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Private Return to R&D Activities in Chile

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Abstract

Using a panel data of innovative Chilean firms, we obtain a private return for R&D expenditure over 30% during this decade. Despite the fact of being almost twice the return obtained for physical capital, 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, private firms, Chile.
JEL Codes: L6, O3.

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1 Introduction

According to the latest figures from Minecon (2018), R&D expenditure in Chile approaches 0.4% of GDP, placing it among the highest of the Latinamerican region. Nevertheless, this level is comparatively low with regard to more developed countries and the gap is quite significant[1]. Moreover, from the point 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.

[1]See OCDE (2017)

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

The objective of this study is the revisit the determination of R&D return rate for private firms in Chile. Specifically, data panels for productive plants are used to estimate the aggregate return as well as the return for particular industrial sub-sectors of specific interest between 2009 and 2014. Additionally, the variables affecting R&D expenditure in Chile are analyzed, and a relationship between these variables and the rate of return is established.

This study improves the available knowledge in this area in at least two dimensions. Firstly, it upgrades a previous study for Chile (Benavente et al, 2006) with more actual and detailed data. 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 private 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 productive 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

[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

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 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 TFP may be estimated through growth accounting in the following form:

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

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:

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

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, keeping in mind that $\Delta lnX = \Delta X/X$, we have the following:[5]

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

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

$$\Delta lnY = r^P \frac{R}{Y} + r^K \frac{I}{Y} + \beta \Delta lnL \tag{7}$$

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 allows 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 TFP. An alternative specification is that used by Lederman and Maloney (2003) whose framework is based on the link product - R&D.

2.3 The equation and estimation method

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

$$\Delta \ln(Y)_{i,t} = r^P \left(\frac{R}{Y}\right)_{i,t} + r^K \left(\frac{I}{Y}\right)_{i,t} + \beta \Delta \ln(L_{i,t}) + \eta_i + \omega_{i,t} + \upsilon_{i,t} \tag{8}$$

[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

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 TFP in this context. As Olley and Pakes (1996) suggest, the conventional estimators such as Ordinary Least Squares (OLS) 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: OLS, 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.

[6] A detailed discussion of these methods, their strengths and weaknesses is presented in Bond (2002). An application using Monte Carlo simulations for the Chilean energy case can be found in Benavente et al (2003).

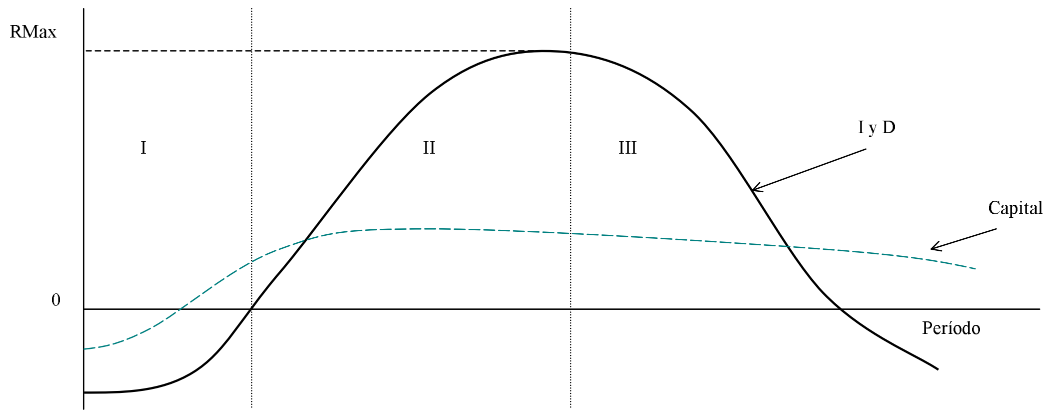
A firm that invests in R&D does so to improve an existing product or process. However, the effective incorporation of this improvement may require a significant time span to implement. The more radical this change is, the longer the adaptation process will be. The R&D return rate may be associated to 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 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.

Figure 1:



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 TFP 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 Annual National Industrial Survey (Encuesta Nacional Industrial Anual- ENIA) together withe National Survey of R&D (Encuesta Nacional de Gasto en Investigacion y Desarrollo) that has a panel structure. The joint information for both of these is available from 2009 to 2014. These permitted the construction of a unbalaced panel of 486 firms.[7]

[7]see Appendix for dataset details

Table 1: Basic Statistics

Variable	Average	Standard Dev	Max	Min	N
lnY	14,6	1,26	11,23	16,41	2.353
$\frac{R}{Y}$	3,05	4,02	0	14,21	2.353
$\frac{I}{Y}$	2,74	4,10	0	27,72	2.353
$\Delta lnL)$	-0,02	0,50	-7,24	4,43	1.637
Δh	0,01	0,64	-4,63	2,07	408

Source: Own elaboration

Table 1 shows some descriptive statistics of the whole sample of firms. The considered period is between 2009 and 2014 for a panel of 2.353 plants where 486 of them declare that they perform R&D activities throughout this period.

Table 2 shows the correlation matrix of all variables whose construction is detailed in the appendix section where ΔY 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 $Lag.I$ and $Lag.R\&D$ respectively.

The results show that the production growth rate has a positive correlation with most of the variables except for investment and R&D investment. However, the highest correlation of ΔY occurs with lagged R&D investments. The employment rate displays a positive, albeit relatively low, correlation with all variables.

Table 2: Correlation matrix

	Δy	N	I	R&D	Lag. I	Lag. R&D
Δy	1					
N	0.057	1				
I	-0.139	0.049	1			
R&D	-0.331	0.064	0.002	1		
Lag. I	0.024	0.010	0.284	-0.005	1	
Lag. R&D	0.418	0.002	-0.105	0.239	-0.033	1

Capital investment displays a positive relationship with all variables of the model except with lagged R&D. The correlation between both types of investment is positive, which indicates a certain degree of complementarity. However, this correlation is relatively low and is not enough to hold that both factors are complements.

Finally, R&D displays positive correlations with all variables except with investments. It is interesting to note that the correlation between the contemporary R&D and its lag is high suggesting a research routine at a plant level. This is consistent what has been observed in previously for the Chilean case (Benavente (2004), Benavente et al (2006)).

3.1 Use Intensity and Sectorial Growth

As suggested by previous work (Benavente et al (2006)) there is considerable heterogeneity among different Chilean productive sectors in terms of their

R&D efforts. In Table 4 we present 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 3 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 26 and 20, where the per worker production growth rates reach 42.2% and 8.8% respectively, while the least dynamic sector is 37 with a growth rate of -3.6%. Regarding the production growth rate, sector 26 has the highest value followed by sectors 20 and 17 respectively, while sector 37 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.

In terms of factors, investment in physical capital as a proportion of 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 be-

Table 3: Summary Table

Sector	**Factor**				**Var. endogenous**	
	Capital	**R&D**	**Investment**	**n**	g_y	g_Y
15	5,56	4,70	10,26	473,82	0,76	2,22
17	0,30	0,16	0,46	107,17	3,17	6,07
19	8,42	0,80	9,22	211,41	0,25	1,51
20	0,30	0,37	0,67	605,47	8,80	7,04
22	0,76	0,00	0,76	89,07	0,39	0,46
24	0,31	2,74	3,05	229,43	0,29	0,56
25	3,37	0,88	4,25	155,75	0,56	1,13
26	0,24	2,70	2,94	344,56	42,22	45,11
27	1,30	3,76	5,06	483,31	0,70	1,15
28	0,28	4,73	5,01	145,37	1,47	1,90
29	0,33	0,77	1,10	177,30	-0,17	-0,10
31	0,27	0,10	0,37	49,72	0,37	0,39
33	0,37	0,32	0,69	54,43	5,43	4,88
34	1,54	0,23	1,77	246,84	0,61	0,38
35	0,24	0,09	0,33	740,82	2,43	3,31
36	1,82	0,57	2,39	603,33	1,76	1,79
37	-0,32	0,00	-0,32	22,00	-3,60	-2,09
D	7,69	0,86	8,55	210,07	0,24	0,29
S/	0,05	0,95	1,00	1148,20	0,07	2,45
Total	2,74	3,05	3,03	314,42	2,05	2,87

low 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.

Table 4 shows the number of firms per sector that invest in R&D and the percentage of the total sample. It cab be observed that sectors 15, 24 and 28 concentrates almost two thirds of the total R&D expediture of the Chilean firms. On the other hand, sectors 17, 34 and S/ are those with the lowest

Table 4: Number of firms that invest in R&D per sector

Sector	**N Plants**	**Percent**
15	776	33.65
17	16	0.69
19	17	0.74
20	57	2.47
24	555	24.07
25	176	7.63
26	74	3.21
27	57	2.47
28	255	11.06
29	80	3.47
31	51	2.21
34	10	0.43
36	15	0.65
D	120	5.20
S/	5	0.22
Total	2,306	100.00

Table 5: Summary Table

Sector	**Factor**				**Var. endogenous**	
	Capital	**R&D**	**Investment**	**n**	g_y	g_Y
2009	3,63	2,59	6,22			
2010	5,25	4,72	9,97	0,04	-0,83	-0,73
2011	1,66	1,21	2,85	-0,14	2,39	6,66
2012	3,66	2,31	5,96	0,02	-0,50	-0,53
2013	2,46	1,06	3,52	0,01	6,46	6,77
2014	1,41	6,68	8,09	-0,06	-1,39	-0,55
Total	2,74	3,05	6,10	-0,02	1,05	1,87

participation.

In terms of time, there is also high heterogeneity among different years. As can be observed in Table 5, R&D intensity has varied between 1,21 in year 2010 up to 6.68 during 2014. In terms of the endogenous variables, larger heterogeneity could be observed where there are some years with negative growth rate while others like 2011 with very positive increases.

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:

$$\Delta lnY_{i,t} = r^P \frac{R}{Y}_{i,t} + r^K \frac{I}{Y}_{i,t} + \beta \Delta lnL_{i,t} + \eta_i + \varepsilon_{i,t} \tag{9}$$

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 6 presents the estimated coefficients on an aggregate level. The estimations are carried out using the complete sample. The 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 does nos reject 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

Table 6: Return Rates of Chilean firms

Sample	**(1)**	**(2)**
Coefficients		
Employment growth rate	0.47	1.91
	(0.04)	(0.06)
R&D investment	-0.15***	-0.18***
contemporaneous	(0.12)	(0.02)
Lag R&D investment	0.33***	0.34***
	(0.05)	(0.07)
Qualified Workers	No	Yes
Total Empleyment	Yes	Yes
Capital return	12%	17%
R&D return (sum)	18%	16%
N observations	1539	397
Second order Autocorrelation Test	0.122	
Sargan Test	0.20	0.45

Note: Time dummies are included in all the regressions.

*** Significant at 1%

** Significant at 5%

* Significant at 10%

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 6 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 0.5 for the balanced panel and 1.91 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 could be interpreted as if the 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*[8] 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. It is worth mentioning that the Innovation and Technology Survey carried out during these years[9]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 cases) and statistically significant. It shows that firms that survive the

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

[9]See Minecon (2014)

introduction stage obtain positive benefits. Once the firm is trained to 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 6, and corresponds to the sum of the coefficient of the contemporaneous and lagged value of R&D as an approximation of the mid-run return to these activities; i.e. those that considers the sunk (learning) cost of doing R&D.

The return rate for the Chilean productive firms is slightly over 30% when only considering the lagged effect of this investment over productivity at a plant level. The return on capital ranges between 12% and 17%. Therefore, in the complete sample, the return on capital is half that of the return on R&D, 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 7 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 profitabil-

Table 7: 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
Benavente et al (2006)	29%-54%	16%-18%	Chile
Owns	16%-34%	12%-17%	Chile

*This rate is approximate.

ity of R&D over capital holds.

5 Conclusions

We have estimated the private return for R&D and traditional investments in Chile. Results show that 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%[10] during the period of the study. This dismisses

[10]Average monetary policy rate.

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.

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.

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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 between 209 and 2014 were adjusted to thousands of year 2016 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 8 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.

Table 8: 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

Table 9: Observations by Year

Year	Observations
2009	214
2010	257
2011	470
2012	490
2013	436
2014	486
Total	***2353***

Source:Own elaboration