SELF-SELECTION INTO EXPORTS: PRODUCTIVITY AND/OR INNOVATION?*

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Abstract

Recent research has related the firm decision to export with firm innovation activities and productivity. The aim of this paper is to disentangle the *direct* and *indirect* links through which self-selection into exports, coming both from productivity and innovation, may operate. For this purpose we use Spanish manufacturing firm data for the period 1990-2000, drawn from the *Encuesta sobre Estrategias Empresariales*. The main results we obtain can be summarized as follows. First, there is a self-selection into exports *direct* effect coming from productivity. Second, there is also a self-selection *indirect* effect into exports stemming from productivity to the probability of exporting through process innovations: the higher the productivity the higher the probability of introducing process innovations and, therefore, the likelihood of starting to export. Third, there is a self-selection into exporting *indirect* effect of process innovations that operates through productivity: process innovations increase productivity and, therefore, the probability to export.

Keywords: self-selection, exports, productivity, innovation, persistence.

JEL classification: F1, L1, C3

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1. Introduction.

A large empirical literature has documented that firm-level differences in productivity are crucial to explain firms' export decisions. From Bernard and Jensen (1999), there has been growing international evidence, in the trade literature, in favour of the self-selection hypothesis of the *ex-ante* more productive firms into export markets.[1] Melitz (2003) model formulates predictions that are consistent with this empirical finding.

However, works explaining firm dynamics such as Jovanovic (1982) and Hopenhayn (1992) and its application to international trade (Melitz, 2003) do not explain the firm's pre-trade productivity level, which very likely is the result (among others) of previous innovation activities undertaken by the firm.

As regards the relationship between innovation and productivity, there is a large tradition within the Industrial Organization literature that analyses in depth the direction of causality between innovation activities and productivity. Recent findings suggest the existence of a double causality relationship. On the one hand, Mañez *et al.* (2005), Rochina-Barrachina *et al* (2009) and Mañez *et al.* (2009) find evidence in favour of self-selection of the most productive firms into innovation activities.[2] On the other hand, there is a large stream that analyses the impact of innovation activities on productivity using firm level data (see Griliches, 2000 for a survey). Although most of the studies focus on the effects of R&D investments on productivity, recent availability of data has made possible to analyse the impact of innovation output on productivity. Thus, Crépon and Duget (1997), Verspagen (1999), Gu and Tang (2004), Huergo and

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[1] See, for instance, Greenaway and Kneller (2007), Wagner (2007) and ISGEP (2007, 2008). Delgado *et al* (2002) and Mañez *et al.* (2005) provide evidence for Spanish manufacturing about the most productive firms being self-selected into foreign market.

[2] Some support for the self-selection hypothesis into R&D activities (formal part of innovation activities) of the most productive firms can be found, among others, in Hall (1992), who uses a financial constraint argument, González and Jaumandreu (1998), González *et al.* (1999) and Máñez *et al.* (2005).

Jaumandreu (2004), Parisi *et al.* (2006), Rochina-Barrachina *et al.* (2009), and Máñez *et al.* (2009), among others, considering direct measures of innovation output (such as patents, products or process innovations), find that innovations foster productivity growth.

Some recent literature recognises that pre-trade productivity levels depend on firm innovation activities, and introduces a new dimension into the productivity-export relationship by exploring the causality link firm innovation-productivity-exports. That is considering the role of active firm level investments in productivity enhancing activities, such as R&D and the introduction of product and process innovations, and its link to the decision to export. Within this literature, the works by Constantini and Melitz (2008), Lileeva and Trefler (2009) and Bustos (2006) study the relation between innovation, productivity and the decision to export in liberalization of trade regimes. In this line, Constantini and Melitz (2008) show that anticipation of trade liberalization may lead firms to bring forward the decision to innovate, in order to be ready for future participation in the export market.

To the best of our knowledge, Aw *et al.* (2008) is the first attempt to develop a structural model of the joint innovation-exporting decision. In this model, firms invest in R&D and this can affect the path of future productivity of the firm. Therefore, by investing in innovation activities a firm increases its expected profits from exporting, and exporting contributes positively to the returns to R&D investments. They also pose that investments to raise new products or product quality are more related to exposure to export markets than investments pursuing process innovations, more closely tied to the efficiency and size of the firm.[3]

The aim of this paper is to gain further insight into the casual link innovation-

[3] Other papers that empirically analyse (at least partially) the innovation-productivity-exports casual link are Cassiman and Martinez-Ros (2007), Cassiman and Golovko (2007), Girma *et al.* (2008) and Damijan *et al.* (2008).

productivity-exports paying special attention to self-selection into exports. More specifically, we intend to explore: (i) whether pre-trade productivity levels determine export participation (*direct self-selection*); and, (ii) whether innovating firms self-select into export markets. Further, we aim to take into account whether implementing innovations affects directly the probability to export (*self-selection into exports through innovations*); or, by enhancing pre-trade productivity levels (*self selection into exports indirect effect*). In our work, we analyse both the effect of process and product innovations. We conjecture (as in Damijan *et al.*, 2008) that process innovations, rather than product innovations, drive firm productivity growth. Process innovations have labour displacement effects and are therefore expected to result in significant productivity growth. However, product innovations are likely to cause employment growth through demand expansion, but not significant productivity growth. Therefore, we expect process innovations to affect export participation through improving pre-trade productivity levels. This productivity improvement would allow firms to overcome the productivity threshold required to participate in foreign markets (Melitz, 2003). As for product innovations, they could either have a direct impact on export participation (new or improved quality products would ease the access to foreign markets), or an indirect effect through productivity in case they increase firm pre-trade productivity, or both of them.

To carry out our empirical analysis, we estimate a dynamic trivariate probit that models simultaneously: the decision to export, the decision to implement process innovations and the decision to implement product innovations. In this framework, and to explore possible self-selection effects, we check whether previous productivity and innovations (both process and product) affect the decision to export; and, whether previous productivity and export status affect the decisions of implementing product and process innovations.

We use Spanish manufacturing firm panel data for the period 1990-2000, drawn from the *Encuesta sobre Estrategias Empresariales* (ESEE, hereafter).

The main results in this paper can be summarized as follows. First, there is a *direct* self-selection process into exports coming from productivity (i.e., the formerly more productive firms have a higher probability to start exporting). Second, there is also a self-selection *indirect* effect into exports stemming from productivity to the probability of exporting through process innovations: the higher the productivity, the higher the probability of introducing process innovations and, therefore, the likelihood of starting to export. Third, there is a self-selection *indirect* effect of process innovations into exports that operates through productivity: process innovations increase productivity and, therefore, the probability to export.

Our findings make a contribution to the understanding of the determinants of the firms' decision to start exporting and have important implications for public policy export promotion measures. Policies aimed to increase productivity would have a *direct* impact on the firms' likelihood of starting to export. Furthermore, policies targeted at stimulating the introduction of process innovations would have an *indirect* effect on the likelihood of starting to export by increasing productivity. Finally, in relation to the observed persistence/sunk costs in the firms' decisions to export and to innovate, policies directed at providing information and access to foreign markets and innovation activities, or providing exporting infrastructures and facilitating innovation networks, could reduce the sunk costs of starting to export and the sunk costs of starting innovative activities.

The rest of the paper is organized as follows. Section 2 presents briefly the data. Section 3 is devoted to modelling, variables and estimation issues. The estimation results are summarised in section 4. Finally, section 5 concludes.

2. Data.

The data used in this paper are drawn from the ESEE for the period 1990-2000. This is an annual survey sponsored by the Spanish Ministry of Industry and carried out since 1990 that is representative of Spanish manufacturing firms classified by industrial sectors and size categories. It provides exhaustive information at the firm level, and its panel nature allows following firms over time.

The sampling procedure of the ESEE is the following. Firms with less than 10 employees were excluded from the survey. Firms with 10 to 200 employees were randomly sampled, holding around 5% of the population in 1990. All firms with more than 200 employees were requested to participate, obtaining a participation rate around 70% in 1990. Important efforts have been made to minimise attrition and to annually incorporate new firms with the same sampling criteria as in the base year, so that the sample of firms remains representative over time.[4]

The average number of firms surveyed every year is 2747. From them, we have excluded firms exiting the panel as including them would involve modelling jointly the probabilities of exiting by different exit routes (merger, failure, attrition or non-response). This type of exclusion is similar to other papers in the same tradition (see, for instance, Roberts and Tybout, 1997). However, we do not expect this to have a significant impact in our analysis as only 2.7% of firms with information on the export, product and process innovation statuses exit the panel. From the remaining sample, to analyse firm export trajectories and estimate a dynamic specification with lagged endogenous variables, we sample out those firms that fail to supply relevant information in any given year, and select a panel of continuously operating firms from 1990-2000. The result is a balanced panel of 693 firms.

[4] See http://www.funep.es/esee/ing/i_esee.asp for further details.

As for the representativeness of our sample, Table 1 shows that relevant characteristics, such as the sample probability of being an exporter or the share of exporting firms on total sales and employment, are similar to the ones of the complete sample. Therefore, we consider that our sample is suitable to perform the analysis.

[Insert Table 1 about here]

The three dichotomous variables about exporting and innovation statuses are obtained from the survey using the following questions. The firm export status is computed using the following question: "Indicate whether the firm, either directly, or through other firms from the same group, has exported during this year (including exports to the European Union) and its value".[5] For product innovations the question we use is: "Indicate if during this year the firm has obtained product innovations (either utterly new products or with so important modifications that they are perceived as different to those produced in the past)". Finally, and for process innovations, the

[5] In relation to foreign markets, the ESEE provides information on whether a firm exports and the percentage of its exports to EU countries, to the rest of the OECD countries, and/or to the rest of the world. A shortcoming of the survey is that whereas the yes/no export question is asked every year, the question on exports destinations is asked once every 4 years. This is the reason why to model in a dynamic way the firm export behaviour, we focus in the yes/no export question. However, we include as explanatory variables (fixed over every 4-years period) dummies controlling for export destinations (majority of exports to the EU) and export market diversification (dummies related to the number of markets the firm serves). Therefore, in our analysis we do not explicitly study the dynamics of entrance in new export destinations or the evolution of exporting levels. However, crossing the destination markets dummy and the export market diversification ones with the dummy indicating firm export status in the previous period allows to get some information about whether sunk cost differ with the number of markets and/or the type of the markets served. Andersson, Lööf and Johansson (2008) and Andersson and Johansson (2008) stress the relevance of considering variables related to the number of export destinations to be able to explain not only a binary choice export status variable but also a gradual choice where past export experience can affect the decision to open new destinations.

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particular question in the survey is: “Indicate if during this year the firm introduced some important modification of the productive process (process innovation)”.

3. Modelling, variables and estimation.

3.1. The export decision.

In the analysis of the decision to export it seems sensible to think that firms face costs associated with entering foreign markets that may be sunk in nature. For instance, non-exporting firms have to research foreign demand and competition, establish marketing and distribution channels, and adjust their product characteristics to meet foreign tastes and/or fulfil quality and security legislation of other countries. Acknowledging the existence of sunk costs implies that current exports depend on past export trajectories and, more interestingly, that transitory changes in trade policy or conditions may lead to permanent changes in market structure, that is, sunk entry or exit costs produce hysteresis-persistence in export flows.

The first attempt to test the sunk-cost hysteresis-persistence hypothesis in exporting is Roberts and Tybout (1997), who directly analyse entry and exit patterns for Colombian manufacturing. More recent empirical evidence are Bernard and Wagner (2001), and Bernard and Jensen (2004), for Germany, and the U.S., respectively. For Spain, we find Campa (2004), Cassiman and Martínez-Ross (2007), Máñez *et al.* (2008), and Blanes-Cristóbal *et al.* (2008).

In this paper, we follow Roberts and Tybout (1997) dynamic model of export market participation in the presence of sunk costs. A firm i exports in period t if the current increase to gross operating profits associated with the decision to export plus the discounted expected future returns from being an exporter in year t (that is π_{it}^{*}), adjusted for sunk costs, are positive:

$$y_{it} = \begin{cases} 1 & if \quad \pi_{it}^{*} - F_{it}^{0} + \left(F_{it}^{0} + G_{it}\right) y_{i,t-1} \geq 0 \\ 0 & otherwise, \end{cases} \tag{1}$$

where F_{it}^{0} is the sunk entry cost that faces a firm to entering exporting and $-G_{it}$ is the exit cost for an exporting firm to leave the export market.

We approximate $\pi_{it}^{*} - F_{it}^{0}$ as a reduced-form expression on firm/market characteristics (X_{it}) that are observable to producers in period *t*, macro conditions (μ_t), and noise (ε_{it}). Therefore,

$$\pi_{it}^{*} - F_{it}^{0} = \mu_t + \beta X_{it} + \varepsilon_{it} \,. \tag{2}$$

If we assume that sunk costs do not vary across time or across firms, $F_{it}^{0} = F^{0}$ and $G_{it} = G$. Re-defining $F^{0} + G = \gamma^{0}$ and substituting (2) into (1), we have the estimation equation:

$$y_{it} = \begin{cases} 1 & if \quad \mu_t + \beta X_{it} + \gamma^{0} y_{i,t-1} + \varepsilon_{it} \geq 0 \\ 0 & \text{otherwise} \,. \end{cases} \tag{3}$$

Notice, from last expression, that the export decision in *t* does not depend on the firm exporting background if sunk costs are zero. This allows checking for the importance of sunk costs by testing whether γ^{0} is equal to zero.

According to the empirical implications of our setting, sunk costs should induce persistence in firms exporting behaviour. However, it is important to note that firms exporting persistence might be also due to either underlying (observed and unobserved) firm heterogeneity or transitory shocks to exporting profits. Therefore, in order to infer the role of sunk costs one needs an econometric framework controlling for other competing sources of persistence. Most of this task is accomplished by including a vector of observable characteristics in the exporting decision. However, as there may still remain unobserved factors causing persistence (such as product attributes, foreign contacts, managerial ability or technology), and these are potentially permanent or highly serially correlated, in practice, we assume that ε_{it} in (3) has two components, a firm-specific effect (α_i) and a transitory component (u_{it}). Therefore, with our approach we would be able to infer the presence and relevance of sunk costs in exporting from conditional persistence in exporting patterns. Unlike firm heterogeneity, sunk costs induce true state dependence. Therefore, from true state dependence we infer that sunk costs affect exporting decisions.

In our application, the variables included in the vector of observed characteristics for the export equation, X_{it}, are mainly the variables used in Máñez *et al.* (2004, 2008), but we incorporate some new variables such as product and process innovation.[6] We also include productivity as we are interested to check whether the effect of product and process innovations on the decision to export differs when including or not productivity. We further allow sunk costs to differ not only between small and large firms (as in Máñez *et al.*, 2008), but also according to the following variables: whether the firm often changes the type of product sold; whether the product sold by the firm is standardized; the distribution channel the firm uses to export (own network, mother firm abroad, commercial intermediary, association of exporters, and others); whether the firm exports to one, two or three markets (to EU countries, to the rest of the OECD countries, and/or to the rest of the world);[7] and, whether the highest percentage of firm exports goes to the EU.

[6] These variables are also used in Cassiman and Martínez-Ros (2007).

[7] This will allow analysing the level of diversification in destination markets for exporters (the highest level of diversification would be selling to the three areas and the lowest level exporting only to one of them). We expect a higher diversification in destination markets to be associated with higher sunk costs.

3.2. The product and process innovation decisions.

To analyse the decision to implement process (product) innovations, we estimate an equation such as (3) in which the dependent variable, y_{it}, is whether the firm has introduced a process (product) innovation in period *t*. The aim of this specification is to control for the role of persistence in the implementation of process (product) innovations. Máñez *et al.* (2004, 2009) propose a comparable model adapted to analyse the R&D decision subject to sunk costs, which closely follows Roberts and Tybout (1997) approach. An empirical analysis on the role of persistence in the R&D decision can also be found in Peters (2009). Further, there are other empirical studies about persistence in innovation output (see, Flaig and Stadler, 1994; Rogers, 2004; Duguet and Monjon, 2004; Raymond *et al.*, 2006; and Peters, 2007). Most of these studies find persistence both in the innovation input (R&D) and output (product and process innovations).

In our approach, for the innovation equations, the vector of observed firm characteristics, X_{it}, uses mainly the same determinants as in Máñez *et al.* (2006, 2009). In the equation for the decision to implement a product (process) innovation we further incorporate the lagged value of the product (process) innovation variable, and the lagged value of process (product) innovation. We also include the lagged value of the export status variable to capture whether exporters are more likely to implement product (process innovations). Both for the product and process equations, we estimate two specifications: with and without including productivity as explanatory variable. The aim is to check whether the effects of other variables included in our econometric specification change when introducing productivity in the set of explanatory variables.

Table 2 provides detailed information on all the variables involved in estimation of the three equations.[8] Nominal variables are deflated using specific industry deflators according to 20 sectors of the NACE-93 classification. In estimation, most of the explanatory variables are lagged one period. The reason is twofold: first, because there are some lagged variables capturing persistence in the decisions to export, to implement a process or a product innovation; and, second, because the firm/market characteristics, X_{it}, should be observable to firms when taking their decisions in period t and, therefore, its real effect is lagged. This is the case of the variables used to test for the self-selection hypotheses, e.g. the one period lagged value for productivity in the export, process and product innovation equations. Finally, it is worth to note that for some relevant variables in our analysis we will explore even further lags to capture its effects.

[Insert Table 2 about here]

3.3. Estimation issues.

Using as starting point equation (3) and explicitly introducing in this equation the individual unobserved heterogeneity component, α_i, we have:

$$y_{it} = \begin{cases} 1 \quad if \quad \mu_t + \beta X_{it} + \gamma^0 y_{i,t-1} + \alpha_i + u_{it} \geq 0 \\ 0 \quad \text{otherwise} \ . \end{cases} \tag{4}$$

[8] Although from a theoretical point of view total factor productivity is a more adequate productivity measure, in this paper we use labour productivity due to data availability. However, Bartelsman and Doms (2000) point to the fact that heterogeneity in labour productivity has been found to be accompanied by similar heterogeneity in total factor productivity. Furthermore, including in the estimation equations variables such as industry dummies, time dummies, individual firm unobserved heterogeneity, firm size and labour quality helps to control for differences in the capital-labour ratio, and would control for expected differences between the two productivity measures.

Therefore, the general modelling for the decisions to export, to introduce a product innovation, and to introduce a process innovation, is a dynamic multivariate discrete choice model. In such a model it is necessary to address the following “initial conditions” problem: we observe the firm exporting, product innovation, and process innovation statuses in years *1* through *T*, and our lag structure reaches back *1* period. Therefore, values corresponding to the first year (y_{i1}) cannot be treated as exogenous determinants of y_{it} when $t > 1$, because both y_{i1} and y_{it} depend on α_i. To solve this problem we follow Wooldridge (2005) method that proposes to model the distribution of the unobserved effects, α_i, conditional on the initial value of y_{i1} and any exogenous explanatory variables in the model (conditional to α_i) in all time periods (we call this vector of variables $\bar{z}_i$):[9,10]

$$\alpha_i = \alpha_0 + \alpha_1 y_{i1} + \bar{z}_i \alpha_2 + a_i, \qquad (5)$$

where $a_i \left| \left(y_{i1}, \bar{z}_i \right) \sim \text{Normal}\left(0, \sigma_a^2\right)\right.$. Next, y_{i1} and $\bar{z}_i$ are added as additional explanatory variables in each time period *t* in equation (4). If the initial condition regressor, y_{i1}, is statistically significant this will mean that there is a relevant correlation between the

9 $\bar{z}_i = T^{-1}\sum_{t=1}^{T} z_{it}$ denotes the time averages of z_{it}. Following Mundlack (1978) and Chamberlain (1984) we use $\bar{z}_i$ (the time-averages) instead of $z_i = \left(z_{i1},\ldots,z_{iT}\right)$.

10 In estimation of our three equations, as a first approach we started by including in the conditioning set for the individual effects $\bar{z}_i = \bar{x}_i$ (all the explanatory variables in equation 4). As many of them where not statistically significant to explain α_i in equation (5) (once conditioning also to y_{i1}), in the estimations provided in this paper we have finally used a parsimonious specification including industry and time dummies for the three equations, and we have added corporate, age and the cashflow ratio for the export equation, appropriability for the product innovation equation, and the cashflow ratio and the variable change of product for the process innovation equation (those variables that were statistically significant to explain α_i).

initial status and the individual unobserved heterogeneity and, therefore, that we cannot estimate the model treating initial conditions as exogenous.

Finally, there is a further problem to be taken into account in estimation. We recognize the potential interdependence for firms in the export, product and process innovation decisions. In our framework it is very likely that the error terms of the three equations are correlated. To solve this problem, in our application the three decisions will be simultaneously estimated by a trivariate probit framework. Therefore, our estimation strategy uses appropriate methods to account both for unobserved individual heterogeneity and initial conditions. Further, we also account for the potential simultaneity problem in the three firm decisions involved in our analysis (the export decision, and the product and process innovation decisions), consistently with the structural model in Aw *et al.* (2008).

4. Results.

In this section we report the estimation results from the joint estimation of the decisions to export and to implement process and product innovations (see Table 3). These three equations have been estimated using a dynamic trivariate probit specification, in which we account for the initial conditions problem. In estimation, we reject both the null of no correlation between the three decisions (see the test at the bottom of Table 3) and also the null of exogeneity of initial conditions for each one of the three equations (see in Table 3 the coefficients for the variable *Initial conditions* (y_{i1})). [11]

4.1. Analysis of the export decision.

As for the decision to export, we find that regardless of including or not productivity in estimation, implementing a product innovation in period *t-1* does not have any impact

[11] In the estimation of the three equations we include both year dummies and industry dummies. We have considered 20 industrial sectors according to the NACE-93 industry classification.

on the probability of starting to export in period *t* (i.e. we do not find any evidence of self-selection into export through product innovations). However, the estimates of process innovation (lagged three periods)[12] depend on whether we include the productivity variable. Whereas in the estimation without productivity, the estimate for process innovation is positive and significant (at a 10% significance level), when we include productivity, process innovation loses its significance. This suggests that process innovations affect the probability of exporting through its effect on pre-trade productivity. To explore this possibility in depth, we analyse, using stochastic dominance techniques (see Máñez *et al.*, 2008, 2010, for the technicalities of this empirical approach), if process innovators in *t-3* have higher productivity in *t*-1 than non-process innovators in *t-3*, and whether productivity growth from *t*-3 to *t*-1, for process innovators in *t*-3, is higher than that for non process innovators in *t*-3.

To formally test if the productivity distribution in *t-1* (productivity growth distribution from *t-3* to *t-1*) of process innovators in *t-3* stochastically dominates the productivity distribution in *t-1* (productivity growth distribution from *t*-3 to *t*-1) for non-process innovators in *t-3*, we compare:

$$F_{t-3}\left(P_{t-1}\right) \ vs.\ \mathrm{G}_{t-3}\left(P_{t-1}\right)$$

using the Kolmogorov-Smirnov (KS) one and two-sided tests, where F_{t-3} and G_{t-3} are the productivity distribution functions in *t*-1 (or productivity growth from *t*-3 to *t*-1 distribution functions) for process innovators and non-process innovators in *t-3*, respectively.

From the results of the KS tests in Table 4, we can infer that the productivity distribution in *t-1* and the productivity growth distribution (from *t-3* to *t-1*) of process

[12] Exploring past values for the product and process innovation variables, we find that process innovation (lagged 3 periods) seems to have a significant effect on the probability of exporting in *t*.

innovators in *t-3* stochastically dominate those of non-process innovators.[13] These results suggest that process innovation in *t-3* fosters productivity growth from *t-3* to *t-1* and results in higher productivity in *t-1* for those firms implementing process innovations in *t-3*. The fact that productivity in *t-1* is very likely related to former process innovations would explain why when lagged productivity is included in estimation the variable capturing process innovation loses its significance.

[Insert Table 4 about here]

The joint consideration of this last result and the fact that the estimate for productivity in *t*-1 in the export decision equation is positive and significant suggests the existence of a self-selection into exports *indirect* effect of process innovation that operates through productivity: process innovation increases productivity, and therefore the probability of exporting.

As for other variables included in the export equation, the estimate of the previous period export status is positive and very significant indicating that exporting is subject to persistence (this result can also be found in Roberts and Tybout, 1997, for Colombia and also in Máñez *et al.*, 2008, for Spain).[14] Furthermore, we observe that export persistence is increasing both with the number of destination markets, and the degree of standardization of the firm product.

Finally, our results also suggest that more productive firms enjoy a higher probability to sell in foreign markets. This result is in line with the literature providing

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[13] Both for productivity in *t-1* and productivity growth from *t-3* to *t-1*: we reject the null hypothesis of equality of the distributions for process innovators and non-process innovators in *t-3* (two-sided test) at a 1% significance level; and, we cannot reject the null of favourable differences for process innovators in *t*-3 (one-sided test).

[14] The coefficient for the previous exporting status can be considered as an estimate of the sum of sunk entry costs for a firm that never exported and exit costs for current exporters (Dixit, 1989).

evidence in favour of the well-known self-selection of more productive firms into exporting, that we will call self-selection into exporting *direct* effect.

We further analyse this result using stochastic dominance techniques (see Table 5) to test whether the productivity distribution in *t-1* for exporters in *t* stochastically dominates the productivity distribution in *t-1* for non-exporters. The results of the KS tests suggest that the productivity distribution in *t-1* for exporters in *t* stochastically dominates that for non-exporters, confirming the self-selection into exports *direct* effect found above.[15]

[Insert Table 5 about here]

4.2. Analysis of the decision to implement product innovations.

In this equation the variables of interest are whether the firm implemented a process innovation in the previous period, and previous period export participation. Our estimates suggest that, irrespective of including productivity or not, implementing process innovations in the previous period increases the probability of implementing a product innovation in period *t*. This suggests complementarity between the implementation of product and process innovations.[16] As for exporting in the previous period, we get that firms exporting to two or three markets enjoy a higher probability of implementing product innovations (moreover, this probability is increasing in the number of markets firms serve). Salomon and Shaver (2005) also obtain that past exporting status increases the likelihood of firms' product innovations.

[15] From our results for the KS tests we reject the null hypothesis of equality of the two distributions (two-sided test) at a 1% significance level, and we cannot reject the null of differences in favour of exporters in *t* (one-sided test).

[16] This evidence is reinforced by the significant and strong correlation between the error terms of the equations modelling the decision to implement a product innovation and a process innovation (ρ_{23} in Table 3).

Our results suggest persistence in the implementation of product innovations, as the estimate for product innovations in *t-1* has a positive and highly significant coefficient. Supporting evidence of persistence in innovation output has also be found in Máñez *et al.* (2004, 2009), Flaig and Stadler (1994), Rogers (2004), Duguet and Monjon (2004), Raymond *et al.* (2006) and Peters (2007).

Further, productivity affects positive and significantly the probability of implementing product innovations. This evidence is consistent with, among others, Hall (1992), González and Jaumandreu (1998), González *et al.* (2005), and Máñez *et al.*, (2005). We further analyse this result using stochastic dominance techniques (see Table 6). The KS tests comparing the productivity distributions in *t-1* of product and non-product innovators in *t* suggest stochastic dominance of the former over the later.[17] These results confirm the existence of a self-selection process of the most productive firms into the implementation of product innovations.

[Insert Table 6 about here]

4.3. Analysis of the decision to implement process innovations.

In this equation the variables of interest are whether the firm implemented a product innovation in the previous period, and previous period export participation. We find that those exporting firms whose main foreign market is the UE are more likely to introduce process innovations. Further, obtaining product innovations in the previous period has a positive and very significant effect (irrespective of including productivity) on the probability of implementing process innovations. This confirms the complementarity between process and product innovations pointed out above.

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[17] Our results suggest to reject the null hypothesis of equality of the two the distributions (two-sided test) at a 1% significance level, and not to reject the null of favourable differences for product innovators in *t* (one-sided test).

Likewise product innovations, previous period productivity affects positive and significantly the probability of obtaining process innovations, suggesting the existence of a process of self-selection into the implementation of process innovations by the most productive firms. We further analyse this result using stochastic dominance techniques (see Table 7). The KS tests comparing the productivity distributions in *t-1* of process and non-process innovators in *t* suggest stochastic dominance of the former over the later.[18]

The joint consideration of this last result and the positive and significant estimate of lagged process innovation in the export equation (without including productivity) suggests the existence of a self-selection into exports *indirect* effect that operates from productivity to the probability of exporting through process innovations. The higher the productivity, the higher the probability of implementing process innovations, and therefore the probability of exporting.

[Insert Table 7 about here]

Our results may also suggest the existence of a phenomenon of persistence in the introduction of process innovations (the estimate of the previous process innovation variable is positive and significant); i.e., the probability of implementing a process innovation today depends on whether or not the firm introduced a process innovation in the past.[19]

[Insert Table 8 about here]

[18] From our results we reject the null hypothesis of equality of the two distributions (two-sided test) at a 1% significance level, and we cannot reject the null of favourable differences for process innovators in *t* (one-sided test).

[19] Related works about persistence in innovation are Flaig and Stadler (1994), Máñez *et al.* (2004, 2009), Rogers (2004), Raymond *et al.*, (2006), and Peters (2007).

4.4. Summary of the results.

Our results provide evidence that the decisions to export, to implement product innovations and process innovations are very likely correlated (i.e. interdependent), and so this points out the need of analysing them jointly. The main results for the variables of interest (decision to export, productivity, process and product innovations) are summarised in Table 8.

5. Concluding remarks.

Our paper sheds light on the role played by productivity, process and product innovations in the process of self-selection into starting to export. By means of estimation of a dynamic trivariate probit model that takes into account the potential simultaneity in the decisions of exporting and implementing product and process innovations, as well as endogeneity of initial conditions, we detect the existence of three self-selection into exports effects: a *direct* one and two *indirect* ones.

The *direct* effect is the well-known self-selection effect based on productivity: the most productive firms self-select into export markets. The first self-selection into exports *indirect* effect stems from productivity to the probability of exporting through process innovations: the higher the productivity, the higher the probability of introducing process innovations and, therefore, the likelihood of starting to export. The second self-selection *indirect* effect of process innovations into exports operates through productivity: process innovations increase productivity and, therefore, the probability to export.

Our findings make a contribution to the understanding of the determinants of the firms' decision to start exporting and have important implications for public policy export promotion measures. Policies aimed to help firms to increase productivity would have a *direct* impact on the firms' likelihood of starting to export. Furthermore, policies targeted at stimulating the introduction of process innovations would have an *indirect* effect on the likelihood of starting to export by increasing productivity, what will subsequently have a positive effect on the likelihood of starting to export. Finally, in relation to the observed sunk costs in the firms' decisions about exporting and innovation, policies aimed at providing information and access to foreign markets and innovation activities, or providing exporting infrastructures and facilitating innovation networks, could reduce the sunk costs of starting to export and the sunk costs of starting innovative activities.

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Table 1. Sample representativeness: exporters versus non-exporters, 1990.

	Complete sample		*Continuing Sample*	
	Non-Exporters	Exporters	Non-exporters	Exporters
1. Small firms				
% of total sample of firms	68.95%	31.05%	66.17%	33.83%
% of total employment	53.15%	46.85%	49.49%	50.51%
% of total sales	47.25%	52.75%	43.82%	56.17%
2. Large firms				
% of total sample of firms	16.78%	83.22%	15.67%	84.33%
% of total employment	9.78%	90.22%	8.98%	91.02%
% of total sales	8.49%	91.51%	7.17%	92.83%

Table 2. Variables definition.

Export	Dummy variable taking value 1if the firm exports, and 0 otherwise.
Dummy size	Dummy variable taking value 1 if the number of workers of the firm is below or equal to 200, and 0 otherwise.
Process innovations	Dummy variable taking value 1 if the firm has implemented a process innovation.
Product innovations	Dummy variable taking value 1 if the firm has implemented a product innovation.
Productivity	Ratio of sales over number of employees.
Export to # markets	Dummy variable taking value 1 if the firm exports to # markets. The ESEE provides information on whether a firm exports to EU countries, to the rest of the OECD countries, and/or to the rest of the world. With this information we classify exporters in three groups according to whether they export to one, two or three of the areas considered.
Standardized product	Dummy variable taking value 1 if the firm produces a standardised product.
Change product	Dummy variable taking value 1 if the firm declares to have changed often the products it produces.
Majority exports to UE	Dummy variable taking value 1 if the highest percentage of the firm exports has as destination the U.E.
Access to int. market own network	Dummy variable taking value 1 if the firm access to the international markets is using its own network.
Access to int. market mother firm abroad	Dummy variable taking value if the firm access to the international markets is through its mother firms abroad.
Access to int. market com. intermediary	Dummy variable taking value 1 if the firm access to the international markets is using intermediaries.
Access to int. market association exporters	Dummy variable taking value 1 if the firm access to the international markets is through association with other exporters.
Access to int. Market: other	Dummy variable taking value 1 if the firm access to the international markets is using other means.
Size	Log of the number of employees.
Age	Number of years since the firm was born.
Labour quality	Ratio of the number of highly qualified workers to total employment (in %).
Corporate	Dummy variable taking value 1 if the firm is a limited liability corporation, and 0 otherwise.
Foreign Physical Equipment	Firm's average percentage of foreign physical equipment.
Public sales	Dummy variable taking value one if more than 25% of firm sales go to the public sector and zero otherwise.
Expansive demand	Dummy variable taking value 1 if the firm declares to face an expansive demand.
Recessive demand	Dummy variable taking value 1 if the firm declares to face a recessive demand.
Cash flow	Cash flow ratio on sales (in %). Cash flow is calculated as sales + stocks variation in sales – intermediate inputs – labour costs + R&D expenditures. Intermediate inputs are calculated as purchases + external services – stocks variation in purchases.
R&D intensity	R&D expenditure normalized by sales (in %).
Appropriability	Ratio of the total number of patents over the total number of firms that assert to have achieved innovations in the firms industrial sector (50 sectors of the three-digit NACE-93 classification) (in %).
Number of competitors 0-10	Dummy variable taking value 1 if the firm asserts to have less than (or equal to) 10 competitors with significant market share in its main market, and 0 otherwise.
Number of competitors 10-25	Dummy variable taking value 1 if the firm asserts to have more than 10 and less than (or equal to) 25 competitors with significant market share in its main market, and 0 otherwise.
Number of competitors > 25	Dummy variable taking value 1 if the firm asserts to have more than 25 competitors with significant market share in its main market, and 0 otherwise.
Market share	Dummy variable taking value 1 if the firm asserts to account for a significant market share in its main market, and 0 otherwise.
Year dummies	Dummy variables taking value 1 for the corresponding year, and 0 otherwise.
Industry dummies	Industry dummies accounting for 20 industrial sectors of the NACE-93 classification.

Table 3. Dynamic trivariate probit model estimations for the export, product innovation and process innovation decisions

	Export				Product innovation				Process innovation			
	Without productivity		With productivity		Without productivity		With productivity		Without productivity		With productivity	
	coeff.	*s.e.*	coeff.	*s.e.*	coeff.	*s.e.*	coeff.	*s.e.*	coeff.	*s.e.*	coeff.	*s.e.*
Constant	-2.335***	0.314	-5.095***	0.673	-2.108***	0.256	-3.087***	0.466	-1.893***	0.211	-3.383***	0.438
Export$_{t-1}$	2.205***	0.279	2.180***	0.278	0.176	0.116	0.139	0.117	0.080	0.126	0.038	0.127
(Export*dummy size)$_{t-1}$	-0.173	0.227	-0.153	0.230	0.060	0.099	0.076	0.100	0.037	0.091	0.058	0.090
Process innovations$_{t-1}$					0.127**	0.053	0.115**	0.054	1.175***	0.057	1.165***	0.056
Product innovations$_{t-1}$	0.097	0.122	0.081	0.123	1.384***	0.066	1.384***	0.000	0.279***	0.056	0.277***	0.056
Productivity$_{t-1}$			0.317***	0.066			0.110**	0.046			0.169***	0.043
Process innovations in t-3	0.139*	0.088	0.107	0.091								
(Export to 2 markets*dummy export)$_{t-1}$	0.586***	0.164	0.602***	0.170	0.152*	0.083	0.154*	0.084	-0.074	0.078	-0.064	0.078
(Export to 3 markets*dummy export)$_{t-1}$	0.911***	0.286	0.978***	0.298	0.319***	0.095	0.320***	0.095	-0.133	0.091	-0.117	0.091
(Standardized product*dummy export)$_{t-1}$	0.441***	0.133	0.401***	0.135					-0.065	0.070	-0.095	0.070
(Change product*dummy export)$_{t-1}$	0.194	0.151	0.280*	0.160					-0.278***	0.098	-0.268***	0.098
(Majority exports to UE*dummy export)$_{t-1}$	0.083	0.164	0.093	0.167	-0.045	0.078	-0.043	0.078	0.134*	0.077	0.139*	0.077
Access to int. market own network$_{t-1}$	0.162	0.207	0.401	0.135								
Access to int. market mother firm abroad$_{t-1}$	0.178	0.387	0.128	0.207								
Access to int. market com. intermediary$_{t-1}$	-0.193	0.230	0.106	0.370								
Access to int. market association exporters$_{t-1}$	0.074	0.286	0.044	0.286								
Access to int. market: other$_{t-1}$	-0.205	0.218	-0.190	0.219								
Size$_{t-1}$	0.147***	0.051	0.136***	0.052	0.072**	0.037	0.070*	0.037	0.133***	0.033	0.132***	0.033
Age $_{t-1}$	1.190*	0.725	1.145*	0.752	0.013	0.050	0.001	0.051	-0.048	0.045	-0.068	0.045
Labour quality$_{t-1}$	-0.001	0.011	-0.011	0.013	0.002	0.005	-0.002	0.005	-0.002	0.005	-0.007	0.006
Corporate$_{t-1}$	-0.419**	0.185	-0.460**	0.190	0.014	0.064	-0.017	0.066	0.019	0.060	-0.029	0.060
Foreign$_{t-1}$	-0.050	0.198	-0.108	0.913	-0.249***	0.085	-0.271***	0.085	-0.080	0.078	-0.111	0.078
Public sales$_{t-1}$	-0.450*	0.236	-0.333	0.227	-0.294	0.205	-0.264	0.202	0.011	0.132	0.062	0.134
Expansive demand$_{t-1}$	-0.009	0.085	-0.021	0.085	0.049	0.055	0.047	0.055	0.107**	0.051	0.103**	0.051
Recessive demand$_{t-1}$	-0.151	0.111	-0.132	0.118	0.088	0.074	0.096	0.075	-0.076	0.064	-0.060	0.066
Cash-flow$_{t-1}$	-0.003	0.004	-0.004	0.004	0.000	0.000	0.000	0.000	-0.000**	0.000	-0.000***	0.000
(Cashflow*dummy size)$_{t-1}$	0.002	0.004	0.004	0.004	-0.001***	0.000	-0.001***	0.000	-0.000	0.000	-0.000	0.000
R&D intensity$_{t-1}$					-0.035	0.044	-0.034	0.044	0.048	0.042	-0.004	0.081
Appropriability$_{t-1}$					-0.014	0.024	-0.014	0.024	-0.013	0.017	-0.014	0.017
Foreign physical equipment$_{t-1}$					0.000	0.001	-0.001	0.001	0.001	0.001	0.001	0.001
Number competitors 10-25$_{t-1}$					-0.091	0.078	-0.097	0.078	0.071	0.071	0.065	0.070
Number competitors >25$_{t-1}$					0.003	0.090	0.008	0.090	0.101	0.084	0.110	0.085
Market share$_{t-1}$					0.127**	0.059	0.108*	0.059	0.070	0.060	0.044	0.060
Initial conditions (y_{i1})	0.622***	0.110	0.612***	0.107	0.450***	0.068	0.453***	0.068	0.227***	0.055	0.216***	0.055

Log-likelihood without productivity: -4114.707; N observations: 4158 (Number of firms:693)
ρ_{12} = -0.029 (*p-value* = 0.384), ρ_{13} = 0.096 (*p-value* = 0.018), ρ_{23} = 0.341 (*p-value* = 0.000)
LR test $\rho_{12} = \rho_{13} = \rho_{23} = 0$, $\chi^2(3)$ = 122.528

Log-likelihood with productivity: -4095.286; N observations: 4158 (Number of firms:693)
ρ_{12} = -0.024 (*p-value* = 0.453), ρ_{13} = 0.090 (*p-value* = 0.026), ρ_{23} = 0.339 (*p-value* = 0.000)
LR test $\rho_{12} = \rho_{13} = \rho_{23} = 0$, $\chi^2(3)$ = 119.986

* significant at 10%, ** significant at 5% and *** significant at 1%.

Table 4. Process innovations foster productivity growth: productivity in t-1 and productivity growth from t-3 to t-1 for process innovators and non-process innovators in t-3

				Equality of distributions		Favourable diff. to process innovators	
	Process innovators in *t-3*	Non-process innovators in *t-3*	Productivity differences[a]	Statistic	*p*-value	Statistic	*p*-value
Productivity in *t-1*	1446	2712	0.294	5.454	0.000	0.000	1.000
Growth productivity (*t-3* to *t-1*)	1446	2712	0.031	2.331	0.000	0.224	0.905

[a] Productivity differences (between both groups of firms) are calculated at the median of the distributions.

Table 5. Self-selection into process innovations: comparison of previous productivity for exporters and non-exporters in *t*.

				Equality of distributions		Favourable diff. to exporters	
	Exporters	Non-exporters	Productivity differences[a]	Statistic	*p*-value	Statistic	*p*-value
Productivity in *t-1*	2593	1565	0.687	10.087	0.000	0.000	1.000

[a] Productivity differences (between both groups of firms) are calculated at the median of the distributions.

Table 6. Self-selection into product innovations: comparison of previous productivity for product innovators and non-product innovators in *t*.

				Equality of distributions		Favourable diff. to product innovators	
	Product innovators	Non-product innovators	Productivity differences[a]	Statistic	*p*-value	Statistic	*p*-value
Productivity in *t-1*	1113	3045	0.284	5.005	0.000	0.046	0.996

[a] Productivity differences (between both groups of firms) are calculated at the median of the distributions.

Table 7. Self-selection into process innovations: comparison of previous productivity for process innovators and non-process innovators in *t*.

				Equality of distributions		Favourable diff. to process innovators	
	Process innovators	Non-process innovators	Productivity differences[a]	Statistic	*p*-value	Statistic	*p*-value
Productivity in *t-1*	1437	2721	0.353	6.056	0.000	0.037	0.997

[a] Productivity differences (between both groups of firms) are calculated at the median of the distributions.

Table 8: Summary of the main results.

Results from the exports participation equation	Productivity	More productive firms in *t-1* self-select into exporting in *t* (*Self-selection into exports direct effect*).
	Product Innovation	No effect on the probability of exporting .
	Process Innovation	Process innovations in *t-3* increase productivity in *t-1,* and this increases the probability of participation in export markets in *t* (*Self-selection into exports indirect effect*).
Results from the product innovation equation	Productivity	Self-selection to the implementation of product innovations in *t* of the more productive firms in *t-1*.
	Process Innovation	Previous process innovation affects positively the probability of implementing product innovations.
Results from the process innovation equation	Productivity	Self-selection to the implementation of process innovations in *t* of the more productive firms in *t-1*.
	Product Innovation	Previous product innovation affects positively the probability of implementing process innovations.
Results from combining the exports participation equation and the process innovation equation		The most productive firms self-select to implement process innovations (from the process innovation equation) and those firms that introduce process innovations have a higher probability of exporting (*Self-selection into exports indirect effect* coming from the exports equation).