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**INNOVATION, EXPORTS AND
PRODUCTIVITY: LEARNING AND SELF
SELECTION IN CHILE**

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Innovation, Exports and Productivity: Learning and Self selection in Chile¹

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Abstract

Since long ago economists have shown that research and development (R&D) and business innovation are key factors for the growth of firms and the development of the economies. There is also some consensus that greater degrees of trade openness are beneficial for the long-term growth of countries. Nonetheless, there is still no evidence on the combined impact of both factors even though the link between them seem of particular relevance, especially for developing countries. This article examines the relationship between productivity, expenditure in R&D and exports at a plant level for the case of Chile. The main results show that firms that actually spend on R&D are considerably more likely to export but the reverse is not true. Moreover, we observe that both R&D and exports have a joint effect on the improvement in productivity in the Chilean plants. These results allow us to recover the private return to R&D and to learning by exporting across different sectors.

Keywords: Productivity, Exports, Innovation, R&D.

JEL: O30, F10, O33.

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1. Introduction

During the past fifteen years, the relationship between productivity of firms and their participation in foreign markets has been vastly investigated. Since the seminal work of Bernard and Jensen (1995), most studies consistently show that for different cases, specifications and economies, exporters are larger, more productive, more capital-intensive, accumulate more human capital, pay higher wages and invest more in technology and research and development (R&D)⁵. However, the vast previous literature has only recently highlighted the importance of innovation and related activities in this virtuous relationship between productivity and export performance. This article aims to contribute to this literature by providing evidence of this relationship for the case of a developing country like Chile. The study, in addition, addresses most of the econometric problems in this type of analysis such as simultaneity, endogeneity and the discrete nature of some variables.

In particular we focus on analyzing how firms improve productivity by means of R&D and/or through foreign markets participation. For this purpose we rely on the rich information available in the Chilean Innovation and Industrial Surveys that cover the period 1997-2004. We address the relationship between export and R&D controlling for its endogeneity based on detailed information on exports, expenditure in R&D as well as estimates of total factor productivity at a plant level. We are particularly interested in identifying the existence of the processes of *innovating by exporting* (exports as determinant of R&D expenditure) and/or *exporting by innovating* (R&D as determinant of exports), together with the well documented *self-selection* in exporting hypotheses. We conclude our analysis addressing the relationship between R&D and productivity and the possible learning by exporting hypothesis as source of plant's productivity growth.

By properly identifying the relationships between exports, productivity and innovation - controlling for the inherent endogeneity in these activities- it can be recovered information of great importance for a better design of public policy instruments especially in developing countries. Particularly, for those designed to promote exports and innovation. As we shall see, the causal direction between these variables is not neutral for the design of policy instruments.

If firms that invest more in R & D then become exporters, and R&D activities generate improvements in productivity, a subsidy policy addressed to current exporters would focus in

⁵ See for example Bernard and Jensen ((1998), (1999) and (2004)), Richardson and Rindhal (1995), Bernard and Wagner (1997), Bernard et al. (1997), Clerides et al. (1998), Álvarez and López (2005), Van Biesebroeck (2004), De Loecker (2007), Harris and Li (2009), Pattnayak and Thangavelu (2006), Diao, Rattso and Stokke (2006), among others.

the wrong group of firms. However, if firms increase productivity and innovation by exporting, then programs that generate the necessary incentives for firms to export or reduce barriers to access foreign markets, would certainly entail improvements in aggregate productivity.

In order to capture these effects and control for the existent endogeneity, we model the R&D expenditure, exports and productivity changes at a plant level through a multi-equation system, which is estimated by Asymptotic Least Squares (ALS). This methodology, new in this context, allow us to estimate the system simultaneously taking into account the discrete nature of some variables and the simultaneity of effects with superior statistical properties to other methods such as GMM or 2SLS.

Our results do not provide evidence in favour of the innovating by exporting hypothesis, but we do find some support for the exporting by innovating hypothesis. This later result means, that after controlling for the inherent endogeneity in this relationship, we find that firms that invest more in R&D tend to become exporters. Furthermore, contrarily to an important part of the literature on exports and productivity, we do not find evidence on the self-selection in exports hypothesis, and neither for R&D self-selection hypothesis.

Regarding the productivity equation, after controlling for endogeneity between expenditure on R&D and exports, we can conclude that both variables are important determinants of productivity. We find evidence that R&D is an important source of productivity improvements and that there is learning by exporting.

Our paper contribution is threefold. First, we make an extensive survey on the self-selection in exports, exporting by innovating, innovating by exporting and learning by exporting hypotheses. Second, we address the endogeneity and selection problem by estimating the joint relationship between R&D, exports and productivity using ALS, a new methodology in this context. Finally, we provide estimates of the private returns to R&D and learning by exporting.

The paper is structured as follows. The following section summarizes the empirical literature that examines the links between R&D, exports and productivity. Section 3 presents the model to be estimated on the basis of that review. The estimation results are presented in Section 4, then we proceed to discuss our results and estimate the private returns to R&D and export learning in Section 5. Finally, Section 6 concludes.

2. Literature Review

2.1 Analysis of the Causality Hypothesis

As previously suggested by the literature, there is a close link between productivity and trade and also other variables that are affecting both, like R&D and innovation. In order to better understand these linkages specially when performing an empirical work, causality among these variables is a relevant issue. In the following lines we explore these in detail starting with productivity and exports and then moving to the link between R&D and exports.

2.1.1 Self-selection: High Productivity generates Exports

This hypothesis has been the most treated and demonstrated by the recent theoretical and empirical literature, although the alternative hypothesis of trade as a productivity determinant has a greater theoretical foundation in the growth and trade models⁶. The self selection hypothesis comes from the idea that to start exporting firms must incur in fixed and sunk costs. They are generally market research costs, marketing, training, permits and licenses. Other costs faced, and those are not always so explicit, are the increased in competition and adaptation of products to consumers' tastes or the legal regulations of the destination country. For this reason "bigger" or more "efficient" companies can afford or successfully bear this entry. Therefore companies are self-selected to participate in global markets.

Old theoretical models of trade were not able to explain the self-selection of exporters. These, do not capture certain empirical facts as the heterogeneity of firms within an economy in terms of productivity, size, exporting status, quality of labor, among others.⁷

Melitz (2003) innovates significantly and proposes the first of the dynamic general equilibrium models with exogenous productivity for the firm, which is consistent with the evidence of self-selection. He also assumes imperfect competition and fixed and variable exporting costs. As a result, only some firms, the most productive ones, export and exporters are better and larger than non-exporters.

From an empirical point of view, Bernard and Jensen (1999) with U.S. data, find evidence that firms that become exporters are successful prior to entry. For German firms, for example, Arnold and Hussinger (2005) find positive evidence of self-selection. Moreover, they argue that this equation is not sufficient to denote causality in this regard. They carried out a Granger causality test and show that productivity Granger precedes exporter status. Also for German firms Bernard and Wagner (1997) find strong evidence of self-selection through productivity ex ante. For Chile, Alvarez and Lopez (2005) also have evidence of the existence of self-selection of firms, with a similar specification. Greenaway and Kneller (2004) for the

⁶ As the models presented by Romer (1990) and Grossman and Helpman (1990).

⁷ Bernard, Eaton, Jensen, Kortum (2003) and Yeaple (2005) are examples of firm heterogeneity.

UK find that, everything else equal, the probability of exporting increases with the level of Total Factor Productivity (TFP).

In conclusion, there is considerable consensus on the existence of self-selection of the most efficient firms into international markets. The evidence is overwhelmingly in favour. And it has been found countries like Canada, Colombia, Chile, USA, UK, Denmark, Taiwan, among others, with different methodologies and samples.⁸

2.1.2. Learning by Exporting: Exports increase Productivity

This hypothesis is probably the one that comes to mind when we mention the relationship between exports and productivity. However, in comparison to the alternative hypothesis, it has less supporting evidence.

According to Greenaway and Kneller (2007) the label of "learning by exporting" contains at least three channels:

1. The interaction with foreign competitors and customers provides information on products and processes therefore reducing costs and improving quality.
2. Exports allow scaling up production. That is, access to larger markets.
3. Increased competition in foreign markets may force firms to be more efficient and increase their investments in innovation.

These three factors are contained in most of the literature of endogenous growth and trade that explains and motivates the intuition⁹. As a common factor, the exchange of technology, the increase in scale of production and the greater innovation either generating lower costs or greater variety of products, increase productivity at the firm level and the growth of the economy.

From an empirical point of view Bernard and Jensen (1999), with U.S. data, do not obtain robust results. They therefore do not risk of arguing, based on the information and estimates available, that there is indeed *learning by exporting*.

A methodology widely used is that of Matching Propensity Score. Wagner (2002) and Girma et al. (2004) are pioneers in applying this methodology to the problem. The first with data from Germany find that labor productivity for newcomers is higher than for the "twin"

⁸ See evidence of Bernard y Jensen (1995), (1998), (1999) y (2004), Richardson y Rindhal (1995) for the US, Bernard y Wagner (1997) y Bernard et al. (1997) for Germany, Clerides et al. (1998), for México, Marruecos y Colombia, Álvarez y López (2005) for Chile, Van Biesebroeck (2004) for África Subsahariana, De Loecker (2007) for Eslovenia, Harris y Li (2009), for the UK, Pattnayak y Thangavelu (2006) for Indias y Diao, Rattso y Stokke (2005) for Thailand. All these paper support the hypothesis that exporter firms are more productive than local firms.

⁹ Rivera and Romer (1990), Grossman and Helpman (1990), (1991) and (1994), Aghion and Howitt (1992), Aghion and Howitt (1998, chapter. 11), Ericson and Pakes (1995), Klette and Griliches (2000), Aghion et al. (2003), Atkeson and Berstein (2007) among others.

non-newcomers, but not statistically significant. In contrast, the second paper with UK data, finds significant effects of *learning by exporting*. Arnold and Hussinger (2005), using the same technique and with data for Germany do not find evidence of *learning by exporting*. De Loecker (2007) also uses matching techniques with a sample of data for Slovenia. He finds positive effects on productivity of newcomers after entering to export, which increases over time. He also uses destination information on exports of each firm and concludes that the destination of exports is an important factor in the presence of *learning by exporting*.

Clerides et al. (1998) uses a dynamic learning model of data for Mexico, Morocco and Colombia. They find learning effects only in Mexico, and for some specifications in Morocco, but cautions that the results are not very robust. On the other hand, Alvarez and Lopez (2005) find evidence of *learning by exporting* in the case of Chilean firms.

For an analysis and summary of the evidence on these topics see Wagner (2007), Greenaway and Kneller (2005) and Girma et al. (2004). The first two are literature summaries on productivity and exports. The first considers almost all the literature on the subject. The second is broader, less comprehensive and extends to issues such as foreign direct investment. The third is a study of *learning by exporting* which presents a summary of the cases hitherto studied about self-selection and learning.

2.1.3 Exporting by innovating: R&D as determinant of exports.

One of the first articles, which studied the relationship between exports and R&D, is that of Ito and Pucik (1993). These authors analyze the determinants of exports¹⁰ in Japan. They check if the R&D expenditure causes exports and if the R&D intensity¹¹ causes exports, both at a firm and industry level. They find positive effects for the size and expenditure on R&D over exports for the firms, but not robust effects for the intensity of R&D.

Lefebvre et al. (1998), with data for small manufacturing firms in Canada, analyzed the participation of R&D investments in the determinants of two dependent variables: "groups of exporters" and "export intensity". The authors find that the efforts in R&D, either in basic research or improved products and cooperation with competitors, positively differentiate exporters from non-exporters. In Addition, global exporters invest less in R&D than the ones that export to North America, but these investments are to a great extent, in new product developments and applied research. In the second specification, export intensity is affected by basic research and improvement of new products for exporting to the U.S. markets.

¹⁰ Exports sales.

¹¹ Expenditure on R&D as a proportion of total sales.

Becchetti and Rossi (2000), verified the possible effects of clusters of firms, or districts of exporting firms on the probability of exporting in Italy. Under the hypothesis of *spillover* of knowledge, economies of scale and sharing of information among these firms, found positive effects for the variables that identify the various districts. The effects do not disappear by including investment in R&D of firms, which has no effect on the probability of exporting, as opposed to other variables of innovation as the fact of investing in R&D, subsidies for R&D and external participation in R & D activities.

For Denmark, Smith, Stroe and Dilling-Hansen (2002) estimate two Probit equations on the determinants of export orientation and investment in R & D. First they do it individually and then simultaneously. They found significant positive effects of investment in R&D on exports.

Cassiman and Martinez-Ros (2007) also study the effect of innovation on the decision of firms to export to Spain. According to their results, 22% of the probability of becoming exporters is attributable to investments in innovation. The effect increases when estimated by instrumental variables. They also found superior effects of product innovation relative to process innovation. The difference in the results for product innovation or processes does not seem to be a generality. For micro data for Germany, Lachenmaier and Wöbmann (2006) found that process innovations have greater effects on the share of exports in production, than product innovations.

Aw et al. (2005) take a sample for electronic companies in Taiwan, analyse the dependence of productivity changes on the likelihood of becoming an exporter. The methodology involves performing a bivariate probit in a first stage, with two simultaneous equations: one with the decision to export as a dependent variable and the other with investment in R&D. The authors find positive impact of lagged investment in R&D on the probability to export.

Also Arnold and Hussinger (2005) for Germany found positive effects of investment in R&D on the probability of exporting, but not for other measures of innovation such as the percentage of new products.

In one recent work on this relationship is that of Girma et al. (2008). Here they analyze the bidirectionality of the relationship R&D and exports for Irish firms and the UK. Using the same methodology of simultaneous equations of Aw et al. (2005), the authors find positive results but different among countries and firms.

In conclusion, the empirical evidence shows that investment in R&D affects the export behavior of firms generating a greater likelihood to export or greater share in the output of a

firm. The result depends on the type and origin of the sample, the variables used to measure R&D and export performance, and the estimation methodology. Nonetheless it shows robust across specifications.

Other articles dealing with this hypothesis both for innovation in general and for investment in R&D, and get results in the same direction are: Hirsch and Bijaoui (1985), Sriram, Neelankavil and Moore (1989), Brower and Kleinknecht (1993), Kumar and Siddharthan (1994) and Sterlacchini (1999).

2.1.4 Innovating by exporting.

In relation to the aforementioned causality the impact of export orientation on investments in R&D has been less treated by the empirical literature. Most studies are recent and were written after the work of Hughes (1986), Clerides et al. (1998) and Bernard and Jensen (1999).

Empirical studies that exist on this issue are those of Salomon and Shaver (2005), Aw et al. (2005) and Girma et al. (2008). And only the latter aims to measure explicitly the effects of exports on investment in R&D.

Salomon and Shaver (2005), test the presence of *innovating by exporting* for exporting firms in Spain. They apply productivity approaches as does Baldwin and Gu (2003) and Grima et al (2004). In their study, they use the innovation expenditure as a measure of productivity and find that exporting is positively related to subsequent increases in innovation.

On the other hand Aw et al. (2005), who aim to identify on what depends the productivity of the firm after becoming export oriented, conducted in a first stage, a bivariate probit, which simultaneously identifies both directions of causality. They find that the export experience is an important source of productivity growth for the electronics industry.

Finally Girma et al. (2008) aim to measure the bidirectionality of the relationship for British and Irish firms, as analyzed in the previous hypothesis. They find positive evidence of the exporter status on the decision to invest in R&D only for Ireland.

As we can see there are only studies about *innovating by exporting* on very particular economies, such as England, Ireland, Spain and Taiwan. Where the first three European economies are generally intensive in physical capital and technology, that mostly target markets in developed countries. On the other hand, economies like Ireland and Taiwan have electronics and computer sectors quite predominant, with very particular characteristics that are not possible to extrapolate to other economies. This relative scarcity of studies that this hypothesis has so far it does not make possible to generalize the findings to other economies.

This is because they can be conditioned by market structure, production and the destination market of exports.

3. The Empirical Model

Both endogenous growth models and the "new" literature of international trade have generated hypotheses about the relationship between productivity, R&D performance in our case, and export status. As discussed in the literature, there are both theoretical and empirical models that support the bicausal relationship between these variables. There is evidence of a positive impact on firm's productivity stem from the participation in international markets and on the other hand, the belief that more productive firms self-select into the international market.

That is why we need a model, and a methodology that captures both relationships in order to examine the structural relationship from productivity to export status and vice versa. Adjusting as best as possible, the endogeneity problems of the relationship. Additionally, for this particular case, we are interested in the variable R&D and its relation to exports and vice versa which complicates things further. Indeed, export status may have effects on investment in R&D and also directly on productivity. Therefore, the export variable should be present in the relationship between R&D and productivity given that affects the innovative process and productivity.

The proposed model aims to describe three processes and obtain the structural relationships of its variables. The first is the decision to invest in R&D and the amount of investment. The second process describes the decision to export of a firm and the amount exported. Finally the third reflects the determinants of the firm's productivity.

3.1 Research Equations

Most of the literature on the behavior of R&D is based on a generalized Tobit model. This consists of two equations that in turn reflect two separate decisions. One related to the decision to invest in R&D and the other in the amount of resources devoted to this activity.

It is assumed that there is a latent dependent variable g_i^* , for firm i , given by the following equation:

$$(1) \ g_i^* = x_{i0}b_0 + u_{i0} + f_i^* \alpha_G$$

Where x_{i0} is a set of explanatory variables, b_0 is the associate parameter and u_{i0} is an error term. g_i^* represents some decision criterion as the present value (PV) of benefits of the

investment project. That is, we will observe investment in R&D if the value of the PV, namely g_i^* , is positive or greater than an arbitrary threshold.

Furthermore, to be consistent with the process above, we establish that the decision to innovate depends on the export status. In particular we say that it depends on the export intensity, reflected by f_i^* . Therefore, α_G is the correlation coefficient between exports and the probability to invest in R & D.

Subsequently we assume that the intensity of R&D expenditure is determined by the second equation:

$$(2) \ k_i^* = x_{i1}b_1 + u_{i1}$$

Where $k_i^* = k_i$ is expenditure on R&D per worker of firm i when it carries out innovation activities, that is when g_i^* is greater than the minimum defined threshold. Here k_i^* and k_i are expressed in logarithms, x_{i1} , is the vector of explanatory variables, b_1 is the vector of coefficients and u_{i1} an error term that captures stochastic, omitted or unobservable variables.

Given that we observe k_i^* when g_i^* is greater than zero, we must specify the joint distribution to estimate the model. In order to use the generalized Tobit estimation methodology (Tobit type II) we assume that the equations (1) and (2) are normally distributed, which can be tested later.

For this specification we use the logarithm of expenditure on R&D in Chilean constant pesos per worker. The explanatory variables considered are size variables, market share, features of innovation, export status and the lag productivity. To include these variables we rely primarily on the literature of R&D and applications in Chile. More precisely for each equation the set of variables is:

$$x_{i0} = (l_i, \text{Imit}, \text{Coop}, \text{TFP}_{i,-1}, \text{ma}, \text{quality}, \text{msh}, \text{learn}, \text{FDI}_i, \text{pub}_i, \text{Med}, \text{Gre}, S_i^1, \dots, S_i^7)$$

$$x_{i1} = (l_i, \text{Imit}, \text{Coop}, \text{TFP}_{i,-1}, \text{ma}, \text{quality}, \text{msh}, \text{learn}, \text{FDI}_i, \text{pub}_i, \text{Med}, \text{Gre}, S_i^1, \dots, S_i^7)$$

Where l_i is employment; *Imit*, is a *dummy* if imitation is considered an obstacle to innovation; *Coop* is a dummy which take the value of 1 if the innovation ideas come from cooperation with other industry actors; $\text{TFP}_{i,-1}$, is the lagged total factor productivity of the firm; *ma* and *quality* are dummies that reflect whether innovations are oriented to the environment and the product quality, respectively; *Msh* is the market share of the firm, obtained by its share of sales, out of the total sales of the industry; *learn*, is a dummy which is equal to 1 if the

company recognizes that innovation is generated from an ongoing internal process; FDI_i , is a dummy variable the presence of foreign capital; pub , is a dummy which take the value of 1 if the company receive grants from the public sector. We include a set of 7 sectoral *dummies*, which reflect the productive sectors: Machinery, Textiles, Chemicals, Wood, Paper, Metal and Non Metallic. The control is the *dummy* Other sectors. Finally, we add three size dummies, Med, Gre, if the firm are medium or large, respectively, leaving the small companies as control.

In addition, in order to reflect the export intensity we used the logarithm of the value of export sales per worker only in equation (1).

3.2 Export Equation

The export equation has a similar structure to the Research Equation. It is assumed that the dynamics of the exporting firm can also be represented by a generalized Tobit process. That is, we separate the decision to export from the size of exports, as it has been explained above.

We therefore have two equations: The first comprises a latent variable reflecting the decision to export. It can be understood, as is the case of innovation, as the PV of the decision to export or participate in international markets:

$$(3) \ e_i^* = x_{i2}b_2 + u_{i2} + k_i^*\alpha_E$$

where x_{i2} is a vector of variables explaining the decision to participate and is u_{i2} an error term. As the decision to invest in R & D is influenced by the size of exports, it also occurs the reverse. Here is where we complete the inclusion of endogeneity, or bicausality of the relationship. That is why we add the term k_i^* , which is the logarithm of investment in R&D per worker, where α_E reflects the relationship between R & D and the probability of exporting.

On the other hand, we have an equation of the size of the exports, which is active for those who have decided to export, that is when ei^* is above the threshold that makes profitable to participate:

$$(4) \ f_i^* = x_{i3}b_3 + u_{i3}$$

where $f_i^* = f_i$ is the logarithm of sales from exports of the company i which decides to export, x_{i3} is a set of explanatory variables and u_{i3} is an error term.

We also assume that the joint distribution of both equations is normal, to represent the process as a Tobit Type II.

In the model setup, we use as explanatory variables those which define the company, some related to innovation and others that reflect market conditions. This is because there are no variables that describe the destination of exports, institutions or facilities to undertake an international business, among others. In any case, we include a set of explanatory variables, such as determinants of exports, excluding investment in R&D, the following variables:

$$x_{i2} = x_{i3}(l_i, \text{Coop}, \text{pub}, \text{quality}, FDI_i, \text{Lic}_i, \text{Med}, \text{Gra}, \text{Inv}_{i-1}, \text{Skill}, \text{TFP}_{i-1}, S_i^1, \dots, S_i^7)$$

Most of the variables were described above, we also add Skill, which is the percentage of qualify worker over the total workers, and Lic_i, which reflects the number of licenses that the firm have.

3.3 Productivity Equation

The last equation of the system corresponds to productivity. From here we analyze what is the impact of investment on R & D and export intensity on productivity. For this, we regress, using OLS, productivity on both variables, plus a control group (x_{i4}).

Therefore:

$$(5) \quad p_i = x_{i4}b_4 + f_i^* \alpha_E + k_i^* \alpha_I + u_{i4}$$

where p_i is a productivity index and the vector of factors other than R & D and exports is as follows:

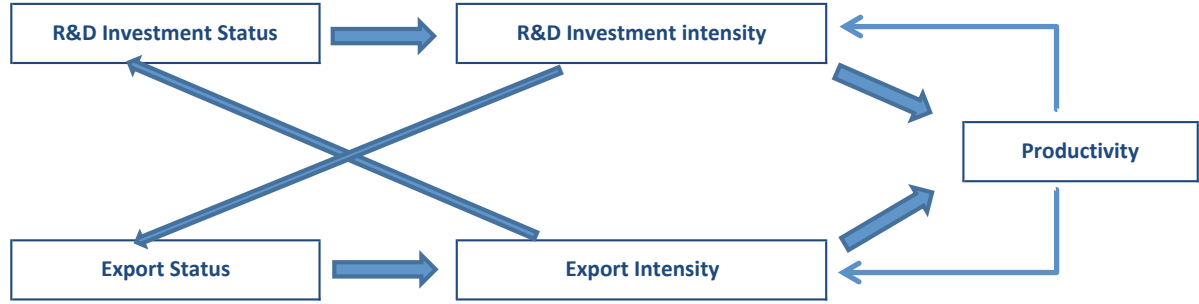
$$x_{i4} = (l_i, \text{msh}, \text{pub}, \text{quality}, FDI_i, \text{Lic}_i, \text{Inv}, \text{Med}, \text{Gra}, \text{Inv}, \text{Skill}, S_i^1, \dots, S_i^7)$$

Letter b_4 in (5), is the vector of coefficients of this variable. While α_E is the elasticity of productivity with respect to the quantity exported represented by f_i^* and α_I is the elasticity with respect to investment in R&D, denoted by k_i^* .

Following the literature, to calculate productivity we use the methodology described by Levinsohn and Petrin (2002). They calculate productivity by controlling for unobservables. We therefore assume a Cobb-Douglas production function, with capital and labor, skilled and unskilled, obtaining productivity as a residual.

Estimation of the Complete Model

Figure 1: Estimation Model



As described at the beginning of the section, the five equations form a system where exports and investment in R & D interact, and both determine the productivity of the firm (*see Figure 1*):

Decision and expenditure on R & D

$$(1) \ g_i^* = x_{i0}b_0 + u_{i0} + f_i^* \alpha_G$$

$$(2) \ k_i^* = x_{i1}b_1 + u_{i1}$$

Decision and size of Exports

$$(3) \ e_i^* = x_{i2}b_2 + u_{i2} + k_i^* \alpha_E$$

$$(4) \ f_i^* = x_{i3}b_3 + u_{i3}$$

Finally, the productivity equation

$$(5) \ p_i = x_{i4}b_4 + f_i^* \alpha_X + k_i^* \alpha_I + u_{i4} .$$

The most efficient way to estimate this system is by Asymptotic Least Squares (ALS). This system, similar to Indirect Least Squares, consist in estimating each equation individually in a way that best fits the data. That is, in our case, by Generalized Tobit for the first two systems and equation (5) by OLS, without neglecting the endogeneity relationship of the equations.

In fact, we estimate different specifications in their reduced forms, that is, without endogenous variables, and then we estimate the parameters of the structural system by GLS (Generalized Least Squares), minimizing the distance between the first, so-called "auxiliary" and the seconds. The key step is to obtain estimates of the variance-covariance matrix necessary for the estimation of the structural parameters, which corrects for the relationships between variables, imposed in our specification.¹²

¹² For further details on the estimation methodology see Appendix 2.

4. Estimation Results

In this section we show and analyze the results of the estimates to test our hypotheses about the relationship and causality of the exporting behavior of firms and investment in R&D and the relationship of both towards productivity. To present the results of the estimation by ALS, which controls for endogeneity, we must keep in mind that the equations of interest are those of selection of export and investment in R&D and productivity.

In order to analyze parameter sensibility, for our system of equations between R&D, exports and productivity we estimate four specifications, which can be grouped into two clusters and are presented in Table 4. Columns (1) and (2) correspond to a parsimonious model, where in (1) we test the relationship between the dependent variables with productivity in the previous period, while in (2) we do not allow this relationship. Columns (3) and (4) include a larger set of variables, according to the ones reviewed in the literature on R&D, exports and productivity. In the same way as before, they differ in the inclusion of productivity as a regressor. In other words, we allow productivity to be endogenous to investment in R&D and exports in (1) and (3).

4.1 R&D Status

In the equation of the probability of investing in R&D (Table 4) we observe that apparently most productive firms are less likely to conduct R&D as shown in column (1). But once controlled for size and other firm characteristics, this effect tends to be less significant. As column (3) clearly shows firms size here measured by the number of employees captures most of the effect related with lagged productivity.

In relation with export intensity, result show that exporting efforts does not cause a higher probability that a firm invest in R&D. More over, results suggest that firms more involved in trade efforts tend to set aside R&D efforts discarding a *innovating by exporting* process for the Chilean firms.

Results also show that market share is positively associated with the probability of performing R&D, consistent with most of previous empirical studies. This positive effect reinforces the notion that firms with greater participation, or, in the extreme case with higher monopoly power, have greater incentives to conduct research activities since they are more likely to appropriate the results from this investment.

Concerning firm size, results show that larger firms measured by employment, have larger chances to be involved in R&D investments. This result also consistent with theoretical as well as previous empirical works, show that there exist a scale effect similar to market

power. As noted before the effect of size tend to dilute if lagged productivity is not included, suggesting that larger firms are less productive.

An interesting result is related with ownership. Foreign owned firms tend to have smaller chances to invest in R&D compared with domestic-owned ones. This result consistent with previous studies, show that R&D efforts are probably mainly done at the headquarters rather than at their Chilean subsidiaries (Benavente, 2005). If we consider that there is no major tax exemption and/or other explicit support for R&D activities in Chile, large MNCs may decide to perform their R&D elsewhere.

Firms that see imitation as a potential obstacle to innovation invest more in R&D. The interpretation of this result comes from the separation we make between R&D and innovation, where the first is an input for the second. Therefore a higher risk of imitation would be forcing firms to invest in new and original idea that have more tacit and plant specific knowledge that makes the imitation most difficult.

Firms that innovate to improve the environment invest more in R&D. This result is likely to be found for the manufacturing industry of the 90's and beginning of the last decade in Chile, where the implementation of environmental regulations and greater control could have been pivotal in modifying the manufacturing productive matrix by encouraging a greater investment in R&D.

Finally, results show that firms that have been involved in innovation projects with partial public funding have a larger probability to invest in R&D resources. It is interesting to know that public support here is not related with R&D directly but what results show that there is a crowding-in effect of state funding in innovation on the research agenda of Chilean firms.

Table 4**ALS Estimation: Reserch and Development Equation ⁽¹⁾****Dependent Variable: Dummy Research and Development Investment**

(Standard errors between parenthesis)

	(1)	(2)	(3)	(4)
Exports	0.073 *	-0.060 ***	-0.084	-0.095 ***
(log value of Exports per worker)	(0.042)	(0.015)	(0.078)	(0.034)
TFP (t-1)⁽²⁾	-0.117 ***		0.014	
	(0.048)		(0.085)	
Market share	0.030	0.077 ***	0.078 ***	0.079 ***
(percentage of sector sales)	(0.020)	(0.017)	(0.036)	(0.035)
Employment			0.054 *	0.139 ***
(number)			(0.032)	(0.051)
Imitation as an obstacle to innovation⁽³⁾			0.081 **	0.087 ***
			(0.032)	(0.032)
Cooperation as a motivator to innovation⁽³⁾			0.113	0.087
			(0.201)	(0.178)
Public Resources to innovation⁽³⁾	0.474 ***	0.453 ***	0.502 ***	0.539 ***
	(0.131)	(0.129)	(0.158)	(0.142)
Innovation to improve the environment⁽³⁾			1.811 **	1.604 *
			(0.921)	(0.898)
Innovation to improve the quality⁽³⁾			-0.086	0.078
			(0.967)	(0.905)
Foreign Property ⁽³⁾	-0.432 ***	-0.386 ***		
	(0.141)	(0.141)		
Size Dummies	Yes	Yes	No	No

Sample: 1321 plants.

(1) Include 7 industry dummies.

(2) By a Levinsohn and Petrin Estimation.

(3) Dummy variable

4.2 R&D level.

Once we have controlled for those firms investing in R&D now we discuss the determinants of the amount of resources invested in these activities. Results presented in Table 5 clearly show that once decide to invest, those firms with better productivity invest larger amount of resources in research activities. Results show that the elasticity of R&D investment to TFP is between 0,5 and 0,7. It is interesting to note that despite the fact that TFP is not related with the probability of investing in R&D (market share and size are more relevant), for the subsample of R&D performers, productivity does matter in the amount of resources involved.

On the contrary, despite that larger market shares may predict that firms will be involved in R&D activities, it say nothing related with the amount that firms invest on them as observed in column (4). One explanation is related with the idea that R&D signals potential competitors about firm strategy - like marketing as a entry barrier. But the rest of players do not know the

amount of resources invested in R&D – because is confidential, therefore the amount does not matter significantly as observed in Table 5.

Consistent with previous work, we found that R&D investments have decreasing economies of scale. The negative sign of the coefficients related with employment, show that larger firms tend to invest proportionally less in R&D. Given that the dependent variables is R&D per worker, firm size predict that larger firm tend to have a higher probability to perform R&D activities but the amount of resources growth at a slower rate than size.

The positive sign associated with public funding shows that public resources linked to innovation indeed complements private ones in R&D which are good news. On the other hand, and regarding innovation variables, both imitation as an obstacle to innovation and innovation aim at improving product quality exhibit a positive relationship with R&D intensity. In sum and related with R&D activities, results confirm most of previous studies for less developed countries. What is new is, firstly, that export intensity negatively affect the probability that a firm invest in R&D discarding a *innovating by exporting* hypothesis, and secondly, that productivity seems only to be relevant on the amount of resources invested in R&D and not on the decision to invest in these activities.

Table 5**ALS Estimation: Reserch and Development Equation ⁽¹⁾****Dependent Variable: Logarithm of Research and Development**

(Standard errors between parentesis)

	(1)	(2)	(3)	(4)
TFP (t-1) ⁽²⁾	0.719 *** (0.037)		0.530 *** (0.053)	
Market share (percentage of sector sales)			0.054 (0.067)	1.677 (1.761)
Employment (number)			-0.287 *** (0.044)	-0.093 * (0.044)
Imitation as an obstacle to innovation ⁽³⁾			0.039 (0.060)	0.119 * (0.066)
Cooperation as a motivator to innovation⁽³⁾			0.252 (0.298)	0.092 (0.331)
Public Resources to innovation⁽³⁾	0.014 (0.254)	1.462 *** (0.302)	0.645 *** (0.219)	0.871 *** (0.244)
Innovation to improve the environment⁽³⁾			1.204 (1.592)	1.677 (1.761)
Innovation to improve the quality⁽³⁾			-1.296 (1.586)	5.353 *** (1.592)
Foreign Property ⁽³⁾	0.207 (0.311)	-0.442 (0.375)		
Size Dummies	Yes	Yes	No	No

Sample: 1321 plants.

(1) Include 7 industry dummies.

(2) By a Levinsohn and Petrin Estimation.

(3) Dummy variable

4.3 Export status

We now move to the export dimension. In table 6 we present results of the variables behind the probability that a firm show some of its production being sold in foreign markets. The first interesting result is concerned with lagged TFP. As in the case of R&D, results show that firms with previous poor performance in TFP have a larger probability to export once controlled for other effects. Taking in consideration that results also show that larger firms (measured by the number of employees) and those that invest more in R&D have a higher probability on exporting, lagged TFP is capturing those firms which see exporting as a channel of productivity enhancement. As we will see later, results confirm that firms which exports have positivity effect on productivity.

The second interesting result is related with the negative effect that public supports to innovation have on the probability that the firm exports. Again, considering that results presented in Table 6 shows that larger firms and those investing in R&D have a positive effect on exporting, this negative effect of public funding is mainly related with the focus that firm

is having. It seems that there is a trade off between innovation and exporting efforts. If we consider that those firms already exporting have a negative effect on the probability of performing R&D – as shown in table 4, but those receiving public funds for R&D do not export, results are consistent with the idea that either firms concentrate on exporting or to invest in R&D activities. But cannot do decide to do both at the same time.¹³

Results also show that past investments do not predict that a firm will become an exporter nor licenses, skilled labour or if the firm is foreign-owned. However, if firms innovate because they want to improve their production quality, this is negatively associated with the probability of being an exporter. This result may sound contra intuitive since we may expect that foreign market pressure will push firms to enhance their quality. However, if exports are heavily linked with commodities where no major quality improvements are expected, this negative effect reflects that this kind of efforts are more oriented to local markets rather than foreign ones.

¹³ We are talking about the decision to export or to perform R&D activities and not in the amount invested in them once decided.

Table 6**ALS Estimation: Export Equation ⁽¹⁾****Dependent Variable: Dummy Export Value**

(Standard errors between parenthesis)

	(1)	(2)	(3)	(4)
R&D	0.005	0.0005	6.918 ***	2.923 ***
(log R&D per worker)	(0.148)	(0.040)	(1.550)	(0.610)
TFP (t-1) ⁽²⁾	-0.006		-3.565 ***	
	(0.107)		(0.830)	
Employment			1.809 ***	0.297 ***
(number)			(0.414)	(0.076)
Cooperation as a motivator to innovation ⁽³⁾			-1.877 ***	-0.403
			(0.670)	(0.427)
Public Resources to innovation ⁽³⁾			-4.152 ***	-2.404 ***
			(1.023)	(0.618)
Innovation to improve the quality ⁽³⁾			3.056	-22.485 ***
			(2.063)	(4.448)
Foreign Property ⁽³⁾	0.025	0.019	0.025	0.046
	(0.185)	(0.171)	(0.164)	(0.174)
Licenses			0.0003	-0.0005
(number)			(0.009)	(0.009)
Skill Labor			-0.012	-0.006
(percentage of total workers)			(0.182)	(0.186)
Investment (t-1)	-0.001	-0.002	0.003	0.016
(log investment)	(0.024)	(0.011)	(0.025)	(0.022)
Size Dummies	Yes	Yes	No	No

Sample: 1321 plants.

(1) Include 7 industry dummies.

(2) By a Levinsohn and Petrin Estimation.

(3) Dummy variable

4.4 Export Intensity

Now, once we only consider firms that export, results show that those with better productivity performance tend to export more. This result is consistent with previous literature. At the same time, results shows that those firms which invest more and have more skilled labour, also tend to export more in terms of value.

Results show that foreign ownership does not have a significant effect on exports once controlled for lagged productivity. In the same line, neither licensee expenditures nor cooperation have a significant effect on the exports of firms. Results also show that public support for innovation has no impact on exports that is in line with the argument that is mainly affecting (negatively) the decision to export rather the amount of exports.

Table 7**ALS Estimation: Export Equation ⁽¹⁾****Dependent Variable: Logarithm of Export value**

(Standard errors between parenthesis)

	(1)	(2)	(3)	(4)
TFP (t-1) ⁽²⁾	0.603 *** (0.071)		0.813 *** (0.078)	
Employment (number)			-0.051 (0.068)	0.162 *** (0.066)
Cooperation as a motivator to innovation ⁽³⁾			0.531 (0.369)	-0.181 (0.355)
Public Resources to innovation ⁽³⁾			-0.222 (0.264)	0.386 (0.243)
Innovation to improve the quality ⁽³⁾			5.198 *** (1.056)	6.739 *** (0.895)
Foreign Property ⁽³⁾	0.421 * (0.245)	0.936 *** (0.272)	-0.431 (0.273)	0.668 *** (0.247)
Licenses (number)			-0.024 (0.017)	0.008 (0.016)
Skill Labor (percentage of total workers)			1.444 *** (0.366)	1.322 *** (0.344)
Investment (t-1) (log investment)	0.447 *** (0.046)	0.801 *** (0.030)	0.246 *** (0.054)	0.550 *** (0.042)
Size Dummies	Yes	Yes	Yes	Yes

Sample: 1321 plants.

(1) Include 7 industry dummies.

(2) By a Levinsohn and Petrin Estimation.

(3) Dummy variable

4.5 Productivity

Results for the estimation of the determinants of labour productivity at the firm level are presented in Table 8. We have included different specifications depending on the selection equations that have been considered. That is why, despite the fact that the variables considered in column (1) and column (2) are the same, estimated effects associated with the variables differ. An analogous argument follows for column (3) and column (4). In particular, in (1) and (3) only lagged TFP has been considered in the R&D and exports equations while a full selection model was applied for (2) and (4).

Table 8**ALS Estimation: Productivity Equation ⁽¹⁾****Dependent Variable: Total Factor Productivity ⁽²⁾**

(Standard errors between parenthesis)

	(1)	(2)	(3)	(4)
R&D (log R&D per worker)	-0.062 (0.073)	0.243 *** (0.055)	0.031 (0.111)	0.534 *** (0.251)
Export (log value of Exports per worker)	1.532 *** (0.129)	0.405 * (0.226)	0.899 *** (0.060)	0.774 *** (0.191)
Market share (percentage of sector sales)			0.064 *** (0.026)	-0.124 (0.073)
Public Resources to innovation⁽³⁾			0.276 * (0.161)	-0.494 (0.307)
Foreign Property ⁽³⁾			0.533 *** (0.118)	-0.095 (0.201)
Licenses (number)			0.026 ** (0.007)	-0.009 (0.009)
Skill Labor (percentage of total workers)			-0.958 *** (0.191)	-0.347 (0.354)
Investment (t-1) (log investment)	-0.632 *** (0.092)	0.443 *** (0.183)	-0.184 *** (0.036)	-0.076 (0.120)
Size Dummies	Yes	Yes	Yes	Yes

Sample: 1321 plants.

(1) Include 7 industry dummies.

(2) By a Levinsohn and Petrin Estimation.

(3) Dummy variable

The most important result presented in Table 8 is that in all specifications we observe that from those firms who do export, the size of their export per worker affects their productivity once controlling for the potential endogeneity of this relationship. In particular, if we consider the full model, the elasticity of productivity to exports level lies between 0,8% and 0,9%.

This interesting and new result contradicts the standard self-selection argument. That is, productivity explains export performance and not the opposite. Moreover, results presented in Table 6 shows this self selection process is not in place at least using this database. And this may be the case since the causality goes the other direction: exports explain productivity rather than productivity affecting exports levels.

In the same line, results also show that R&D intensity also explains productivity levels. As in the previous result, we have controlled for potential source of endogeneity and finding that a dynamic effect is in place. R&D intensity affects productivity (as shown in Table 8) and in a lagged manner, productivity affects export levels (as shown in Table 7). But

exports that have been affected by productivity (lagged) also affect current productivity closing the virtuous circle.

On the other hand, results show that foreign owned firms and those with larger markets shares tend to have larger labour productivities despite that these results depend on the variables related with the selection process. Is worth mention that this result in addition to the fact that foreign firms also showed a greater export intensity (Table 6) and less intensity in R&D (Table 5), reflects a bias of foreign firms to use the country as a business platform, but without carrying out, in average, an increased in expenditure on R&D.

In the same token, results for the full model suggest that lagged investments have a negative effect on current productivity that may be explained by well known learning curve argument. Interesting is the fact that labour skills may have a negative effect on current labour productivity. For this result we do not have a theoretical based argument and we need further research in order to understand it.

5. Discussion.

Our estimations deal –among other issues- with the simultaneous effects of R&D, export learning and export selection on productivity, measured as TFP. Our main finding is that there is no evidence of exporters selection, but positive evidence for export learning together with the traditional positive R&D impact on productivity. Moreover, we find evidence of exporting by innovating. Thus, the effect of R&D on productivity is twofold, directly and indirectly through exports. This should be taken in consideration in the discussion of the results that follows.

Given these results, we now could estimate the return of R&D activities and learning by exporting, a relevant issue for a small and export oriented less developed country like Chile. However, no jointly estimates at this regard have been previously documented and for this purpose we adapt the framework presented in Griliches (1998).

Returns to R&D in the export sector could be computed as the derivative of the growth rate of TFP with respect to R&D/GDP. Following the standard notation, this corresponds to:

$$\rho = \frac{df}{d(RD/GDP)} = \frac{\beta_1}{RD/GDP}$$

, where f accounts for the TFP growth and β_1 to the estimated coefficient multiplying the logarithm of per worker R&D in our estimations.

Analogously, we could also calculate the return to export learning, which is then computed as:

$$\rho = \frac{df}{d(RD/GDP)} = \frac{\beta_2}{RD/GDP}$$

and where β_2 corresponds to the estimated coefficient multiplying the logarithm of per worker exports in our estimations.

The later result is derived from the assumption that the stock of exports plays a similar role to the R&D stock in the production function of the firms, assumption that has been used in the literature to relate productivity to learning by doing processes.

Tables 9 and 10 show the implied returns derived from our estimations. Table 9 shows that R&D has a private return that fluctuates between 8% and 65%. In the same token, Table 10 shows that the return to export learning fluctuates between 19% and 151%.

In both cases the minimum returns are associated to Chemicals sector while the highest values to Apparel. Is worth mentioning that the second highest return in both cases is in Pulp and Paper, an industry in which Chile has strong comparative advantage. The third highest return is in both cases for Non Metallic manufactures.

Both tables show that, in terms of productivity, returns for exporting are higher than those of R&D, so that from a private point of view is better to become a exporter than to invest in R&D. Moreover, exports are a source of income while R&D is a source of expenditure. Unfortunately, with our computations we could not assess this relative importance from a social point of view. Nevertheless existing estimations for developing countries (See Bravo-Ortega and Garcia (2011)) show a social return to R&D on the range of private returns to export learning.

Table 9. R&D returns by sectors

Estimation	Sector							
	Paper	Wood	Chemicals	Non Metal	Metal	Food	Apparel	Machinery
(1)								
(2)	0.23	0.12	0.05	0.18	0.05	0.15	0.41	0.14
(3)								
(4)	0.51	0.27	0.11	0.40	0.10	0.34	0.89	0.30
Average	0.37	0.20	0.08	0.29	0.08	0.24	0.65	0.22

Source: Author's calculations.

Table 10. Export learning returns by sector.

Estimation	Sector							
	Paper	Wood	Chemicals	Non Metal	Metal	Food	Apparel	Machinery
(1)	1.46	0.77	0.32	1.14	0.30	0.96	2.56	0.86
(2)	0.39	0.20	0.08	0.30	0.08	0.25	0.68	0.23
(3)	0.86	0.45	0.19	0.67	0.18	0.56	1.50	0.51
(4)	0.74	0.39	0.16	0.57	0.15	0.49	1.29	0.44
Average	0.86	0.45	0.19	0.67	0.18	0.57	1.51	0.51

Source: Author's calculations.

Our results can be complemented with the literature on the evaluation of export promotion agencies. Indeed, Lederman, Olearraga and Payton (2010) find positive effects of these agencies across the world. Additionally, the evidence supports the idea to narrow the support to non-traditional exports and to larger firms that have not yet become exporters.

One major finding of our results is that, despite the relative importance of exporting vis a vis increasing R&D expenditure, both mechanisms in general provide higher returns than capital investments thereby providing a rationale for public intervention as a way to increase firms productivity.

6. Conclusions

In this study we contrast the hypothesis of *self-selection* and *learning by exporting*, and the linkages between export activity and R&D investments with productivity using firm-level data for Chile. We aim also to answer the question of whether the firms with innovative activities and R&D investments are more likely to export or is the export experience that determines their larger propensity to invest in R&D.

These hypotheses have been largely studied in the literature on export and productivity, but only recently they have been linked with other firm efforts like R&D and innovation. This paper follows the literature on exports and innovation - generally tested for developed countries- and tests these hypotheses in the context of a developing country characterized by low barriers to trade and where innovation presents a growing public and private concern.

For this purpose we develop and implement an original econometric model for this context that includes the relationship between innovation and exports and the linkages of both with the productivity of the firm. Given the complex relationships among variables such as nonlinearities, simultaneity and endogeneity together with some features of the information

available such as censorship and truncation, we use an Asymptotic Least Squares (ALS) estimation procedure that has a better performance in these circumstances than traditional methods like GMM or Two-Stage Least Squares (Gourieroux & Monfort, 1989).

Our results are not consistent with the hypothesis of *self-selection* in exports nor innovating by exporting, understood as firms that export more are more likely to do R&D. However, our results show that there is exporting by innovating, which implies that firms that invest more in R&D have a greater tendency to become exporters.

We find an interesting loop of feedback between R&D productivity and exports. In particular we find that in half of our estimations R&D results in an increase of productivity, but also that exports increase productivity –this is, learning by exporting. Our results therefore imply that R&D affects productivity by two channels –directly- and –indirectly- through export levels. The second loop is the export-productivity virtuous circle. While larger export increase productivity, this greater productivity induces larger exports. The identification of these loops were worth the effort to implement ALS, and thus - differently from an important part of the previous research - our results are obtained controlling for endogeneity and the interaction of exports, R&D and productivity simultaneously.

Finally, this study opens a new set of questions on to the importance of R&D and related activities on the productive performance of firms. Its links to the exporting area is a major breakthrough but we still have many questions regarding not only the determinants of investment in these activities, but also their complementarity with other investments. In particular, physical capital, and more important still, with human capital. These are certainly challenges for future studies, which may now be possible to perform due to the existence of detailed information on innovative activities, production and investment by Chilean firms as well as the development of estimation methods that account for the particularities of this information. The challenge is open.

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