CHILEAN R&D POLICY

Pablo Serra*

ABSTRACT

This paper analyzes Chilean research and development (R&D) policy. To do so, it describes the institutions responsible for policy design and implementation as well as those which conduct R&D. In addition, it addresses the R&D policy and the instruments used to carry it out. The analysis is based on market failures justifying State intervention in R&D. The policy instruments used in Chile respond broadly speaking to market failures in R&D. Where there is a greater deficit is at the institutional level as there are many institutions, which are in no way interrelated, that are responsible for defining and conducting the science and techonology policy.

SINTESIS

Este trabajo analiza la política chilena en investigación y desarrollo (I&D). Para ello, se describen las instituciones encargadas de diseñar y ejecutar la política, así como los organismos que desarrollan I&D. Se estudia también la política de I&D y los instrumentos usados para llevarla a cabo. El análisis se hace a partir de las fallas de mercado que justifican la intervención del Estado en I&D. Los instrumentos de política usados en Chile responden a grandes rasgos a las fallas de mercado en I&D. Donde hay mayor déficit es en la parte institucional, pues existe una diversidad de organismos encargados de definir y ejecutar la política de ciencia y tecnología escasamente coordinados entre sí.

* Universidad de Chile.
Paper submitted to Meeting on "Economic Growth, Technology and Human Resources", Tucumán, Argentina. The author is grateful to the participants in the Meeting for their comments, especially Guillermo Mondino.

CHILEAN R&D POLICY*

Pablo Serra

1. INTRODUCTION

This paper's objective is to analyze the Chilean policy regarding Research and Development (R&D). In order to do so, we describe the agencies responsible for policy design and implementation, as well as the institutions involved in R&D. We also study the R&D policy and the instruments resorted to in order to implement the policy. The analysis is based on market failures justifying State intervention in R&D.

Several authors have emphasized that the factors involved in a country's scientific and technological development are manifold and are interrelated to constitute what has been called the National System of Innovation (NSI)[1]. Two key elements in the NSI are human resources and the internal technological effort to either tap technology from abroad or develop its own R&D. In addition, the NSI is strongly influenced by general macroeconomic conditions.

The countries that have grown most over the last decades have been characterized by having a stable and open economy, oriented to exports and with high foreign investment and internal saving rates. Dahlman (1994), based on a study on the South East Asian countries, points out that the above conditions are the same ones which foster scientific and technological development. In particular, these conditions facilitate the absorption of foreign technologies. In fact, the chief forms to absorb technology are direct foreign investment, capital goods imports, license contracts and efforts to tap foreign technologies, all of which are favored by the above stated conditions.

The Chilean economy exhibits, in very broad terms, the characteristics described in the preceding paragraph, and the current Chilean economic policy is geared to its consolidation. Even though macroeconomic conditions are favorable to technological development, market failures in R&D may well justify

* *Estudios de Economía*, publicación del Departamento de Economía de la Facultad de Ciencias Económicas y Administrativas de la Universidad de Chile, vol. 22, N°2, diciembre de 1995.

[1] See, for instance, the works compiled by Nelson (1993).

State intervention in this arena. The Welfare Theory purports that –in an economy with private ownership – competition leads to an equilibrium which is Pareto optimal. This result, however, calls for several assumptions. The existence of a market failure, –i.e., the non-compliance of some Welfare Theory assumptions–, is the foundation for developing a public policy.

In every public policy it is convenient to discern three components. The first is the market failure which determines that, in principle, government intervention is desirable; next, the policy designed to cope with the problem; and finally, the implementation of the policy itself. A well designed policy addresses these three aspects on an overall basis. Therefore, policy design should consider the institutional aspect, and especially the administration capability of the agencies responsible for conducting the policy[2]. However, it is recommendable that the design of the policy and its implementation should be undertaken by different agencies. As different tasks are involved, division of labor yields better results, apart from permitting a better evaluation of each agency or institution thereto.

The following stage, once the market failure that need be corrected has been established, is to develop an appropriate solution strategy. The design of the policy is critical to the solution of the problem, as on occasions an unsuitable policy tends to aggravate the problem rather than solve it. Besides, it is indispensable to consider the problems of political economy proper to any government intervention. When a public policy is defined, different interest groups attempt to obtain a preferential treatment, which may give rise to distortions that reduce social welfare. Finally, resources spent in lobbying activities have to be borne in mind. Hence, the preference which exists for instruments having a general character rather than those having a particular character.

Likewise, a well designed policy may be poorly implemented. The success or failure of a policy depends fundamentally on its implementation. However, economists in general concentrate on designing policies, disregarding everything related to their enforcement. In particular, it is necessary to bear in mind that it is difficult to attain efficiency in activities which are not subject to the discipline of the market, especially when the product turned out by them is not easy to measure. Hence, the importance of having indicators enabling us to evaluate

[2] Justman and Teubal (1995) point out that the analysis based on market failures is insufficient to implement a technological policy, as in many cases the market does not exist and it need be created. They propose, in lieu of it, a structural approach where the critical aspect is to determine what institutional set-up can be developed by the government to help resolve this problem. In our opinion, the advantage of the analysis based on market failures is that it gives a clear signal of the problem that need be resolved, which obviously needs to be complemented by an adequate institutional design.

public management[3]. With the above limitations in mind, it is possible that it may not be convenient to intervene in some cases, even if the market failure does exist.

Chilean industrial policy primarily considers three types of market failure[4]. The first is related to small and medium-size entrepreneurs' lack of access to credit. The second relates to information problems, because, as it is a public good, its provision is below the socially optimal level. Finally, due to appropriability problems, there exist market failures in R&D. Grossman (1990) in a recent article examines the different arguments which have been forwarded in favor of an industrial policy and the evidence supporting them. His conclusion is that empirical evidence is limited, and that it follows from it that the strongest case to sustain a government intervention is to be found in R&D.

In this paper, we concentrate on the technological policy. This is truly a serious limitation. In fact, there does exist a close relationship between technological progress and human capital formation in the technical area, as illustrated by the experience of the countries in South East Asia. In Chile, the scanty relationship between the educational system and the needs of the country's productive sectors, increases the necessity to consider both subjects in conjunction. However, we have deemed it pertinent, given the subject's complexity, to concentrate on one aspect, leaving a more integral analysis to another paper.

The literature characterizes two market failures associated with R&D. First, given that knowledge has certain characteristics which are specific to a public good, the generator of an innovation, can not appropriate all the benefits it yields. Consequently, the social returns of an R&D investment exceeds it private returns, a reason why spending in R&D, without any State support, would be below the socially optimum level. The second market failure arises from duplicated efforts taking place when firms do not share their R&D results. If the different firms carry out their own R&D independently there takes place a multiplication of efforts, involving the ensuing waste of resources.

The policy instruments resorted to in Chile respond, broadly speaking, to market failures in R&D. Research is subsidized, and R&D efforts are concentrated in R&D at technological institutes in order to avoid duplications.

3 One of the most important challenges faced by the country is to modernize public administration, where one of the most fundamental aspects is human resources management. The public sector has many constraints in the management of its human resources. On the one hand, wages are low and, on the other, laws warranting tenure make it practically impossible to dismiss incompetent employees, and even dishonest ones.

4 It is true that there exist other market imperfections, whose correction is not a part of the industrial policy, as for instance, the regulation of monopolies.

Likewise, there exist programs aimed at encouraging technological inter-firm cooperation and between them and the universities and technological institutes.

Where the greatest deficit occurs is at the institutional level, because there is a diversity of agencies, responsible for defining and conducting the science and technology policy and which are scarcely coordinated or interrelated in any manner. It would be appropriate to entrust only one agency with the responsibility of defining the policy; this agency, however, should not be involved in enforcing the policy. In addition, although there are indicators for public spending in R&D, those measuring its impact are few. A greater effort should be made to define indicators which evaluate R&D spending results. In turn, institutes have not been very successful as regards identifying and satisfying industries' technological needs. Accordingly, it is necessary to restructure institutes so as to ensure that they orient themselves in order to solve the problems of the productive sectors.

Most of the resources which the State allocates to R&D are devoted to basic (precompetitive) research, carried out mainly at universities. Two reasons account for this. It is at this level where externalities are stronger, as it concerns research serving as a basis for innovations with a commercial impact. Second, the firms' interest in conducting R&D has been lesser, a situation that is beginning to revert itself. Over the next years, the greatest growth in R&D spending should take place at the firm level, if R&D is to be successful. This will be in part a natural consequence of the country's economic development. However, due to the awareness that there exist important market failures related to R&D, the government does have a role to play.

Creating technological committees managed by consortiums of firms may be one of the most effective solutions to market failures in R&D. These committees will develop research programs to be outsourced to universities and technological institutes. This is an idea which more or less has taken shape in the country. A proof of this are the two institutes which have received partial funding from FONTEC and Fundación Chile's GTT program. A legislation to foment the creation and continuance of such committees is needed. Such committees could be financed by the firms in the sector, but the contributions would partially constitute a tax credit for the firms. The chief advantage of such committees is that they correct the two market failures occurring in R&D, thereby reducing enforcement and control costs by comparison to the case when subsidies or tax advantages are granted to individual firms and ensuring that the effort is oriented to solving technological problems of the productive sector.

Technological management committees would enable the decentralization of the R&D policy. It is difficult for a central agency to determine and coordinate the needs of the different productive sectors with respect to each of the aspects exerting an influence on their technological development: the technological transfer mechanisms, the human capital formation policy –researchers as well as skilled workers–, instruments to finance innovation, opening new markets and defining quality certification criteria, etc. Technological centers could assist in designing an overall technological policy at the level of the corresponding sector. Thus this system based on centers could become the main technological development instrument.

The remainder of the paper is organized in the following manner. The second section offers a summary of the literature on externalities in R&D. The third section analyzes Chilean investment in R&D. The fourth section focuses on Chilean policy in R&D. The final section submits the conclusions arrived at.

2. EXTERNALITIES IN RESEARCH AND DEVELOPMENT[5]

The first market failure associated with R&D is due to the incapability which the generator of an innovation has to appropriate all the benefits yielded by it. In fact, an innovation produces technological externalities (spill-overs) benefitting not only rival firms in the same industry, but also other industries and final consumers as well[6]. Consequently, the social returns to investment in R&D exceed its private returns and, therefore, R&D spending –without any State intervention– is below the socially optimum level.

Unfortunately, all existing information on externalities in R&D is related to developing countries. Bernstein (1988) believes that in Canada the social rate of return in R&D exceeds the private one by 70 percent in the case of industries with a low propensity to spend in R&D, a figure which goes up to 115 percent in industries with a high propensity to spend in R&D[7]. Bernstein and Nadiri (1989) measure social and private returns in R&D across four industries in the USA. Their results show that in R&D the social return exceeds the private one in amounts ranging from 30 percent in the machinery industry up to 123 percent in the petroleum industry. There exist other studies evidencing that the magnitude of the externalities is significant (Jaffe, 1986 and Pakes and Shankerman, 1984). Bernstein and Mohmen (1994), in turn, study externalities across countries and find that they are significant.

[5] This section is based on Serra (1994).

[6] A survey to executives in the USA shows that the most effective way to learn about a rival firm's technology is by conducting R&D (Levin et al., 1987, and Levin, 1988). The purchase of licenses is another way to gain access to the new technology, though less important. Other possibilities are engineering in reverse, interpersonal communications (publications, informal conversations and hiring employees from other firms).

[7] Bernstein (1988) posits that a firm's production cost is given by: $c = C(y, w, S_1, S_2)$, where y is the vector of production, w is the vector of factor prices, S_1 the sum of the R&D stock of the firms in the industry and S_2 the sum of the R&D stock of the industries in the country. Econometric estimates permit measuring the importance of technological externalities and the gap between social and private returns.

Hall (1993), in turn, provides indirect evidence that the gap between social and private returns would be expanding. According to their estimates, in 1980 the stock exchange market valued one dollar of physical capital at 0.60 dollars, whereas they valued one dollar of capital in R&D at US$ 1.50. In 1990 this situation had reverted, one dollar in physical capital went up to US$1.20, whereas one dollar in R&D capital dropped to US$0.40. These changes are consistent with an increasing gap between social and private returns in R&D[8].

The second market failure occurs when firms do not share their R&D results. If the different firms in an industry develop their own R&D independently, there occurs a multiplication of efforts with the resulting waste of resources (see, for instance, Gandal and Scotchmer, 1993, and Katz and Ordover, 1990). In addition, if the cost to undertake a specific R&D project is very high, it is possible that no firm at all will be in a position to carry it out on an individual basis. The problem of effort duplication is particularly serious in developing countries, where resources, especially those used by R&D, are very scarce[9].

Following Justman and Teubal (1994), a third market failure may be perceived: the difficulty to diversify risks in R&D. In the case of innovations, the market does not exist and, therefore, it is necessary to simultaneously develop both the supply and demand. Accordingly, the uncertainty is much higher than in other activities, and firms may not be willing to invest in R&D on an individual basis. The capital market institutions are not always willing to cover this type of risks given the problems of informational asymmetry and the very high likelihood of opportunistic behavior in R&D. This problem is more acute in developing countries where risk capital markets are still at an incipient stage[10].

A good Intellectual Property Law (Patent Law) reduces appropriability problems and facilitates the development of a technology market by clearly establishing the rights of the generator of an innovation, though in no case it eliminates market failures in R&D. Developing countries import technology and concentrate their efforts in adapting it to each country (Evenson, 1984); in

[8] Hall (1993) performs the following regression:

$$\frac{V_{it}}{A_{it}} = q_t + \gamma_t \frac{K_{it}}{A_{it}} \varpi_{it}$$

where V_{it} is the firm's total market (it includes debt), A_{it} is the book value of physical assets, and K_{it} is the stock of R&D constructed from the history of expenditure and t denotes the year. The estimated coefficients are q the market valuation of the book value of physical assets and γ the market valuation of the R&D stock.

[9] Obviously, if different firms carry out R&D, the probability of success increases. In this case the problem is that not all firms share the innovations.

[10] Although, on the other hand, in these countries there is less uncertainty in R&D, because it usually is a matter of adapting imported technology.

general, this technology is not patentable and, accordingly, market failures are greater in those countries. The literature distinguishes two solutions –which do not exclude each other– to the above problems[11]: a subsidy to R&D and inter-firm cooperation in an industry.

Subsidy to R&D. The subsidy may go directly to R&D carried out by firms or be channelled through free or subsidized technological assistance. The subsidy to R&D carried out by individual firms eliminates or, at least, reduces the gap between social and private returns, but does not eliminate the problem of effort duplication. Additionally, the authority is obliged to control that the subsidy to R&D is used for this purpuse.

Providing free or subsidized technological assistance calls for the creation of technological institutes. In R&D it is possible to distinguish two stages: gestation and diffusion. Gestation is the stage at which the research objective is defined and the mechanisms to carry it out are provided, with the experimental part either being performed at the institute or externally. In turn, diffusion involves transmitting new technology to the productive sector[12]. In developing countries, the primary task of R&D institutes should be absorbing foreign technology and disseminating it in the country.

R&D institutes funded either totally or partially by governments have existed for decades, both in developed countries as well as in developing ones. In the Appendix some examples of R&D institutes are given. The effectiveness of these institutions has depended on their organizational structure (Katz and Ordover, 1990, and Nelson, 1986). The challenge in this field is to develop institutional set-ups permitting an efficient use of the resources allocated. In particular, there is the need to make these institutes respond to the requirements of the productive sectors.

Intimately linked to the attainment of results is the way in which an institute is financed. We can distinguish two financing alternatives: the first, through the nation's general funds and, the second, from revenues from contracts with firms and sales of technological services. Obviously, in most of real cases the financial contributions are mixed in nature. A third possibility is that the funds are contributed by firms benefitting from R&D, an alternative analyzed as a form of cooperation.

When funding originates from the nation's general funds, R&D beneficiaries normally do not exert control over the institute, a circumstance which generates an agency problem. For instance, the institution could either concentrate its

[11] See, for instance, Katz and Ordover (1990).

[12] Diffusion is carried out through several channels: dissemination talks and technical seminars, direct technical assistance and, eventually, through demonstrative firms.

efforts on generating new knowledge, hence postponing foreign technology absorption, or otherwise conduct R&D having greater scientific appeal, but with lesser commercial interest. A possible solution to the agency problem is to compel the institution to self-finance itself by invoicing the direct beneficiaries for the research.

To finance an R&D institute by directly invoicing those who resort to its technological assistance services has some limitations. It should be borne in mind that a part of the benefits of an innovation reaches producers through informal channels. Therefore, an R&D institute's invoice may not exceed the benefit which derives from securing its assistance rather than imitating firms that have already adopted the innovation. A second problem is that high invoicing for technological services delays the adoption of the innovation. In fact, there exist both theoretical arguments as well as empirical evidence showing that the velocity of diffusion increases with the benefits of introducing the innovation (Mansfield, 1961).

A third reason to provide institutes with funds is to create a generic R&D capability making it possible to give efficient solutions to technological problems in the industries. Goldman (1994) in a comparative study of three European countries ascertained that the successful institutes are those whose activities and financing depend to a great extent on market demands, but which at the same time carry out long-term research with no immediate industrial application. Institutes exclusively centered on short-term commercial pursuits are not able to provide an appropriate technological support, as they lose sight of the long term. Normally generic research –owing to the appropriability problems involved –is financed by the State through contracts.

The existence of institutes does not eliminate the appropriability problem of R&D results altogether. In fact, R&D carried out by an institute has externalities (spill-overs) affecting firms that do not participate, industries or consumers directly[13]. For instance, an innovation that reduces a competitive industry's costs chiefly benefits consumers, because the price of the product decreases. One way of taking advantage of inter-industry externalities in R&D is to concentrate research at a limited number of institutes. In addition, in R&D there are economies of scope. An R&D institute may be organized in divisions that correspond to different productive branches. It is necessary to compare the

[13] Wolf and Nadiri (1993) using input-ouput information in the United States extending from 1947 to 1977 find that the technical progress of the different manufacturing industries is positively and significantly related to that of the companies which are their suppliers. Bresnahan (1986) shows that an important component of the social benefits of technological progress are the externalities that benefit sectors located farther up in the production chain. He measures the impact which innovations in the computer industry have on the financial services industry.

correspond to different productive branches. It is necessary to compare the benefits to be derived from concentrating R&D to problems occurring in large size institutes[14].

For the above reasons, it is unsuitable to expect self-financed technological institutes when the objective is to maximize social benefit. The State must contribute to their financing. How can we ensure that the resources which the State allocates to R&D institutes will attain the desired objectives? A criterion may be that of splitting subsidies up among different R&D institutions, so as to compare their individual effectiveness. The competition between the different institutions would encourage the efficient use of the resources allocated to them. A criterion –for purposes of comparison– could be that part of the expenditures which is actually financed by the users. In any event, it should be borne in mind that each industry's structure has a bearing on the percentage that it contributes to R&D. It is possible to foresee that, in the more concentrated industries, the firms' contribution should be higher. Therefore, the foregoing indicator should also be complemented with some effort to measure the social benefits of R&D institutions.

Cooperation. Inter-firm cooperation may be on an ex ante or ex post basis. There is ex post cooperation when a firm that has developed an innovation disseminates it among the remaining firms in the industry in exchange for a payment for the corresponding license. Unfortunately, there are limitations to ex-post cooperation. Even though a good Intellectual Property Law –in addition to lessening appropriability problems– facilitates the operation of the license market, its effectiveness is strongly impaired due to informational asymmetry problems and free-riding behavior. In addition, the innovator's impossibility for perfect discrimination makes the price for the license higher than what is socially optimum (Katz and Ordover, 1990).

There exists ex-ante cooperation when firms agree to share an R&D project benefits, dividing the expenses among themselves. It is necessary to bear in mind that this method of cooperation is only practical when it involves only a limited number of firms. Ex-ante cooperation does away with effort duplication problems and reduces those of appropriability, though it does give rise to some inconveniences. The literature points out that ex-ante cooperation facilitates collusion between firms to invest less in R&D and to eventually restrain production (see, for instance, Cohen, 1994, and Gandal and Scotchmer, 1993). When it comes to tradable goods industries in a small economy this possibility is not relevant.

14 For instance, the CSIR in South Africa employs 3,000 people and is organized in 13 business areas. In Taiwan the ITRI has more than 5,000 people, but a clear definition of its mission –solving the technological problems of the productive sectors– has enabled it to attain its objectives.

Justamn and Teubal (1994) hold that the need to cooperate goes beyond that of avoiding effort duplication. They point out that the solution to R&D problems is hardly related to subsidies, especially in the long term. The risks involved in R&D have such a magnitude and complexity that the most efficient way to face them is by coordinating the efforts made by firms. Coordinating the firms reduces uncertainty in multiple ways. For instance, it facilitates product standardization, without interfering with compatibility as regards other product lines. Likewise, a mutually agreed on inter-firm action accelerates the development of a supplier industry, which reduces costs. Consequently, they point out, the emphasis should be placed on the design of an institutional set-up enabling firms to cooperate among themselves, and by virtue of this the technological policy should be focused on encouraging inter-firm cooperation.

The ex-ante cooperation methods may be classified according to their organizational design. A first difference is between those forms of cooperation where firms design an R&D plan and then outsource it and those where the firms themselves are responsible for its implementation. If we consider the case in which firms carry out R&D it is possible to distinguish three alternatives: coordinating R&D carried out by the different firms in an industry; creating a temporary R&D unit to undertake a specific project; and, setting up a permanent technological center with a long-term action plan[15].

To coordinate several firms' research activities is not an easy task. There is the need to distribute R&D among the different firms involved by some criterion and to ensure that firms carry out the tasks they committed themselves to perform and share in good faith the results obtained. On the other hand, whenever a temporary association is set up to undertake a specific R&D project, most of the staff belongs to the firms participating in the consortium. Such an organization has two advantages: research reflects the needs of consortium members and the researchers involved in the project also facilitate the dissemination of the results when they return to their own firms.

To get such research associations started is not an easy task. It demands that, among other things, the parties reach an agreement on the research objective and set aside mutual distrust between firms that are accustomed to compete against each other. Therefore, a possibility lies in creating R&D institutes with their own staff. When an R&D institute is administered by firms in a sector, agency problems are lessened. However, there is the need to ensure that the new organization does respond to the firms' interests. The institution may be centered on generic investigation of a precompetitive nature or otherwise carry out specific R&D projects, whose results are transferred to consortium members. A mixed

[15] Other cooperative alternatives are agreements to mutually grant any licenses to be generated or permit researchers from different firms to share the knowledge.

organization, having a permanent basic structure along with an organization dealing with temporary projects, may alleviate the agency problem.

The second possibility is that the consortium of firms outsources its R&D to technological institutes or university-related centers. The key advantage of this option lies in its flexibility, because there exists a great adaptative capacity. In addition, its startup costs are relatively low. Romer (1993) proposes an institutional set-up with these characteristics. In keeping with his proposal, when most firms in a particular industry so decide it, a tax is to be levied on the firms and its proceeds would finance R&D in the area. These funds would be turned over to administration boards whose directors are to be appointed by the firms contributing to the fund. Each firm would choose the fund it would join or would eventually create a new one. The boards would approve the research program, which then would be commissioned to institutions such as technological centers and universities.

Even though inter-firm cooperation lessens duplication of efforts, it does not totally do away with the appropriability problem of R&D results, and hence subsidies to centers set up by consortiums of firms can not be ruled out. Likewise, the transaction costs involved in creating an R&D institution funded by the productive sector may be very high. Inter-firm cooperation can be simplified through the participation of an external institution to articulate the cooperative process. In Japan and the United States this role has been taken up by the State (Ministry of International Trade and Industry in Japan and Department of the Defense, among others, in the United States)[16]. The role as a catalyst may also be left in the hands of private or autonomous agencies devoted to generating and diffusing technological knowledge. In any event, it is the State's responsibility to develop an institutional set-up to make inter-firm cooperation easier.

3. TECHNOLOGICAL INVESTMENT IN CHILE

This section analyzes R&D investment in Chile. The data was obtained from the report "Scientific and Technological Indicators for 1993", prepared by the National Committee for Scientific and Technological Research (CONYCIT). The indicators used are R&D spending as a percentage of GDP and the number of researchers for every thousand active inhabitants. Their recent evolution is analyzed and compared to indicators in more advanced countries and recently industrialized countries. Private sector participation in financing R&D spending is also analyzed.

[16] Cohen (1991) analyzes the difficulties involved in developing a technological policy in the United States.

R&D spending was 312.7 million dollars during 1993, and it corresponds to 0.78 percent of GDP. Over the last decades, national R&D spending has grown faster than GDP. In point of fact, in 1965 national R&D spending only accounted for 0.32 of GDP. Likewise, it is important to state that there is an acceleration in the rhythm at which R&D spending grows as from 1991. In fact, when the period going from 1965 to 1993 is considered, the yearly growth rate of spending in R&D is 10 percent[17], but if the period going from 1965 to 1990 is analyzed, this figure goes down to 8 percent. In the period 1990-1993, however, the yearly growth rate is 12 percent.

According to CONICYT's report, in the year 1992, 55 percent of R&D was financed by the State. In turn, technological institutes contributed 18 percent of the total, firms 12 percent, universities 9 percent and international technical assistance the remaining 6 percent. These figures present some problems. Institutes' total spending was, in 1992, 32 thousand million pesos, of which roughly 11 thousand million pesos correspond to the direct fiscal contribution. The difference is what the report considers as the institutes' contribution to fund R&D. As can be seen in Table 1, about 43 percent of the Institutes' funding comes from selling services to firms and, to a lesser extent, from contracts with firms. Accordingly, if we consider the original source of funding and we assume that there is no double book-keeping, firms would have funded about 25 percent of R&D spending and the State 61 percent.

National R&D spending is low by comparison to that in more developed countries, because during 1991 it amounted to 2.9 percent in Japan and to 2.8 percent in the United States. In any event, R&D spending in Chile as a percentage of GDP is higher than in other Latin American countries, where, in general, it does not exceed 0.4 percent, save for Brazil where it is in the order of 0.5 percent. Regardless of the figure adopted, firms' participation in funding R&D is still low if compared to those in developed countries. In the United States firms finance more than 50 percent of R&D and in Japan 70 percent (firms' lower participation in the United States is explained by the importance of R&D spending in defense).

Taiwan, in turn, spent in 1991 about 1.2 percent of its GDP in R&D, with more than half financed by the State. Korea spent 1.9 percent, with 80 percent funded by firms. In the mid seventies Korea only spent 0.5 percent of GDP in R&D and the State financed 80 percent. Dahlman (1994) gives three reasons to explain the rapid growth of technological investment in Korea. In the first place, its industrial organization centered around large conglomerates makes it easier to conduct R&D, because it lessens the problems that are proper to R&D. Korea's decision to depend less on foreign investment has limited one of the primary

[17] The growth rate is obtained by regressing annual R&D spending to R&D spending for the preceding year.

sources for technology absorption and has made the acquisition of foreign licenses difficult, owing to its profile as a potential competitor.

TABLE 1

FUNDING OF R&D INSTITUTES YEAR 1993

	Total THCh$	Firms' Contribution THCh$	Percentage Firms' Contribution
CORFO Institutes			
INTEC	1790	532	30
IFOP	3449	1200	35
INFOR	1285	86	7
CIREN	1534	54	4
INN	393	70	18
Sub-total	8451	1942	23
Ministry of Agriculture			
INIA	7160	3927	55
Ministry of Mining			
CCHEN	3685	303[a]	8
SERNAGEOMIN	3841	421[a]	11
CIMM	5053	5053	100
Sub-total	12579	5777	46
Fundación Chile	5329[b]	2751	52
TOTAL	33519	14397	43

Sources: Inventory of Research and Development Public Institutes, Science and Technology Program, Ministry of Economics, July 1994. INIA, 1993 Annual Report.

[a]Includes selling of services to public sector.

[b]Operating Costs and Expenditures. Financed with a decrease in equity.

Another indicator used to measure investment in science and technology is the number of researchers for every thousand active inhabitants. In 1992, the country had 5,926 researchers in all, involving 1.2 researchers for every thousand active inhabitants. Although this figure represents a 25 percent increase relative to 1981 when the corresponding figure was 0.95, it is still low if compared to those in developed countries. In Japan this quotient exceeds 9 and in the United States it is higher than 7. Another important difference resides in the researchers' occupational source. Of Chilean researchers, 8 percent works at firms, whereas in the United States this percentage is higher than 75 percent and in Japan it is over 55 percent.

From the above figures, it follows that in Chile R&D spending is low if it is compared to that in developed countries and that firms play a less important role in Chile, unlike the situation in developed countries where firms finance and conduct the major part of R&D spending. However, it is not to be concluded from the above comparisons that to increase spending in R&D is bound to have a positive effect on the economy. In addition, it is to be recalled that the above-stated indicators only measure spending and not the results deriving from it. We illustrate the above arguments with an example. Given that the number of scientists for every thousand active inhabitants is much lower than that in developed countries, the possibility of increasing their number could be envisioned through a strong expansion of the postgraduate scholarships program. However, many Chileans who complete postgraduate studies already find it difficult to secure an employment in the country. The university system, despite its low salaries, is already saturated and could not absorb new researchers, unless those with a low productivity were substituted or its resources were increased substantially, neither of which seems feasible. As long as the firms do not begin to resort to scientists in a significant way there is no sense in increasing their supply and, to the contrary, it would become a waste of resources as many of them would remain abroad.

To evaluate the effects of R&D spending is a difficult task because they take a long time to reveal themselves. There exist indicators meant to measure a country's level of science and technology, as can be the number of patents that the country's residents apply for. This indicator involves a drawback because the greater part of a developing country's R&D is non-patentable technological adaptation. There also exist several indicators attempting to measure the technological gap, as can be the quotient between the (net) expenditure in royalties for foreign licenses and R&D expenditures, where the obstacle is that the indicator is based on spending. Another indicator used is the quotient of capital goods exports relative to capital goods imports. Its limitation is that it is affected by other variables, as are the tariff system and the exchange rate. A good indicator of the technological level is productivity per worker, but this again depends on other factors as, for instance, the stock of human capital.

As a country develops, national R&D spending will increase naturally. This is what in fact the evolution of Chilean R&D spending shows. Over the next year years the chief thrust to R&D should be generated by the firms. Firms' current low R&D expenditure is explained by the conditions prevailing in the country. When a strong economic instability dominated, it was important for entrepreneurs to concern themselves with reading market signals rather than with technology. Later in an economy where the chief comparative advantages are low and a high exchange rate, the primary engine of growth was to open up new markets, with technology relegated to a secondary role. But when the above-mentioned conditions vary as an outcome of the economy's expansion, firms have to concern themselves about technology so as not to disappear. For the time being it is already possible to perceive a concern regarding innovation in management techniques (soft technologies).

The above in no case involves that there should not exist a national R&D policy, but the State's action is to be based on the existence of market failures that need be solved. In fact, when R&D spending is below its socially optimum level due to market imperfections, the economy grows below its possibilities. Therefore, it is the government's duty to solve these market failures.

4. R&D POLICY IN CHILE[18]

The country's agencies governing science and technology are CONICYT created in 1967, and the Ministry of Economy, through the Science and Technology Program set up in 1992. Though the tasks pertaining to each one have not been clearly defined, CONICYT has focused its activity on institutions of higher learning and scientific research, whereas the Ministry of Economy has focalized its effort on the technological development of the productive sector. There also exist two advisory boards in science and technology, one reporting to the President of the Republic and another to CONICYT. The Chilean Agency for Development (CORFO), in turn, plays an important role in implementing technological policy.

The Ministry of Planning, through its International Technical Assistance Agency administers international assistance funds for science and technology that have attained importance over the last years. This Ministry also administers the President of the Republic's Scholarship Program aimed at providing further training to both teaching and research members of higher learning centers and the officials of public services and agencies. In addition, as is to be seen later, other Ministries in productive sectors implement their own technological policy.

The chief Chilean R&D policy instruments are the technological institutes and the different Funds that subsidize R&D. Most of the former were created during the sixties while the latter were set up in the eighties and nineties. It is

[18] The information resorted to in this section is taken from the publications "The System of Science and Technology in Chile" (CONICYT, July 1994), "Inventory of Public Research and Development Institutes", (Program of Science and Technology, Ministry of Economy, July 1994) and " Science and Technology Program Report" (Science and Technology Program, Ministry of Economy).

also necessary to consider the university system, the chief recipient of funds allocated by the State to R&D. Unfortunately, there do not exist indicators of the impact that the different policy instruments have on R&D. In 1992 the State financed R&D to a total amount of 72 thousand million pesos. Of that total, 27 thousand million pesos were allocated directly to the universities and 18 thousand million pesos to the technological institutes. The different funds, in turn, financed R&D to an amount of 23 thousand million pesos, with the universities as the main beneficiaries. In fact, two of these funds, amounting to slightly more than 13 thousand million pesos were transferred to the universities and to a lesser degree to the institutes, while around 9 thousand million pesos went to the productive sectors.

Also, the government with a view to partly eliminate the market failures proper to R&D has shown a concern as regards updating the Intellectual Property legislation. It is within this frame that during 1991 the new Law on Intellectual Property was enacted to replace the Law which had been in force since 1931. In that same year Chile undersigned the Paris Agreement on Intellectual Property. The Government is also actively involved in modernizing the agency responsible for administering Intellectual Property. For instance, it set up the Technological Patents Information Service giving access to more than 6 million patents from Europe and the United States. This service makes it possible to reduce the cost of obtaining recent technological information and, as a result, to negotiate with technology suppliers under better terms. On the other hand, there are no encumbrances to establish license contracts with foreign firms, facilitating technology imports.

Congress is currently discussing a Bill of Law to protect the development of new plant varieties. It will no longer be possible to either propagate or sell them without due authorization for a period going from 15 to 18 years. At present there exists a law regarding plant varieties, but it is not functional due to its discretional nature. This Law's approval will make it possible to give a new thrust to the seed industry, owing to our advantageous hemispheric location. In addition, it would attract foreign investment and encourage the development of new plant varieties in Chile.

A. Institutes

There exist 11 public research institutes and one technological transfer center of a semi-public nature. Of the 11 public institutes, five correspond to the Technological Institutes System that belong to the Chilean Development Agency (CORFO). One belongs to the Ministry of Agriculture and another three are connected to the Ministry of Mining. The remaining two are smaller in size and have a very scarce connection with the productive sectors. In 1922 the institutes as a whole employed 1,116 researchers, representing 18.8 percent of the national total. Unfortunately, there does not exist greater information regarding the impact of these institutes on the productive sectors[19]. However, there exists the impression that they have failed in terms of appropriately performing their role as regards satisfying the technological needs of productive sectors.

As can be seen in Table 1, selling services and, to a lesser extent, contracts made with firms finance about 43 percent of the spending at the Institutes. It can also be observed that CORFO Institutes are the ones receiving a lower percentage of the funding that originates from the private sector. IFOP has a greater private contribution due to a very specific fact. The Fishing Law allowed entrepreneurs in the sector during the years 1991-1992 to use their money contributions to IFOP as a credit to fishing license payments.

CORFO Institutes. CORFO Institutes belong to CORFO's Division of Subsidiaries for Development. Their objective is to contribute to the country's technological development through the gestation, transfer and adaptation of technologies, as well as by rendering technological services. The Institutes are the Fishery Development Institute (IFOP), the Forestry Institute (INFOR), the Technological Research Institute (INTEC), The National Standardization Institute (INN) and the Natural Resource Information Center (CIREN).

The evaluation which CORFO itself makes of its own institutes is not very positive. The institutes have not contributed to any extent to industry's technological development. This fact is explained to a great degree because its budget has been financed by the State. Accordingly, in an increasing manner the institutes' revenues originate from contracts and selling services to firms. Another source of funding are the contests called by FONDEF. CORFO, in turn, is providing its institutes with funds against specific projects. Perhaps the provision of fiscal funds could be connected to the firms' contribution to develop R&D. Finally, CORFO is going to channel an important part of the resources to its institutes through contestable funds. For these purposes the Research Programs and Projects of Public Interest and Services Fund (FONSIP) was instituted, which is to be eventually available to other agencies, both public and private.

Ministry of Agriculture[20]. The National Agriculture and Livestock Research Institute (INIA), set up in 1964 as an autonomous corporation belonging to the Ministry of Agriculture, has six experimental stations. Its objective is to

[19] Fundación Chile (Weinrich, 1994) has measured the social benefit of some projects which it has carried out. To this end, it has resorted to a model of diffusion of innovations similar to the one developed by Mansfield(1961). Resorting to time series information they have estimated econometrically the speed of diffusion, and subsequently through conjectures they have estimated what it would have been without Fundación Chile's contribution. The conjectures are based on a record of the activities undertaken by the Fundación and the way in which the innovation was disseminated across firms. This effort made by Fundación Chile is without any doubt an important step in the direction of measuring the results of R&D spending.

[20] Information obtained from INIA's 1993 Yearly Report.

develop technologies aimed at solving productive problems in the agriculture and livestock sector and to encourage the process of industrial transformation of its products. It is also involved in technological transfer activities. INIA is governed by a board made up of 7 members, representing the Ministry of Agriculture (2), farmer associations (2), INIA's researchers (2) and the founding universities (1). This Institute is characterized by a wide network of contacts, both at a national and an international level.

Ministry of Mining. There exist three institutes connected to the Ministry of Mining. The Chilean Nuclear Energy Board, created in 1965, is a Government agency and it relates itself to the latter through the Ministry of Mining. The Board, in addition to its research activities, is a consulting body to the President of the Republic and a nuclear and radiological safety regulator. The Mining and Metallurgic Research Center (CIMM) is a private corporation founded in 1970. Its objective is to develop technology in the field of mineral extraction and processing. Since 1989 it does not receive any contribution from the State and finances itself by selling technological services to mining concerns. The President of the Board of Directors is appointed by the Minister of Mining.

The National Geology and Mining Service (SERNEAGEOMIN) arose in 1980 by combining the Geological Research Institute and the State Mining Agency. Among other matters it foments and conducts specialized research in geology and mining. It also provides expert advise to courts of law in procedures related to the filing of mining claims, enforces and issues rules related to safety in mining operations and approves environmental impact studies in mining operations. Finally, the government allocates about 20 million dollars yearly to the National Mining Company (ENAMI) in order to support its activities aimed at fomenting mining; of this total, a small percentage is assigned to technological transfer, carried out primarily by CIMM.

Fundación Chile. Created in 1974 with contributions from the Chilean Government and International Telephone and Telegraph, with a view to involve itself in the research, development and application of technological and scientific advances. It has oriented itself primarily to technological transfer. To accomplish this task, it adapts technologies –which have proven to be successful in other countries– to local condition and disseminates them. Its chief field of action has been in fruit and vegetable production and processing, aquiculture and forestry. Fundación Chile operates through different mechanisms. It provides technical assistance to productive firms in technological and market matters and in project evaluations. It disseminates technological and marketing knowledge through courses, seminars, publications, and also by developing demonstrative enterprises (so far it has created 31 such enterprises).

B. The Funds

The funds finance R&D through different methods as are transfers and subsidized credits. Of the 28 thousand million pesos financed by the funds during 1992 –and which is equivalent to 55.5 million dollars– 71 percent corresponds to resources channeled through the Science and Technology Program, which also coordinates them. These funds are the National Scientific and Technological Development Fund (FONDECYT), with transfers of 7,264 million pesos during 1992, the Fund to Foment Scientific and Technological Development (FONDEF), with 9,579 million pesos during the same years and the National Technological and Productive Development Fund (FONTEC), with 2,818 million pesos. The first two are administered by CONICYT and the third one by CORFO.

There is also the Technological Transfer Program (PTT) of the Agriculture and Livestock Development Institute (INDAP) –a Ministry of Agriculture agency– with a total expenditure of 6,001 million pesos during 1992, which is equivalent to 22 percent of all funds and the Fishery and Aquiculture Research Fund (FIP), an Undersecretaryship of Fishery institution, with 1,877 million pesos, equivalent to 6.8 percent of the total financed by the different funds. There are also two smaller funds: the Research Fund of the Undersecretaryship of Fishery and the Agriculture and Livestock Research Foundation Fund (FIA). Finally, CORFO recently created the FONSIP[21].

FONDECYT. Created in 1981 with the purpose of encouraging upper level scientific and technological research. It operates through contests, with researchers from universities and other research centers applying to them. It is governed by the National Science and Technology Board, whose members are the Ministers of Finance, Planning and Education, who presides it.

One way to measure FONDECYT's impact is in terms of publications. During 1982, 745 papers were published in journals with an international circulation. In 1992, the number of papers published went up to 1,156, standing for a 55 percent growth in ten years. Chile has the greatest number of papers per capita in the region with 8.7 papers per 100,000 inhabitants, followed by Argentina with 5.7. In 1986 the papers published per 100,000 inhabitants were 7.8. Consequently, the increase is slightly more than 10 percent over 6 years. This growth is relatively low. The explanation is that the FONDECYT effect has been offset by a lower direct financing to the university system.

[21] Fundación Andes, a private non-profit corporation, finances different initiatives in support of the development of science and technology, such as international assistance programs, doctoral scholarships and research visits, as well as high technology educational centers.

It is also worthwhile to analyze the destination of the resources provided by FONDECYT. Over the period 1982-1993, 43.6 percent of the funds were allocated to exact sciences, with more than half of them assigned to biological sciences (21.9 percent). To the latter figure, 17 percent allocated to medical technologies and sciences is to be added. On the other hand, only 15.5 percent was assigned to engineering sciences. It was followed by 9.7 percent allocated to forestry and agriculture. Social sciences were assigned 7.7 percent of the total, juridical sciences 2.2 percent and Humanities and Beaux Arts 4.0 percent. These figures reflect with some accuracy the composition of the body of researchers at universities. There is therefore a clear hypertrophy, in relative terms, of the funds apportioned to biology and medicine, which, as a whole, obtain 40 percent of the total.

The advantage of contestable funds resides in that they allow a better allocation of the resources available for R&D, as they are assigned to the most productive researchers, given that the university system has not been very efficient in this respect. The foregoing does not mean that the contests are problem-free. It is not an easy task to find competent evaluators for all projects submitted, especially in those areas featuring a lower relative development. Besides, very frequently extra-academic considerations exert an influence on the evaluator's appreciation, especially in the field of social sciences. In any event, a great progress has been attained with respect to what occurred during the military government. A way to solve these problems is to give greater weight to objective indicators, which may be computed directly by FONDECYT. For instance, contestants' previous publications, duly weighted in terms of the journal's importance, are perhaps the best predictor of the probability that the contestant successfully completes the project. Also the results attained in previous FONDECYT projects, if they do exist, should also have a high weighting. In this manner, adequate incentives would be offered.

FONDEF. It began to operate in 1992 and its chief objective is to strengthen the R&D capability in productive areas, through an increase in the relationship between the universities and research institutes, on the one hand, and firms, on the other. The growth for technological demand should arise primarily from firms over the next years, and a greater part of research will be conducted at universities and institutes. Therefore, the idea is to link supply and demand. FONDEF operates financing R&D projects at universities and institutes with a transfer of the results to the productive sector. Projects are selected through a contest[22].

[22] Thus far, 70 percent of the funds are allocated to universities, 23 percent to technological institutes and the remaining 6.9 percent to other institutions.

In order to ensure their relevance and the transfer of knowledge to the productive sector, projects financed by FONDEF are to incorporate the participation of the productive sector. At the first two contests, in which 99 projects in all were approved, more than 150 firms participated. However, the financial contribution of the firms —a reflection of their interest— only amounts to 15 percent of the total. 50 percent of the resources are contributed by the research institutions (normally they correspond to existing resources and not fresh money) and the remaining 35 percent by FONDEF. The low contribution of the firms indicates that FONDEF still does not manage to fully attain its objectives.

FONTEC. It was created in 1992 to encourage technological innovation in the productive sector, and finances firms' innovative projects directly through credits and subsidies. It operates through two lines. The first one finances technological innovation projects. In projects with a total cost of up to 100 thousand dollars FONTEC finances 60 percent of the total. When the project ends, the firm may opt to the exclusivity of the results by covering 50 percent of FONTEC's contribution. In projects over 100 thousand dollars it grants a credit of up to 80 percent of the total with a limit of 300 thousand dollars. If the expected results are not attained, the firm obtains a subsidy equivalent to 50 percent of FONTEC's contribution. The second line finances investments in R&D infrastructure in the firms. FONTEC grants a credit of up to 80 percent of the investment. In the case of projects submitted by three or more firms a subsidy with a maximum equivalent to 25 percent of the amount financed by FONTEC is considered. Accordingly, inter-firm cooperation is encouraged.

FONTEC operates through an open window system, that is to say, a firm which has an innovation project may submit it at any time. Representatives from the main entrepreneurial associations participate in FONTEC's decisions. The contribution of the firms represents slightly more than 50 percent of total financing. Of the funds allocated as up to September 1993, 35 percent went to manufacture, 32.4 percent to the primary sectors, 16.6 to computer sciences, 9.9 percent to services and only 5.6 percent to biotechnology.

Even though FONTEC has contributed to the implementation of technological projects having an undeniable interest, it is far from being a decisive tool for the country's technological development, as is illustrated by the very scanty demand it has had. There are different reasons for this. In the first place, it has high transaction costs arising from the need to prepare the initial project and also from the required periodical progress reports. The requirement to provide detailed information discourages many eventual applicants to the fund. The concern for confidentiality determines that many firms, particularly the largest ones, should not use FONTEC's resources. There are ways to reduce these problems. One is to directly subsidize some expenses in technology, as for instance the case of contracts with technological institutes. For R&D carried out internally the requirements for information could be cut down through an accreditation system: duly qualified firms —especially those that have performed well in previous projects— could be allowed provide more general information.

Recently FONTEC has implemented a new modus operandi making it possible to finance the setting up of technological transfer centers administered by groups of firms. Among them are the Chilean Salmon and Trout Technological Institute, encompassing 85 percent of national production. FONTEC will provide 45 percent of the 659 thousand dollars needed to get it started. Likewise, FONTEC will contribute 79 percent of the 500 thousand dollars needed to set up the Footwear Technological Institute, supported by 19 firms in the sector and the Manufacturing Exporters Association (ASEXMA).

PTT[23]. The Program created in 1982 is aimed at financing small farm producers' technological development. In the season 1993-1994, 51,273 families participated in the program. This process is carried out through the setting up of technological transfer groups, intended to bring researchers and farmers together. The groups analyzed the problems detected and attempted to solve them. PTT is implemented by 129 technological transfer organizations, chiefly consulting firms, employing about 1,200 professionals and technicians. The agencies participate in bidding processes for technological transfer certificates. Likewise, recently a methodology was developed to make an evaluation of the services rendered by the technological transfer organizations, which is to be based on production, productivity and revenue indicators. Given the close relationship between technological development and human capital formation, INDAP is going to commence a training program for PTT beneficiaries. For this reason, it is concerned with disseminating its activities at rural schools (in 1996 it operated with 216 of them). In like manner, it articulated technological transfer with marketing and agro-industrial transformation processes and with INDAP's credit programs.

FIP. It was created within the frame of the Fishing Law enacted in 1991. Its purpose is to finance fishery and aquiculture research projects, whose results provide information for a rational management of hydro-biological resources. The Fund is administered by the Fishery Research Council, whose members are the Undersecretary of Fishery, who presides it, one Chilean Navy representative, and six councilors appointed by the President of the Republic at the proposal of the National Fishing Board. Councilors are specialists in fishery and are recruited from the public sector, the private sector and the universities. FIP's funding is tied up to the payment of fishing and aquiculture rights. In fact, when a shipper or a fish farmer advances the payment of his patent by one year, the funds obtained are allocated to the FIP instead of becoming a part of the country's

[23] The information was obtained from INDAP's Institutional Report, 1990-1994.

general revenue. Entrepreneurs benefit also by obtaining an important discount on the payment.

The Council approves a yearly research program to be assigned through a public contest. Contestants are qualified by external experts. FIP contemplates that all projects implemented should be evaluated by international experts. In 1993, the first 10 projects were assigned, six of them to IFOP and the remaining 4 to universities. It is hoped that in the future the private sector will participate in the bidding processes. In 1994, 18 projects were granted and contracted. During 1991 and 1992 the FIP operated with provisional rules, whereby the contributions in money to IFOP from the shippers was a credit for the payment of fishing licenses.

In turn, the Undersecretaryship of Fishery's Research Fund finances studies aimed at designing the fishery resource management policy.

FIA. The Foundation of the Agriculture and Livestock Research Fund (FIA), created in 1981, seeks to promote and encourage scientific and technological research in the agriculture, livestock and forestry sector, in order to provide producers with technological tools enabling them to solve the problems they face. FIA is governed by a Board of 7 members appointed by the Minister of Agriculture, who presides it. The Foundation formulates a yearly research program assisted by external advisers. Then, the specific projects in the program are bidden. The institutions responsible for the implementation of the projects have been chiefly the INIA with 59 percent of the funds allocated to it, and the universities with 38 percent[24]. Over the period 1981-1993, FIA sponsored 63 projects with a total cost of 6,625 million pesos at June 1993 value, contributing 54 percent of the total. The contribution made by institutions responsible for the implementation of the projects correspond to physical infrastructure and researchers' work.

FONSIP. It was recently created by CORFO and is aimed at allocating resources to research programs and projects contributing to the generation of public policies, global and sectoral plans and activities of general benefit to the productive sectors. CORFO's Executive Vice-president presides the Committee and appoints nine members, six of them belonging to other public agencies. FONSIP has already provided resources to the Undersecretaryship of Fishery in the order of 400 million pesos.

This Fund's objective for the mid term would be to define an agenda to create generic research capabilities considering the country's future needs. After defining the agenda, it would call a bidding process for the specific projects

[24] The financial resources granted by FIA represent 1 percent of INIA's funding.

among the different institutes and universities. If a technological institute is devoted exclusively to undertake commercial projects the quality of its technological research worsens, meaning, in turn, that the solutions offered to the firms are of lower quality. FONSIP's contributions would make it possible to develop a capability to perform generic research and to anticipate the needs of the productive sectors at the institutes.

C. University System

In 1992 the university system had 3,942 researchers in all[25], that is to say, a 65.5 percent of the national total. Most of the research is carried out at traditional universities. Of the 1,156 papers published in journals with an international circulation and written in Chile in 1992, university researchers account for 85 percent, involving 0.25 papers per researcher. 21.9 percent of the researchers are active in biology, 17.7 percent in medicine, while only 12.2 percent devote themselves to engineering sciences and 11.1 percent to agriculture and livestock sciences.

5. CONCLUSIONS

In Chile the responsibility to define and implement an R&D policy is divided among a great number of institutions. It would be recommendable to concentrate policy definition in only one agency, which, in turn, should in no way be involved in carrying it out. In addition, there is an evident need to generate more statistics regarding R&D, especially indicators aimed at measuring the impact of R&D spending.

The R&D policy instruments respond in very broad terms to market failures in R&D. Research is subsidized, and institutes, by virtue of their existence should, help to avoid duplications. Likewise, inter-firm cooperation is encouraged through FONTEC and between these and the universities and technological institutes through the FONTEC projects. In turn, to modernize the legal and institutional framework connected to Industrial Property seeks to reduce market imperfections in R&D. However, a recurrent criticism against institutes is that they have not devoted efforts enough to solve the technological problems of the productive sectors. It is urgent, therefore, to bring about an institutional change so as to ensure that institutes' activities be in a good measure determined by the demands of the productive sectors.

[25] The 3,942 researchers stand for approximately 20 percent of the teaching and research staff at the universities, which totals 20,000.

The greater part of the resources allocated by the State to R&D are devoted to basic (precompetitive) research, carried out chiefly at the universities, a fact which may have two explanations. It is at such level where externalities are stronger, because it is precisely the research that serves as a basis for innovations with a commercial impact. Second, the firms' interest to conduct R&D has been lesser, a situation that is beginning to change.

Over the next years, if the R&D effort is to be successful, the greater increase in R&D spending should occur at the firm level. This should happen as a natural consequence of the country's economic development. However, the government can make this process easier. In the first place, it is necessary to warrant that when the technological demand in the enterprises arises, the supply should be more adequate. The latter implies a human capital formation policy to qualify researchers who should fit the needs of the enterprises. Truly, a coherent training policy is not restricted to preparing researchers, it should also aim at training workers.

Given the scanty research experience at the enterprises, it is difficult that their R&D should grow very rapidly without support from the universities and institutes. To attain this, the technological institutes and universities should be able to respond to enterprises' needs in science in technology. The importance of FONDEF –which seeks to bring the universities and technological institutes closer to the enterprises– derives from this circumstance. Since universities concentrate the greatest number of researchers, they will obviously be the chief suppliers of technology. A suitable road to connect the universities to the enterprises would be by creating institutes associated with the universities. The contact through institutes would avoid the negative impact on basic research tasks.

To solve market imperfections also requires supporting R&D in the productive sectors. One possibility is to subsidize the R&D carried out by enterprises on an individual basis. In this case there are two ways to operate: one is a direct subsidy and the other by granting tax advantages. In general, direct subsidies are preferable for three reasons. First, they make it possible to quantify the cost they have to society. Second, tax advantages are always a source of tax evasion and dodging. Third, enforcement problems are greater in the case of tax advantages. In turn, the benefits of tax advantages are that they do not require a specific institutional set-up, as their enforcement rests with the Internal Revenue Service, and they offer a greater attractive to the enterprises, which due to image and confidentiality problems are not always very willing to apply for subsidies for specific R&D projects.

An alternative to solve market failures in R&D is by creating technological committees specialized in different activities and administered by consortiums of enterprises. The consortium's board would be elected by the firms themselves according to pre-established guidelines, and its mission would consist in defining a specific research program, to then be outsourced to universities and technological institutes. For these purposes, there is a need to enact a law to foment the creation and operation of such centers. Given that there are transaction costs involved in creating such centers, the State either directly or through autonomous agencies should serve as a catalyst and provide funds to get them started. The operation of these centers would be funded by enterprises belonging to the sector, but the funds provided would be in part a tax credit. Even though these consortiums could well be self-financed, the State's subsidy would accelerate their action. To have access to the tax advantages the consortium of enterprises should represent at least a minimum of the production in the industry or be made up by a minimum number of enterprises.

The chief virtue of these committees is to correct the two market failures occurring in R&D and hence to reduce enforcement costs as compared to the case of subsidies or tax advantages that are assigned to individual enterprises. In fact, in the case of the independent institutes, it is easier to ascertain if the funds –that are transferred to R&D– are actually devoted to this purpose. In any event, R&D financed by technological committees would not replace the R&D activity within the enterprises and, to the contrary, the existence of a technological base financed by the consortiums could encourage research at the enterprises. But in this case the requirements for direct subsidies to the enterprises decreases, because externalities are lower.

The task of these committees could be extended to other areas associated with the innovative process. One of them is the area of human resource formation. Committees could advise higher learning centers as to the needs for qualified scientists and engineers for the productive sector. A second role would be to support skilled labor training. It is known that the lack of the latter delays the introduction of more advanced technologies in some industries. They could also assist in obtaining funding for the technological development of the sector. The financial system in general does not grant loans for R&D activities due to information problems. The centers would contribute to solve this problem by reducing the information gap.

This is an idea that to some extent has taken shape in the country and has proven to be successful[26]. A proof of it are the 2 institutes that have received partial funding from FONTEC. In addition, there is the GTT program of Fundación Chile. It is an interesting case of cooperation among the different firms in an industry. The forestry sector enterprises have financed research activities aimed at reducing their production costs, many of which have had a commercial application. Fundación Chile has been the catalyst in this respect. This institution

[26] It bears resemblances to Romer's (1993) proposal.

along with helping to focalize R&D has obtained the assistance of many agents, primarily universities, to implement research activities.

The technological committees here proposed resembles the research associations in Germany (see Goldman, 1994). Research associations originate normally as a result of an industrial association's initiative, they are relatively small and their interest is focalized. These associations decide on the research agenda and then they become responsible for i) finding the best place to carry it out, ii) finance it, and iii)supervise it. At times they are co-funded by from the ministries. The studies are carried out by specialized centers belonging either to the universities or to technological institutes. These associations are closely related to technical training centers, which is one of their key strengths.

The technological committees proposed would make it possible to decentralize the R&D policy. In a country's scientific and technological development many interrelated factors are at play and they constitute what some authors have designated as the National System of Innovation. Some of these factors have been mentioned previously: the instruments for technological transfer, the human capital formation policy –both researchers as well as skilled workers–, and the development of a strategy to finance innovation. It is difficult for a central agency to determine the needs of the different productive sectors in each one of these fields. The technological centers could develop an integral technological policy within each productive sector. In this way this system of technological centers could become the chief R&D policy instrument.

APPENDIX

A. Research Institutes and Consortiums

In the world there exist a great variety of R&D institutions and in order to show this diversity we describe 4 of them, belonging to as many other countries. Two of them are public institutes and two are consortiums of enterprises.

The Wood and Furniture Technical Center in France, created in 1952 under the impulse of the professionals in the sector. The Center has three missions: (i) to make know-how available to enterprises, helping them to integrate technological innovations and to adapt to the evolution of the markets, (ii) to prepare the profession for a leadership position, and (iii) to acquire, centralize and manage scientific and technical information. The center employs about 230 people and has three technological transfer centers. The election of the action plans and the evaluation of the results are submitted to Professional Committees, made up by representatives from the enterprises, the Center and the government. 48.6 percent of its funding comes from specific taxes on wood and furniture sales, 11.6 percent from research contracts with the public sector, 38.3 percent from contracts with enterprises and 16 percent from product certification.

The Wood Technology Center in Sweden is aimed at rendering services to the enterprises of the sector and carrying out long term research. 25 percent of its financing comes from the dues paid by the wood and timber industries, 25 percent from the National Technological Development Directorate (the State provides a sum of money equal to the dues paid) and 50 percent from projects commissioned by either State institutions or private enterprises. The enterprises are members on an individual basis or through their professional associations. Members exert an influence on research activities through their participation in 25 reference groups.

In the United States the Microelectronic and Computer Technology Corporation (MCC) began its operations in 1983 as a large scale research consortium with a numerous staff of its own. The focus of R&D has been primarily on precompetitive research. The desire to share expenses more than a concern for the appropriability of the results was the primary motive for its creation. Each member pays a due in addition to an amount for each specific project it participates in. Owing to the limited interaction between the enterprises and the consortium and the vague powers vested on the latter, the research programs have departed to some extent from the objectives of the firms, and as a result only a few technologies produced at the MCC have originated commercial products.

The consortium Very Large Scale Integrated Circuits (VLSIC) in Japan, in operation between 1976 and 1979, was sponsored by the Ministry of International Trade and Industry (MITI). The mechanism was an engineering research association created specifically to develop that project and was dissolved when it was over. It was financed under the hojokin formula, whereby the government provides from 40 to 60 percent of the funds as a conditional interest-free loan to be paid off with the profits generated by the project.

B. Evaluation of Technological Institutes

To evaluate an institute devoted to R&D is even more difficult than to measure the benefits from innovations. In the first place, the sole existence of the R&D institutes helps to create an innovation culture in society. To estimate the benefits is practically impossible and therefore they are usually omitted.

In an exhaustive revision of the literature no evaluations of R&D institutes have ben found, except for the work of Avila and Evenson (1994). The authors' objective was to measure the contribution of agricultural research carried out by EMBRAPA (Brazilian Enterprise of Agricultural Research) on agricultural productivity in Brazil. To do so they considered the Total Factor Productivity corresponding to 370 micro regions in 4 different years (1970,1975, 1980 and 1985)[27]. They regressed these values on different variables, one of which was EMBRAPA's expenditures at its different centers. The marginal performance of the resources allocated to EMBRAPA were estimated by resorting to coefficients of the regressions.

As the analysis made by Avila and Evenson (1994) needs information that is rarely available, a discussion of an alternative follows. It consists in measuring first the social benefits generated by the different innovations in whose gestation and/or innovation the institution under evaluation participated. Once the benefits have been estimated –obviously not an easy task[28]– it is established that a part of them is attributable to the institution. Here we can distinguish two possibilities: one is the prorate distribution of the benefits among the different institutes involved; the second is a comparison of the actual situation to what would occurred had the institution not become involved.

Prorate distribution. When several actors have participated in the development and diffusion of an innovation it is difficult to allocate the benefits associated with it among the different agents involved. One first approximation is to assume that the return to any investment in R&D which was generated by

[27] Quotient between total production and an aggregate of factors used.
[28] Grilliches (1992) emphasizes that to adequately measure the benefits derived from R&D is difficult owing to technological externalities.

an innovation is the same, in which case the benefits attributable to each institution would be proportional to their expense in that particular project. These allocations could be corrected on the basis of effectiveness criteria derived probably from interviews to experts in the sector. The procedure's disadvantage lies in its subjectivity.

Let us now suppose that there exists a great number of innovation projects where it has not been possible to estimate the benefits. Additionally, the expense incurred by the different institutes involved in each one of the innovations under consideration is known. In this case it could be possible, by resorting to econometric analysis and by assuming that each institution's effectiveness has been the same in all projects, to estimate the effectiveness of each participant. Although this approach is simple, its application calls for the availability of a great number of evaluated projects.

Counterfactual Method. A second alternative to measure the social benefits attributable to an R&D institute involves establishing what would have happened had the institution not carried out the project, that is, to compare the situation with and without the institution's intervention. This approach, also presents conceptual and practical difficulties. Let us imagine an innovation developed and disseminated by one institute alone. If another institute had played a similar role, following the above criterion –with and without its intervention– we would arrive at the conclusion that the benefit creditable to the former institution is zero. For the same reason, it would not be possible to assign any benefit at all to the second institution, and hence the innovation's social benefit would not be assigned to any institution whatsoever. Another extreme case occurs when two institutions have been instrumental in bringing about an innovation, then according to the criterion indicated any social benefit should be ascribable to both institutions, and hence there would be double accounting.

When this approach is adopted it is necessary to consider both the successes as well as the failures. In fact, let us imagine an R&D project where there is no innovation with a commercial application. The counterfactual –without a project undertaken by the institution– could have been that two independent firms had conducted the same R&D, both of them with negative results and using more resources. If this is the case, the project's implementation –even though it may have not meant any meaningful innovation– would have generated a social benefit.

The above cases are extreme ones and in ordinary situations to compare both possible situations –with and without intervention– may be useful in order to estimate the contribution of an R&D institution to a specific project. The situation without intervention will be necessarily a construct based on conjectures. However, there exist some criteria that may help to arrive at the situation without intervention. In the first place, innovations which the institution did participate in could be compared to those in which it had no participation.

Second, it is possible to use the empirical evidence that the diffusion of an innovation normally accommodates to a logistic curve, having the shape of an S (Grilliches, 1958, Mansfield, 1961). Consequently, it is possible to summarize all information in three parameters: the initial date; the velocity of innovation; and the ceiling. The velocity of innovation depends primarily on the return obtained from introducing the innovation. An R&D institution's action affects both the starting point as well as the velocity of diffusion, and it is less likely that it also affects the ceiling.

Consequently, to have a better idea an R&D institution's impact, it is good to break down the total expense (and revenues) into development expenditures and diffusion expenditures, not only those made by the institute studied but also by others. This would make it possible to know in more detail what the innovation's trajectory would have been without the institution's intervention. For instance, if the institution did conduct the initial R&D, and knowing the total investment, it could be conjectured when and who would have effected such an investment. After the initial R&D has been carried out, the institution's efforts are directed at accelerating the adoption of the new technology. Here the conjecture is what would the velocity of dissemination have been without the presence of the institution being evaluated.

REFERENCES

AVILA, A.F.D. and ROBERT EVENSON (1994): "Total Factor Productivity Growth in Brazilian Agriculture and the Role of Agricultural Research: An Analysis by Sector and Agro-Ecological Zones," *mimeo Economic Growth Center*, Yale University.

BERNSTEIN, JEFFREY I. (1988): "Costs of Production, Intra and Interindustry R&D spillovers: Canadian Evidence," *Canadian Journal of Economics* Vol. XXI, 324-347.

BERNSTEIN, JEFFREY I. and M. ISHAQ NADIRI (1988): "Appropriability, R&D Spending, and Technological Performance," *American Economic Review* Vol. 78, 429-434.

__________ (1989): "Research and Development and Intra-industry spillovers: An Empiric Application of Dynamic Duality," *Review of Economic Studies*, Vol. 56, 249-269.

BERNSTEIN, JEFFREY I. and PIERRE MOHMEN (1994): "International R&D Spillovers Between the US and Japanese R&D Intensive Sectors," NBER WP 4682.

BRESNAHAN, TIMOTHY (1986): "Measuring the Spillovers from Technical Advance: Mainframe Computers in Financial Services," *American Economic Review*, Vol. 76, 742-755.

COHEN, LINDA (1994): "When Can Government Subsidize Research Joint Ventures? Politics, Economics and Limits to Technology Policy," *American Economic Review*, Vol. 84, 159-163.

CONICYT (1994): "El Sistema de Ciencia y Tecnología de Chile", Julio.

DAHLMAN, CARL (1994): "Technology Strategy in East Asian Developing Economies," mimeo, Private Sector Development Department, World Bank.

GANDAL, NEIL and SUZANNE SCOTCHMER (1993): "Coordinating Research Through Joint Ventures," *Journal of Public Economics*, Vol. 51, 173-194.

GOLDMAN, MELVIN (1994): "Technology Institutions: When are they Useful Lessons from Europe," Mimeo, Asia Technical Department, World Bank.

GRILLICHES, ZVI (1992): "The Search for R&D Spillovers," *Scandinavian Journal of Economics* , Vol. 94, Supplement 29-47.

GROSSMAN, GENE M. (1990): "Promoting New Industrial Activities: A survey of Recent Arguments and Evidence," *OECD Economic Studies*, Vol. 14, 87-125.

HALL, BRONWYN (1993): "Industrial Research during the 1980s. Did the Rate of Return Fall?," *Brookings Papers on Economic Activity* 2, 289-343.

JAFFE, ADAM (1986): "Technological Opportunity and Spillovers of R&D Evidence from Firms' Patents, Profits and Market Value," *American Economic Review*, Vol. 76, 984-1001.

JUSTMAN, MOSHE and MORRIS TEUBAL (1994): "Technological Infrastructure Policy (TIP): Creating Capabilities and Building Markets," mimeo, The Jerusalem Institute.

KATZ, MICHAEL L. and JANUS A. ORDOVER (1990): "R&D Cooperation and Competition," *Brookings Papers on Economic Activity*, Microeconomics, 137-191.

LEVIN, RICHARD (1988): "Appropriability, R&D Spending and Technological Performance," *American Economic Review*, Vol. 78, 424-428.

LEVIN, RICHARD et al. (1987): "Appropriating the Returns from Industrial Research and Development," *Brookings Papers on Economic Activity*, 3.

MANSFIELD, E. (1961): "Technical Change and the Rate of Imitation," *Econometrica*, Vol. 2, 741-766.

NELSON, RICHARD R. (1986): "Institutions Supporting Technical Advance in Industry," *American Economic Review*, Vol. 76, 186-189.

NELSON, RICHARD R. (1993): *National Innovation Systems. A Comparative Analysis*, New York, Oxford University Press.

PAKES, ARIEL and MARK SCHANKERMAN (1984): "The Rate of Obsolescence of Patents, Research Gestation Lags, and the Private Rate of Return to Research Resources," in R&D, *Patents and Productivity*, Zvi Grilliches (ed.), Chicago: University of Chicago Press.

PROGRAMA CIENCIA Y TECNOLOGÍA (1994): "Memoria del Programa de Ciencia y Tecnología 1990-1993", (Report Science and Technology Program 1990-1993), Ministry of Economics.

PROGRAMA CIENCIA Y TECNOLOGÍA, "Catastro de Institutos Públicos de Investigación y Desarrollo," (Inventory of Research and Development Public Institutes), Ministry of Economics.

ROMER, PAUL (1993): "Implementing a National Technological Strategy with Self-Organizing Investments Boards," *Brookings Papers on Economic Activity* 2, 345-399.

SERRA, PABLO (1994): "Externalidades en Investigación y Desarrollo", (Externalities in Research and Development), Working Paper No. 94/08/F, Department of Industrial Engineering, Universidad de Chile.

WEINRICH, ROLF (1994): "El Beneficio Social de los Projectos de Fundación Chile", (The Social Benefit of Fundación Chile's Projects), Fundación Chile.

WOLF, EDWARD and ISHAQ NADIRI (1995): "Linkage Structure, and Research and Development," *Structural Changes and Economic Dynamics*, Vol. 4, 315-332.