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RATES OF RETURN FOR INDUSTRIAL R&D IN CHILE

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Abstract

Using a panel data of innovative Chilean firms, we obtain a private return for R&D expenditure close to 30% during the nineties. Despite the fact of being almost twice the return obtained for physical capital - 17 %, results show that R&D expenditure causes contemporaneous negative impacts over firms' profits suggesting that a learning process is in place. Nevertheless, after two years, the net effect is positive and may explain why private participation in research activities is still very low in Chile.

Keywords: R&D return, Manufacturing, Chile.

Resumen

Utilizando datos de panel correspondientes a empresas inovativas en Chile, se obtuvo que el retorno privado para los gastos de investigación y desarrollo fuera cercano al 30% durante la década del noventa. A pesar del hecho de que el retorno en investigación y desarrollo es mayor en casi dos veces al obtenido para el capital físico (17%), los resultados muestran que el gasto en investigación y desarrollo causa impactos negativos sobre las ganancias de las empresas, lo que indica la presencia de un proceso de aprendizaje. En ese sentido, después de dos años, el efecto neto es positivo y podría explicar porqué la participación privada en actividades de investigación aún se encuentra muy bajo en Chile.

Palabras claves: I&D retorno, manufacturing, Chile

[1] Department of Economics, University of Chile and Central Bank of Chile. We would like to express our gratitude to Patricio Meller and Andrea Repetto for their comments. All errors are the sole responsibility of the authors.

Rates of Return for Industrial R&D in Chile *

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11 de agosto de 2006

Resumen

Using a panel data of innovative Chilean firms, we obtain a private return for R&D expenditure close to 30 % during the nineties. Despite the fact of being almost twice the return obtained for physical capital - 17 %, results show that R&D expenditure causes contemporaneous negative impacts over firms'profits suggesting that a learning process is in place. Nevertheless, after two years, the net effect is positive and may explain why private participation in research activities is still very low in Chile.

Key Words: R&D return, Manufacturing, Chile.
JEL Codes: L6, O3.

1. Introduction

According to the latest figures from Conicyt (2004), R&D expenditure in Chile approaches 0.7 % of GDP, placing it in the second highest place in Latin America behind Brazil. Nevertheless, this level is comparatively low with regard to more developed countries and the gap is quite significant[1]. Moreover, from the point

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[1]See Benavente (2004).

of view of the externalities generated by R&D, the breakdown of the spending in Chile is even more worrying. In developed countries, the private sector carries out and funds the bulk of R&D expenditure. This is a highly pertinent factor since it tends to ensure that the research undertaken is both productively relevant and has real economic effects. In Chile, the private sector funds 35 % of all R&D expenditure, broken down into 28 % by private companies and 7 % by state companies; the remaining 54 % is funded directly by the government and 11 % by other sectors. Therefore, it seems pertinent to ask, why does the Chilean private sector not fund a greater share of R&D expenditure? In particular, can the low economic returns of this type of investment be one of the causes of this low participation in Chile.

Cross-country comparative studies, such as Lederman and Maloney (2003), show that the social return rate of R&D in Chile approaches 60 %. Meanwhile, specific studies, mainly for developed countries[2], show the private return rate of R&D is around 40 %. These returns far exceed that of physical capital, displaying an inverse relationship between the R&D return rate and the intensity of the use of the factor.

The objective of this study is to determine the R&D return rate for Chile. Specifically, data panels for manufacturing plants are used to estimate the aggregate return as well as the return for particular industrial sub-sectors of specific interest in the 1990s. Additionally, the variables affecting R&D expenditure in Chile are analyzed, and a relationship between these variables and the rate of return is established.

[2]Goto and Suzuki (1989) and Griliches and Litchtenberg (1982).

This study improves the available knowledge in this area in at least two dimensions. Firstly, there is no estimation of the private R&D return rate for Chile available. Secondly, the methodology used demonstrates dynamic effects on firm productivity of expenditure on these activities, which is barely broached in earlier studies.

The results show that the R&D return rate in Chile is approximately 30 %, far surpassing the 17 % rate for physical capital. Nevertheless, the results also show that R&D expenditure generates contemporaneous negative impacts on firm profits. However, these reductions are subsequently compensated by the existence of significant dynamic effects associated with this kind of activity. It is suggested in this study that this element would partly explain the low level of private sector participation in manufacturing R&D, together with the fact that they face liquidity restrictions to carry out those investments.

This study is organized as follows: the conceptual framework employed as well as the empirical evidence related to the calculation of R&D returns is discussed in the section below. The methodology used is proposed in the subsequent section and the corresponding results are presented in section four. The findings are summed up at the end together with the conclusions.

2. Conceptual Framework

2.1. The Jones and Williams model

The usual model for estimating the R&D return rate is Jones and Williams (1997) where R&D is treated as an alternative form of physical capital[3]. In this model, the R&D social return rate is the profit in future consumption units arising from the increase in present R&D expenditure. Meanwhile, the private return rate corresponds to the increase in profits derived from greater firm innovation. This benefit is associated to an increase in profits, arising from increased demand for the product or from a more efficient production process[4].

By way of example, suppose that the firm produces under a Cobb Douglas technology type using capital, work and R&D stock. The partial derivative of the product with respect to the stock of knowledge corresponds to the R&D return rate, which are the additional units of the product generated by R&D. The basic relationship is described by the following equation:

$$Y = e^{\mu} Z^{\xi} K^{\beta} L^{\alpha} \tag{1}$$

$$\dot{Z} = R$$

With Z as the measure of R&D stock, K as the stock of physical capital and L is employment where Z increases with the increase in R&D investment denoted by

[3]This assumption ignores distortions associated with R&D, such as: monopoly income, intertemporal knowledge flows, congestion and destructive creation externalities. These distortions are not so important when the objective is to estimate the private return rate; however, if the objective is to estimate the social return rate, they are important.

[4]The objective of innovation can be separated into two groups: those that aim to increase final demand for a product, which improve product quality, and those that increase firm competitiveness, which improve production processes

R. Assuming that the depreciation rate of capital and R&D is zero, the marginal product of Z is interpreted as the R&D return rate r^P. Meanwhile, supposing that work and capital elasticities are known, the growth of PTF may be estimated through growth accounting in the following form:

$$\Delta \ln(PTF) = \mu + r^P \frac{R}{Y} \tag{2}$$

Where, upon estimating the coefficient r^P and assuming that in equilibrium the productivity growth rate is 0, the R&D return rate is given by the following expression:

$$r^P = \frac{\Delta \ln(PTF)}{R/Y} \tag{3}$$

Thus, under this model, the optimum R&D investment rate where the return on capital (market interest rate, r) equals the return on R&D, in other words, the balanced growth path may be denoted as the quotient between the private return rate and the market interest rate.

$$\frac{r}{r^P} = \frac{I/Y}{R/Y} \tag{4}$$

Where I is investment in capital.

2.2. Empirical Model

The following is obtained by applying logarithms to equation 1:

$$lnY = \mu + \xi lnZ + \alpha lnK + \beta lnL \tag{5}$$

Thus, the R&D return rate may be obtained by transforming elasticity ξ in the marginal productivity in equation 5, for which it is necessary to multiply the coefficient by Y/R. This method (measuring the returns through productivity) comes from the cost minimization process carried out by firms. Under the assumption of perfect competition in the finished-goods market, from the first order condition, the return on a factor should be equal to marginal productivity. However, in order to estimate the elasticity of R&D beforehand, the stock level of the factors must be known, which is generally difficult to find out.

One way of dealing with this stock estimation problem is by using variables measured in flows. Thus, taking first differences of equation 5, and assuming that the depreciation rate of capital and R&D is zero, we have the following[5].

Where r^P and r^K are the R&D and capital return rates respectively; R/Y is R&D as a proportion of the product; I/Y is the physical capital investment by product unit and $\Delta \ln(L)$ is the employment growth rate. This equation permits the R&D return rate to be estimated based on the relationship between product and R&D. The difference between equation 5 and the equations used by Griliches and Litchtenberg (1982) and Goto and Suzuki (1989), is that the latter are based on the relation between the intensity of R&D use and the growth of PTF. An alternative specification is that used by Lederman and Maloney (2003) whose framework is based on the link product - R&D.

[5]This transformation is simple when we consider that the coefficients ξ and α are the product elasticities with respect to R&D and capital. Keeping in mind that $\Delta lnX = \Delta X/X$, we have the following:

$$\beta \Delta lnX = \frac{\partial Y}{\partial X}\frac{X}{Y}\frac{\Delta X}{X} = r^X \frac{\Delta X}{X} \tag{6}$$

where r^X is the product derivative with respect to the stock of X, in other words, it is the return on X.

2.3. The equation and estimation method

In view of the above, the following functional form shall be estimated:

$$\Delta \ln(Y)_{i,t} = r^P \left(\frac{R}{Y}\right)_{i,t} + r^K \left(\frac{I}{Y}\right)_{i,t} + \beta \Delta \ln(L_{i,t}) + \eta_i + \omega_{i,t} + \upsilon_{i,t} \qquad (7)$$

Where Y is the added value of production, r^P is the R&D return rate, R is R&D expenditure, r^K is the return on capital, I is physical capital expenditure, L is employment, ε is the model error, and η_i is a non-observable individual effect, the sub-indices i, t indicate firm and year of the observation, respectively.

It should be said that for the estimators to be consistent, the error cannot correlate with the rest of the regressors. One way of solving this problem is by eliminating the non-observable individual effect, for which it is possible to restate the model removing its average over time from each individual observation. This Fixed Effect estimator is consistent even when the individual effect correlates with one of the regressors.

However, there is a second problem related to estimating PTF in this context. As Ollay and Pakes (1996) suggest, the conventional estimators such as Least Ordinary Squares (LOS) and fixed effects (FE) are biased and inconsistent since firstly, given that plants with a high expected productivity remain in the market, there is only information available on the more productive plants, and secondly, the investment decision is endogenous to productivity which is captured in this model in the error.

The form proposed in the literature to resolve this problem is the Arellano and Bond (1991) model, particularly when the model incorporates the lagged dependent variable as just another variable in the vector of explanatory variables, as in our model. These authors suggest taking first differences from the previous equation and using the regressor lags as instruments (future values in the case of strictly exogenous variables), and subsequently estimate using the Generalized Moment Method (GMM).

However, the three estimators considered: LOS, FE and GMM in first differences may present considerable bias if the coefficient associated to the lagged dependent variable is near to one, in other words, if the series is highly persistent. Blundell and Bond (1998) suggest that under highly persistent series and finite samples, the Arellano and Bond estimator bias may decline, introducing new moment conditions to the correlation between the lagged dependent variable and the error. The additional moment conditions suggested are that the covariance between the lagged dependent variable and the difference in errors, as well as the change in the lagged dependent variable and the error level are null. This estimator is termed "System GMM" because it combines a group of equations in differences that are instrumented with the lags in the equations in levels, with a group of equations in levels that are instrumented with the lags of the equations in differences[6]

2.4. R&D Lags

Finally, prior to estimating the above equation, a central aspect related to Research and Development activities in production plants should be mentioned.

A firm that invests in R&D does so to improve an existing product or process. However, the effective incorporation of this improvement may require a significant

[6] A detailed discussion of these methods, their strengths and weaknesses is presented in Bond (2002).

time span to implement. The more radical this change is, the longer the adaptation process will be. The R&D return rate may be associated to the additional product units generated by an incremental R&D unit, in other words, marginal productivity. As such, the product-R&D relationship would be expected to be positive in the long-run; however, in the short-run, it will depend on the time taken by a firm to adopt the new technology.

Specifically, one may consider there to be two processes running simultaneously. On the one hand, the existence of a learning process whose rate affects a firms capacity to capitalize profit from R&D, and on the other hand, an obsolescence factor whose rate would negatively affect firm profits. Assuming that the trajectory of the learning rate grows at a declining rate, this given that it would be more difficult to learn from the innovation, and on the other hand, that an increasing and convex obsolescence rate, since as time passes more companies will copy the innovation, the sum of the obsolescence and learning rate would produce a growth path in R&D expenditure returns, which is presented in figure 1. The pointed line represents the returns associated to capital and the thick line represents the returns on R&D. Based on this, three periods may be characterized: the first is dominated by the learning effect, the firm is in an introductory stage and therefore makes great efforts to learn to use the new technology, however, it does not have the capacity to operate and obtain maximum performance. Nevertheless, in this stage there would be monopoly income where the spillovers would be low, and therefore have a small obsolescence rate. In the second period, the firm has learned to use most of the potential of the innovation, together with a higher spillover effect although not significant enough to affect income. The firm obtains the highest income from the innovation in this stage, which would surpass income from physical capital investment. Income starts to decline in the

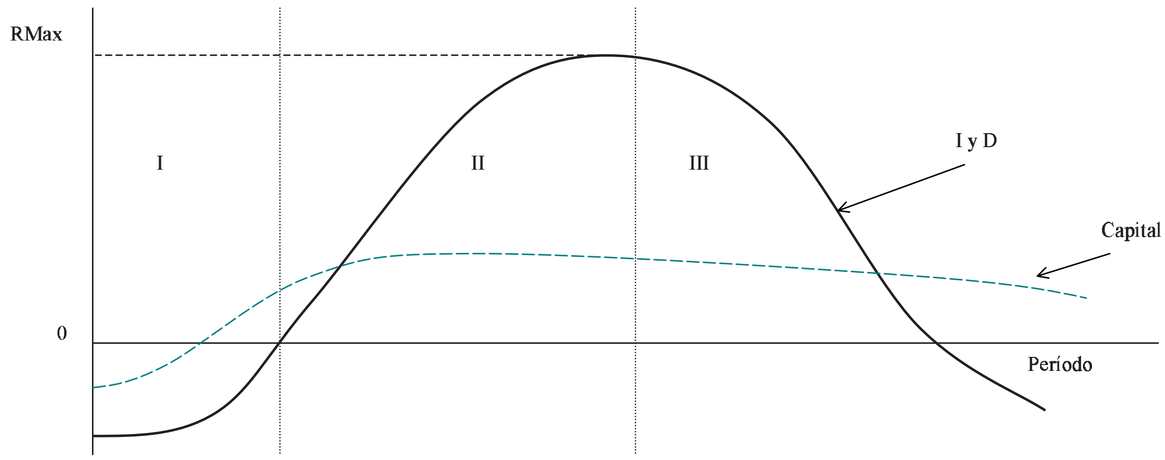

Figura 1:

third stage and the spillover effect starts to become significant and therefore the monopoly income begins to be shared with the catch-up firms. The learning rate remains at levels similar to the second stage, since the learning effect is marginal. This stage is marked by the obsolescence rate effect, which produces a significant effect on profits. If the company wishes to remain in the market, it must needs to innovate again, thus re-starting the cycle once again.

The above shows that the early stages of R&D investment may be associated to negative returns though this effect does not necessarily hold over time. As such, it is not necessary for the firm to make enormous learning efforts to obtain the maximum benefit from the capital, since its operation does not require a lot of knowledge. Assuming a competitive capital market, the maximum return is less than that of R&D in all its stages, where it operates in a monopolistic market, at least temporarily, as was suggested by Schumpeter in 1911. Finally, a decline in the return on capital should begin, due to the depreciation of machinery, equipment and buildings.

It should be highlighted that an effect that involves the decision-making process of the firm is related to the investment risk. It has been stated that R&D increases a firms returns in the long-run; however, the heterogeneity of firms should be kept in mind. The rate at which firms learn to use the capital or the R&D may vary. More efficient firms or those with a greater proportion of specialized workers tend to learn faster than those with a less skilled labor force. A firm that does not learn how to use R&D rapidly may have negative return rates, even in the long-run. If it is not capable of passing into the second stage of the return cycle, and given that the spillover effect is inevitable, it will have positive income for a lower period of time; in other words, it will shift directly to the third stage. If a firm considers that it does not have the necessary personnel or experience, it will not embark on an innovative project even if the expected returns are high. This main explain why a firm does not invest in R&D even when the average return is high.

The latest empirical evidence supports the above hypothesis. While there is not a large amount of empirical studies on these issues, one may highlight the study by Rouvinen (1999), that demonstrates, using an OECD country panel, that, firstly, R&D causes, in the sense of Granger, to PTF and not the opposite, and secondly, that the best specification for this causality considers between five and six lags.

Meanwhile, Goto and Suzuki (1989) estimated the private and social return rates in various industrial sectors in Japan, and found that not only is there a lag in the impact of R&D activities on firm productivity but that the lags also vary depending on the industry. Specifically, they showed that the impact takes an average of two years in the case of electrical machinery, electronic and communication equipment parts, and mechanical machines. This is a substantially different period than that for drugs and medicines whose lag period exceed five years. The authors suggest that this heterogeneity is explained by idiosyncratic variables such as technological differences between sectors or by different employee skill levels and competition.

Overall, these studies show the importance of the temporal structure of R&D on the product. The use of R&D lags is necessary since it improves the estimate. Additionally, the quantity of lags differs among sectors; this is because there are variables characteristic of each sector that influence the innovation adoption period.

3. Descriptive Analysis

The main sources of information used are the Technological Innovation Survey (Encuesta de Innovaciòn Tecnològica- EIT) and the Annual National Industrial Survey (Encuesta Nacional Industrial Anual- ENIA). The joint information for both of these is available from 1993 to 2000. These permitted the construction of two samples: a balanced panel with 106 firms that are common to all three innovation surveys carried out and an unbalanced panel with 308 firms.

Table 1 shows the correlation matrix of all variables whose construction is detailed in the appendix section where Y represents the production growth rate, N represents the employment growth rate, I represents fixed capital investment, $R\&D$ represents R&D expenditure whose corresponding lags are Rez. I. and Rez R&D respectively.

The results show that the production growth rate has a positive correlation with most of the variables except for capital and R&D investment and the production and production per worker lags. The highest correlation occurs with the employment growth rate, which is to be expected since the composition of both is the same. The per worker production growth rate is negatively related to all variables, except the physical capital investment lag.

The employment rate displays a positive, albeit relatively low, correlation with all variables. The highest correlation for employment occurs with the production growth rate.

Capital investment displays a negative relationship with all variables of the model except with the R&D and employment lag. The correlation between both types of investment is negative, which indicates a certain degree of substitution. However, this correlation is relatively low and is not enough to hold that both factors are substitutes. It should be noted that the values of the correlations among the investments are sensitive to changes in the number of observations. The value is positive when only the correlation between capital and R&D investment is taken. Therefore these results should be interpreted with caution. Overall, investment displays a low correlation with the other regressors.

R&D displays negative correlations with all variables except with the lags of both investments. The correlation between the R&D and contemporary R&D lags is high, which indicates that if a firm carried out an R&D investment in the previous year, it is likely that it will carry out an investment again on R&D in the next year. This is consistent with Benavente (2004).

Cuadro 1: Correlation matrix

	Δy	N	I	R&D	Rez. I	Rez. R&D
Δy	1					
N	0.226	1				
I	-0.022	0.016	1			
R&D	-0.079	0.047	-0.023	1		
Rez. I	0.044	0.079	-0.01	0.62	1	
Rez. R&D	0.081	-0.074	0.242	0.046	0.076	1

3.1. Use Intensity and Sectorial Growth

Table 2 shows the average values of the production factors considered in the empirical model disaggregated by production sector, the production growth rate and the production per worker growth rate respectively.

The first column of Table 2 indicates the sector to which the observation belongs, columns two to five correspond to the factors of production and columns six and seven to the endogenous variables of the model, in other words, the production and production per worker growth rate. The most dynamic sectors are 31 and 34, where the per worker production growth rates reach 8 % and 7 % respectively, while the least dynamic sector is 33 with a growth rate of 4 %. Regarding the production growth rate, sector 33 has the highest value, while sector 38 has the lowest rate. It should be noted that these rates correspond to the average growth rates per annum, in other words, they show the trend.

Table 3 shows the number of firms per sector that invest in R&D and the percentage of the total sample. Investment in physical capital as a proportion of

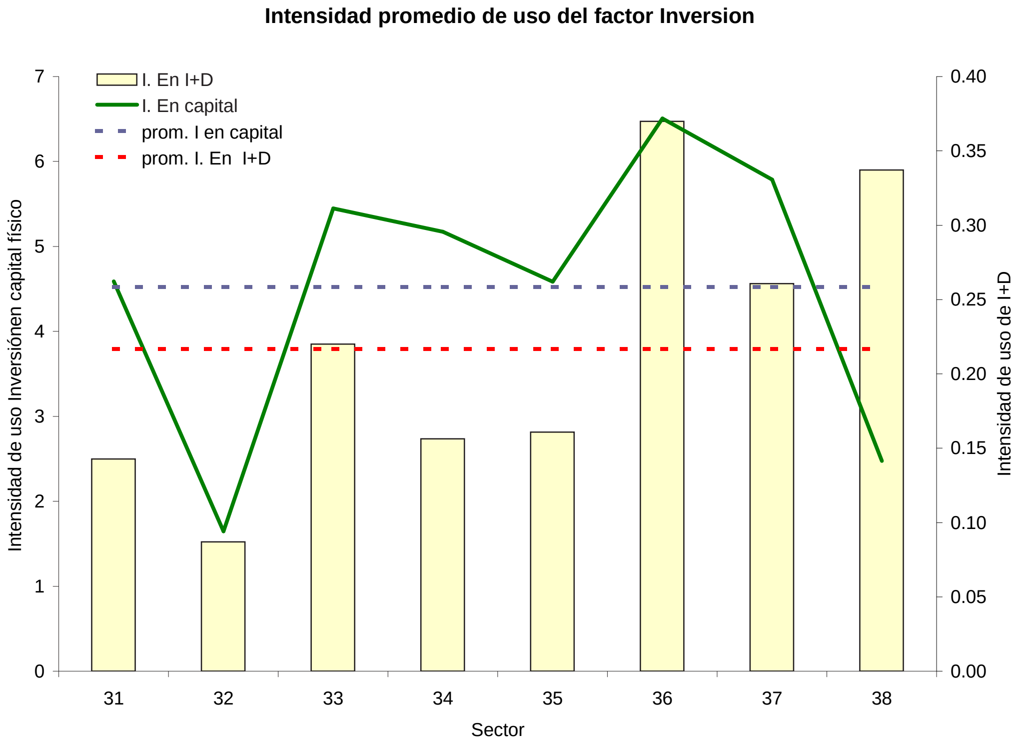

Figura 2:

Cuadro 2: Summary table

Sector	**Factor**				**Var. endogenous**	
	Capital	**R&D**	**total investment**	**n**	g_y	g_Y
31	4.59	0.14	4.73	-2.12	8.34	4.15
32	1.65	0.09	1.73	-5.88	6.5	2.07
33	5.45	0.22	5.67	0.84	4.04	4.88
34	5.17	0.16	5.33	-4.42	6.96	2.54
35	4.58	0.16	4.75	-3.41	5.26	0.4
36	6.51	0.37	6.88	-6.67	5.62	-1.05
37	5.79	0.26	6.05	-2.91	5.08	-0.29
38	2.48	0.34	2.81	-6.69	6.22	-2.3
Total	4.53	0.22	4.74	-3.91	6.00	1.3

Cuadro 3: Number of firms that invest per sector

Sector	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**Total**
N Plants	35	6	5	9	17	6	16	12	106
Percent	33.0 %	5.7 %	4.7 %	8.5 %	16.0 %	5.7 %	15.1 %	11.3 %	100.0 %

production (intensity of investment use) displayed one-digit figures in all sectors of the sample. The intensity of capital use among industrial sectors does not differ much, except for 32 and 38 which are less intensive than the rest. The sector that most uses capital investment is 36. However, this sector is represented by a small number of firms, and it is therefore likely that a single firm is responsible for raising the general average of the investment.

As regards R&D, all sectors display figures below one-digit and even below the decimal, and it is clearly the least used factor. The sector with the lowest intensity of use of this factor is corresponds to 32, while the highest intensity corresponds to 36. However, the number of firms in those sectors (in the sample) is relatively low compared to the rest; as with investment in capital it is possible that some firms may significantly influence the aggregate sector average. A significant aspect concerning sector 38 is that it possesses one of the highest growth rates in per worker production, one of the lowest intensities of capital use and the highest intensity of R&D use; R&D is the growth engine for this sector. Sectors such as 31 and 34, which have the highest growth rates in per worker production, are not so intensive in R&D use but are intensive in the use of physical capital investment. Column four corresponds to the sum of capital and R&D investment expenditure. The sectors that are most intensive in the use of aggregate investment are 36 and 37, as well as with investment in capital.

In general terms, four sectors displayed a lower intensity of use than the aggregate average (all sectors) and only three surpassed it. Investment in capital displays the same pattern as R&D; four sectors below the average and three above it. Sector 36 is most intensive the use of both types of investment, even though the production growth rate was negative.

4. Results

This section presents the results of the estimation of the Chilean manufacturing industry R&D return rate employing the methodological framework developed in the previous section. Additionally, the second part looks at the variables that influence R&D expenditure. Finally, a relationship between profits and the R&D return rate is determined, which allows the profitability of the investment by industrial sector to be determined.

4.1. Industry Level Results

The equation for estimation in this case is:

$$\Delta lnY_{i,t} = r^P \frac{R}{Y}_{i,t} + r^K \frac{I}{Y}_{i,t} + \beta \Delta lnL_{i,t} + \eta_i + \varepsilon_{i,t} \tag{8}$$

Where Y is the aggregate value of production, r^P is the R&D return rate, R is R&D expenditure, r^K is the return on capital, I is physical capital investment, L is employment, ε is the model error and η_i is a non-observable individual effect, the sub-indices i,t indicate firm and year of observation, respectively.

Table 4 presents the estimated coefficients on an aggregate level. The estimations are carried out using the balanced panel and the complete sample. The

Cuadro 4: Return Rates of Chilean Manufacturing Sector

Sample	**Balanced**	**Unbalanced**
Coefficients		
Employment growth rate	0.276	0.697
R&D investment contemporaneous	-12.088**	-6.100***
Lag R&D investment	12.630**	6.396***
Capital investment	0.188**	0.165***
Capital return	0.188	0.165
R&D return (sum)	0.544	0.296
N observations	290	546
Second order Autocorrelation Test	0.312	-0.1181
Sargan Test	57.60	39.97

Note: Time dummies are included in all the regressions.

*** Significant at 1 %

** Significant at 5 %

* Significant at 10 %

last three rows show the number of observations for each estimation, the Sargan test, and the second order autocorrelation test; both estimates use the GMM System estimator. The Sargan test as well as the autocorrelation test accept the null hypothesis at 1 %, which indicates adequate instruments and the absence of autocorrelation.

One of the greatest difficulties of this study was to determine the R&D lag structure used in the estimate; this is because the time that it takes for R&D expenditure to influence the return varies among sectors and countries. Goto and Suzuki (1989) use different lag structures depending on the industrial sector; for example, they use five lags for the medicine and pharmaceutical industry, but only two lags for the electrical machinery and communications equipment. The lag structure is closely related to the time that it takes a firm to learn how to use the new technology and the complexity of the innovation. There is a learning process during which firms may have negative returns. This situation changes once the plant acquires the necessary experience to be able to take advantage of the benefit from the new product or process. Most empirical studies find a negative relationship between the growth rate and the contemporary R&D. The regressions presented in Table 4 include a R&D lag with the objective of capturing the intertemporal effect of the returns on this type of investment. Tests were carried out which included a greater quantity of R&D lags, however the estimated coefficients were not significant (from the second lag).

It should be highlighted that while the results show the R&D return rate per year, these may not, in fact, be the real values for each year. This is because in order to transform the stock of R&D into flow, an approximation of the logarithmic difference was used ($\Delta \ln(x) \simeq \Delta/x$). This approximation is valid when the changes are small; however, R&D investment is extremely volatile among years.

R&D investment displays minor variations among years when a two year period is considered. Therefore, we will define the R&D return rate as the sum of the return of each year; however for the effects of the analysis, we shall consider the signs of the short-run coefficients (annual returns) but not their magnitudes.

The coefficient corresponding to the employment growth rate is the elasticity of the employment product. The elasticity is 0.3 for the balanced panel and 0.7 for the balanced sample; however, in both cases the value is not statistically significant. The estimated value for R&D returns, contemporaneous and lagged, is statistically significant at 5 % in the panel and at 1 % with the complete sample. The negative contemporaneous return rate indicates that the firm does not know how to use the technology or that it is in a permanent training state and cannot obtain immediate fruits from the investment; we term this the *introduction*[7] stage. The introduction stage may explain why only a small proportion of firms invest in R&D; that is, only firms that can afford to finance an initial period of losses. The Innovation and Technology Survey carried out in 2001 showed that the most important obstacles to innovation are: the high cost of innovation; the economic risk that it entails; and the period of time necessary to recover the investment made. These obstacles are represented by negative coefficient of the first year of R&D returns.

In contrast, the coefficient corresponding to the R&D lag is positive (for both samples) and its value is above that of the contemporaneous. Firms that survive the introduction stage obtain positive benefits. Once the firm is trained to

[7]For the effects of this study, this period is close to one year.

Cuadro 5: return rates in Chile and other countries

Author	**R&D return**	**Capital return**	**Country**
Griliches y Litchenberg (1982)	34 %	-	U.S.A
Scherer (1982)	29 %	-	U.S.A
Goto y Zusuki (1989)	40 %	-	Japan
Bernstein (1989)	32 %	10 %	Canada
Klette y Johansen (1998)	11 %	-	Norway
Griffit, Harrison y Hawkins (2003)	43 %	30 %	United Kingdom
Lederman y Maloney (2003)*	-	20 %	Chile
Owns	29 %-54 %	16 %-18 %	Chile

*This rate is approximate.

use the innovation, R&D expenditure drops considerably because it is no longer necessary to keep investing. The firm starts to receive positive returns in this period. We term this the maturity stage. The positive lagged R&D return indicates that a firm is in the mature stage. The aggregate R&D return is located in the lower section of Table 4, and corresponds to the sum of the coefficient of the contemporaneous and lagged value of R&D. The return rate for the Chilean manufacturing sector hovers between 30 % (balanced panel) and 54 % (complete sample). The return on capital ranges between 17 % and 19 %. In the complete sample, the return on capital is half that of the return on R&D, and in the case of the balanced panel, the return on R&D is nearly three times higher than that of capital. It should be noted that the depreciation effect has not been considered, and therefore the estimated return rate may be interpreted as a rough measure of the medium-term marginal productivity.

Table 5 displays the results of some studies undertaken in industrialized countries. The rate of return on capital and R&D is similar to that found in those studies. The upper level for the R&D return rate in Chile is slightly above that in industrialized countries. Furthermore, the return on capital is below the level estimated for other countries. However, the higher profitability of R&D over capital holds.

4.1.1. Estimation of plant level returns

One way of characterizing the sectorial returns of R&D expenditure is by means of the relationship between that expenditure and firm profits. Assuming that the profits are part of the variables behind the decision to invest in scientific-technological activities, the coefficient of the product between R&D and profit per product unit was estimated. The estimated coefficient represents the points of increase (decrease) the R&D return rate in the face of an increase (drop) in the profit per product unit.

Table 6 shows the results of the estimate, which uses the growth rate of the aggregate value of production.

Both regressions use the complete sample and use and similar structure to that used in the aggregate level return rate estimates. Regression (1) includes the effects on the profit returns, and regression (2) examines the effect of the competition on returns.

The coefficient corresponding to profit has a negative sign and is significant at 5 %. This indicates a negative relationship between profit per product unit and the R&D return rate. In the margin, firms that most spend on R&D are those that have the highest profits but that also have lower R&D return rates.

Cuadro 6: R&D, profits and product growth

Coefficients/regressions	**(1)**	**(2)**
Employ growth rate	0.438**	0.419
R&D investment contemporaneous	-8.703***	-13.869*
Lag R&D investment	15.801***	10.271**
Capital investment	0.361***	0.434***
profit plus R&D investment	-109.091**	
profit plus R&D investment		5.07
Nž observations	465	546
Second order Autocorrelation Test	-1.897	-1.39
Sargan test	42.55	40.24

Meanwhile, even when the return on a R&D project is higher in firm with lower profits, it does not have access to credit lines or sufficient own resources to be able to finance it. This explains why highly profitable R&D projects are not carried out. The elimination of these restrictions would increase R&D expenditure significantly and affect the current composition of total R&D expenditure in Chile.

The second variable, market concentration, has a negative and non-significant coefficient, and it is therefore not possible to infer the existence of a relationship between R&D and this variable.

4.1.2. Sectorial Returns

One of the problems in estimating the return rates by sector is that the quantity of data available declines significantly. Sector 31 and 35 are the only ones that exceed 100 observations, and therefore the rate for each sector cannot be estimated. Nevertheless, an approximation for it can be obtained, using the relationship between the profit per product unit and the return rate of Table 6 (column 1).

The estimated return rate may be observed in figure 3. This return rate normalized to the point that the average approaches the aggregate value obtained in section 4.1 (100 %). The first column shows the average profit by sector and the second shows R&D expenditure by sector, both measured as a percentage of the gross value of production.

The negative relationship between R&D expenditure and the return rate may be observed in figure 3; the horizontal axis shows R&D as a percentage of the

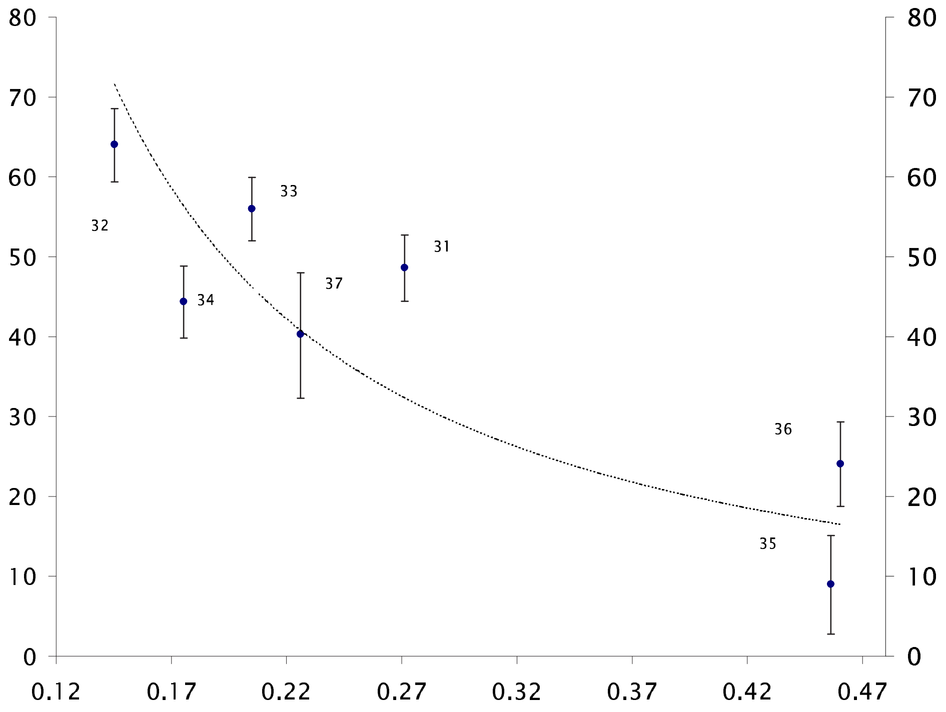
80
70
60
50
40
30
20
10
0
0.12
0.17
0.22
0.27
0.32
0.37
0.42
0.47
32
33
34
37
31
36
35

Figura 3:

product and the vertical axis shows the same for the return[8]. The points represent the average return rate of each sector, while the lines coming from these (upwards and downwards) correspond to the interval in which the return rate may be located. This interval corresponds to the sum (subtraction) of half a standard deviation of the profit per product unit.

As the graph shows, sector 32 (textile industry, clothing and leather) has the highest returns (between 59 % and 68 %). It is followed by sector 34 (paper and paper products industry) with a rate that ranges between 51 % and 59 %. In contrast, sector 35 (basic and finished chemical products, petroleum and derivatives, rubber and plastic) has the lowest return rates (between 2 % and 15 %). The chemical products industry (sector 35) and glass and not-metallic mineral products (sector 36) are the most R&D intensive and therefore incorporating an additional factor unit produces lower returns than in other sectors. Out of all of the sectors considered in the present study, sectors 35 and 36 are at the technological peak and consequently offer the lowest return rates. In contrast, the textile and leather goods industry (sector 32) is characterized for being more labor intensive than R&D intensive and consequently offer higher returns.

5. Conclusions

The rates of return of R&D and capital have been estimated in the present paper. The variables that affect R&D expenditure have also been determined, and through these, a relationship for determining the return rate between sectors has been found.

[8]The points represent the average R&D by sector. This average is different from that presented in chapter 3 since the sample is composed of the balanced panel in that case.

The return rate on R&D is 30 %, which nearly doubles that of the return on capital at 16 %. This phenomena is also found in earlier studies, however the magnitude of this difference varies among countries. This may be understood as an incentive to investment; an average profit rate of 30 % is quite reasonable when compared to market interest rates, which average around 7.3 %[9] during the period of the study. This dismisses the possibility that low returns account for the low investment rates by the private sector in the medium-term in Chile. Nevertheless, the return may have a negative effect on investment in the short-run. We found that a firm's profitability is negative while it is investing in innovation; this factor is enough for many firms to avoid investing in R&D.

The intertemporal effect should not be a problem if the market allows research projects to be funded. When estimating the variables that affect R&D investment, we found that it depends on the investment made by the firm in the preceding period and on the profitability per product unit. The first variable indicates that if a firm is involved in a research project, the probability that it invests in R&D in the following year increases. The second variable indicates that firms fund R&D with their own resources. This indicates the existence of liquidity restrictions; even when a project is highly profitable, it will not be carried out if the firm does not have the resources to do so. As such, the projects that are financed are those corresponding to firms that have, in fact, the resources to fund them.

Based on the relationship between profit and R&D, it was possible to establish the effect of profit on R&D return rates(como afectan al retorno de la I y D el nivel de utilidad). We found that larger firms fund more innovation projects,

[9]Average monetary policy rate.

but that those projects are less profitable. In effect, the most profitable projects are not being funded. Following this pattern, it is possible to establish an average return rate per sector. The chemical and glass and non-metallic mineral sectors have the lowest profitability, with respective rates of 2 %-25 % and 18 %-29 %. The corresponding profitability in the textile sector ranges from 59 % to 68 %, and is the sector that least spends on R&D. The sectors that most spend on R&D are those with the lowest return rates. This indicates a negative relationship between R&D expenditure and returns; however, this is due to liquidity restrictions that prevent firms from the sectors in which research is most profitable to actually invest more heavily on research.

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Appendix A: Information Sources

Surveys

The ENIA is carried out on an annual basis by the INE (National Statistics Institute) and covers all manufacturing plants with at least ten employees. It includes all new plants and those that continue with more than ten employees, and excludes all those that have ceased operating or that have reduced their workforce to below ten employees. The ENIA represents around 50 % of total manufacturing employment. It takes information for manufacturing sub-sectors to four digits CIIU classification of plant characteristics, such as investment, sales, employees, intermediate inputs and address.

The R&D data is drawn from the EIT carried out by the INE. This survey measures qualitative and quantitative aspects of innovation. The questionnaire design follows the general guidelines suggested by the OECD for this type of survey and they are recorded in the Oslo Manual and are applied in most member countries. The survey is applied to the manufacturing sector. However, the third survey gathered information regarding innovation activities in the mining and electricity generation and distribution sectors. The first application of the EIT was in 1995, when firms were questioned regarding R&D expenditure in 1994 and 1995; the second survey was carried out in 1998, and uses R&D expenditure data from 1997 and 1998; and the third survey was undertaken in 2001 and uses data from the years 2000 and 2001.

The objective of the Technological Innovation survey is to measure the degree of technological innovation present in Products and Processes in the Chilean economy. The Oslo Manual of the OECD defines Technological Innovation in Products and Processes activities as "new technology implementation products and significant technological improvements in products and processes". Technological innovation is taken as implemented if it has been introduced into the market or has been used in a production process. Technological innovation involves a series of scientific, technological, organizational, financial and commercial activities. A firm is said to have innovated technologically if “it has implemented new technological products or processes or with a significant technological improvement during the period of review of its activities”. In order to distinguish between technological innovation activities and those that are not, the survey identifies some types of innovation:

- Product Innovation, such as technological improvements of products (adaptive innovation), new products that already exist in the market (imitation innovation), and totally new products in the market (radical innovation);

- Process Innovation, such as the partial technological changes or improvements (adaptive), the incorporation of new technological processes that already exist among the competition (imitation), and the incorporation of completely new technological processes into the market (radical);

- Packaging Innovation, innovation in product design, and
- Organizational innovations in administration, production and personnel.

As mentioned earlier, the survey is based on the Oslo Manual guidelines, which establishes that Technological Innovation Expenditure on products and processes (TIPP) “includes all costs related to all scientific, technological, commercial, financial and organizational steps whose aim or ultimate use is the implementation of technologically new or improved products or processes”. It also states that

“Research and Development is only one step in the innovation process chain”. Therefore, R&D expenditure is only a part of the total financial component". However, in the present study, the word innovation has been frequently used interchangeably with R&D, even though it is not the same. It should be noted that in reality only the return of a part of innovation is being measured, the part related to scientific and technological activities of the process. Innovation Technology expenditure is composed of:

1. Research and Development Expenditure (R&D),
2. Training Expenditure,
3. Expenditure on production trials, patents, licenses, etc. and,
4. Expenditure on technologically new machines and equipment.

The sum of all of the above represents total expenditure by a firm on Technological Innovation. This study only uses R&D expenditure, in other words, only a part of total innovation spending. The R&D expenditure data for 1994, 1995, 1997, 1998 and 2000 were adjusted to thousands of year 2001 pesos, using the Consumer Price Index published by the INE.

The information obtained refers to establishments and not firms. Where these had more than one unit, the surveys passed through the central direction level in order to capture the innovation activities that could occur at the margins of the establishments. The interviewees were the technical executives responsible for the respective units. Finally, the information was subjected to a validation process and expanded to the universe considered, in line with the usual statistical procedures. The base unit for all surveys was establishments with 10 employees or over (one firm may have more than one establishment).

Description and Construction of Variables

10 variables in total were used in this study, not including the temporal dummies. They are measured in constant 1986 currency, employing a gross production value deflator. The equation used to estimate the return is based on the flow relationship and therefore, the capital and R&D stock factors were measured using investment in capital and R&D respectively. The aggregate value of production was used as an indicator of the product (endogenous variable). Since the model was made linear applying logarithms when differentiating, the growth rate of the variable is obtained. Table 7 describes all the variables in the estimate. This table is divided into three columns for the variables: name, description and source; and two categories: endogenous and regressors.

Regarding the R&D series with the quantity of data available, there are two years, 1996 and 1999, in which there are no observations for plant R&D spending. In order to solve this problem, the R&D expenditure for those years has been estimated using the model proposed by Benavente (2004) that was described in the literature. The coefficients used to estimate R&D expenditure for the year 1996 and 1999 may be found in the appendix to this document. The database used to estimate that model is the same as that used in this study.

The construction of some of these variables was not problem-free. Some of these problems related to estimating series with a small number of observations or problems with the model. The main problems and solutions implemented are described as follows.

Cuadro 7: Description of Variables

Variable	**Endogenous Variable**	**Source**
Aggregate production growth rate	Corresponds to the logarithmic difference of aggregate production.	ENIA
Variable	**Regressors**	**Source**
Physical capital Investment	Corresponds to aggregate investment in physical capital, in other words, it is the sum of investment in land, machinery, vehicles and buildings. It is measured as a proportion of the gross value of production.	ENIA
Employment Growth	It is the total employment growth rate. The Total number of workers is the sum of all laborers and employees.	ENIA
R&D	Corresponds to the amount invested in scientific and technological activities. It is measured as a proportion of the gross value of production.	EIT