Innovation & Exports in Chile: Reciprocal Causality in the Case of Acquisition of Knowledge

Fernando Greve*

***Fernando Greve:** Civil Engineering, University of Chile, and MSc in Applied Economics, University of Chile. Researcher *Nucleo Empresa Sociedad y Tecnología* - NEST, Business School, Mayor University. E-mail: fernando.greve@umayor.cl.
Corresponding Author: Postal Code: 7500000. Phone Number: 011 56 022 5189429

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Fernando Greve[2]

Abstract

To correctly identify the relationship between exports and innovation is a key component for the development of efficient public policy tools. However, there is still no consensus regarding their relationship of causality. In this article, we conduct an empirical analysis for the manufacturing industry in Chile, which seeks to clarify this relationship. Specifically, we present an econometric model for manufacturing firms in the Chilean economy for the 1995-2012 period, which considers the effort in innovation and exports, controlling for the productivity level among other variables. Unlike other studies, we take into account general innovation expenditure, not just R&D expenditure, because of the relevance of soft innovation and technological acquisition -and not just research carried out individually by a small number of local firms- in developing economies that are followers in technology. In turn, we differentiate between the following types of innovation expenditure: expenditure on general innovation, technological innovation, acquisition of knowledge, and R&D. The results obtained show, at the aggregate level, a difference in the causal direction between innovation and exports according to the type of innovation that was carried out, where, considering all types of innovation, causality is found from exports towards innovation (Learning-by-Exporting) and not in the opposite direction. However, when considering innovation relative to the acquisition of knowledge, we find that they mutually reinforce each other, which shows a statistical significance in both directions (reciprocal causality). When studying this behavior at the sub-sector level, it is heterogeneous and inconclusive. Based on these results, we discuss policy conclusions for Chile regarding tools to encourage exports and innovation.

Keywords: Exports, Innovation, Learning-by-Exporting, Self-Selection, Mutual Reinforcement, Granger Causality Test.

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[2] Mayor University, Fernando.greve@umayor.cl

1 Introduction

There is overwhelming evidence in economic literature that exporting companies are more productive than non-exporting companies (Bernard & Jensen, 1999). Furthermore, there are studies that show that innovation leads to increases in firm productivity (Crepón, Duguet, & Mairesse, 1998). Finally, there is also evidence that export activities by themselves encourage technological innovation and R&D (López Rodríguez & García Rodríguez, 2005). Thus, exports, innovation and productivity are heavily correlated.

However, there is still no consensus regarding what the specific relationship of causality is between innovation and exports. While Bernard and Jensen's[3] paper indicates a relationship in which firms must improve their productivity before they begin to export, De Loecker[4] finds evidence of a positive effect on new entrants' productivity after their export activity has begun. In turn, it has been proved that exporting leads companies to innovate (Monreal-Pérez, Aragón-Sánchez, & Sánchez-Marín, 2012) and, furthermore, we have seen how innovation (R&D intensity, product and process innovation) on the one hand and export activity (breadth and depth) on the other hand can mutually influence each other, bringing about what is called in literature on this topic *mutual reinforcement* between innovation and exports.[5] This way, the relationship of causality between innovation and exports seems to be an empirical matter that must be analyzed on a case-by-case basis.

And so we can propose the following questions: Is innovation what allows firms to be competitive at a global level and to increase its exports, or is participating in foreign markets what exposes firms to an environment that helps and prompts companies to innovate? Or rather does mutual reinforcement exist between innovation and exports? Supposing that there is a clear causality, is it similar in all activities or is there heterogeneity in this relationship at the sub-sector level? This paper aims to answer these questions, at least partially, specifically in the case of Chile as a small developing economy, with a wide commercial and exporting breadth, and a significant proportion of its industry based on natural resources.

Regarding public policy, the following questions arise: Is it more efficient to have horizontal policies in place that stimulate innovation or is it better to encourage non-traditional exports, given that firms will innovate ex-post? Should these policies be different depending on the manufacturing sub-sector where they will be applied? From a public policy perspective, it is important to clarify the causal relationship between innovation and exports in order to obtain a clearer idea of the answers to the interesting questions that we have just made.

In the particular case of Chile, for example, the raw materials boom that began in 2003 has caused a relative standstill in exporting diversification, which has consequences on the quality of demand for jobs, income distribution, the exchange rate and the economy's vulnerability in the face of external shocks. In this context, the design of policies that allow for the diversification of exports takes on a fundamental role, in a context in which the country increases the investment effort in human capital. Again, correctly identifying the relationship between exports and innovation, as well as the level of sub-sector heterogeneity in the

[3] (Bernard & Jensen, 1999)
[4] (De Loecker, 2007)
[5] (Filipescu, Prashantham, Rialp, & Rialp, 2013)

manufacturing industry, may represent a significant contribution for the design of efficient public policy tools in developing countries with characteristics that are similar to Chile's; particularly, for policies that encourage export activity and innovation in companies. Specifically, the importance of this study lies in knowing the incidental heterogeneity in the relationship between innovation-exports that is present in the different manufacturing sub-sectors, understanding the different sector-specific transmission mechanisms, in order to better guide public-private decisions that point towards an efficient resource allocation, all the while considering that the manufacturing industry constitutes an important niche of innovation that can be exported to other industries (chaining) and, therefore, enables the aggregate value of the economy as a whole to expand.

This paper makes several contributions regarding relevant empirical literature. As our first contribution, we consider innovation expenditure to be the sum of expenses related to the acquisition of patents, licenses and know-how; training for innovation activities; installation and adjustment of new equipment, and commissioning of production; introduction of innovations in the market; acquisition of machinery and equipment for innovation; and lastly, R&D. This less restrictive definition allows us to cover a wider range of activities that seek to improve the firm's productivity, and thus to increase the amount of companies to be studied instead of being restricted only to R&D expenditure, as we have seen in previous studies.

This item is quite important, considering that Chile is a not a leading country in terms of technology: R&D expenditure in Chile makes up just 0.42% of GDP,[6] which places it among the three OECD member countries that least invest in R&D, along with Mexico and Greece. Furthermore, within this expenditure, the private sector only contributes 0.16% of GDP (close to 1/3 of total expenditure), the lowest amount among all OECD member countries. Because of this, we have broadened our view of technological improvements and efforts carried out by manufacturing firms in two ways: on the one hand, by considering a wider range of activities that seek productive improvements; on the other hand, by typifying the innovations that firms carry out in Chile that would have an actual effect on the TFP.

As our second contribution, in this paper we study the causal effects on the relationship between innovation and exports by manufacturing sub-sector. This allows us to investigate the effects of innovation on firms' capacity to participate in more competitive and global markets, and its subsequent impact on self-selection and learning-by-exporting, which allows us to notice possible virtuous cycles (mutual reinforcement) at the sub-sector level. This constitutes a novel contribution, given that most studies have used dummies to detect sub-sector differences. When studying sub-sectors separately, their distinctiveness is revealed in these variables' relationship of causality, which is the main focus of this paper.

As our third contribution, we analyze the causality of export intensity and innovation expenditure effort, differentiating between the different types of innovation expenditure in the following way: firstly, we study general innovation expenditure—that is, all the aforementioned expenses; secondly, we consider technical innovation expenditure, defined as the sum of Expenditure on the Acquisition of external knowledge (patents, licenses, know-how) for Innovation, Other Activities (installation and adjustment of new equipment, commissioning of production) for Innovation, and finally, Research and Development (R&D) Expenditure. Our

[6] Information from 2010 (OECD, 2012).

objective is to look for heterogeneity in the causal behavior related to the level of sophistication of the type of innovation expenditure.

Finally, as our fourth contribution, this paper studies innovation in Chile based on information from 1995 to 2012, thus taking into consideration a greater amount of information than any other study published until today on technological design and innovation at the firm level in Chile.

This paper is organized in the following manner: in the first place, we review the relevant literature regarding the relationship between exports and productivity, and the relationship between innovation and exports; secondly, we present the data we used and their descriptive statistics; thirdly, we present the model and its results; and finally, we reach a conclusion regarding the evidence that we found and its potential consequences in terms of public policy.

2 Literature Review

As was mentioned in the previous section, productivity, exports and innovation are heavily correlated. Therefore, in order to isolate the export-innovation causality, we must thoroughly correct the inherent effect on productivity in such a way that the export-innovation causality may be identified in isolation, which is the focus of this study. For this reason, we will begin by reviewing literature that studies the productivity-export and productivity-innovation relationships, in order to subsequently study the export-innovation relationship.

2.1 Export causality towards innovation and productivity

There is plenty of empirical evidence that shows that exporting firms have a higher productivity than firms that only participate in domestic markets. Among these studies, Jensen and Bernard's[7] paper stands out as the most renown on this topic. This paper—and studies that have stemmed from it—shows that exporting companies are bigger, more productive, more capital-intensive, have greater human capital, pay higher wages and invest more on technology and R&D (Benavente, Ortega-Bravo, & González, 2013).

In terms of the causality between exports and productivity, there are hypotheses that aim to explain this phenomenon in different ways. A first approach is referred to as learning-by-exporting, which says that companies increase their productive performance only by exporting. This approach considers at least three causality mechanisms:[8]

1. On the one hand, the knowledge and technology that firms absorb in international markets, which non-exporting companies do not have access to, will increase exporting firms' performance and, consequently, their productivity.
2. Exporting firms have access to a global market that is bigger than the local market, and so their production will benefit from economies of scale.
3. Firms participating in global markets are subject to a greater competition level, which will force them to invest in innovation in order to reach greater efficiency levels.

[7] (Bernard & Jensen, 1999)
[8] (Greenaway & Kneller, 2007)

De Loecker[9] finds evidence of a positive effect on new entrants' productivity after they have begun their exporting activities. Through a data sample from Slovenia, he also concludes that the destination of exports is an important factor in determining learning-by-exporting.

2.2 Innovation and export causality towards productivity

It is argued that firms that have access to global markets must have previously improved their performance, particularly their productivity. It is to be expected that firms with better performance in terms of their productivity may access and continue participating in global markets, where worldwide firms participate and which, in turn, previously improved their performance. This way, a greater competition level will exist in global markets. This hypothesis, which states that only firms with certain characteristics will access export activities, is called self-selection and may be linked to certain entrance expenses (such as those regarding transportation, distribution, skilled personnel to handle the international network, information asymmetries regarding quality, etc.), expenses that would only allow firms that have innovated and increased their productivity to have access to the competitive export markets.

Bernard and Jensen's[10] paper is the most renowned work studying this self-selection. Using USA data, the authors find evidence that firms that become exporters are successful before beginning their export activities. Wagner's[11] study is more current and compiles evidence in the same manner.

A paper worked on by Monreal-Pérez et al.[12] studies the causal relationship between innovation and exports, and whether innovation improves firms' ability to export more products or if exporting propensity is what leads companies to innovate. Additionally, the authors study how productivity changes this relationship. Using a database with 14,142 observations from Spanish manufacturing firms during the 2001-2008 period, we can see that innovation prompts firms to increase their exporting propensity, a result that proves to be sturdy in the face of endogeneity tests. However, the test does not conclusivly demostrate that exports generate learning through product or process innovation. Lastly, it does not show that productivity modifies any of these relationships.

2.3 Mutual reinforcement between exports and innovation

The relevance of innovation at the firm level has been analyzed in several studies, which have found that the development of abilities to innovate, which are endogenous to firms, is one of the main incentives that allow firms to export.[13] Most of these studies have suggested that innovation positively affects the development of exports by showing that innovation can set a firm apart and therefore constitute a source of competitive advantages in international markets,[14] due to the fact that innovation acts as a source of competitive advantages that are hard to imitate. A firm's ability to innovate represents a combination of the organization's

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[9] (De Loecker, 2007)
[10] (Bernard & Jensen, 1999)
[11] (Wagner J. , 2008)
[12] (Monreal-Pérez, Aragón-Sánchez, & Sánchez-Marín, 2012)
[13] (Leonidou, Katsikeas, Palihawadana, & Spyropoulou, 2007)
[14] (López Rodríguez & García Rodríguez, 2005)

resources that has been developed throughout the firm's existence. To imitate innovations is difficult, given that competitors may not possess the necessary resources to exploit these abilities.[15] In turn, firms that have developed a certain innovation will have incentives to exploit said innovation in larger markets and in different markets in the search to improve their economic performance.[16] Furthermore, it has been argued that the high competition level in global markets forces firms to constantly update their products and adapt to these markets' new conditions. Salomon and Shaver (2005)[17] studied Spanish firms and found that the knowledge that is gained in international markets allows firms to register an even higher amount of patents and to develop more innovative products in general. The authors emphasize the importance of studying how long it takes for Learning-by-Exporting to have an effect, given that this effect may not be immediate. The authors find that Learning-by-Exporting first affects product innovation two years after the firm has begun exporting and that the amount of patent filings increases with a much greater lag. On the other hand, Silva and Leitão (2007), in a study conducted about Portuguese manufacturing firms, come to the conclusion that firms with higher export levels are less able to innovate. The authors argue that most companies with high export intensity outsource services and adopt a low-price strategy, which does not correspond with product innovation.[18]

A more recent study conducted by Filipescu et al. (2013) investigates how innovation (R&D intensity, product and process innovation) on the one hand and exports (breadth and depth) on the other hand can mutually influence each other. The causality between both effects is examined by means of a panel of 696 Spanish manufacturing firms during the 1994-2005 period. There is evidence of a reciprocal relationship between technological innovation and exports (mutual causality). In turn, the authors find positive, but not significant, connections between product innovation and exports, as well as between export depth and process innovation. The authors argue that these results are consistent with most existing international studies on this topic. This relationship of reciprocal causality could be centered on the relevance of resources and learning based on the development and use of intangible resources. As companies develop export activities, they gain knowledge and abilities that help them develop new technological innovations, which in turn allow exporting firms to increase their export intensity on the one hand and diversify the global markets in which they participate on the other hand.

2.4 Evidence for Chile

In the case of Chile, Álvarez et al.[19] study the relationship between exports, productivity and technological productivity. By means of information from manufacturing plants, they explore what factors might explain the positive relationship between exporting performance and their productivity. The approach that was used to identify if Chilean companies that begin to export

[15] (Miller & Shamsie, 1996)
[16] (Pla-Barber & Alegre, 2007)
[17] (Salomon & Shaver, 2005)
[18] (Silva & Leitão, 2007)
[19] (Álvarez, García, & García, 2008)

become more productive was implemented by means of matching techniques.[20] The evidence that the authors found favors the idea that only more productive firms are able to export. This Self-Selection phenomenon could be explained through the existence of prices for trading with the rest of the world. Given the small amount of evidence that points towards the fact that exports increase firms' productivity, this paper analyzes whether there are other kinds of learning linked to the exporting process: using information regarding the location of plants and their productive sector, there is evidence regarding whether the probability of entering international markets is affected by the existence of other exporters in the same region and/or sector. The results for Chile do not suggest a significant profit stemming from the high geographic and sectorial concentration of exporters. Finally, the authors analyze whether firms' innovation activities favor their exporting performance, and find no evidence that these activities increase their probability of exporting.

Benavente et al.[21] study the relationship between R&D expenditure, exports and productivity. The authors find that companies that invest in R&D are considerably more prone to export, but not the opposite situation; that is, the fact that a firm exports does not increase the probability that it carries out research and development. Furthermore, there is evidence that exports and R&D have a joint effect on increasing Chilean manufacturing plants' productivity levels. In this manner, although exporting activities do not encourage R&D investment, there is evidence of learning-by-exporting. All these results are sturdy in the face of endogeneity corrections.

Most of the studies mentioned have used dummies to capture sub-sector differences. However, this methodology does not reveal sub-sector distinctiveness. The main focus of this paper is to analyze how innovation affects exports, and vice versa. In order to achieve this, we have estimated the relationships of causality for every sub-sector separately,[22] which allows us to evaluate to what extent existing differences between the various sub-sectors condition the relationship of causality between exports and innovation.

Our assumption in this paper is that these differences (which include the following: differences regarding technological intensity, aggregate value level, whether the sub-sector represents a natural-resource intensive sector or not, the internalization of companies that belong to the sub-sector, and the location where the firms from one or another sub-sector are found, among other differences) have a heterogeneous sub-sector impact on the relationship of causality between exports and innovation, an assumption that seems relevant when considering Pavitt's[23] important contributions regarding sector specificity on innovation sources and effects.

The methodology that we used is modeled to a large degree on Filipescu et al.'s[24] paper, which uses the Granger Test to study the existing relationship of causality between innovation and the breadth and depth of exports. In turn, we took into account the analytical approached used by

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[20] Exporting companies may be slightly biased to be more productive than the average company, given that precisely more productive companies would self-select themselves to export. This problem is known as selection bias and, in order to control for these and other non-observable variables, endogeneity treatment and selection bias methodologies must be used in order to capture the desired effects efficiently and without biases.

[21] (Benavente, Ortega-Bravo, & González, 2013)

[22] This methodology is closely modeled on the one used by Wagner (2008) to study the difference between East and West Germany in the exporting behavior of German manufacturing firms.

[23] (Pavitt, 1984)

[24] (Filipescu, Prashantham, Rialp, & Rialp, 2013)

Monreal-Peréz et al.,[25] who, in order to study the causal relationship between innovation and exports, consider the moderating effect of productivity. Regarding the study of sub-sector heterogeneity, our methodology is based on the one used by Wagner[26] to study the existing geographic differences in the export-innovation relationship in his paper analyzing the differences between East and West German manufacturing plants' existing exporting propensity. It differs from previous studies on Chile in that it considers a wider range of types of innovation expenditure instead of limiting itself to studying R&D expenditure. Additionally, we make a distinction between the different levels of expenditure sophistication, considering expenses related to technological innovations on the one hand, and expenses related to more general innovations on the other hand, in order to, this way, find differences in the relationship of innovation expenditure and exports, depending on the type of innovation expenditure. We also look for heterogeneities given by the manufacturing sub-sector that the firm belongs to, which also represents a novel contribution for the study of innovation in Chile. Additionally, we study the causal relationship between innovation expenditure and exports, by means of the Granger test, which is also new for studies regarding this topic in Chile. Finally, this paper studies innovation in Chile based on information compiled from 1995 until 2012, which is the largest amount of data that has been used until today in studies on innovation and technological development at the firm level in Chile.

3 Data and Descriptive Statistics

The data source that was used to study innovative activities in Chile at the firm level is, first and foremost, the Technological Innovation Survey (EIT, for its acronym in Spanish) conducted by the National Statistics Institute (INE). This survey includes a questionnaire that follows the guidelines set forth by the Frascati Manual regarding innovation, which was published by the OECD. Our study takes into account the eight innovation surveys that were conducted from 1995 until 2012. Particularly for 1995, 1998 and 2001, we worked with samples that correspond to crosses between the EIT and the Annual Industrial National Survey (ENIA) so that we could also study the firms' quantitative variables,[27] particularly the Employment variable, which had been absent from the EIT those years. We only studied manufacturing companies in order to have more homogeneous observations. In order to manage this, we had to align the classification for the studied surveys due to the fact that, over the years, the survey underwent several changes to cover a higher amount of productive industries (Mining and Energy was added on the third survey, and all sectors were added on the fourth survey, respectively). **Table 1** shows the manufacturing sub-sector classification that was used.

Table 1: Manufacture by Sub-sector

Sub-sector

[25] (Monreal-Pérez, Aragón-Sánchez, & Sánchez-Marín, 2012)
[26] (Wagner J. , 2008)
[27] In this paper, the terms "firm" and "company" are equivalent to the concept of establishment. This is a faithful enough approximation to reality in the case of small and most medium establishments, but not in the case of other medium and some large establishments (Programa Innovación Tecnológica - Ministerio de Economía, 1997).

Food	Food, Beverages and Tobacco
Text	Textile, Wearing Apparel and Leather Industries
Wood	Wood and Wood Products, including Furniture
Pap	Paper and Paper Products, Printing and Publishing
Chem	Chemicals and Chemical, Petroleum, Coal, Rubber and Plastic Products
M-BM	Non-Metallic Mineral Products and Basic Metal Industries
M-M	Fabricated Metal Products, Machinery and Equipment

Source: Author's elaboration.

The studied data contains more than 6.300 observations.[28] As was previously mentioned, we considered a wider range of activities that seek productive improvements inside the firm. **Table 2** shows the different types of innovation expenditure considered by the data that we used.

Table 2: Types of Innovation Expenditure

R&D	Research & Development
know	Acquisition of External Knowledge for Innovation (Patents, Licenses, Know-How, etc)
maq*	Installation of machinery, equipment and Software for innovation
train	Training for Innovation (training for the development or introduction of new or improved prod/proc)
pat	Production tests, Patents, Licenses, Commercial introduction of new products, others
mark	Entering Market Innovations, Market Research, Advertising Campaigns
des	Design for Innovation (shape and appearance of products, not their technical specifications)
other*	Other activities for Innovation (installation of new equipment, commissioning of production)

Source: Author's elaboration from EIT data.
(*) Technological innovation.

Regarding the remaining variables, **Table 3** and the graph in **Figure 1** show descriptive statistics, where we can observe the percentage by manufacturing sub-sector of companies that carry out some sort of innovation expenditure (generally speaking), companies that export, companies that carry out both activities simultaneously, and lastly companies whose property is partly owned by foreigners.

At the aggregate level, we can notice that the amount of firms that innovate[29] is close to 40%, which is similar to the amount of firms that export. However, if we take into account both firms

[28] It must be noted that this study did not use the EIT expansion factors, given that it has been considered that their use does not measure firm behavior well, in particular the export-innovation relationship. This must be kept into account when extrapolating estimates, calculations and conclusions in this paper for behaviors at the sector and sub-sector level, sub-sector GDP, sub-sector export level, and Foreign Property, among other values.

[29] In order to make reading this paper easier, we will write 'Innovation' interchangeably to refer to 'Innovation Expenditure.' In turn, we will write 'Technological Innovation' interchangeably to refer to 'Technological Innovation Expenditure.' This terminology flexibility is possible due to the fact that this work does not mention nor study Innovation Outputs, Product Innovation, Process Innovation, Management Innovation, etc., and so it should not be confusing. However, please keep in mind that under no circumstances have we made the assumption that

that innovate and export at the same time, we see that they make up 22% of the sample, so we can reach the conclusion that approximately half of exporting firms innovate. The same situation happens with innovative companies; that is, half of them export. Finally, 11% of firms have foreign property.
At the disaggregate level, we can observe that the Chemical sub-sector is where the highest percentage of firms export part of their production (50%); the highest percentage of companies innovate (47%); the highest percentage carries out both activities (31%); and where more than 20% of the firms have some level of foreign property. At the same time, the Food and Paper sub-sectors display above-mean percentages for all studied variables, except exports and foreign property for the Paper sub-sector. Finally, the Minerals and Basic Metals sub-sector displays above-mean innovation expenditure and foreign property levels, although its export levels are below the mean. On the other hand, the Metal-Mechanic, Textile and Wood sub-sectors generally display below-mean levels for all studied variables. We can see that for the Basic Metals, Paper and Metal-Mechanic sub-sectors, the amount of companies that spend on innovation is higher than the amount of companies that export, unlike the other sub-sectors. In accordance with existing literature, the sub-sectors with the highest amount of foreign property possess the greatest amount of firms that innovate and export.

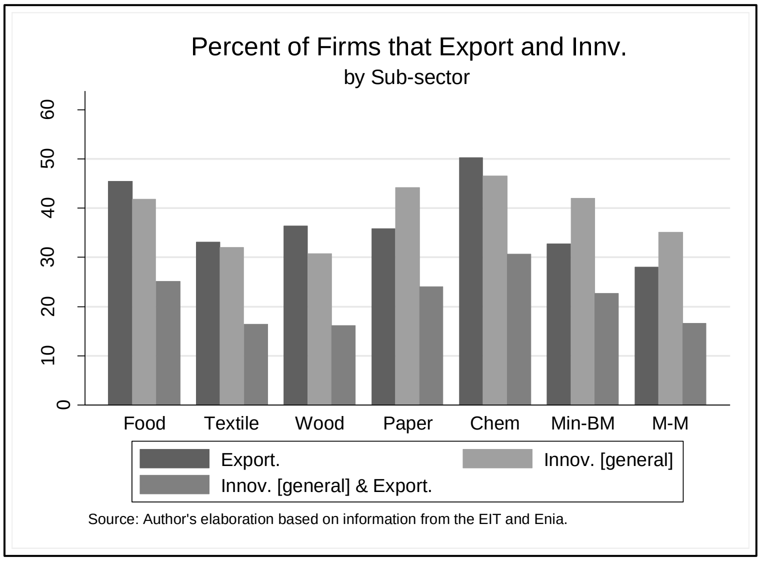
Table 3: Innovation and Export, by Sub-sector (%)

	Total	Food	Text	Wood	Paper	Chem	Min-BM	M-M
Export.	38.0	45.5	33.2	36.4	35.8	50.3	32.8	28.0
Innov. Expend. [general]	39.4	41.8	32.0	30.8	44.2	46.6	42.0	35.1
Innov. [general] and Export.	22.1	25.1	16.4	16.2	24.1	30.6	22.7	16.6
Foreign Property	11.0	12.2	4.5	6.6	7.0	20.3	18.3	5.9
Observations	6374	1473	597	588	611	979	705	1421

Source: Author's elaboration based on information from the EIT and ENIA.

innovation expenditure will necessarily lead to innovation (Output), nor that Technological Innovation Expenditure will necessarily induce technological innovation (Output), although they are intrinsically related.

Figure 1: Innovation & Export, by Sub-sector



In order to study the innovation-export relationship more thoroughly, **Table 4** shows a Mean Test of innovation expenditure effort for exporting and non-exporting companies. To carry out this test, innovation effort is defined as the innovation expenditure per worker.[30] As you can see, there are statistically significant differences between both groups of firms if the whole sample is considered at the aggregate level, where exporting companies have a higher innovation effort level than non-exporting companies. This evidence is coherent with previous studies, and we are able to confirm that exporting companies have a (statistically significant) better innovation performance than non-exporting companies. We observe a difference (difference between means) of more than 750 and a proportion between means[31] (ratio) that is more than double. At the disaggregate level, although we can observe mean differences, only the Paper, Mineral and Basic Metal sub-sectors are significant. Regarding the magnitude of these differences, we observe differences in the proportion between means (ratio) of between 1.1 and 16.5. This is detailed graphically in **Figure 2**.

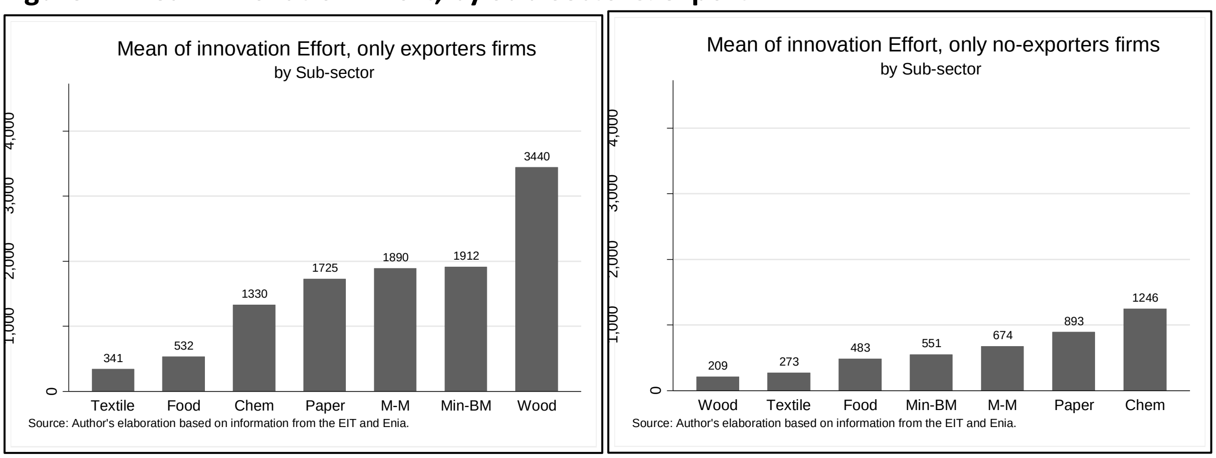
[30] This is carried out according to existing literature. Both innovation effort and export intensity allow for corrections based on factors relative to plants and fixed effects per industry. At the same time, both innovation expenditure values and export values are calculated at real value.
[31] The mean ratio is measured as the innovation effort mean of exporting firms divided by the innovation effort mean of non-exporting firms.

Table 4: Mean Test Innovation Effort, by Export

	Total	Food	Text	Wood	Paper	Chem	Min-BM	M-M
3.1								
gl								
no-export	632	483	273	209	893	1,246	551	674
export	1,395	532	341	3,440	1,725	1,330	1,912	1,890
Prob> t	0.01	0.64	0.56	0.16	0.09	0.85	0.00	0.18
dif. of means	763.9	48.6	68.1	3,231.7	832.7	83.7	1,360.5	1,215.9
ratio	2.21	1.10	1.25	16.49	1.93	1.07	3.47	2.80
N	6,374	1,473	597	588	611	979	705	1,421
non-Exp.	3,966	803	388	365	403	491	480	1,036
Export	2,408	670	209	223	208	488	225	385

Source: Author's elaboration based on information from the EIT and ENIA.

Figure 2: Mean Innovation Effort, by Sub-sector& export



In order to study the export intensity relationship between innovative and non-innovative firms, we carried out a Mean Test regarding exporting propensity, measured as the proportion of sales intended for foreign markets. The results are shown in **Table 5** and the graph in **Figure 3**. We can observe statistically significant differences between both groups of firms if the whole sample is considered, where innovative companies, on average, have a higher export intensity level than non-innovative firms, with a 7% difference (dif) and a proportion between means[32] (ratio) of almost 2 (1.8). That is, the percentage of exported sales of innovative firms is almost twice that of non-innovative firms, which is also significant at the sub-sector level, reaching ratios between 1.3 and 3. The sub-sectors with the highest ratios, above or near 3, are Minerals and Basic Metals, Metal-Mechanic, and Paper. The relationship we found—at both the aggregate level and disaggregate level by sub-sector—is coherent with previous studies, and thus we can prove that exporting companies have a better innovation performance than non-exporting companies.

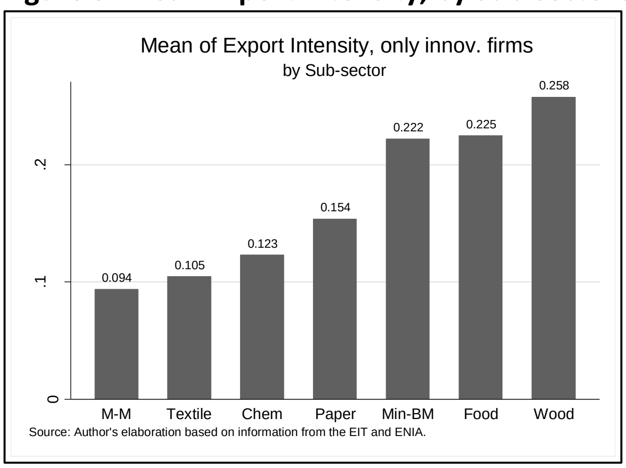
[32] The mean ratio is measured as the innovation effort mean of exporting firms divided by the innovation effort mean of non-exporting firms.

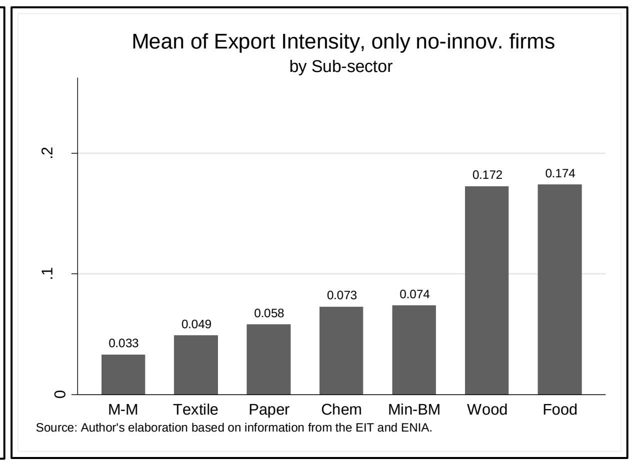
Table 5: Mean Test Export Intensity, by Innov.

	Total	Food	Text	Wood	Paper	Chem	Min-BM	M-M
ev								
no-Innov	0.093	0.174	0.049	0.172	0.058	0.073	0.074	0.033
Innov	0.165	0.225	0.105	0.258	0.154	0.123	0.222	0.094
Prob> t	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
dif. of means	0.072	0.051	0.056	0.085	0.096	0.051	0.148	0.061
ratio	1.78	1.29	2.14	1.49	2.66	1.70	3.01	2.85
N	6,374	1,473	597	588	611	979	705	1,421
non-Innov.	4,016	894	406	428	363	550	425	950
Innov.	2,358	579	191	160	248	429	280	471

Source: Author's elaboration based on information from the EIT and ENIA.

Figure 3: Mean Export Intensity, by Sub-sector& innovation.





4 The Model

We analyze the causality of 2 relevant variables: innovation expenditure effort and export intensity. We control this estimate for productivity to capture economies of scale, scope and all possible existing relationship of learning-by-exporting and censured variables. This is achieved by distinguishing between the types of innovation expenditure. In the first place, we study general innovation expenditure (g); that is, all the expenses that are presented in **Table 2**. Secondly, we consider technological innovation expenditure $(g1)$, defined as the sum of all Expenditure on machinery for innovation and on other Activities (installation and adjustment of new equipment, commissioning of production) for Innovation. In the third place, we consider expenditure on acquisition of external knowledge $(g2)$. Finally, we consider only Research and Development Expenditure $(g3)$. The objective of differentiating between kinds of expenditure is to look for heterogeneities in the causal behavior related to the level of sophistication of the type of innovation expenditure.

We mainly followed the methodology used in the most recent paper on this topic, which studies the causality between innovation and exports (Filipescu, Prashantham, Rialp, & Rialp, 2013). This paper studies causality by means of a Granger Test (Granger, 1969) with two lags. Along

with the previous paper, we consider the analytical approached used by Monreal-Peréz et al.,[33] which also controls for productivity in order to study the causal relationship between innovation and exports. In order to study the sub-sector heterogeneity, we make estimates for every sub-sector separately.
The study was carried out based on pooled cross-sectional data, estimating a Granger test based on one lag. Considering the manufacturing sub-sectors (s), the model specification was established in the following manner for every sub-sector:

$$\mathrm{exp_t} = \beta^1_{\mathrm{exp,s}} \cdot \mathrm{exp_{t-1}} + \beta^1_{\mathrm{gs}} \cdot \mathrm{g_{t-1}} + \beta^1_{\mathrm{vs}} \cdot \mathrm{v_{t-1}} + \beta^1_{\mathrm{l}} \cdot \mathrm{l_{t-1}} + \beta^1_{\mathrm{k}} \cdot \mathrm{k} + \vec{\beta}^1_{\vec{A}} \cdot \vec{A} + \varepsilon^1_s \quad \text{(Ecuation 1)}$$
$$\mathrm{g_t} = \beta^2_{\mathrm{gs}} \cdot \mathrm{g_{t-1}} + \beta^2_{\mathrm{exp,s}} \cdot \mathrm{exp_{t-1}} + \beta^2_{\mathrm{vs}} \cdot \mathrm{v_{t-1}} + \beta^2_{\mathrm{l}} \cdot \mathrm{l_{t-1}} + \beta^2_{\mathrm{k}} \cdot \mathrm{k} + \vec{\beta}^2_{\vec{A}} \cdot \vec{A} + \varepsilon^2_s \quad \text{(Ecuation 2)}$$

Where:

g: Innovation expenditure effort
exp: Export intensity
v: Productivity
l: Work
k: foreign capital (dummy)
$\vec{\mathrm{A}}$: Set of categorical variables by year and sub − sector

These innovation and export equations are estimated by means of a Tobit model (Amemiya, 1973), considering that both exporting firms and firms that carry out innovation efforts are censured samples.
The variables are calculated in the following manner: the different amounts of innovation expenditure are calculated according to the aforementioned definition, and afterwards the amount of innovation expenditure per worker is calculated, which is called innovation effort. Exports are considered to be the real value of total exports. This value is divided by the total sales, and the result is the company's export intensity. Finally, labor productivity is measured by means of the number of sales per worker.[34]
In order to correct the effect of the year in particular in which the variable was measured, we used categorical variables ($\vec{A}$) to capture the variance stemming from the year of observation. This is relevant to lessen the different temporal exogenous effects that there may be as much as possible. Clear examples are the Asian financial crisis and the subprime mortgage crisis, which happened in 1998 and 2009, respectively, as well as the fact that, as we saw earlier, the amount of exporting and innovative companies might by permeable to macroeconomic tendencies (Real Exchange Rate). **Table 6** displays a summary of the variables that were used along with their definition.

[33] (Monreal-Pérez, Aragón-Sánchez, & Sánchez-Marín, 2012)
[34] Innovation effort, export intensity and labor productivity were calculated with values at constant prices.

Table 6: Definition of variables

l	Work	total amount of workers
g	Innovation expenditure effort [general]	$(R\&D + know + maq + train + \ pat + mark + des + other)/l$
g1	Technological innovation expenditure effort	$(maq + other)/l$
g2	Innovation expenditure effort [know]	$know/l$
g3	Innovation expenditure effort [R&D]	$R\&D/l$
exp	Export intensity	$exports/sales$
k	Foreign Property	Categorical variable: 1 if part of the property is foreign-owned; or if not.
A	Categorical variables by year and sub-sector	

Source: Author's elaboration.

5 Main Results

Given that the focus of this paper is to study the existing causality between exports and innovation, and following the definition of the Granger Causality Test, we report the F-statistics of the variables to be tested for the different sub-sectors. We begin our analysis by studying innovation expenditure at the general level $(g1)$.

In **Table 7**, we can see that there is statistically significant Granger causality from exports towards innovation[35] at the aggregate as well as the sub-sector level (except for the Food and Wood sub-sectors, although the Food subsector has a 10% significance level), considering innovation in general terms.

Table 7: F-statistics, Granger Causality Test: Innovation Effort [General Innovation]

	Total	Food	Text	Wood	Paper	Chem	Min-BM	M-M
model								
$Export.Intensity_{t-1}$	+	+	+	-	+	+	+	+
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector dummies	Yes	No	No	No	No	No	No	No
F-stat.	42.24	2.74	11.71	1.71	8.10	10.32	9.07	7.19
Prob> F	0.00	0.10	0.00	0.19	0.00	0.00	0.00	0.01
Obs.	6,374	1,473	597	588	611	979	705	1,421
Obs. Uncensored	2,509	616	191	181	270	456	296	499
Obs. Censored	3,865	857	406	407	341	523	409	922
Estimation	tobit	tobit	tobit	tobit	tobit	tobit	tobit	tobit

Source: Author's elaboration based on information from the EIT and ENIA.
Control Variables: Labor Productivity, Labor, Foreign Property.

[35] From this point onward, the terms innovation and exports will be used to refer to innovation effort and export intensity respectively.

Furthermore, in **Table 8** we observe that, at the aggregate level, there is no statistically significant Granger causality from innovation towards exports. At the disaggregate level, we can only observe statistical significance for the Wood, Minerals, Basic Metals and Metal-Mechanic sub-sectors.
It is therefore evident, at the aggregate level, that exports may stimulate innovation expenditure.
However, innovation expenditure may not have a relevant causal effect on export intensity. At the disaggregate level, there may be sub-sectors with similar behaviors to those observed at the aggregate level, where exports may cause innovation and not the other way around. In turn, there are sub-sectors with mutual reinforcement, where causality is present in both directions. Finally, there is causality in the Paper sub-sector in the opposite direction; that is, from innovation towards exports.

Table 8: F-statistics, Granger Causality Test: Export Intensity [General Innovation]

	Total	Food	Text	Wood	Paper	Chem	Min-BM	M-M
model								
$Innov.Effort_{t-1}$	-	+	-	-	+	+	+	+
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector dummies	Yes	No	No	No	No	No	No	No
F-stat.	1.41	0.95	2.09	11.16	1.54	0.14	8.66	5.86
Prob> F	0.24	0.33	0.15	0.00	0.22	0.71	0.00	0.02
Obs.	6,374	1,473	597	588	611	979	705	1,421
Obs. Uncensored	2,422	670	198	214	219	492	231	398
Obs. Censored	3,952	803	399	374	392	487	474	1,023
Estimation	tobit	tobit	tobit	tobit	tobit	tobit	tobit	tobit

Source: Author's elaboration based on information from the EIT and ENIA.
Control Variables: Labor Productivity, Labor, Foreign Property.

The results of the estimations using technological innovation are presented below$(g1)$. In **Table 9**, we can see that there is no causality from innovation towards exports at the aggregate level, although there is causality at the disaggregate level for the Wood and Minerals and Basic Metals sub-sectors.

Table 9: F-statistics, Granger Causality Test: Export Intensity [Technological Innovation]

	Total	Food	Text	Wood	Paper	Chem	Min-BM	M-M
model								
$Innov.Effort_{t-1}$	-	+	-	-	+	+	+	+
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector dummies	Yes	No	No	No	No	No	No	No
F-stat.	0.03	1.59	0.00	9.61	0.37	0.30	12.84	1.19
Prob> F	0.86	0.21	0.95	0.00	0.54	0.58	0.00	0.28
Obs.	4,942	1,103	442	481	494	712	532	1,178
Obs. Uncensored	1,618	435	121	150	156	315	153	288
Obs. Censored	3,324	668	321	331	338	397	379	890
Estimation	tobit	tobit	tobit	tobit	tobit	tobit	tobit	tobit

Source: Author's elaboration based on information from the EIT and ENIA.
Control Variables: Labor Productivity, Labor, Foreign Property.

Regarding causality from exports towards innovation, in **Table 10** we can observe significance in the causal relationship. At the disaggregate level, save for the Food and Wood sub-sectors, there is causality. Thus, there is no relevant difference in the causality of technological innovation expenditure and general innovation expenditure.

Table 10: F-statistics, Granger Causality Test: Innovation Effort [Technological Innovation]

	Total	Food	Text	Wood	Paper	Chem	Min-BM	M-M
model								
$Export.Intensity_{t-1}$	+	+	+	-	+	+	+	+
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector dummies	Yes	No	No	No	No	No	No	No
F-stat.	43.79	0.87	4.60	2.17	8.10	11.50	22.54	9.92
Prob> F	0.00	0.35	0.03	0.14	0.00	0.00	0.00	0.00
Obs.	4,942	1,103	442	481	494	712	532	1,178
Obs. Uncensored	1,328	315	92	101	167	222	141	290
Obs. Censored	3,614	788	350	380	327	490	391	888
Estimation	tobit	tobit	tobit	tobit	tobit	tobit	tobit	tobit

Source: Author's elaboration based on information from the EIT and ENIA.
Control Variables: Labor Productivity, Labor, Foreign Property.

Continuing with our analysis, we present the results for innovation expenditure effort regarding acquisition of knowledge ($g3$). For the case of causality from innovation towards exports (**Table 11**), we can observe that, at the aggregate level, there is significance in this relationship. At the disaggregate level, 2 sub-sectors have statistical significance: Textile and Minerals and Basic Minerals.

Table 11: F-statistics, Granger Causality Test: Export Intensity [Innov. Acquisition of Knowledge]

	Total	Food	Text	Wood	Paper	Chem	Min-BM	M-M
model								
$Innov.Effort_{t-1}$	+	+	-	+	+	+	-	+
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector dummies	Yes	No	No	No	No	No	No	No
F-stat.	5.89	0.69	4.29	0.24	2.29	0.02	0.10	7.20
Prob> F	0.02	0.41	0.04	0.62	0.13	0.89	0.75	0.01
Obs.	4,942	1,103	442	481	494	712	532	1,178
Obs. Uncensored	1,618	435	121	150	156	315	153	288
Obs. Censored	3,324	668	321	331	338	397	379	890
Estimation	tobit	tobit	tobit	tobit	tobit	tobit	tobit	tobit

Source: Author's elaboration based on information from the EIT and ENIA.
Control Variables: Labor Productivity, Labor, Foreign Property.

Furthermore, **Table 12** shows the Granger Test results for the causality from exports towards innovation. We can see that there is causality in this direction at the aggregate level. At the disaggregate level, there is significance in the Textile, Chemical, and Minerals and Basic Metals sub-sectors.
Therefore there is evidence of Mutual Reinforcement at the aggregate level, and there is statistical significance in both directions (reciprocal causality). At the disaggregate level, only the Textile sub-sector shows evidence of this mutual reinforcement.

Table 12: F-statistics, Granger Causality Test: Innovation Effort [Innov. Acquisition of Knowledge]

	Total	Food	Text	Wood	Paper	Chem	Min-BM	M-M
model								
$Export.Intensity_{t-1}$	+	+	+	+	+	+	+	+
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector dummies	Yes	No	No	No	No	No	No	No
F-stat.	9.43	0.15	3.72	1.16	1.98	4.90	4.79	1.71
Prob> F	0.00	0.70	0.05	0.28	0.16	0.03	0.03	0.19
Obs.	4,942	1,103	442	481	494	712	532	1,178
Obs. Uncensored	287	58	21	18	24	67	42	57
Obs. Censored	4,655	1,045	421	463	470	645	490	1,121
Estimation	tobit	tobit	tobit	tobit	tobit	tobit	tobit	tobit

Source: Author's elaboration based on information from the EIT and ENIA.
Control Variables: Labor Productivity, Labor, Foreign Property.

Finally, we study causality considering innovation effort in Research and Development (R&D) expenditure. **Table 13** shows the results of the estimation from innovation towards exports. We found no statistical significance at the aggregate level. At the disaggregate level, there is causality in the Wood and Metal-Mechanic sub-sectors.

Table 13: F-statistics, Granger Causality Test: Export Intensity [Innov. R&D]

	Total	Food	Text	Wood	Paper	Chem	Min-BM	M-M
model								
$Innov.Effort_{t-1}$	+	-	+	+	+	-	+	+
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector dummies	Yes	No	No	No	No	No	No	No
F-stat.	2.40	1.15	0.00	3.66	1.06	0.54	1.74	7.28
Prob> F	0.12	0.28	0.95	0.06	0.30	0.46	0.19	0.01
Obs.	5,127	1,001	597	418	494	801	633	1,183
Obs. Uncensored	1,995	494	198	172	182	401	199	349
Obs. Censored	3,132	507	399	246	312	400	434	834
Estimation	tobit	tobit	tobit	tobit	tobit	tobit	tobit	tobit

Source: Author's elaboration based on information from the EIT and ENIA.
Control Variables: Labor Productivity, Labor, Foreign Property.

Table 14 studies the causal direction from exports towards innovation. The evidence that we found points to the existence of causality at the aggregate as well as disaggregate level, save for the Metal-Mechanic sub-sector. Therefore, there is evidence of Mutual Reinforcement in the Wood and Metal-Mechanic sub-sectors.

Table 14: F-statistics, Granger Causality Test: Innovation Effort [Innov. R&D]

	Total	Food	Text	Wood	Paper	Chem	Min-BM	M-M
model								
$Export.Intensity_{t-1}$	+	+	+	+	+	+	+	+
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector dummies	Yes	No	No	No	No	No	No	No
F-stat.	42.29	6.97	8.80	2.76	12.75	4.91	0.85	6.84
Prob> F	0.00	0.01	0.00	0.10	0.00	0.03	0.36	0.01
Obs.	5,127	1,001	597	418	494	801	633	1,183
Obs. Uncensored	1,297	311	106	68	109	278	187	238
Obs. Censored	3,830	690	491	350	385	523	446	945
Estimation	tobit	tobit	tobit	tobit	tobit	tobit	tobit	tobit

Source: Author's elaboration based on information from the EIT and ENIA.
Control Variables: Labor Productivity, Labor, Foreign Property.

Consequently, the evidence that we found points first towards a difference in the causal direction between innovation and exports according to the sophistication level and/or type of innovation effort that was carried out, where, at the aggregate level, when considering all types of innovation (in general terms), we find causality from exports towards innovation (Learning-by-Exporting) and not in the opposite direction. However, when considering innovations related to the acquisition of knowledge, there is mutual reinforcement, as there is statistical significance in both directions (reciprocal causality). In the case of the innovation effort related to R&D, the causal relationship is not relevantly different than that of the general case. At the sub-sector level, there is a high heterogeneity in the causal relationship.

6 Conclusions

In this paper, we study the relationship of causality between the innovation effort and export intensity of manufacturing firms. In order to study the causality in these variables, we carry out a Granger causality test (Granger, 1969). Although more studies are necessary to confirm and support the hypotheses that are studied in this paper, we suggest that these findings be considered when making public-private decisions at the sub-sector level, in order to ensure that resources are used efficiently with a view to manage higher technological development, increases in productivity, and diversification and intensification of exports in the manufacturing industry. At the global level, the industry as a whole presents evidence of Granger causality from exports towards innovation, where companies with a higher participation in foreign markets make higher innovation efforts. The various benefits and profits related to learning, abilities and intangible knowledge capital must be differentiated, given that exporting firms are exposed to international knowledge and information related both to management and technology, which constitutes an opportunity that firms who operate only in local markets do not have access to. In addition, the benefits that firms will receive for using this knowledge to make technological improvements must be considered in order to intensify and diversify their exports.

Furthermore, the more limited causality from innovation towards exports may be a result of the existence of export barriers, where productive firms may not be able to export their products, which may be due to the fact that they may not be able to overcome the entrance barriers to foreign markets, originating from different entrance sunk costs.

The existence of Mutual Reinforcement at the innovation effort level related to the acquisition of knowledge points towards the fact that the ability to manage new knowledge is provided by the firm's participation in global foreign markets. Furthermore, this acquisition of knowledge, because it encourages export intensity, may have direct and short-term efficiency and competitiveness benefits, unlike the findings related to R&D effort, whose effects may not be different to those of general innovation effort. The latter, however, may be a result of a greater lag in the effect of R&D on performance.

These results allow us to propose a few policy conclusions for Chile, in particular the evidence that we found related to the high heterogeneity in the causal relationship at the disaggregate level, relative to tools that encourage exports and innovation.

These tools are aimed towards CORFO[36] supporting firms' individual or collective innovation (or products or processes) or PROCHILE[37] supporting the foreign market study and introduction effort. The lack of synchrony and ties in the support of market offer and access are a limiting factor that reduces the impact of public support tools. Additionally, companies that export and wish to horizontally diversify their exports have a higher probability of innovating and diversifying their exports. Designing a tool for companies that wish to diversify their exports, involving joint approval from CORFO and PROCHILE, with both market study and product and process innovation components, may have a greater effect on the diversification of exports and

[36] The Production Development Corporation (CORFO) is a national agency that is in charge of encouraging and financing business ventures, innovation and competitiveness in the country.

[37] PROCHILE is an agency that belongs to the Ministry of Foreign Affairs and is in charge of encouraging the exportation of national products and services.

innovation. The joint evaluation of these tools allows for the improvement of the company's design and strategy by incorporating the obstacles and requirements of the international market.

Another policy conclusion is that the support for first exporters' exports must be higher than for companies that are already present in the export market, given that a company's export activity in itself increases the propensity to innovate, strengthening its presence in foreign markets.

The sub-sector heterogeneity that we found suggests that certain policy and tool designs that encourage horizontal innovation and exports must be reviewed according to the existence of different abilities and opportunities for each industry sub-sector. These findings must be considered when making public-private decisions at the sub-sector level in order to use resources efficiently, with a view to manage technological development and productivity increases, and to diversify and intensify exports in the industry.

One of the criticisms regarding the results that are shown in this paper is that these results are based on data regressions subject to several biases. One of the main biases is the possibility that large and successful firms, which are the most productive, can afford certain luxuries such as carrying out innovation projects (Griliches, 1986), which do not necessarily point towards improving their performance. That is, there is a possibility that spending on these activities does not explain firms' performance but rather the other way around (although the causality analysis showed that this may not by true depending on the year and sector). However, we partly sought to correct this by controlling for productivity and other variables.

Furthermore, it must be considered that the objective of the model is to measure the effect of innovation expenditure on exports and vice versa, because many of the innovations carried out by firms may not have a direct impact on exports,[38] or the effects lag for more than a year. Additionally, part of a firm's increase in sales—and, consequently, in sales by worker—may occur due to an increase in its market power or due to exchange benefits, and not as a result of innovating. Furthermore, there may be innovations that point towards lowering the companies' productive costs, which may not be observed by the specification that was used. Finally, increases in export diversification produced by innovations or productivity will not be visible.

Another point to consider is the assumption that all innovation expenditure may equally determine exports, which is questionable, to say the least. Clearly, the effects of R&D expenditure will have a greater lag, and, in turn, machinery and equipment acquisition for innovation will have a specific impact depending on the type of machinery and on how capital-intensive the firm's sector is, and the same will occur with training expenditure. There will exist as well a difference in the impact and lags of their effects on productivity and exports.

Finally, we must ask ourselves: when studying the causality of R&D investments, why does Benavente (2013) find inverse causality? That is, why does he find that a higher R&D expenditure increases exports?

[38] Moreover, it has been argued in literature on this topic that innovation can, in the short term, cause lethargy in a firm's performance due to resource reassignment, adjustment costs, machinery adjustments, etc.

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