Technological Innovation and Exports: Unpacking Their Reciprocal Causality

Diana A. Filipescu, Shameen Prashantham, Alex Rialp, and Josep Rialp

ABSTRACT

The authors aim to advance extant understanding of the dynamics of firms operating abroad by considering the effects of innovation (research-and-development intensity, product and process innovations) on exports (breadth and depth), and vice versa. The study analyzes a panel data set of 696 Spanish manufacturing firms during 1994–2005 using Tobit and logit regressions and the Granger test of causality to offer a more complete picture of this complex relationship. They find broad support for the notion that innovation and exports have a reciprocal causal relationship, although the findings are partly nuanced by positive but nonsignificant associations between product innovation and exports and between export depth and process innovation. Furthermore, both export and innovation processes Granger-cause each other, demonstrating that there is a double causal relationship.

Keywords: technological resources, innovation, export breadth, export depth, causal effect, Granger test

Technological resources and their outputs (product and process innovations) represent one of the most important factors in increasing firms' national and international competitiveness. It is not surprising, then, that there is considerable literature on the effects of technological resources and innovation on firms' exporting behavior (Barrios, Görg, and Strobl 2003; Cho and Pucik 2005; Díaz-Díaz, Aguiar, and Saá-Pérez 2008; Kyläheiko et al. 2011; Vila and Kuster 2007). Some authors (Basile 2001; Cassiman and Golovko 2010) assert that technological innovation leads to exporting when the firm is able to generate new products or services that satisfy demand not only domestically but also in other foreign markets. Moreover, the consensus in the literature indicates that more innovative firms are usually more likely to obtain more positive results from exporting (Wakelin 1998).

In addition, some literature has examined the reverse relationship—namely, the effect of exports on firms' technological resources and innovation (Golovko and Valentini 2011; Hitt, Hoskisson, and Kim 1997). Internationalized firms are able to maintain their international competitiveness by acquiring more experience and technological knowledge in foreign markets (Zahra, Ireland, and Hitt 2000).

However, most prior research on this topic is cross-sectional (i.e., not longitudinal) and examines only a single causal direction of the technological innovation–export relationship (Cho and Pucik 2005; Damijan, Kostevc, and Polanec 2010; Kyläheiko et al. 2011), so the potential double causality of this relationship has been generally overlooked (Kumar and Saqib 1996; Salomon and Shaver 2005; Zahra, Ireland, and Hitt 2000). With only

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a few notable exceptions (Filatotchev and Piesse 2009; Golovko and Valentini 2011; Monreal-Pérez, Aragón-Sánchez, and Sánchez-Marín 2012), which jointly examine innovations and exports, there is almost no evidence with regard to whether more innovative firms (based on research and development [R&D] and product and process innovations) subsequently perform better in terms of export breadth (number of export markets) and depth (export intensity) and, conversely, whether more active export activities conducted by the firm foster further innovations.

Golovko and Valentini's (2011, p. 375) study highlights a "dynamic virtuous circle" with regard to innovation and exports, arguing that they are "complementary activities that reinforce each other, and whose individual marginal contribution to [small and medium-sized enterprises'] sales growth is higher if the other activity is also in place." Their study complements that of Filatotchev and Piesse (2009) by examining the joint effect of innovation and exports over small and medium-sized enterprises' growth. However, the gap we attempt to fill with our research is the need to examine the potential double causal effect between a firm's export and innovation activities, which has been overlooked insofar as they have typically been related to one another unidirectionally (Pla-Barber and Alegre 2007; Vila and Kuster 2007).

More specifically, we address the following two research questions: Is there a causal effect between technological resources and innovation and firms' export breadth and depth? Is there a causal effect between export breadth and depth and firms' technological resources and innovation?

The answers to both questions yield a twofold contribution of this article. First, we provide greater theoretical clarity to the literature by suggesting a reciprocal causality whereby a firm's technological resources and innovations lead to increased export breadth and depth, which in turn helps the firm acquire more experiential market knowledge, which then favors the improvement and/or development of technological resources and innovation. We empirically test the suggested double causality link by employing the Granger test of causality (Granger 1969). Second, we provide greater empirical precision to the literature by testing relationships between specific facets of exports (breadth and depth) and innovation (process and product innovations, R&D intensity). We believe that by better disentangling the direction of these relationships through longitudinal research, a clearer and more complete picture of the complex relationship between innovation and exports can be developed (Kyläheiko et al. 2011).

We organize the rest of the article as follows: The next section presents the theoretical framework, a literature review, and our hypotheses development. We then introduce the data source, the variables, and our empirical analysis. This is followed by the results and a discussion of the links to the existing literature. Finally, a concluding section points out the primary implications and limitations while offering directions for further research.

CONCEPTUAL FRAMEWORK AND HYPOTHESES

The core theory of this article is the resource-based view. This theoretical approach focuses on the firm's exploitation of its strategic resources and capabilities to gain a sustainable competitive advantage and superior firm performance (Barney 1991). Among these strategic resources, the intangible ones are the most likely to generate sustainable competitive advantages (Grant 1991; López and García 2005). Within the intangible resources, this article focuses on R&D intensity and product and process innovations.

Firms' investments in technological resources can generate a twofold competitive advantage for a firm: either in costs or in differentiation (Grant 1991). The former is acquired mainly through the development of new and more efficient productive processes, whereas the latter is achieved primarily by means of product innovations, allowing firms to modify products according to customer requirements or develop new products of a higher quality. Both product and process innovations are among the main sources of firms' sustainable competitive advantage due to rapid technological change, short product life cycles, and increasing global competition (Cho and Pucik 2005). Therefore, three aspects of innovation in terms of inputs and outputs become relevant: the total amount that a firm invests in R&D as a percentage of total sales (R&D intensity), the number of new products a firm is able to generate (product innovation), and the ability of the firm to change and improve its way of doing things (process innovation).

Technological Resources and Innovation as Determinants of Exports

Technological resources and innovation can serve as a source of sustainable competitive advantage both

domestically and abroad (Filipescu, Rialp, and Rialp 2009; Pla-Barber and Alegre 2007). The development of a certain innovative capacity may indeed facilitate a firm's export engagement and subsequent export growth. In general, the literature reports a positive relationship between firm technological innovation and internationalization (Bianchi 2009; Filipescu, Rialp, and Rialp 2009; López and García 2005). There are, however, some controversial findings regarding this expected positive relationship (Lefebvre, Lefebvre, and Bourgault 1998; Vila and Kuster 2007).

In the context of export behavior research in particular, empirical studies widely support the idea that innovation induces firms to increase exports, with technological resources having a positive and significant effect on firms' export activities (Basile 2001; Cho and Pucik 2005). The early consensus in the literature indicates that innovation acts as an important driver of exports, thus suggesting that the direction of causality runs from undertaking innovation activities to exports (Harris and Li 2009). In this sense, international markets may represent an area in which firms can exploit their innovations and thereby enhance their economic performance (Filipescu, Rialp, and Rialp 2009; Hortinha, Lages, and Lages 2011; Love and Mansury 2009). Accordingly, innovative firms will have a greater tendency to enter foreign markets to increase sales volume and spread the fixed costs of innovation over a larger number of markets (Pla-Barber and Alegre 2007; Zahra, Ireland, and Hitt 2000). Investments in technological resources enhance organizational knowledge and learning capabilities, which in turn are important antecedent factors of a firm's capability to develop cost-/differentiation-based international competitive advantages and, consequently, pursue international expansion by engaging in exporting and/or increasing its activities in foreign markets (Eriksson et al. 1997; Filatotchev and Piesse 2009; López and García 2005). Thus, innovative firms have strong incentives to subsequently expand their activities into markets beyond their domestic one to earn higher returns from their technological investments (Bianchi 2009).

Furthermore, some authors identify R&D intensity as an important determinant of firms' exports (Barrios, Görg, and Strobl 2003) because firms with a technological, R&D-based advantage can expand into new overseas markets at little or no marginal cost over the cost of developing this advantage in the domestic market (Davis and Harveston 2000). In addition, as exporting expands the potential customer base, investments performed in activities whose costs are largely fixed (e.g., R&D) may be recovered through greater sales volume (Love and Mansury 2009). However, Lefebvre, Lefebvre, and Bourgault (1998) do not find a significant influence of R&D expenditures on firms' export intensity.

However, product and process innovations (outputs) may also have a positive effect on a firm's exports, as well as R&D intensity (input). Technological innovations, in the form of either product or process innovations, also generate competitive advantages based on cost and/or differentiation, which provide the firm with a greater competitive capacity at home and also opportunities in foreign markets (Eriksson et al. 1997; López and García 2005). As Ganotakis and Love (2011) argue, the ability to compete in international markets is ultimately influenced by the firm's capacity to successfully market new and improved products that attract foreign customers, rather than merely being based on its R&D investments. This holds especially true for small and medium-sized enterprises, whose formal R&D measures markedly underreport research activity and degree of innovativeness (Kleinknecht 1987). In a similar vein, a firm's international presence and export success, usually measured in terms of export intensity, depends on distinct strategic factors linked to superior new product development and/or process innovations (Eriksson et al. 1997; Pla-Barber and Alegre 2007).

Therefore, we pose the following hypotheses in relation to R&D intensity and product and process innovation and their effects on export breadth and depth:

H_1: R&D intensity positively affects (a) export breadth and (b) export depth.

H_2: Product innovation positively affects (a) export breadth and (b) export depth.

H_3: Process innovation positively affects (a) export breadth and (b) export depth.

Exports as Determinants of Technological Resources and Innovation

Internationalization provides a firm with the opportunity to capture ideas from a greater number of new and different markets that can facilitate further innovation (Hitt, Hoskisson, and Kim 1997; Zhang et al. 2010). It can also reduce costs associated with innovation and, consequently, achieve greater returns from continuous technological innovations. Thus, a firm's export activities are considered one of the main determinants of its

innovation (Kotabe, Srinivasan, and Aulakh 2002). In other words, increased exports induce a firm to subsequently develop more innovations and to achieve greater returns from innovation by operating in more markets (Harris and Li 2009; Hitt, Hoskisson, and Kim 1997).

Several authors have postulated the so-called learning-by-exporting effect (Damijan, Kostevc, and Polanec 2010; Golovko and Valentini 2011; Love and Mansury 2009), which states that because of exporting firms' exposure to international markets, they may benefit from the knowledge generated through conducting international activities. Usually, the greater competitive pressure of international markets forces firms to constantly update their products and adapt to new market conditions. This would suggest a positive relationship between a firm's exposure to foreign markets and the level and growth of the firm's technological innovations (Bindroo, Mariadoss, and Pillai 2012). Indeed, when a firm is involved in more international markets and/or more deeply in a given one, it is more likely to proactively acquire new knowledge about foreign competition, markets, and products that are unavailable in the home market (Damijan, Kostevc, and Polanec 2010). This is useful for pursuing larger-scale R&D projects and developing other innovative activities through further investments in technology, because constant innovation is required to sustain competitiveness (Salomon and Shaver 2005; Zhang et al. 2010).

Autio, Sapienza, and Almeida (2000, p. 911) argue that exporting firms "must apprehend, share and assimilate new knowledge in order to compete and grow in markets in which they have little or no previous experience." This ability influences the firm's efforts to adapt products to local market conditions, offer customized applications, and take advantage of new market opportunities through rapid new product/process developments (Zahra, Ireland, and Hitt 2000). The acquired knowledge is helpful to maintain their strength and competitiveness abroad, but it also translates into more investments in technology. Indeed, to maintain competitiveness abroad, firms typically choose to invest in R&D and develop innovations (Cassiman and Golovko 2010). Therefore, a firm's increased presence in international contexts boosts the returns to its sustained innovative efforts (Alvarez and Robertson 2004) and may also lead to more rapid capitalization of R&D and innovation costs.

From a resource-based perspective, exporting firms could take advantage of the diverse knowledge inputs that they can potentially obtain abroad by being exposed to a richer source of knowledge/technology often not available in their home market (Hitt, Hoskisson, and Kim 1997; Pla-Barber and Alegre 2007; Zahra, Ireland, and Hitt 2000). Therefore, firms could enhance their competency base by learning from their interactions with international markets and thus develop their innovative capacities even further (Bindroo, Mariadoss, and Pillai 2012; Harris and Li 2009; Zhang et al. 2010). Such learning derived from global markets can foster increased R&D and product/process innovation within firms through gains in firm productivity. However, some studies have also found controversial results, showing that industrial firms with high export intensity are less capable of innovating or do not experience any learning-by-exporting effect on product or process innovations, not even when moderated by productivity (Monreal-Pérez, Aragón-Sánchez, and Sánchez-Marín 2012).

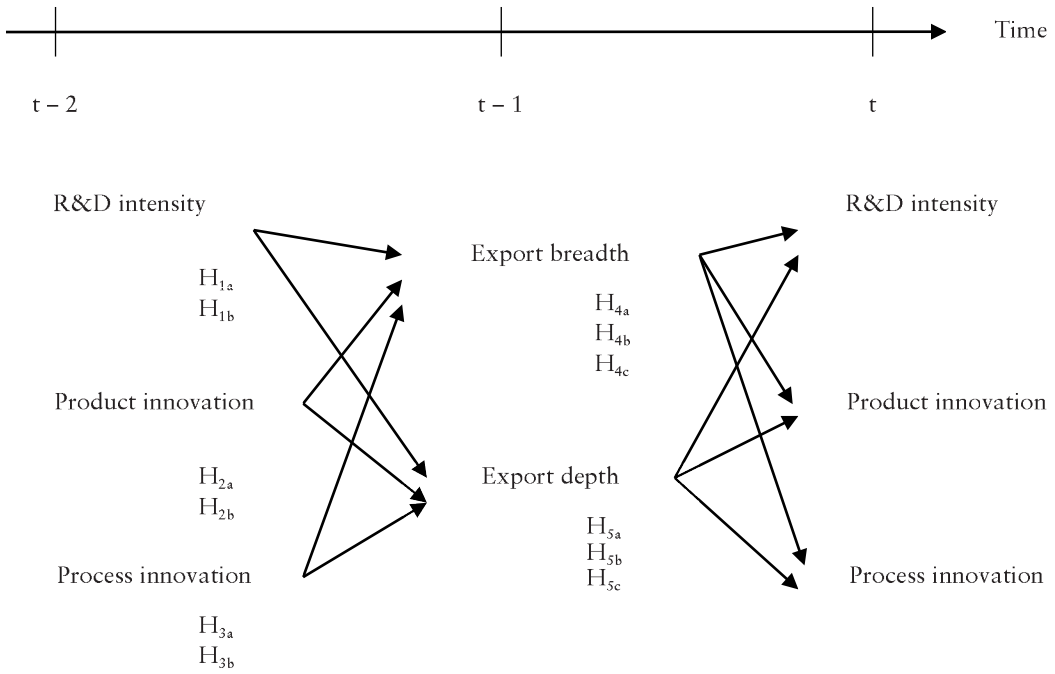
Thus, it can be expected that, in general, a firm's export breadth and depth have a subsequent positive effect on its technological resources and innovations. This is particularly true in today's complex competitive conditions, in which increased global competition in many geographical markets has placed more emphasis and importance on product and process innovations as a way to develop and sustain competitive advantages (Golovko and Valentini 2011). Specifically, exports can help firms draw on the advantages of operating in multiple countries, and product and process innovations can help overcome potential local disadvantages (Hitt, Hoskisson, and Kim 1997). Therefore, we pose the following hypotheses in relation to export breadth and depth and their effect on technological resources and innovation:

H_4: Export breadth positively affects (a) R&D intensity, (b) product innovation, and (c) process innovation.

H_5: Export depth positively affects (a) R&D intensity, (b) product innovation, and (c) process innovation.

As the model in Figure 1 suggests, we argue that there is a time-dependent, reciprocal causal relationship between technological resources and innovations and export breadth and depth. However, because such impacts are not necessarily expected to occur simultaneously (Filipescu, Rialp, and Rialp 2009), we analyze all the hypothesized effects by applying time lags.

Figure 1. Conceptual Framework



METHODOLOGY

Data Sources, Sample, and Time Frame

To accomplish the objectives of this research, we use the Survey on Business Strategy (SBS) designed and developed in Spain by the public foundation SEPI with the financial support of the Spanish Ministry of Industry, Tourism and Trade. The reference population of SBS is manufacturing companies with ten or more employees. The sample is stratified by 20 Standard Industrial Classification codes. Several journal publications on Spanish firms' technological and/or international activities have been published using SBS data (Cassiman and Golovko 2010; Díaz-Díaz, Aguiar, and Saá-Pérez 2008; Golovko and Valentini 2011; Monreal-Pérez, Aragón-Sánchez, and Sánchez-Marín 2012), as it is representative of the Spanish manufacturing industry. It is an appropriate basis for our research considering that Spanish firms' rather low levels of exports may be caused by their relatively lower levels of innovation in comparison with other advanced European Union countries (Fernández and Nieto 2005).

This study focuses on panel data of Spanish manufacturing firms over a 12-year period, from 1994 to 2005. This sample constitutes an unbalanced panel, as some firms ceased providing information while others continue to do so every year. To avoid possible bias generation (Fritsch and Lukas 2001), we included all firms that participated in the survey during this period in our data set regardless of their levels of technological innovation and exports. After deleting outliers, we retained 8297 observations corresponding to a final sample of 696 firms. Of these firms, 662 (95.11% of the sample) participated in the survey during the entire 12-year period. Table 1 provides a brief description of the sample, particularly the overall percentage of exporters, innovators, firm size, and activity sector.

Variables

Consistent with Kafouros, Buckley, and Clegg (2012), the first analysis focuses on two variables pertaining to exports as dependent variables in the first analysis: export breadth, a continuous variable on the number of foreign markets within different international geographical areas defined by the firm, and export depth, measured by the ratio of exports to total sales, which expresses the firm's propensity to export. With regard to technological resources and innovations, because studies based solely on R&D intensity may be misleading, the

Table 1. Sample Description

Firms' Characteristics	Categories	Overall Percentage
Exporters	No	34.94
	Yes	65.06
Innovators	No	56.14
	Yes	43.86
Size (number of employees)	≤50	51.18
	>50–≤200	17.37
	>200	31.46
Activity sectors (technology intensity)	Low–medium	71.07
	Medium–high	28.93

use of a wider range of indicators is strongly encouraged (López and García 2005). Therefore, we include three independent variables: R&D intensity—defined as the commitment of the firm toward R&D activities and measured by the ratio between R&D expenses and total sales; number of product innovations—a continuous variable defined as the number of product innovations achieved by the firm; and process innovation—a binary variable representing whether the firm has achieved process innovations. These variables allow us to identify firms with an innovative capacity that leads to valuable competitive advantages (Surroca and Santamaría 2007; Wakelin 1998).

The second part of the analysis focuses on the impact that export breadth and depth have on the firm's technological resources and innovations as measured above. We generated five models to determine the effect that technological resources and innovations have on export breadth and depth and vice versa, thus allowing us to detect if there is any sensitivity to which variables are introduced in the estimations (López and García 2005). In both analyses, we control for firm experience, measured by firm age (Galende and De la Fuente 2003); firm size (number of employees); and technological intensity of sectors, calculated according to the Organisation for Economic Co-operation and Development's (1997) classification.

However, because expected impacts between technological innovations and exports and vice versa may not be immediate, as we postulate in Figure 1—that is, we do not expect them to necessarily occur simultaneously (Bayona, Cruz, and García, forthcoming; Filipescu, Rialp, and Rialp 2009), we analyzed their respective effects lagged in time. More specifically, we introduce lagged variables in this investigation by assuming that exports in year t – 1 can be influenced by technological innovation in year t – 2, and consequently, exports in year t – 1 would also affect technological innovations in year t. Thus, we follow Salomon and Shaver's (2005) advice to introduce lags into the analysis to reduce possible simultaneity problems. Similarly, Baum (2006) considers lags important to improve prospects of valid causal inference. In addition, we include year dummies for both analyses.

Empirical Analysis

To test the hypotheses, we employed different statistical methods with panel data such as Tobit and logit regressions. The general specifications of the two sets of analyses are as follows:

$$\begin{aligned}\text{Export breadth}_{t-1} = {} & \beta_1\text{R\&D intensity}_{t-2} \\ & + \beta_2\text{Product innovation}_{t-2} \\ & + \beta_3\text{Process innovation}_{t-2} \\ & + \beta_4\text{Controls}_{t-1} + \tau_{t-1}\end{aligned}$$

$$\begin{aligned}\text{Export depth}_{t-1} = {} & \beta_1\text{R\&D intensity}_{t-2} \\ & + \beta_2\text{Product innovation}_{t-2} \\ & + \beta_3\text{Process innovation}_{t-2} \\ & + \beta_4\text{Controls}_{t-1} + \tau_{t-1}\end{aligned}$$

$$\begin{aligned}\text{R\&D intensity}_{t} = {} & \gamma_1\text{Export breadth}_{t-1} \\ & + \gamma_2\text{Export depth}_{t-1} \\ & + \gamma_3\text{Controls}_{t} + \upsilon_t\end{aligned}$$

$$\begin{aligned}\text{Product innovation}_{t} = {} & \gamma_1\text{Export breadth}_{t-1} \\ & + \gamma_2\text{Export depth}_{t-1} \\ & + \gamma_3\text{Controls}_{t} + \upsilon_t\end{aligned}$$

$$\begin{aligned}\text{Process innovation}_{t} = {} & \gamma_1\text{Export breadth}_{t-1} \\ & + \gamma_2\text{Export depth}_{t-1} \\ & + \gamma_3\text{Controls}_{t} + \upsilon_t\end{aligned}$$

To offer more robust empirical support, we also performed the Granger test of causality (Granger 1969), the most common methodology for evaluating the nature of the causal relationship between two variables (Hood, Kidd, and Morris 2008). Specifically, we test whether technological resources and innovations are Granger-caused by export breadth and depth and vice versa. To incorporate dynamics, we include lagged variables in this analysis as well. As a result, we specify the models for testing Granger causality (Luo and Homburg 2007) as follows:

$$\text{R\&D intensity}_t = \chi_1\text{R\&D intensity}_{t-1} + \chi_2\text{Export breadth}_t + \chi_3\text{Export depth}_t + \chi_4\text{Export breadth}_{t-1} + \chi_5\text{Export depth}_{t-1} + \upsilon_t,$$

$$\text{Product innovation}_t = \chi_1\text{Product innovation}_{t-1} + \chi_2\text{Export breadth}_t + \chi_3\text{Export depth}_t + \chi_4\text{Export breadth}_{t-1} + \chi_5\text{Export depth}_{t-1} + \upsilon_t,$$

$$\text{Process innovation}_t = \chi_1\text{Process innovation}_{t-1} + \chi_2\text{Export breadth}_t + \chi_3\text{Export depth}_t + \chi_4\text{Export breadth}_{t-1} + \chi_4\text{Export depth}_{t-1} + \upsilon_t,$$

$$\text{Export breadth}_t = \varphi_1\text{Export breadth}_{t-1} + \varphi_2\text{R\&D intensity}_t + \varphi_3\text{Product innovation}_t + \varphi_4\text{Process innovation}_t + \varphi_5\text{R\&D intensity}_{t-1} + \varphi_6\text{Product innovation}_{t-1} + \varphi_7\text{Process innovation}_{t-1} + \tau_t,$$

$$\text{Export depth}_t = \varphi_1\text{Export depth}_{t-1} + \varphi_2\text{R\&D intensity}_t + \varphi_3\text{Product innovation}_t + \varphi_4\text{Process innovation}_t + \varphi_5\text{R\&D intensity}_{t-1} + \varphi_6\text{Product innovation}_{t-1} + \varphi_7\text{Process innovation}_{t-1} + \tau_t,$$

Furthermore, we performed a Wald F test to help determine the significance of the equations using the following formula:

$$F = [(SSR1 - SSR2)/q]/[SSR2/(n - s)],$$

where SSR1 represents the sum of squared residuals in the restricted equation (in which χ_j and φ_j are restricted to zero) and SSR2 is the sum of squared residuals in the unrestricted equation, q = the number of restrictions, n = the number of observations, and s = the number of independent variables in the unrestricted equation.

RESULTS

Descriptive Statistics for the Variables

Tables 2 and 3 show the means, standard deviations, and correlations between the variables in both analyses. The majority of the correlation values are lower than .56, which is the maximum level for assessing multicollinearity (Leiblein, Reuer, and Dalsace 2002). However, because there are some correlations slightly higher than the recommended level, we also applied the variation inflation factor test, running a regression for all the variables. The highest variance inflation factor levels are 2.71 and 2.90, respectively, which is substantially lower than the recommended level of 10.0 (Baum 2006) or even 5.0 (Pindado and De la Torre 2006), indicating that the results are not be biased due to multicollinearity (Nester, Wasserman, and Kutner 1985).

Table 2. Means, Standard Deviations, and Correlations Between Variables

Variables	M	SD	1	2	3	4	5	6	7
1. Export breadth$_{t-1}$	.83	1.15	1						
2. Export depth$_{t-1}$	20.73	27.11	.59*	1					
3. R&D intensity$_{t-2}$	.76	2.24	.17*	.15*	1				
4. Product innovations$_{t-2}$	2.93	17.29	.04*	.05*	.10*	1			
5. Process innovations$_{t-2}$	.34	.47	.17*	.17*	.15*	.08*	1		
6. Firm age	26.92	21.40	.14*	.07*	.08*	.04*	.08*	1	
7. Firm size	1.80	.88	.43*	.46*	.19*	.07*	.27*	.34*	1
8. Technological intensity	.28	.45	.22*	.22*	.28*	–.01	.10*	.07*	.21*

*$p < .01$.

Table 3. Means, Standard Deviations, and Correlations Between Variables

Variables	M	SD	1	2	3	4	5	6	7
1. R&D intensity$_t$	.77	2.47	1						
2. Product innovations$_t$	2.73	16.38	.09*	1					
3. Process innovations$_t$	.33	.47	.13*	.08*	1				
4. Export breadth$_{t-1}$	.83	1.15	.15*	.03*	.17*	1			
5. Export depth$_{t-1}$	20.73	27.11	.14*	.06*	.16*	.59*	1		
6. Firm age	26.92	21.40	.09*	.04*	.08*	.14	.07*	1	
7. Firm size	1.80	.88	.18*	.07*	.28*	.43*	.46*	.34*	1
8. Technological intensity	.28	.45	.26*	-.01	.10*	.22*	.22*	.07*	.21*

*$p < .01$.

Empirical Results

First, we estimated two Tobit regressions to explain the influence that R&D intensity and product and process innovation might have on export breadth and depth; we show the results in Table 4. Second, two Tobit and one logit regression show the effect of export breadth and depth on R&D intensity and product and process innovation (see Table 5). Overall, the results reveal a causal relationship between the two processes studied.

In Table 4, we observe that Models A and B show similar results regarding the influence that technological resources and innovations in t – 2 have on export breadth and depth in t – 1. Both R&D intensity and process innovations are positively and significantly associated with export breadth and depth, thus confirming H_{1a} and H_{3a} as well as H_{1b} and H_{3b}, respectively. However, the number of product innovations in t – 2 does not have any significant effect on export breadth and depth in t – 1, thus rejecting H_{2a} and H_{2b}. The first control variable, firm age, has no significant impact on the firm's export breadth and depth in t – 1. The other two control variables (firm size and sector) show a positive and significant effect on the two export-related dependent variables.

In the second part of the analysis, we separated the dependent variable into the firm's R&D intensity and process and product innovations, as shown in Table 5. Our results indicate that the higher the firm's export breadth in t – 1, the higher its R&D intensity and product and process innovations are in t. These results confirm H_{4a}, H_{4b}, and H_{4c}. In contrast, we observe that firm's export depth in t – 1 has a positive and significant impact on R&D intensity and product innovation in t. We observed a positive but not significant effect between export depth (t – 1) and process innovation (t). Thus, H_{5a} and H_{5b} are supported, whereas H_{5c} is not.

Firm's age has a positive and significant effect only on R&D intensity in t. This suggests that the older the firm, the higher are R&D expenditures over sales. Firm size has a positive and significant effect on R&D intensity and product and process innovations, but the industry sector does not significantly affect process innovations.

Next, to investigate the existence of a mutual relationship between technological innovations and exports, we performed the Granger test of causality (Granger 1969). This test's computed Wald F results appear in Table 6. The F statistics account for highly significant *p*-values for both the impact that R&D intensity and product and process innovations have on exports breadth and depth and the impact the latter have on the former. Therefore, we can affirm that innovation Granger-causes exports and that exports Granger-cause innovations.

DISCUSSION

R&D Intensity and Product and Process Innovation as Determinants of Export Breadth and Depth

Our results show that R&D intensity and process innovations developed the previous year subsequently affect

Table 4. Results: Technological Resources and Innovations as Determinants of Exports

	Export-Related Activities (Tobit)	
Variables	**Export Breadth$_{t-1}$**	**Export Depth$_{t-1}$**
Technological Activities		
R&D intensity$_{t-2}$	.0259***	.2503**
	(.0079)	(.1178)
Product innovations$_{t-2}$	.0011	.0047
	(.0008)	(.0120)
Process innovations$_{t-2}$	.0610*	.9085**
	(.0322)	(.4541)
Control		
Firm age	.0008	–.0073
	(.0023)	(.0313)
Firm size 2 (medium)	.5582***	6.2200***
	(.0867)	(1.2625)
Firm size 3 (large)	.8887***	12.772***
	(.1035)	(1.5599)
Technological intensity	.9657***	17.767***
	(.1664)	(2.9541)
Log-likelihood	–5587.602	–18,978.27
Constant	–.9279***	.5230
	(.1258)	(2.0764)
R-square	.1915	.2017

*$p < .10$.
**$p < .05$.
***$p < .01$.

a firm's export activities in terms of export breadth and depth. The development of R&D activities and process innovations provide firms with cost advantages, which can result in higher export activities (mostly in terms of increased export depth rather than breadth), a traditional competitive advantage of Spanish firms abroad, rather than differentiation based on product innovation.

This result is in line with the results obtained by other researchers who also consider that process innovations matter for exporting (Bianchi 2009; Eriksson et al. 1997) and that firms may risk export performance if they ignore technology (Hortinha, Lages, and Lages 2011). Technology, from the perspective of the resource-based theory, can generate competitive advantages not only through product differentiation but also based on cost (López and García 2005), and firms that develop process innovations are highly focused on maintaining their international market position (Becker and Egger 2007).

The results for the control variables (firm age, size, and sector) are as expected, though age does not present any influence on export breadth or depth. The relationship between firm size and export behavior has been extensively analyzed in the literature, the former being considered a useful approximation of firm assets that affect the latter (Barrios, Görg and Strobl 2003; Monreal-Pérez, Aragón-Sánchez, and Sánchez-Marín 2012).

Regarding the firm's industry sector, according to López and García (2005), a particular industry may

Table 5. Results: Exports as Determinants of Technological Resources and Innovations

	Technological Activities		
	Tobit		Logit
Variables	R&D Intensity$_t$	Product Innovations$_t$	Process Innovations$_t$
Export-Related Activities			
Export breadth$_{t-1}$	.1384**	.0408*	.0926*
	(.620)	(.0228)	(.0487)
Export depth$_{t-1}$	.0158***	.0026**	.0028
	(.0032)	(.0011)	(.0023)
Control			
Firm age	.0198***	.0028	.0021
	(.0053)	(.0018)	(.0031)
Firm size 2 (medium)	1.4792***	.3961***	.9632***
	(.2587)	(.0803)	(.1575)
Firm size 3 (large)	2.1738***	.6147***	1.6716***
	(.2890)	(.0913)	(.1676)
Technological intensity	3.0710***	.3287***	.2505
	(.3346)	(.0991)	(.1617)
Log-likelihood	–7915.6767	–4371.6644	–3807.9434
Constant	–5.7516***	–1.658***	–2.6099***
	(.3181)	(.1058)	(.1764)
R-square	.1351	.0654	N.A.

*$p < .1$.
**$p < .05$.
***$p < .01$.
Notes: Standard errors are in parentheses. N.A. = not applicable.

Table 6. Results: F-statistics from Granger Test of Causality

	Dependent Variables				
Independent Variables	Export Breadth	Export Depth	R&D Intensity	Product Innovations	Process Innovations
Export breadth	N.A.	N.A.	15.6**	5.759**	36.139**
Export depth	N.A.	N.A.	14.51**	3.68*	31.25**
R&D intensity	31.654**	15.715**	N.A.	N.A.	N.A.
Product innovations	103.528**	110.791**	N.A.	N.A.	N.A.
Process innovations	8.78**	7.213**	N.A.	N.A.	N.A.

*$p < .05$.
**$p < .01$.
Notes: N.A. = not applicable.

condition a firm's strategy and performance. In this regard, some empirical studies, mainly at the sector level (Dosi, Pavitt, and Soete 1990), have shown that technology-intensive sectors tend to export a higher proportion of their output than other sectors as a result of technological spillovers within the industry, externalities, and accumulated experience, allowing firms to improve their technological resources and competitiveness.

Export Breadth and Depth as Determinants of R&D Intensity and Product and Process Innovation

Our results also indicate that the higher the firms' previous level of export breadth, the higher are its subsequent R&D intensity and product and process innovations because it can gain exposure to new market knowledge and different patterns of consumer behavior. Exporters become more aware of potential innovations taking place abroad and possibly assimilate them to improve their position in both domestic and foreign markets. Salomon and Shaver (2005) consider exports as information generating activities by which firms can access foreign knowledge bases and also increase innovation. They also relate exporting to product innovations because firms gather and process consumer feedback fairly quickly, which subsequently results in tailoring products to meet the needs of heterogeneous foreign consumers.

Conversely, a firms' export depth achieved in a previous year also helps it subsequently increase the R&D intensity and innovation in products rather than in processes. A considerable learning-by-exporting effect on technological innovation, especially reinforcing product more than process innovation capacity, exists for Spanish exporters during the period examined here (1994–2005), which just precedes the economic crisis that began in 2007–2008. However, such an effect on innovation seems to have declined dramatically in the post-crisis period for Spanish manufacturing firms according to other contemporary results (Monreal-Pérez, Aragón-Sánchez, and Sánchez-Marín 2012).

Our results are in line with other previous studies that show that a firm's exports are usually a determinant of higher levels of innovation (Hitt, Hoskisson, and Kim 1997; Vila and Kuster 2007; Zahra, Ireland, and Hitt 2000). Indeed, exporters are heavily pressured to invest in technological resources for continuous updating of processes and product adaptation abroad, and their export orientation positively influences the development of more product innovations (Salomon and Shaver 2005).

Internationalizing firms assimilate new knowledge to compete and grow in markets in which they have little or no previous experience, so they are able to adapt products to local market conditions, offer customized applications, and take advantage of new market opportunities through rapid new product developments (Autio, Sapienza, and Almeida 2000; Zahra, Ireland, and Hitt 2000). Therefore, from a resource-based perspective, exporting firms could take advantage of the diverse knowledge inputs by being internationally exposed to a richer source of knowledge often not available in their home markets. Their competency base can be enhanced because such learning from global markets can foster increased technological resources and innovations.

Conversely, our results also indicate that the older a firm is, the greater is its R&D intensity. This positive impact is consistent with prior research (Kumar and Saqib 1996), though Molero and Buesa (1996) show that younger companies more rapidly acquire experiential market knowledge and use it to develop more technological innovations. As previous studies have generally found, size and industry also affect technological resources and innovation.

Causality Between Technological Innovations and Exports

Firms first need to innovate and gain competitive advantages to compete successfully in international markets, which in turn can favor access to foreign knowledge sources that can firms' technological advantages. Our results also confirm the mutual causality chain: R&D intensity and product and process innovations Granger-cause export breadth and depth, and in turn export breadth and depth Granger-cause R&D intensity and product and process innovations. As we mentioned previously, there is little evidence in the literature regarding this two-way link between innovation and exports, a prospect that authors have often suggested but never empirically tested (Prashantham 2005; Vila and Kuster 2007).

Technological resources and innovations provide sustainable competitive advantages that give firms the possibility of initiating and/or increasing exports and competing more proactively and innovatively in different markets. Furthermore, firms' export breadth and depth can embody more technological resources and innovations because their presence in foreign markets offers new perspectives; therefore, the experiential market knowledge acquired abroad will help them maintain

their competitive advantages and even create new ones (Filipescu, Rialp, and Rialp 2009; Golovko and Valentini 2011; Prashantham 2005). Consequently, the relationship between the two processes is reinforced: when innovative firms become involved in international activities, they acquire international knowledge and experience, which in turns leads them to achieve further technological innovation.

IMPLICATIONS AND CONCLUSION

Scholars have emphasized the need for disentangling the direction of causality between innovation and exports (Hitt, Hoskisson, and Kim 1997). In addition, Knight and Cavusgil (2004) argue that innovation, knowledge, and capabilities are central themes of research on international strategy and performance of the firm. Extant theory implies that firms will participate in international markets more successfully if they are able to innovate in their way of doing things and reduce costs. However, to maintain their competitive advantage, firms must learn from their activity in international markets and translate this knowledge into more innovations that better fit the changing needs of domestic and international consumers. Accordingly, in our study, we argue that technological resources and innovations on the one hand and exports on the other hand may influence each other. We examine the causality between both effects with a longitudinal study using a panel of Spanish manufacturing firms during 1994–2005.

Contributions

We find broad support for the notion that technological innovation and exports have a reciprocal relationship, though our findings are nuanced by positive, but nonsignificant, associations between product innovation and exports, as well as between export depth and process innovation. Furthermore, both processes Granger-cause one another, demonstrating that there is a double causal relationship. Our results are consistent with most of the existing international studies on this topic and complement other recent relevant studies also conducted in the Spanish firm setting (Cassiman and Golovko 2010; Golovko and Valentini 2011; Monreal-Pérez, Aragón-Sánchez, and Sánchez-Marín 2012).

We provide greater theoretical clarity on the dynamics of the export–innovation relationship by focusing on their reciprocal causality. Consistent with calls to examine not only the antecedents of exporting but also its consequences (Salomon and Shaver, 2005), we show that not only do exports and innovation have positive effects on one another separately (as a considerable body of literature has shown), but there is also a double causality chain between innovation and exports. In so doing, we transcend the "silo" perspective evident in much of the literature, which has typically focused on either the effects of innovation on exports or vice versa but not both simultaneously. We also go beyond recent efforts to examine the mutual effects of innovation and exports, notably Golovko and Valentini's (2011), which usefully shows their complementarity (positive interactions) by highlighting their reciprocity over time. We root our arguments theoretically in resource- and learning-based literatures to highlight the development and exploitation of intangible resources as an important mechanism for the causal relationships that we find. Technological resources lead to product and process innovations and ultimately to competitive advantages in international markets. As the firm develops export activities, it gains knowledge and capabilities, which help it develop new technological innovations. Empirically, we employ a rigorous test of reciprocity (i.e., the Granger test of causality) on our longitudinal data set, which adds confidence to our assertions.

Furthermore, we provide greater empirical precision by showing that the reciprocity between innovation and exports is nuanced and complex. In terms of exports, we distinguish export breadth and depth, and in terms of innovation, we distinguish product and process innovation in addition to R&D intensity. In doing so, we not only provide theoretical and empirical credence for the notion that there is a "virtuous cycle" (Golovko and Valentini 2011) and "mutually reinforcing" effects (Filatotchev and Piesse 2009) between innovation and exports but also find that there may be differential effects of each on the other. In other words, the two sides of the innovation–export relationship are not exact mirror images of one another. That is, while confirming our hypotheses for the most part, our fine-grained empirical results yielded two unexpected findings: product innovations did not have a significant effect on exports a year later, and export depth did not have a significant effect on the following year's process innovation. A possible explanation for these results is the relatively short time lag used in the study—namely, one year (between t – 2 and t – 1 and between t – 1 and t). Perhaps process (rather than product) innovations have a significant effect on subsequent exports because these result in immediate improvements to the offerings that are exported. In contrast, product innovations may need

a longer time interval before they are suitably commercialized and launched in new markets, thereby increasing exports. However, in terms of export–innovation relationships, we observe the opposite: product innovations as a consequence of learning in international markets accrue more quickly, probably because ideas for new products or product enhancements can be identified and absorbed more quickly than the more subtle ideas that support process innovation. If so, this finding might suggest that leveraging process innovations in the home market to increase export activity is achieved more speedily than leveraging product innovations, but product innovations in the host market(s) is achieved faster than learning process innovations. At any rate, teasing out the different effects of types of exports and innovation represents an important direction for further research.

Managerial and Policy Implications

The results of this study have some important implications for practitioners. First, exporting firms should be mindful of the full extent of the benefits that internationalization offers. It is important to recognize that there are opportunities for not only enhancing revenue growth but also achieving learning outcomes. It is understandable—especially when a firm's domestic market experiences sluggish growth—that exporting firms are keen to achieve growth. However, failing to articulate, identify, and capture the international and technological learning available to firms represents a significant missed opportunity (Prashantham and Dhanaraj 2010). This calls for a mind-set that takes a holistic rather than a narrow view of the outcomes of exporting. Ultimately, our key message is that companies must recognize that innovation and exports can mutually reinforce one another.

Second, given that the reciprocity between exports and technological innovation is asymmetric, exporting firms should have appropriate expectations about the type of innovation that exporting will help achieve and the type of export expansion that innovation will yield. Thus, if managers are interested in increasing their firms' export breadth and depth, they should pay special attention to the technological resources and innovations developed inside the firm. Specifically, if the objective is to increase export depth quite rapidly (e.g., within a one-year period), R&D intensity and process innovation (more so than product innovation) developed the previous year represent an important input. Conversely, if managers desire to improve technological resources and innovations in their firms, we outline the importance of firms' export breadth and depth. In particular, product innovations appear to benefit (more than do process benefits) from greater exports within a one-year interval.

Third, this study has implications for how exporting firms strategize managerial attention to be expended on absorbing and integrating new knowledge into the existing knowledge base of the firm (Knight and Cavusgil 2004; Zahra, Ireland, and Hitt 2000). While our study offers theoretical arguments and empirical evidence of export-related causes and effects of technological learning, it would be naive for firms to assume that the acquisition of new knowledge is effortless. Indeed, exporting itself is "effortful" in that international markets pose barriers to foreign firms. To add a learning agenda to that of revenue generation calls for adeptness at learning (Autio, Sapienza, and Almeida 2000), which is facilitated by actively cultivating network relationships in export markets (Prashantham and Young 2011).

Finally, our study also has implications for public policy. We draw attention to the importance of the causal effect of innovation and exports and, in so doing, argue that policy makers should no longer consider them separately but rather encourage their achievement simultaneously, thereby fostering growth and competitiveness of local/national firms, which would lead to a more efficient use of public resources. This is a particularly timely message, when economies around the world are struggling to support growth opportunities for their companies. Firms that are able to succeed in multiple international markets are likely to have the best chance of weathering the storm, and this is something that policy makers should recognize.

Limitations

This study is not free of limitations. From a theoretical point of view, recent studies based on the resource-based view stress that resources will only result in superior performance if a firm possesses appropriate capabilities that will transform their resources into competitive advantages in the marketplace (Knight and Kim 2009). We analyze only one type of intangible resource; thus, there is scope to introduce and measure some others and to consider more variables. For example, further research could include export experience and patent citation. Another limitation is that we did not consider *specific* export markets. In addition, because we used a longitudinal sample, there might be some problems in the design, data collection, and data management of

panel surveys (Baltagi 2007). It is also possible that panel data show bias due to sample selection problems and attrition (Wooldridge 1995).

Further Research

Further research could examine whether the causal relationship we observed is also evident in different samples in different countries and whether it is affected by different environmental factors. In this way, it might reveal whether institutional factors play a role in influencing the relationship (Kumar 2009). Furthermore, dynamics might be introduced into the analysis. For example, single equation models could be developed, with autoregressive dynamics and explanatory variables that are not strictly exogenous; generalized method of moments estimators are widely used in this context (Bond 2002). To do this, the learning-by-doing literature represents a valuable basis for developing new models. Finally, firms from specific industry sectors or of specific ownership type could also be analyzed in greater depth.

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