumulación de capital, el progreso tecnológico y sus innovaciones subsecuentes constituyen las fuerzas centrales del proceso de crecimiento económico y aumento del bienestar de las naciones. No existe, a nivel mundial ningún país que haya experimentado incrementos importantes en su grado de desarrollo sin que, en forma consistente, exhiba un incremento sostenido de la dotación de maquinarias y equipos por trabajador, como también mejoras contínuas en la eficiencia y calidad tanto de estos bienes de capital como del recurso humano encargado de operarlos. En función de lo anterior, esta investigación se orienta a caracterizar los procesos que determinan las interdependencias fundamentales y los agentes que gobiernan el fenómeno innovativo para el caso chileno.

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1. INTRODUCTION

Broadly speaking, it may be stated that there exists, within the field of the economy, a growing consensus regarding the fact that together with capital accumulation, technological progress and its associated innovations are the central forces of the process of economic growth and increase in welfare of the countries. There does not exist any country at a world level that has experienced important increases in its level of development without consistently exhibiting a sustained increase in its endowment of machinery and equipment per worker, as well as continuous improvements in the efficiency and quality of both such capital goods and the human resources responsible for their operation.

Based on the above, this research is aimed at characterizing both the processes that are determinant of the fundamental interrelationships as well as the agents responsible for the innovative phenomenon in the case of Chile.

Consequently, this paper has been divided into three sections. The first briefly develops a conceptual framework that will enable us to identify the "key" variables needed to attain an in-depth understanding of the problem we aim to study and within which the causality relationships existing among such variables are established[1]. The second section offers an application of those concepts to the Chilean case. The chief conclusions and policy recommendations are put forth in the third section.

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[1] An in-depth development of the conceptual framework used was submitted at the previous version of this Meeting. See Benavente and Crespi (1995a).

2. CONCEPT OF THE NATIONAL SYSTEM OF INNOVATION

The starting point to more precisely characterize a National System of Innovation (NSI) is to define the innovative phenomenon. Broadly speaking, it can be stated that the concept of innovation is directly related to introducing and starting to use new products, new productive techniques and forms of organization, as well as to substantially improve all such products and processes already existing in the markets.

However, the debate is still open as to which are the forces leading to an innovation. In this paper, we adopt the viewpoint[2] that innovation is the outcome of systematic activities of learning, search and exploration conducted by firms in order to obtain substantial economic rents associated with either displacing competition or opening a new market. The costs of not innovating or to do so less successfully are extremely high: to have a marginal role as a price-taker in the industry over a long period and to be eventually driven out.

The logical sequence of the decisions which firms take in order to accomplish an innovation thrives increasingly on the accumulated experiences --over years-- deriving from active involvement in the productive process, observing the behavior of products in the markets, incorporating new capital goods and training workers. A dependence of future innovation on the past generations is generated in this manner, setting a particular technological trajectory over time. In this sense, innovation appears, not as a single event, but rather as a continuous process taking place --though at different rates-- in all domains of the economic system.

On the other hand, the way in which firms perform their productive processes and market products, introduce new capital goods and train their manpower is strongly associated with the setting in which they operate. Thus, for instance, these actions are not the same for firms which --though belonging to the same industry-- operate in markets having different sizes and/or in a setting that enables them to sub-contract processes, as opposed to other settings --that are more immature-- where subcontracting is not as easy. What we wish to state at this point is that the learning that takes place at each firm in particular will be different, depending on the market it is active in and on the productive maturity of its setting. The structure of each economy and of each industry is a central element which exerts an influence and conditions the firm's ability to learn and hence its ability to involve itself in innovations of some kind.

[2] Originated in the Evolutionary Theory of the Firm (See, for instance, Nelson and Winter (1982))

On the other hand, the learning process does not pertain to an individual alone, but is strongly interactive in nature[3]. As such, it is then a process that can not be understood without giving its institutional and cultural context due consideration.

Having defined an innovative process, in this paper it will be understood that a NSI is a set of agents (consumers, firms, workers and institutions) involved in the introduction of a given innovation in society, by interrelating themselves through the performance of four fundamental processes: absorption of foreign technology, domestic transformation of technology, production of human resources, and diffusion of technology to society.

Process of Technological Absorption in a Developing Country

In general, it is possible to identify three main channels for the absorption of foreign technology: direct foreign investment (DFI), technological licensing contracts and imports of capital goods. The extent to which an economy depends --in one way or another-- on technological transfer is determined by how it culturally perceives domestic versus foreign control of the technology, of the latter's availability through different possible modes and by how aptly an economy can use those modes effectively. Ultimately, the institutional set-up[4] and the productive structure[5] will strongly condition how technological absorption takes place.

Process of Technological Transformation in Backward Countries

In this paper, by transformation will be understood all the processes of creation, adaptation and improvement endogenously carried out by the agents of a NSI. As in the above process, the productive structure becomes a central element conditioning the process of transformation. In this sense, it is possible to distinguish three components in the latter: market size, density of the industrial web and market structure. The first of them in developing countries involves the existence of markedly smaller markets than those existing in countries supplying the technology. This leads to situations where even those technologies demanding the smallest productive scales in a developed country are oversized for markets in developing

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

[4] Through legislation on foreign investment, regulation of foreign technology licensing, the system of intellectual property, the acquisition of technology by the State and the institutional supporting structure, by means of the centers for technological information.

[5] Through the capability, which is an outcome of learning, to use each one of the channels as well as the pattern of sectoral specialization of production.

countries ("Physics and Chemistry are not linear"[6]). The second, determines the absence of both networks of specialized suppliers as well as support systems. Finally, market structure strongly determines the direction of the technological trajectory between process engineering and product engineering.

On the other hand, institutional aspects related to intellectual property rights, long-term implicit contracts, and incentives to work, are all elements whose presence leads to the interaction between the agents and hence they are a second axis conditioning the dynamics of the transformation process.

Process of Human Capital Formation

The Technological Capability consists in knowing how to select, acquire, use, adapt, improve and create technology in an efficient manner. These activities are essentially performed by people and hence human capital is a key input for the processes of absorption, transformation and diffusion. There are two important sources for human capital accumulation: formal training and on the job training as there is a need for a continuous updating of people's skills as a consequence of the strongly changing nature of technology and competition.

The system of human capital accumulation is determined by, on the one hand, the institutional set-up, since the existence of important externalities associated with learning always make private resource allocation to the educational system insufficient[7]. The second determinant of human capital accumulation is the productive structure. At all times there are industrial sectors that are positioned at different levels on their learning curves and that have different levels of maturity. Hence, the capability of the productive sectors to accumulate human capital is not homogeneous and the patterns of productive specialization will strongly affect the accumulation of skills and competencies.

[6] This is one of the chief characteristics of systems, which is denominated "synergy", whereby the whole is not a sum of the constituent parts, but rather --through the interrelationship of the parts in some particular way-- new properties arise which may be ascribed to the system and not to each of the parts in isolation.

[7] These externalities are related to the existence of critical masses at different levels of society. An investment in an engineer increases the national product, plus the differential in additional productivity generated by him in the critical mass of the engineers whom he relates to in his productive activity. On the other hand, education by allowing access to better-paid positions, acts positively on personal income distribution. A more equitable distribution warrants greater assurances as to the stability of the institutional set-up and, besides, should it have to be modified, its changes will be in all likelihood less traumatic. This, ultimately, is favorable to a country's innovative activity.

Process of Technological Diffusion

By diffusion will be understood the process whereby the different agents of a NSI are able to fully gain access to both the technology transferred from abroad as well as that created, adapted and improved locally. One of the most important messages that stems from the above analysis was that innovation was the outcome of a process of learning whose central component was its interactive nature that involves permanent relationships between those introducing, using and producing technology. Such relationships basically involve technological diffusion and their mainstay is the technological infrastructure of a country. In this sense, the latter can be defined as a set of services of technological information whose suppliers coordinate the demands for "technological needs" with the offer of "technological solutions"

In short, what has been outlined thus far is a conceptual framework with a view to come up with a more consistent alternative explanation for the phenomenon of innovation and the process of growth. The effort to formulate a conceptual framework in keeping with the dependent and backward characteristics of a developing country led us to determine the existence of four key processes. Though some of the processes pointed out operate through the markets, the nature of most them is characterized by the existence of strong imperfections (economies of scale, characteristic of a public good of most of the information, imperfect appropriability of the results of an innovation, externalities, etc.) generating a need for public intervention and calling for the creation institutions. Given the nature of the imperfections, some of the intervention measures will be transitory (until the markets which are lacking arise), whereas others will have to exist on a permanent basis. Hence, transitory interventions are those tending to correct market failures originated from increasing returns to scale and economies of learning, as for instance, the argument of the infant industry not only applied to the productive sector, but also to some technological services. On the other hand, permanent interventions are related to those activities characterized by the presence of strong externalities, such as, for instance, a persistent accumulation of new knowledge --rural extension agencies, computer-based poles, "hi-tech" firms.

Briefly stated, the theoretical model outlined defines a methodology to approach the innovative phenomenon of a country. The next chapter addresses an evaluation of the processes, markets and institutions which are a part of a NSI, as it relates to the particular case of the Chilean economy. Finally, in the section on the conclusions we will formulate general policy recommendations in relation to the Chilean case.

3. EMPIRICAL ANALYSIS OF THE CHILEAN CASE

As stated in the foregoing chapter, a NSI can be characterized by three main processes: technological absorption, education and transformation, all of which are interrelated by information transfers, financial resources and skilled manpower; this is a process which we have characterized as "technological diffusion". These interactions may be governed by market mechanisms, or otherwise institutionally, when the characteristics of a public good, static and dynamic externalities inherent to interrelationships, bring about broad failures in the markets.

Considering that a NSI is a social system, made up primarily by people, the quantitative characterization of the evolution of a system having these properties can only be accomplished by reviewing, on a partial basis, some of the components of such a system to then infer the impact of each one of them on the total system. However, candidates are chosen arbitrarily, on the basis mainly of existing literature and the experience of the authors.

With the above in mind, the purpose of this chapter is to provide information and analyze some elements that make up the Chilean NSI that might briefly describe its evolution over the last years.

3.1. Processes of Technological Absorption

Direct Foreign Investment

The economic literature suggests that DFI would be one of the potential paths for the absorption of the technology originating from abroad. Although nowadays the discussion stills persists regarding the quality of the potential transfer of knowledge through this route, there exists consensus as to the different paths through which it can take place.

In the first place, this channel would act as a mechanism to transfer abilities through the formal and informal training of the locally hired manpower. In the second place, the incorporation of a new foreign company to the national productive activity can encourage local technological activities by adapting a new piece of machinery to local conditions or otherwise by outsourcing services to national companies. Finally, as a consequence of the interaction between the transnational firm with its contractors or otherwise through the turnover of national personnel, the arrival of foreign capitals can generate a process of diffusion of new technology in the national economy as a whole.

Table 1 shows the empirical evidence collected on DFI in Chile in the last years, which is disaggregated by origin and destination over the last twenty years.

TABLE 1
SECTORAL DISTRIBUTION OF DFI FLOWS AND FOREIGN DEBT EQUITY SWAP MECHANISMS
(in percentages)

Sector	1974-1978	1979-1983	1984-1988	1989-1993
Agriculture	0.62	3.86	3.74	2.38
Mining	38.01	39.24	52.30	61.90
Industry	39.10	27.56	17.18	16.36
Services	21.82	29.34	26.08	19.36
Total	100	100	100	100

Source : Developed by the authors based on data obtained from the Foreign Investment Committee and Banco Central.

As can be seen the greatest portion of the total flow of external capitals, through DFI, have as their main destination the mining sector. On the other hand, the industrial sector and the services sector, have absorbed the other half of foreign capitals with the peculiarity, unlike the mining sector, that their respective participation have sharply fluctuated over the years. The agriculture sector, which includes activities related to forestry, fishing and livestock, have a relatively low importance as a destination of DFI flows.

Continuing with the analysis of the flow of capitals originating from abroad through the standing mechanisms --Decree Law No. 600 and Chapter XIX-- it is interesting to characterize the origin of such funds.

TABLE 2
GEOGRAPHIC DISTRIBUTION OF DFI FLOWS AND FOREIGN DEBT EQUITY SWAP MECHANISMS

Countries	1974-1978	1979-1983	1984-1988	1989-1992
CEE	36.16	31.76	28.76	24.15
N.America	38.06	52.20	41.66	45.60
Others	0.74	5.08	18.92[a]	19.78[b]
S.E.Asiatico	0.62	0.36	0.42	0.70
A.Latina	8.46	10.50	6.90	6.87
Others	15.96	0.10	30.32	2.90
Total	100	100	100	100

Source : Developed by the authors based on data obtained from the Foreign Investment Committee and Banco Central.

a During this period New Zealand increased its participation from practically nothing to 337 million dollars primarily in the mining sector.

b This increase is explained by the investment made by Australia in the mining sector to a total amount of 509 million dollars.

As can be seen from the table, the origin of foreign capital flows has concentrated primarily in the developed countries. Specifically, the countries belonging to the European Economic Community and the North American countries (Mexico excluded) generate more than 75 percent of the total of the funds recorded in Chile during most of the seventies and all the decade of the eighties.

In order to evaluate the impact of technological transfer via DFI[8], we must keep in mind the technological dynamism --at a world level-- of the sector which these capital flows are oriented to. In this sense, the contribution is greater, the greater the technological gap between the sector of origin at a world level and the domestic destination sector and the more dynamic the sector of origin at a world level[9].

Therefore, it can be seen that, even though the countries of origin of the capitals --channeled via DFI-- are world technological leaders, such investment is oriented chiefly to sectors that are intensive in natural resources[10] and not very dynamic at the frontier; as an outcome of the latter, the country's relative technological gap in these sectors is somewhat low, by comparison to other sectors with a greater level of technological dynamism as are the industries of durable consumption goods, capital goods or electronic goods.

On analyzing the data for Chile, it could be said that DFI has been induced only by the country's natural comparative advantages --thereby being oriented primarily to sectors with a high participation in the product and national exports-- but that their technological contribution is not very high[11]. There actually exist field studies with respect to this area in Chile which show that foreign investments in this country are restricted in technological matters in terms of imposing quality standards to local suppliers, some training of manpower, improvements in administrative processes and a minimal adaptation of the products and processes transferred from the headquarters of the foreign company or its subsidiaries abroad. However, the transfer of completely novel processes and products has been null, and the same can be said as regards the innovative effort made by these companies in Chile[12].

[8] Though this paper focuses on technological matters, we do not overlook the importance of DFI in relation to capital accumulation and exports diversification. See Agosin (1994).

[9] The greater the flow of innovations.

[10] Mining and agri-business --as, for instance, fishery and fruit production.

[11] In fact, the relative participation of the industrial sector in DFI has dropped from 39 percent in the seventies to 16 percent twenty years later.

[12] See Riveros, Vatter and Agosin (1995).

Capital Goods Imports

The second mechanism for the absorption of technology described by the literature are the imports of machinery and equipments from abroad, which is designated as incorporated technical change. The chief trait of this kind of transfer is the technology incorporated in the new equipments.

Despite the above, over and beyond the potential transfer of knowledge, associated with the process of purchasing new equipments, the incorporation of new capital goods to the production line generates a set of new skills and learning in their users. The latter refer chiefly, to the efforts needed to efficiently install, adapt, and operate the new equipments in the productive process.

Finally, the acquisition of these equipments can, on the one hand, create or expand productive branches connected to the production of capital goods, and on the other, significantly increase the domestic technical knowledge stock. To do so, it is necessary to consider that the impact of the technological transfer of knowledge incorporated in the imported goods and equipments depends on two key elements: in the first place, on the technological novelty of the good in question and, in the second place, on the incremental units of domestic learning which the incorporation of such a good to the production line is able to bring about.

In order to capture these effects, imported capital goods were classified into three categories. In the first place, traditional machinery and equipments (industrial tanks, boilers and turbines), which --though increasing the productive capacity-- do not significantly contribute in terms of novelty and learning. In the second place, generic machinery and equipment which can be used without great adaptation efforts by most of the industrial sectors. Although within this category there are goods with soft edge technology --computers, telecommunications, transport-- thereby contributing novelty, they are not able to bring about strong endogenous processes of learning due to their strongly generic nature. Finally, there exists a set of goods which are sector- and firm-specific to an extent such that their incorporation generates incremental innovations throughout practically all the production line. These goods are the ones which can bring about a greater creation of endogenous learning.

TABLE 3
CLASSIFICATION OF IMPORTS OF
CAPITAL GOODS BY DESTINATION
(average in millions of current dollars)

Sectoral	78-81	82-85	86-89	90-93
Agriculture	11.7	5.1	13.3	21.7
Food Products	33.0	14.0	22.0	58.9
Cellulose and Paper	17.6	16.8	17.8	64.6
Printing and Graphic Arts	16.5	7.3	9.0	38.1
Textiles	19.6	8.6	33.5	45.2
Clothing, Leather and Footwear	5.1	2.9	7.4	13.2
Metal-mechanic	14.4	4.9	15.9	32.1
Mining	7.7	2.7	10.3	23.7
Plastic and Rubber	13.2	13.7	20.9	39.6
Medical Services	-	-	3.4	22.2
Fishery	-	-	2.0	10.4
Subtotal	138.8	76.0	155.5	369.7
Generic				
Computers and Office Equipment	56.7	47.8	89.8	172.9
Telecommunications	24.6	18.3	60.2	125.6
Electric Machinery in General	27.8	36.6	93.1	142.0
Earth Moving Machinery	39.9	17.6	59.8	142.4
Loading and Unloading Equipment	31.2	26.0	70.1	91.6
Subtotal	180.2	146.3	373.1	674.5
Other Machinery and Equipment	177.4	141.2	275.3	503.4
Total	505.5	368.3	814.8	1,577.1

Source: Foreign Trade Bulletins, Banco Central de Chile.

It can be seen that the total value of imports of machinery and equipment has grown considerably over the last fifteen years. The exception is the period of the crisis of the eighties when these imports show a great drop, similar to the phenomenon recorded at a general level as regards imports[13]. Even though the growth of imports of capital goods has been relatively sustained over the last fifteen years, it is necessary to emphasize their great increase during the period between 1989 and 1993[14].

The data for Chile shows that machinery and equipment purchases are also strongly biased to the introduction of soft technologies --telecommunications, computers-- rather than to hard technologies, which, though it is good, is not enough on an a priori basis.

Licensing of Foreign Technology

To the extent that the licensing of foreign technology embraces concepts and fundamental ideas contained in the know-how and the designs, their successful transfer calls for the generation of an important local adaptive dynamism, which eventually could be even greater than in the case of the imports of capital goods.

However, to the extent that the technological knowledge market transacts goods whose specification is incomplete, a phenomenon of technological dependence is generated, which is a consequence of the informational asymmetry leading to the buyer's failure adequately to monitor the package purchased; the latter paves the road for the seller to exercise all types of arbitrary and discriminatory practices during the transaction.

Briefly stated, foreign licensing will have greater technological impacts, the more important the novelty of what is transferred in the local context, the greater the number of possible suppliers and designs and the more elastic the demand for the final good[15].

Based on the above elements, we will describe the importance of the agreements for technological transfer in the case of Chile. The following table shows the evolution of the amount of royalties paid both in millions of dollars as well as a percentage of GDP:

[13] This fact can be explained by the liberalization of the exchange rate --which went up more than 200 percent-- and the process of adjustment which the country underwent during those years.
[14] Especially the imports of generic capital goods.
[15] See Arrow (1967).

TABLE 4
EVOLUTION OF THE PAYMENT OF ROYALTIES

Period	US$ (millions)	% GDP
1980	28.9	0.10
1981	38.9	0.12
1982	33.2	0.14
1983	32.4	0.16
1984	25.6	0.13
1985	23.1	0.14
1986	25.8	0.15
1987	29.7	0.16
1988	36.2	0.16
1989	39.9	0.16
1990	37.1	0.13
1991	33.9	0.11
1992	39.2	0.11
1993	43.6	0.11

Source: Banco Central.

From the above table it follows that the country has "used" this vehicle for technological transfer at the same rhythm as the growth of GDP, so that its participation, in terms of total amounts involved, relative to GDP kept constant. As regards the distribution of the contracts by economic sector, the information is shown in the table below[16]:

TABLE 5
SECTORAL DISTRIBUTION OF ROYALTIES
(period 1980-1993)

Sector	Average No.	%
Laboratories, chemicals and petroleum	161	50.3
Motor cars, metallurgical and building	67	20.9
Electronics	10	3.1
Agro-business, tobacco and fischeries	19	5.9
Copyright and Publishers	7	2.0
Software	22	6.8
Services	11	3.4
Rubber and Leather	23	7.2
Total	320	100

Source: Banco Central.

[16] The information shows the averages for the years 1984, 1985 and 1986, as they were the only years in which this information was processed and analyzed.

From the preceding table it follows that the activities where licensing is strikingly dominant are related to the pharmochemical processes. It is to be pointed out that the market for these products is characterized by a strongly oligopolistic conformation in terms of those offering the technology and with generally inelastic local demands. They are then sectors where the amounts transferred are higher and the social benefits concomitantly lower.

3.2. Process of Human Capital Formation

Nelson and Dahlman (1993), state that in order to have local technological capability (TC), it is necessary to be able to successfully use technology that is already available in the world. In their opinion, TC is the ability to search, select, use, adapt, improve and develop technology that is appropriate under changing circumstances. The key for developing countries is to take advantage of the new technological alternatives that arise so as to converge to the frontier.

The processes of search, selection, adaptation and improvement are essentially carried out by people; that is to say, CT and human capital are to a great extent the same thing. To perform these activities simultaneously a formal educational system with a wide coverage is increasingly needed because domestic control of a modern technology is a "multi-agent" concern (i.e., the problem of the critical mass is increasingly more restrictive). In addition, due to the fact that access to it is simple, in terms of those absorbing it, it calls for a minimal conceptual foundation which can only be acquired through a formal education in scientific and engineering disciplines.

On the other hand, there is a vast universe of specialized technological details which can not be learned in the formal system, in part because many academics do not know them, but also in part because they are specific to a process of learning that takes place inside a firm and to its particular environment. It is for this reason that another important source for the accumulation of the human capital needed in order to successfully absorb and adapt a technology calls for a deliberate and considerable on-the-job-training effort.

In order to answer some of the considerations that were brought up earlier, we offer a summary of some indicators of the evolution of human capital in Chile over the last years. It is especially interesting to contrast the Chilean evidence versus the experience in a set of countries chosen in relation to the coverage and type of higher education[17].

The coverage of higher education in the developing world up to 1965 was 48 percent of that in developed countries, while in 1988 such a gap had gone down to

[17] The analysis of the educational indicators at a primary and secondary level have not been dealt with in this study owing to lack of space. However, Benavente and Crespi (1995) offer a detailed analysis of these topics.

70 percent, enabling us to state that there has been a systematic trend to convergence in these aspects. In the specific case of Chile it can be stated that even though the country has made an important effort, it is still lagging behind the developed world, as for instance, while in 1965 Chilean enrolment was only 25 percent of that in developed countries, in 1988 such an indicator was at 40 percent.

TABLE 6
HIGHER EDUCATION ENROLMENT RATES[18]

Countries	1965	1973	1980	1988
Developed	12.0	15.3	27.4	32.2
Japan	12.9	10.6	30.5	30.1
France	14.2	17.3	25.5	34.5
Asia	4.8	5.0	12.3	20.4
Korea	6.2	9.2	15.8	36.8
Thailand	1.5	2.2	13.1	16.1
Latin America	6.6	10.8	18.3	24.7
Argentina	14.5	20.6	21.6	40.8
Brazil	2.2	8.0	11.9	11.2
Chile	3.0	10.0	18.8	13.2
Colombia	2.0	6.0	10.2	13.1
Venezuela	11.0	15.0	21.4	27.8

Source: Developed by the authors based on UNESCO's Statistical Yearbooks.

On the other hand, there is an element which can not but draw our attention and it is the decrease in coverage which took place between 1980 and 1988. Stated in yearly terms, while the enrolment rate increased at a rhythm of 9.4 percent between 1973 and 1980, between 1980 and 1988 it decreases at a rhythm of 4.3 percent. It is to be borne in mind that, of the countries in the sample, Chile and Ecuador are the only ones which undergo a decrease and to such a degree.

The above information, can also be shown in terms of average yearly growth rates of higher education enrolment for the countries in the sample, which is reflected in table No. 7.

[18] Measured as the percentage of students enrolled in higher learning in relation to the total number of inhabitants at tertiary education age.

TABLE 7
GROWTH RATE OF HIGHER EDUCATION ENROLMENT
(1965 - 1990)

Countries	Period 1990-1965
Japan	4.0
Germany	6.5
Korea	10.3
Singapore	7.3
Israel	5.8
Chile	6.4
Colombia	10.3
Uruguay	5.8
Venezuela	11.4
Peru	9.2
Paraguay	7.1
Ecuador	11.3
Brazil	9.6
Bolivia	9.2
Argentina	5.2
Yearly Average	8.0

Source: UNESCO's Statistical Yearbooks.

The growth rate of higher education enrolment has been low, similar to that in developed countries, in a context where Chile's initial conditions were considerably worse than those prevailing in such countries, and were surpassed by countries with a high growth (Korea and Singapore) and by most of the countries in Latin America. To sum up, the general context of expansion of higher education enrolment shows a low relative growth, which has expressed itself in a slow expansion of its coverage.

The following step is to examine the allocation of higher education enrolment to technological disciplines (basically engineering, mathematics, computer sciences and agriculture and animal husbandry). The results are shown below.

TABLE 8
PARTICIPATION OF THE TECHNOLOGICAL DISCIPLINES IN HIGHER EDUCATION ENROLMENT

Countries	1965	1973	1980	1988	Average
Japan	21.7	22.5	19.6	20.3	21.0
Germany	na	28.3	21.6	18.8	22.9
Korea	29.2	35.5	40.6	26.9	33.0
Singapore	na	11.9	46.6	44.7	34.4
Israel	13.5	13.9	21.9	21.5	14.1
Argentina	13.9	19.8	23.2	23.0	20.0
Bolivia	14.5	14.1	29.6	14.1	18.1
Brazil	18.1	8.5	14.5	16.4	14.4
Chile	na	30.0	31.0	32.0	31.0
Colombia	28.8	23.5	17.3	26.8	24.1
Ecuador	27.0	24.8	21.7	15.1	22.1
Paraguay	9.3	15.9	na	14.5	13.2
Peru	11.2	24.5	26.6	16.2	19.6
Uruguay	10.7	16.8	14.9	16.5	14.7
Venezuela	22.5	17.4	22.9	22.2	21.2

Source: UNESCO's Statistical Yearbooks.

The table shows three important facts. First, that countries that made a successful catch-up put the above process into practice through a strong allocation of human resources to higher education of a technological type (at levels always close to a third of total enrolment). In the second place, that Latin American countries have in general a poorer behavior (even poorer than in developed countries) and, in the third place, that the behavior of Chile is surprisingly good, with levels of participation close to that of Asian countries. If this is so, Chile's main problem in higher education is not the poor allocation to the more technological disciplines, but rather the low total growth in enrolment.

The analysis of the composition of technological enrolment in Chile is also enlightening. The most important aspect observed in Table 9 is the marked decline shown by the areas of "hard" engineering, particularly in the period 1973-1980 (which coincides precisely with the "destructive" period of industrial reconversion). This lower participation is offset by an increasing dynamism of the "soft" branches of engineering (chiefly systems engineering) in special over the period 1980-1987 (when the use of computer-based systems becomes generalized in vast sectors of the economy). These facts corroborate the hypothesis of the existence of an important interdependence between the evolution of the economic structure and human capital accumulation.

TABLE 9
COMPOSITION OF TECHNOLOGICAL ENROLMENT IN HIGHER EDUCATION IN CHILE

Years	1970	1972	1980	1987
Engineering	25.9	32.2	23.0	18.9
Agriculture	4.1	4.1	2.1	4.3
Math and computer sciences	0.0	0.0	6.0	8.9
Total	30.0	36.3	31.1	32.1

Source: UNESCO's Statistical Yearbooks.

A special dimension of human capital is that of favoring the incorporation of new knowledge from abroad. Fuentes and Vatter (1991), discuss the role of human capital as a "direct" importer of technology through the students going abroad to obtain scientific and technological training in developed countries. The underlying idea is that in the developed countries new production techniques are being studied and developed, giving rise to what is designated as unincorporated technological change, and this eventually enables them to grow faster than underdeveloped countries. The students, on their return, not only begin to operate and adapt this new knowledge, but they also generate "institutional spill-overs" in attempting to modernize their setting through the assimilation of successful foreign institutions. Table 12 summarizes the total number of students --from the countries sampled-- pursuing studies in developed countries during the years 1973 and 1990.

From the information shown, there follows the existence of a strong correlation between the countries with a high growth and number of students in developed countries. Latin America, in general would seem not to have availed itself of this mechanism for technological transfer. Chile, in particular, follows the general pattern of the region, as no trend in observed as regards using this mechanism intensively[19].

[19] It must be borne in mind that the mere fact that there are students abroad does not warrant technological transfer, unless they return to the country of origin instead of remaining in the host country, cutting off all ties with their own country. Hence, caution is to be exerted in connection with the information in the table, as it is only a proxy.

TABLE 10
STUDENTS IN THE DEVELOPED WORLD FOR EVERY 100.000 INHABITANTS

Countries	1973	1990
Japan	6.4	29.6
Korea	12.7	73.6
Singapore	50.0	247.2
Israel	101.5	98.6
Argentina	5.6	8.6
Bolivia	16.5	18.2
Brazil	3.2	4.9
Chile	17.3	16.6
Colombia	12.5	13.3
Ecuador	12.3	12.0
Paraguay	6.9	7.9
Peru	14.0	17.6

Source: UNESCO's Statistical Yearbooks.

Finally, one of the additional mechanisms which the educational system resorts to in order to train its human capital is on the job training. The country has a regulatory framework for institutional training through the *Sistema de Capacitación y Empleo* (National Training and Employment System) regulated by Decree Law No. 1 of 1986. Through it, the State performs a normative and financing role of the activities which in this connection the firms decide on in an autonomous manner. The institution which runs the training programs is the *Servicio Nacional de Capacitación y Empleo* (National Training and Employment Agency - SENCE), reporting to the Ministry of Labor. The cost of the programs is partially financed by the State through what has been designated as the "TAX SUBSIDY".

As regards the results of the program, a permanent growth in coverage is perceived. Thus, while in 1988 it amounted to 5.6 percent of the labor force, in 1993 it had increased to 8.8 percent. In spite of this growth, the universe of agents who have access to the program is still very low[20].

[20] By way of example, with the current coverage index, a worker is trained on average every fifteen years. In the economies of South East Asia, a worker is trained on average every 4 or 5 years, according to information provided by SENCE.

It is interesting to analyze the composition of the level of coverage by firm size and workers' level of qualification, which is summarized in table 13 below. The recent performance of the system shows that small firms have limited access to it, while the dominant participation is that of the large firms (which are the ones that would have less difficulties in order to finance the accumulation of specific human capital). On the other hand, it is also possible to perceive a very limited participation of workers with no level of qualification, which corroborates our hypothesis that, within the social context, in which the technological foundation is increasingly oriented to be science intensive, it is necessary to initially have a good foundation of formal education to have access on the job training that is meaningful.

A relevant item of information in the table is that the percentage of firms fully using the State "tax subsidy" is lower than 20 percent, which could be reflecting that either the system is oversized with respect to Chilean needs --which is in no way independent from the level of formal training of the labor force-- or that, if it is adequate in size, the dynamics of Chilean firms as regards their investment in learning is very poor.

TABLE 11
SUMMARY OF THE BEHAVIOR OF
THE TRAINING AND EMPLOYMENT SYSTEM
(1993)

Firm size	Small	Medium-sized	Large	Total
Distribution of the "tax subsidy" (as % of labor force)	0.49	1.18	7.11	8.8

Level of qualification	Professional	Technical	Clerical	Skilled	Semi-skilled	Unskilled
Distribution of use of the "tax subsidy" by level of qualification	20.1	13.7	29.7	29.5	5.5	1.5

Use of "tax subsidy"	100%	From 50 to 99%	From 1 to 49%
Percentage of use of "tax subsidy"	17.0%	35.0%	48.0%

Source: SENCE (1994).

3.3. The Process of Technological Transformation in Chile

A first step in approaching this subject is to clarify what elements are involved in this process. As proposed in the first section, by transformation will here be understood as all the processes of creation, adaptation and improvement made endogenously by the agents of a NSI.

However, in order to quantify such efforts is a complex task; to separate the efforts of technological creation, adaptation and improvement not only quantitatively, but also qualitatively is not trivial because at present there is no theoretical foundation making it possible to distinguish them. Despite the above, in practice it is possible to observe some elements that are an outcome of such efforts; new productive products or processes or otherwise a new way to organize the firm, all of which are phenomena that are usually denominated as "innovations".

Unfortunately, in Chile there still are no instruments enabling us to explain the evolution of such technological efforts. That is, there is no certainty as to the success which firms --either public or private-- or else the universities, may have had in developing new productive products or processes[21]. On the other hand, when reviewing the different ways to quantify the processes of transformation in the countries, it is generally ascertained that spending in Research and Development (R&D) is one of the most widely used indicators. However, the problem which this parameter features is that it does not consider either completely or explicitly the results of these investments

Taking into consideration what has been stated above, in this section we offer a brief summary of our findings regarding the R&D efforts made by Chilean society, paying special attention both to the agents making such efforts as well as those responsible for financing them.

The efforts in (R&D) are crucial, not only for a given firm taken individually, but also from the viewpoint of the economy considered on an overall basis. Solow's (1957) finding that only a small proportion of per capita growth was associated with the increase in the labor to capital ratio gave rise to an increasing concern of the economists in terms of analyzing the role of technological progress in improving welfare. This central role involves paying careful attention to the incentives that firms have to innovate and adopt new technologies.

[21] However, during 1995, the Ministry of Economy, in conjunction with the National Institute of Statistics and with the assistance of the authors, will conduct the first national survey on innovation, primarily aimed at characterizing the national innovative effort and its results, elements will be of critical importance in designing a technological policy for the next years.

Though the set of activities which make up a country's R&D are manifold both in their nature, as well as regards those conducting it, there is, however, consensus in the literature to recognize three types of research[22]:

***Basic research:** involving the set of activities aimed at increasing scientific knowledge, with no practical pre- established objective.

***Applied research:** involving creative and systematic activity carried out in order to arrive at new scientific knowledge contributing to the practical solution of specific and definite programs.

***Experimental development:** involving creative and systematic activity originating from the practical use of existing scientific and technical knowledge as well as from empirical knowledge, and aimed at introducing new materials, products, devices, processes and methods or otherwise improving already existing ones.

Schumpeterian competition is the driving force of the R&D process carried out by firms. In it, the entrepreneur's key objective is to obtain monopolistic rents originating from a successful innovation. More in detail, if the innovation involves a process, the reduction in production costs will allow the successful firm to lower the prices of its products and to reduce its competitors' market participation, which depending on their level of efficiency may be forced out of the industry; if the innovation consists basically in the introduction of a new product or process, then the creation of a market niche, will allow the firm to obtain monopolistic benefits.

However, the existence of above the normal benefits will draw the attention of both competitors and other firms outside the market; then a search process will be generated by competitors and firms in an attempt to identify what it is that the leading firm does so well to warrant its leadership[23]. A considerable part of this process thrives on the fact that a non negligisome amount of the information on which success depends stems from the products and forms of production themselves developed by the firm with the best productive practice. That is to say, once the innovation has been made, it diffuses through the industry via licenses, imitation of patented innovations, or the adoption of non patented innovations. This process of diffusion, which is brought about through a drop in the curve of prices in the industry, is what generates the social benefit of the innovation.

There is then in practice a situation of deep dichotomy; on the one hand, the innovative firm needs the monopolistic benefits of its innovation to pay for the R&D processes it undertook; on the other hand, the information on the innovation

[22] The classification which follows is based on UNESCO 1980.
[23] There is a firm willing to pay the leader firm in order to obtain relevant technological information.

circulates and is used by other firms, at a low or null cost, giving a limited scope to the monopolistic benefits obtained by the leader firm. The fact that the benefits of the innovation can be eroded sooner or later is precisely what originates the situation whereby all firms are willing to use such information, though none of them are willing to pay for --without deriving any benefit-- the amounts of money (often very large) needed in order to produce it. This situation generates a gap between the private willingness to pay and the social benefit of the R&D efforts, thereby bringing about the collapse of the allocative efficiency of the market. Accordingly, there is the need to create institutions that make it possible to close the gap between what is social and private, that is, what makes it possible to correct the externality.

From the above, it follows that given the high uncertainty surrounding the innovative process, along with the externalities which knowledge generates as, for instance, its imperfect appropriability, institutional intervention within the frame of the NSI would be justified.

However, the types of intervention would be different depending on the temporal inertia generated by each one of them. Following what has been stated in the first part of this section, there will exist permanent measures of intervention when failures can not be corrected by the market, while a massive intervention will be justified only in the first stage of the process to develop a technological structure displaying dynamic economies of scale.

The chief objective of this section is to partially characterize a NSI. To do this involves a high number of restrictions, beginning by the difficulty to quantify the innovative effort made by firms in the private sector as well as by public institutions. However, we present the results of a survey conducted by the authors in order to estimate, in very broad terms, the level of R&D spending in the country during the year 1993[24] and then compare this effort with respect to a set of selected countries.

The tables which follow offer a summary of information gathered for the country in 1993. In them, a distinction has been made as regards the sources of funding of the innovative effort and the institutions which actually conduct the R&D activities needed, though both should not necessarily coincide[25].

[24] The methodological problems involved in collecting the data by the officially accredited institution (CONICYT) along with the lack of information indispensable to the purpose of this work, as is the absence of a consistent access to information in terms of sources and use of funds from the different sectors, led us to conduct a parallel survey at the expense of a loss in the temporal dimension of the series.

[25] In the previous paper we offered a detailed description of all sources of financing detected as well as the institutions involved in research, either basic, applied or experimental development.

TABLE 12
EXPENSE IN R&D IN 1993
(accrued)

Agents	Ch$ (millions)	US$ (millions)	%
Universities	53,854.98	126.50	41.05
Public Institutes Services	22,299.52	52.38	17.00
Public Institutes Productive	38,751.15	91.20	29.54
State-owned firms	4,151.26	9.75	3.16
Consultants CODELCO	4,108.29	9.65	3.13
Listed L.L.C.	4,225.21	9.92	3.22
PYMES (FONTEC)	3,799.59	8.92	2.90
Total	131,189.98	308.15	100%
GDP	17,663,643.00	41,490.20	
Expenditure R&D/GDP			0.74

Source: Developed by the authors.

Broadly speaking, it can be seen that the level of R&D spending in Chile is low in relation to developed countries (2.14% on average). As regards financing this expenditure, 27.1 percent of it is provided by the private sector. This participation is similar to that of other developing countries, such as, for instance, the case of Brazil (33%) and higher than India (10%), although it is far from the level prevalent in either developed countries (51%) or in countries with an accelerated growth (71%). In this sense, it can not be said that the country has begun the catch-up process, or that such process is very incipient; an example of it is that private participation in spending in Chile is 53 percent of that in developed countries and 38 percent of that in developing countries with a high growth.

TABLE 13
FUNDING OF SPENDING IN R&D

Agents	Ch$ (millions)	U$S (millions)	%
Universities	14,398.47	33.82	10.89
Public Institutes Services	14,902.79	35.01	11.27
Public Institutes Production	17,240.10	40.50	13.04
State-owned firms	10,388.20	24.40	7.86
Private firms	35,843.97	84.19	27.12
Fontec	2,214.02	5.20	1.67
Fondef	23,335.00	54.81	17.65
Fondecyt	8174.02	19.20	6.18
Internat. Assist.	5715.00	13.42	4.32
Total	132,211.57	310.55	100%
GDP	17,663,643.00	41,490.20	
Expenditure R&D/GDP			0.75

Source:Developed by the authors.

The graph shows a summary of the above findings in relation to the sources and use of R&D funds[26].

However, at the moment of establishing relative gaps, an important element is that they serve as a guide in setting policy goals, which involves giving consideration to 'viable' goals.

To establish goals that can be reached as a developing country, involves considering the constraints existing in relation to the productive structure and to the prevailing incentives system. Here, it is necessary to bear in mind that, owing to an important consensus regarding the maintenance of functional and neutral policies at the sectoral level, both the country's productive structure as well as the composition of its exports will not undergo great changes in the long term (that is, they will be biased to incorporating value added to the local endowment of natural resources). If the latter is true, then the comparison of the national effort --for policy purposes-- to the average of the effort in developed or developing countries does not have any great relevance, and it could be that it is more worthwhile to compare Chile to

[26] The grey block shows public financing and implementation of R&D, while the white one illustrates private financing and implementation, private financing and public implementation and public financing and private implementation, respectively.

developed countries where the foundations of the productive structure depends more --though not exclusively-- on processing natural resources; in this sense two countries featuring a potentially comparable structure are: Canada and Australia.

TABLE 14
COMPARISON OF THE INNOVATIVE EFFORT IN CHILE TO DEVELOPED COUNTRIES WITH EQUIVALENT PRODUCTIVE STRUCTURES

Country	Total expense R&D (% GDP)	Private financing (% total)	Personnel in R&D for every 10000 inhab.
Canada	1.46	0.41	34.04
Australia	1.36	0.41	33.31
Chile	0.74	0.27	3.63

Source: UNESCO'S Statistical Yearbooks.

From the perspective of the above table, an important element is that both Canada and Australia show a lower level of total spending in relation to the average recorded in the developed world, as well as a lower private sector participation. The above leads to a reduction of relative gaps in Chile; hence the total innovative effort is now only 50 percent what it is in Australia and Canada and the participation of private financing of the same equals 60 percent of what it is in both countries. The above suggests that to reach Australian levels, Chile should increase total spending by 0.62 points of the product (that is, an 84% increase over current levels) and private financing by 0.36 percentage points (that is, a 100 percent increase over private financing levels), which clearly shows how critical private effort will be in attaining these objectives and it is in such a direction that most of the institutional innovations should be aimed at[27]. However, not only the monetary indicators are to be considered, since there is also an acute deficit in the number of researchers and scientists for every 10.000 inhabitants because the proportion in Chile only amounts to 10 percent of what it is in Canada and Australia. In addition, in the Chilean case, only 25 percent of qualified scientific and technical personnel is involved in applied research, whilst in the case of Australia a 44 percent of the total is; therefore, there exist problems both in terms of a total deficit, as well as at the level of sectoral allocation.

[27] In monetary terms, in 1990 dollars and the GDP for 1991, this would imply an increase in spending by 257 million dollars, of which approximately 150 million dollars should come from the private sector; these amounts would increase substantially if we assume an important growth in GDP and should it be wanted that such growth be promoted primarily by an increase in total factor productivity.

From the data, it can be concluded, in the first place, that there exist important problems in homogeneity and consistency in relation to measuring R&D spending, both in terms of the level attained as well as in its sectoral composition. It is neither possible to define a technological policy without appropriate statistical information nor feasible to implement any such policy. It is important to acknowledge that better statistics involve greater spending in the development of an informational system.

In the second place, it can be seen that the private sector is a net contributor of funds to a NSI, as it finances more than what the private sector itself actually implements, due mainly to private financing of projects carried out by public universities. The situation shows an inverse disequilibrium to that observed in more developed countries.

On the other hand, it can be seen that contestable funds, though they have maintained a characteristic of strong neutrality, appear as a complement and not a substitute of the private sector R&D, which is explained by the shared involvement in their operation. Additionally, the funds to foment R&D have proven to be valid tools to "create" markets above all in what respects the relationships between small and mid-sized firms/institutes, small and mid-sized firms/universities and small and mid-sized firms/small and mid-sized firms.

Finally, the country has a "low" total level of innovative effort in relation to the countries that are in the process of or that have attained a successful catch-up. The same can be said in relation to private financing of this spending, with the gap being in this case greater than in relation to the total amount disbursed. However, the deficits become lower when the comparison is made with respect to developed countries having a productive structure which is more akin to the Chilean one, even though the differences still are very important.

4. CONCLUSIONS AND POLICY RECOMMENDATIONS

From the above paragraphs it follows that the Chilean National System of Innovation has a dynamism such that it allows it to absorb foreign technology in a manner that is biased to those sectors in which the technological gap with the international frontier is less important. On the other hand, most of the concepts that have been incorporated belong to what are known as the "soft" technologies which --though important when it comes to increase national productivity-- have a strongly static nature; that is, they do not generate important future impacts as a consequence of the development of the country's own industry with a high technological content (learning curves).

The above situation is added to the fact that the importance of foreign technology licensing is marginal and concentrated in market sectors whose market structure inhibits attaining important spill-overs and social benefits. In general terms, it is possible to state that Chile is not taking full advantage of all the technological benefits arising from an imitative strategy.

Even though a central element in explaining such a behavior is the lack of a critical mass of qualified human resources, it is also worth looking into the lack of institutional innovations in this area, and which are reflected in the fact that the policy towards foreign investment and the purchase of capital goods is absolutely neutral.

As regards the accumulation of human capital, the most important finding is the recognition of the existence of an allocative structure geared to technological disciplines, which on a comparative basis to other successful countries, is adequate. Hence, the major aspect to be considered in this regard is a low global rate of growth in enrollments. However, it can not be said that it is necessary to immediately increase the coverage of higher education without taking into account the distributive impacts, that are potentially regressive in such a situation. In fact, one of the characteristics of Chilean education at the primary and secondary level are the strong differences between the private and public education, which would inhibit students from the lower income strata to gain access to a higher education.

With respect to the processes of technological adaptation and transformation, the country shows all the characteristics of an infant economy, with the bulk of spending and financing in innovative activities being defrayed by the State. In particular and by comparison to developed countries with a similar productive structure to the Chilean one, even though the deficit in total R&D spending is important, the gap is greater in relation to the private effort in these activities. There is no doubt that such a panorama must be necessarily related both to the lack of institutions and policies to internalize the strong externalities resulting from the accumulation of knowledge as well as to failures in factor markets which inhibit it.

The analysis in the preceding paragraphs warrants creating conditions so as to give some thought to a technological policy. The analysis of a consistent intervention strategy obliges us to examine at least three different aspects. In the first place, there is the need to identify and prove the existence of a distortion, forwarding arguments enough to conceptualize it. In the second place, there is the need to design an adequate intervention[28] and finally to evaluate the administrative capabilities to carry it out efficiently.

Despite what has been said above, both the fact that the market failures can not be identified with precision and that the instruments of intervention are generally second-best, Chilean reality exhibits industrial policies which end up subsidizing the

[28] Broadly speaking, an intervention should be able to more efficiently correct distortions, at the lowest social cost. In this sense, the first best policies suggest correcting through a policy instrument that is to act directly on the same market where it takes place.

wrong sectors (in addition to some right ones), which generates increasing social costs.

The above then shows that the design of an industrial policy for Chile in the 90s could well be structured on the basis of neutral interventions, which are relatively "soft" in relation to their scope, both to avoid wasting resources, as well as to reduce the social costs of unsuitable interventions. In addition, it is also important that many of the interventions proposed above are stable. In the sense that the permanent change in incentives, induced by the volatility of the industrial policy, initially generates important social costs, related to the irreversible nature of many of the investments arising from it, and in the long term it becomes inoperant due to a loss in credibility. On the other hand, to the extent that some of them are designed with a view to promote the process of learning, they should have a decreasing trajectory in time, just as occurs with the subsidies to the sectors with static or dynamic economies of scale. Besides, to the extent that the national capital markets become deeper and globalize themselves, it is likely that the needs for specific funds for R&B become less important. Possibly, the only interventions which could justify permanence in time are related to the labor market and to R&D effort, since it is here where externalities have permanence. All the above is not intended to ignore the importance of selectivity, but the existence of a serious market failure or an important learning ability in a sector have to be proven before it is chosen to promote some type of special learning[29]. Given the randomness of the selection process, it can be said that ultimately a successful selection is a always matter of "good luck", because it happened to be carried out in the right sector, at the right time. Unfortunately, the probability function for the selection either does not exist or it exists but it is far too sophisticated and unstable for a policy-maker to identify it.

[29] As posited by Rodrik (1992), much is said about a successful selective industrial policy in Korea, but never anything is said about a spurious correlation. "The observation that selected sectors grow faster and become successful exporters is not insufficient to prove that such policy is successful...Is it not possible that in the absence of its industrial policy Korea would have done better than what it did? Did Korea grow so fast due to or despite its government? Thus, for instance, it is important to observe that the policies implemented by Korea towards the end of the 70s in order to promote the chemical industry are now judged as costly erroneous.

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