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Complementarity among product, process and organizational innovations for exporting: Evidence from German firm-level data

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Abstract

This paper investigates whether firms' joint implementation of product, process and organizational innovation may foster their propensity of exporting. We study the relationship of complementarity of innovation practices when exporting is the firms' objective function, through the properties of supermodular functions (Topkis, 1995, 1998; Milgrom and Roberts 1990, 1995; Milgrom and Shannon, 1994). A unified strategy is proposed to perform multiple inequality testing implied by the properties of supermodular functions, by addressing the likely endogeneity of binary variables in non linear models through propensity score matching and instrumental variable methods. Using data from CIS4, heterogeneous incentives of exploiting complementarity among German firms' innovation practices emerge by export destinations and when size and sector specific conditions are satisfied.

Keywords: Export propensity, complementarity among innovations, multiple hypothesis testing, binary choice model

JEL Classification: C12, C25, F14, O31

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1. INTRODUCTION

The trade-literature has recently emphasized the role of innovation in the export-productivity relationship[4]. The linkage between firms' investment in innovation and their decision to export is explored and, through the use of micro-level data, a positive correlation between the two firms' choice variables is documented. This result is obtained by assuming heterogeneity of firms' productivity. The basic reasoning is the following: only more productive firms may afford the fixed costs of exporting, as well as only more productive firms may afford the fixed costs of innovating. Moreover, it is widely recognised (Griliches, 1998) the role of innovation in influencing firms' productivity patterns. Therefore innovation may imply higher productivity levels, that is lower marginal costs of production. Hence innovators may charge lower prices on the goods they sell both in the domestic and in the foreign markets, and, if the foreign demand is assumed to be elastic, innovators find exporting more profitable than non-innovators.

Typically, three different kinds of firms' innovation are considered in the literature: product, process and organizational innovation. As already emphasised (Caldera, 2010; Cassiman et al., 2010), all kinds of innovation should have positive effects on firms' exports. Through product innovation firms upgrade their products to meet foreign consumers' preferences and to adequate to foreign market standards and regulations. Through process and organizational innovations firms improve their production process receiving cost advantages; hence, they can charge lower and more competitive prices on foreign markets and expect higher profits from exports, which in turn increase their probability of exporting. In Caldera (2010) the direct effects of the different firms' innovation strategies on their probability of exporting is analysed and a positive relationship is shown by data.

Our aim is to move up from this literature by focusing our analysis on an aspect not yet sufficiently considered. Actually, since all three forms of innovation practices are shown to be relevant for exporting firms, we are interested in exploring if a relationship of complementarity among the three kinds of innovation exists when firms' objective function is exporting. Following Topkis (1995, 1998), Milgrom and Roberts (1990, 1995), Milgrom and Shannon (1994), we will investigate complementarity among firms' innovation practices through the properties of supermodular functions. Moreover we are interested in exploring whether firms' heterogeneity by export destinations may play a role in the analysis of complementarities among firms' innovation practices and their attitude towards exporting. In fact, as highlighted by Melitz (2003) a firm has to bear fixed costs of exporting, which involve distribution and servicing costs for each foreign market to which the firm exports. Hence the more are the foreign markets served by the firm, the larger are the fixed export costs it has to bear. Our aim is to scrutinize if exporter firms with larger fixed export costs exploit technological complementarities among different innovation practices in a stronger way than the other ones.

We investigate the issue by using a sample of 4054 German firms that is of great interest to our purpose since a big percentage of firms (48,8%) export and even a greater percentage of them (82,4%) innovate. Data are from CIS4 survey and include information on the introduction of all three kinds of innovation: product, process and organizational/marketing innovation. Another peculiar element in our dataset is that exporters choose three different destinations for their exports: the EU markets, other foreign markets or both destinations (EU and extra EU markets), which allows us to deepen the empirical analysis about complementarities among innovation practices when heterogeneity of firms by export destinations is considered.

From an econometric point of view, a unified framework for evaluating complementarity among innovation practices for export propensity is proposed, by admitting that innovation practices can be either exogenous or endogenous.

[4] See, among others, Bustos, 2011; Costantini-Melitz, 2007; Cassiman et al., 2010; Van Long et al., 2011; Caldera, 2010; Aw et al, 2007, 2008; Lileva-Trefler, 2010.

To address the issue of complementarity when innovation variables are assumed to be exogenous, constrained and unconstrained logit and multinomial models are estimated and bootstrapping is proposed to perform joint inequality testing implied by the properties of supermodular functions. We contribute to existing literature in the sense that we directly evaluate combined hypothesis testing for more than two innovation practices, by overcoming computational problems associated to the generalization of Wald tests used by Mohnen and Roller (2005) for two practices. Indeed, regressions under inequality constraints are to be computed and the critical values of such tests are cumbersome even for dichotomously practices. For the best of our knowledge, the only paper performing complementarity testing for more than two innovation practices is Carree et al (2011). However, the authors propose an induced test procedure and argue that a combined hypothesis is accepted if all the separate hypotheses are accepted.

To address the issue of complementarity when innovation variables are assumed to be endogenous, propensity score matching and instrumental variable simulated maximum likelihood (MSL) methods can be used. In this case, we use binomial variables able to identify complex innovation strategies. We interpret complex innovators as a treatment group, who adopt two or more innovation practices simultaneously. The set of simple-innovators, deciding to introduce only one type of innovation, and non-innovators join the control group. The estimating methods of treatment-effects models can be used to test for endogeneity of (complex) innovation variables and to evaluate complementarity, when endogeneity is not statistically rejected.

The paper is structured as follows: section 2 analyses the relationship between exporting and complementarity among innovation practices; the theoretical framework and the research hypothesis are presented in section 2.1. Section 2.2 shows the econometric analyses and complementarity tests; then the endogeneity issue is tackled in section 2.3. Section 3 presents the CIS4 dataset and focuses on the relationship between exporting propensity and innovation activities for German firms. Section 3.3 presents and comments the econometric results about innovations complementarity and exporting. Section 4 concludes.

2. EXPORTING AND COMPLEMENTARITY BETWEEN INNOVATION PRACTICES

In the economic literature about trade big emphasis has recently been given to the relationship among firms' attitudes to innovate and to export. Most of the analysis on the relationship innovation-trade passes through the heterogeneity of firms' productivity. The linkage is the following: only more productive firms self-select into export markets; innovation is one of the most important drivers of the firm's productivity; innovators may afford lower marginal costs of production and may charge a lower prices on the goods they sell in the foreign markets; hence, if the foreign demand is assumed to be elastic innovators' attitude to export is higher than non-innovators' attitude. Moreover, the empirical analysis is often conducted considering the correlation between investment in R&D and exporting (Aw et al, 2007, 2008; Bustos, 2011; Lileva-Trefler, 2010;Van Long et al., 2011). Only few works (Caldera, 2010; Cassiman et al., 2010) have examined the direct link between firms' different innovation practices and exporting. In these works a positive correlation between firms' innovation strategies and their attitude to export is shown and product innovation seems to play a more relevant role in firms' participation in export markets than other forms of innovation. On the other hand, evidence has also shown that exporter firms adopt all kinds of innovation practices.

The question that in our opinion has not yet received sufficient consideration is if a relationship of complementarity among the firms' different innovation practices matter when their objective function is exporting. Our aim is just to concentrate on this yet unexplored issue.

For the pursuit of our goal, this section presents the referring theoretical framework for the analysis of complementarity and our proposal of econometric testing of complementarity among the three innovation practices (product, process and organizational/marketing) when the firms' objective function is exporting.

2.1 Complementarity: concepts and methods

When a relationship of complementarity is found between two activities of a firm, this implies that if one of the two activities is increased, it is more attractive for the firm to increase also the other complementary activity. This has obvious implications on the firm's strategic decisions. In fact, the firm's change of some choice variable may have little effect if other choice variables remain unchanged.

Since the seminal applied work by Mohnen and Roller (2005), increasing attention has been devoted by economic literature to testing empirical evidence for complementarities in innovation policies. Remaining within the innovation sphere, our aim is to analyse if evidence for complementarity among some firms' innovation practices exists when their objective function is exporting.

We want to scrutinize whether innovation practices are complementary, because in such situation the firm's choice should be to implement them together in order to maximise their impact on exporting.

Since innovation practices are typically investigated in discrete settings (e.g. adopting or not, adopting at an intensity higher than the average, etc..), we study complementarity among these forms of actions through the properties of supermodular functions.

Following Topkis (1995, 1998), Milgrom and Roberts (1990, 1995), Milgrom and Shannon (1994), we state that two variables x' and x'' in a *lattice*[5] X are complements if a real-valued function $F(x', x'')$ on the *lattice* X is supermodular in its arguments. That is, if and only if:

$$(1) \qquad F(x' \vee x'') + F(x' \wedge x'') \geq F(x') + F(x'') \qquad \forall x', x'' \in X.$$

Or, expressed differently:

$$(2) \qquad F(x' \vee x'') - F(x') \geq F(x'') - F(x' \wedge x'') \qquad \forall x', x'' \in X,$$

that is, the change in F from x' (or x'') to the maximum $(x' \vee x'')$ is greater than the change in F from the minimum $x' \wedge x''$ to x'' (or x'): raising one of the variables raises the value of increase in the second variable as well[6]. It is worth noting that the mathematical approach to complementarity typically considers two independent variables only. Actually the relationship of complementarity may involve more than two variables simultaneously, through a chain reaction that starts from a complementarity relationship between two variables and involves a complementarity relationship between one of the two variables and a third variable and so on (Topkis, 1978). It is sufficient to check pairwise complementarities in case the dimensions of the lattice are more than two.

In our specific case, we consider the 'Exporting function' of firm j $(E_j, \text{for } j = 1,2,...J)$ as the firm's objective function and we focus on the innovation practices set of firm *j*, $I_j = (I_{1j}, I_{2j},..., I_{kj},..., I_{Kj})$ [7], that can affect the firm's exporting function:

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[5] More specifically, "a *lattice* $(X, \geq)$ is a set X, with a partial order ≥, such that for any $x', x'' \in X$ the set X also contains a smallest element under the order that is larger than both x' and x'' ($x' \vee x''$) and a largest element under the order that is smaller than both ($x' \wedge x''$)" (Milgrom and Roberts, 1995, p. 181). For the Euclidean space R^N, $x' \vee x'' = (\max\{x_1, y_1\},..., \max\{x_n, y_n\})$ and $x' \wedge x'' = (\min\{x_1, y_1\},..., \min\{x_n, y_n\})$.

[6] From equations (1) and (2) it is evident that complementarity is symmetric: increasing *x*' raises the value of increases in *x*''. Likewise, increasing *x*'' raises the value of increases in *x*'.

[7] Where *k=1,2,…K* denotes the kind of practice.

(3) $$E_j = f(I_{1j} I_{2j},...I_{Kj},{}^{-}_{j}) = E_j(I_j,{}^{-}_{j}) \qquad \forall j.$$

The problem of firm *j* is to choose a set of innovation practices which maximize its *E* function. ${}^{-}_{j}$ represents the firm's predetermined parameters, such as the firm's foreign markets, and the firm's sector specificity and/or dimension. The maximisation problem is the same for all firms. Notwithstanding each firm is characterised by specific predetermined factors and one could be interested in how different values of the parameter ${}^{-}$ may imply different instances of the firms' decisional problems and hence different firms' optimal choices concerning *E*.

Let the innovation practices set $I_j (I_{kj} \in I_j)$ be a set of elements that form a lattice, then complementarity between the different innovation practices may be analysed by testing whether $E_j = E_j(I_j,{}^{-}_{j})$ is supermodular in I_j.

If we consider, for example, two binary decision variables (I_{1j}, I_{2j}), there are four elements in the set I_j. If in its E_j maximizing problem, a firm chooses to adopt neither of the two practices, namely $I_{1j} = 0, I_{2j} = 0$, the element of the set I_j is $I_{1j} \wedge I_{2j} = \{00\}$. If a firm chooses to adopt both practices, we have $I_{1j} = 1, I_{2j} = 1$ and the element of the set is I_j is $I_{1j} \vee I_{2j} = \{11\}$. Including the mixed cases as well, we have four elements in the set I_j that form a lattice: $I_j = \{\{00\},\{01\},\{10\},\{11\}\}$.

From the above we can assert that the two innovation practices are complements and hence that the function E_j is supermodular, if and only if:

(4) $$E_j(11,{}^{-}_{j}) + E_j(00,{}^{-}_{j}) \geq E_j(10,{}^{-}_{j}) + E_j(01,{}^{-}_{j}),$$

or:

(5) $$E_j(11,{}^{-}_{j}) - E_j(00,{}^{-}_{j}) \geq \lfloor E_j(10,{}^{-}_{j}) - E_j(00,{}^{-}_{j}) \rfloor + \\ + \lfloor E_j(01,{}^{-}_{j}) - E_j(00,{}^{-}_{j}) \rfloor,$$

that is, changes in the firm's objective function when both forms of innovation practices are increased together are more than the changes resulting from the sum of the separate increases of the two kinds of practice.

To sum up, complementarity between the two decision variables exists if the E_j function is shown to be supermodular in these two variables and this happens when either inequality (4) or inequality (5) or other derived inequalities are satisfied[8]. Since each firm is characterized by specific exogenous parameters (${}^{-}_{j}$), even if the maximization problem is the same for all firms, the *E* function may result supermodular in I_j for some firms, but not for others.

Our aim is to derive a set of inequalities (such as those explicated in equations (4) and (5)), that are tested in the empirical analysis.

More specifically, through the supermodularity approach we analyse whether the probability of a firm's exporting is significantly influenced by the presence of complementarities among innovation practices.

In our analysis, we are also particularly interested in verifying whether a wider number of foreign markets served by a firm may play a role in the exploitation of complementarity relationships

[8] Since the substitutability relationship (that is, doing more of an activity reduces the attractiveness of doing more of the other activity), is the opposite of that of complementarity, we can test if a substitutability relationship exists if and only if: $E_j(11,{}^{-}_{j}) + E_j(00,{}^{-}_{j}) \leq E_j(10,{}^{-}_{j}) + E_j(01,{}^{-}_{j})$

among innovation practices. The underlying reasoning is in line with what highlighted by Melitz (2003) that a firm has to bear fixed costs of exporting which are independent from its export volume. They involve servicing and distribution costs in foreign markets and are borne by the firm in each exporting country, hence the more the foreign markets the firm chooses to serve, the larger are the total fixed costs it has to bear.

In this view, it is worth highlighting what Milgrom and Roberts (1995) show (in their fourth and fifth results) that a firm's optimal choice related to a decisional factor may initially be zero. Nevertheless, if environmental change leads to an increase in the level of another variable (which has become more profitable), then the new optimal choice of the first variable may become positive if it shows a relationship of complementarity with the factor that has been increased. Thus, increasing both variables may become more attractive in a newly changed 'environment'. Hence the adoption of both complementary practices by a firm may be an optimal choice in some circumstances but not in others even if its behaviour is maximizing in both cases.
'Environmental changes' may be represented as both dynamic and horizontal variations. In our analysis, which is static, we consider only the second type of variations and the parameter $\bar{\ }_j$ embodies the different environments that the different firms may face.
We will then empirically analyze complementarities by admitting differences between two subsamples of firms[9]: the ones that export to EU markets only (E_{EU}) and the ones that export to both EU and extra EU markets (E_B). We can presume that the fixed export costs are larger for E_B than for E_{EU}.
We want hence to scrutinize whether the increasing fixed export costs that the E_B subset of firms has to bear may induce them to exploit complementary innovation practices in a deeper way than the firms belonging to the E_{EU} subset.

2.2 Econometric modelling and testing strategy of the complementarity hypothesis

In this section, we concentrate on the evaluation of the complementarity hypothesis, by proposing a testing procedure developed for three different innovative activities, based on the multiple-inequality restrictions corresponding to the definition of strict super-modularity (or sub-modularity) introduced in the previous section.
The innovation practices we consider are three: product innovations; process innovations; organizational and marketing innovations. In the presence of three innovation practices of the firm, we have three binary decision variables and the elements of the lattice I are eight (that is 2^3). Specifically:

(6) $$I = \{\{000\},\{001\},\{010\},\{100\},\{101\},\{110\},\{011\},\{111\}\}$$

For each firm, $K = 3$ and, as shown in Mohnen and Roller (2005, p. 1463), the number of nontrivial inequalities is $2^{(K-2)}\sum_{i=1}^{K-1} i$, that is six nontrivial inequalities.
We can assert that for a firm *j* two innovation practices are complements in the presence of three practices if and only if the probability of exporting satisfies the following conditions:

- Complementarity between product and process innovation practices:

$$P(E_j | d110 = 1, \bar{\ }_j) + P(E_j | d000 = 1, \bar{\ }_j) \geq P(E_j | d100 = 1, \bar{\ }_j) + P(E_j | d010 = 1, \bar{\ }_j),$$

  and:

[9] Actually in our sample, besides only EU markets and both EU and extra EU markets, firms choose another destinations for their export, that is only extra EU markets.

$$P(E_j \mid d111 = 1, \text{¯}_j) + P(E_j \mid d001 = 1, \text{¯}_j) \geq P(E_j \mid d101 = 1, \text{¯}_j) + P(E_j \mid d011 = 1, \text{¯}_j),$$

with at least one of the two inequalities holding strictly[10]. We note that d_i ,with $i \in I$, is a dummy equal to one when the combination of innovation activities is *i* and zero otherwise, where *i* is an element of the lattice *I*, as defined in (9).

- between product and organizational/marketing innovation practices:

$$P(E_j \mid d101 = 1, \text{¯}_j) + P(E_j \mid d000 = 1, \text{¯}_j) \geq P(E_j \mid d100 = 1, \text{¯}_j) + P(E_j \mid d001 = 1, \text{¯}_j),$$

and:

$$P(E_j \mid d111 = 1, \text{¯}_j) + P(E_j \mid d010 = 1, \text{¯}_j) \geq P(E_j \mid d110 = 1, \text{¯}_j) + P(E_j \mid d011 = 1, \text{¯}_j),$$

with at least one of the two inequalities holding strictly[11].

- between process and organizational/marketing innovation practices:

$$P(E_j \mid d011 = 1, \text{¯}_j) + P(E_j \mid d000 = 1, \text{¯}_j) \geq P(E_j \mid d010 = 1, \text{¯}_j) + P(E_j \mid d001 = 1, \text{¯}_j),$$

and:

$$P(E_j \mid d111 = 1, \text{¯}_j) + P(E_j \mid d100 = 1, \text{¯}_j) \geq P(E_j \mid d110 = 1, \text{¯}_j) + P(E_j \mid d101 = 1, \text{¯}_j),$$

with at least one of the two inequalities holding strictly[12].

Our testing procedure requires the estimation of the following logit model (Model 1):

$$(7) \quad \ln \Pr\left(E_j = 1 \mid \text{¯}_j\right) = a_0 + a_1 C_j + a_2 \text{®}_j + \sum_{s \in S} a_s D_{sj} + \sum_{i \in I} b_i D_{ij} + \text{£}_j$$

where D_{ij} ,with $i \in I$, is a dummy equal to one when the combination of innovation activities is i and zero otherwise, where *i* is an element of the lattice *I*, as defined in (6). For example, if *i* = 111 the firm decides to adopt all three innovation practices simultaneously. Again, C_j is a dummy indicating which firms are part of a group, D_{sj} are sector-specific dummies, and ®_j is a measure of firm's relative profitability, which captures heterogeneity of firms' productivity levels.

Alternatively, when multiple exporting strategies are considered, the econometric model is multinomial (Model 2):

$$(8) \qquad \ln \frac{\Pr\left(E_j = m \mid \text{¯}_j\right)}{\Pr\left(E_j = No\ \exp \mid \text{¯}_j\right)} = a_{0m} + a_{1m} C_j + a_{2m} \text{®}_j + \sum_{s \in S} a_{sm} D_{sj} + \sum_{i \in I} b_{im} D_{ij} + \text{£}_{jm}$$

with *m* = {EU only, extra EU only, both EU and extra EU}.

With reference to Model 1 reported in (7), the conditions of complementarity testing are the following:

- Complementarity between product and process innovation practices:

$$b_{000} + b_{110} - b_{100} - b_{010} \geq 0$$

[10] The first condition is verified if the third innovation practice is 0, the second condition if the third practice is 1.

[11] The first condition is verified if the second innovation practice is 0, the second condition if the second practice is 1.

[12] The first condition is verified if the first innovation practice is 0, the second condition if the first practice is 1.

$$b_{111} + b_{001} - b_{101} - b_{011} \geq 0$$

with at least one of the two inequalities holding strictly.

– Complementarity between product and organizational/marketing innovation practices:

$$b_{000} + b_{101} - b_{100} - b_{001} \geq 0$$

$$b_{111} + b_{010} - b_{011} - b_{110} \geq 0$$

with at least one of the two inequalities holding strictly.

– Complementarity between process and organizational/marketing innovation practices:

$$b_{000} + b_{011} - b_{010} - b_{001} \geq 0$$

$$b_{111} + b_{100} - b_{101} - b_{110} \geq 0$$

with at least one of the two inequalities holding strictly.

How to test inequality constraint hypotheses has largely been studied in literature; the likelihood ratio test (LRT) is generally used to test the inequality constraint hypothesis at hand. The null distribution of this test is a chi-square distribution with degrees of freedom equal to the difference between the number of parameters of the models under comparison. An important result from the work of Barlow et al. (1972), Robertson et al. (1988), and Silvapulle and Sen (2004) is that one of the regularity conditions of the LRT does not hold when testing inequality constraint hypotheses, consequently, the asymptotic distribution of the LRT is no chi-square distribution and its p value cannot straightforwardly be computed.

Moreover, model selection criteria, such as the Akaike's Information Criterion or Bayesian Information Criterion, cannot be used to distinguish between statistical models with inequality constraints between the parameters of interest. These criteria use the likelihood evaluated in its maximum as a measure of model fit, and the number of parameters of the model as a measure of complexity. The problem is that model selection criteria cannot distinguish between hypotheses when these hypotheses do not differ in model fit, but only in the number of constraints imposed on the parameters of interest.

With reference to the literature on complementarity testing, Mohnen and Roller (2005) apply statistical Wald tests along the lines of Kodde and Palm (1986), for dichotomously practices. Linear regression under inequality constraints are to be computed and the critical values of such tests are cumbersome. Carree et al (2011) propose a procedure arguing that a combined hypothesis is accepted if all the separate hypotheses are accepted along the lines of Savin (1980).

Our idea is to evaluate informative hypotheses (where the parameter space is restricted), like those presented in the previous section, by using a parametric bootstrap procedure for directly testing the combined hypothesis. Bootstrapping is an approach for statistical inference falling within a broader class of resampling methods (Efron and Tibshirani, 1993).

The procedure here adopted consists of three steps. In Step 1 a parametric bootstrap from a population, in which the null hypothesis H0 is true, is computed. First, parameters are estimated under H0 using the observed data. T bootstrap samples of size n are generated. Then, parameters are estimated for each replicated data set under H0. Further, the parameters are estimated under the alternative hypothesis H1, similarly. The second step, is to repeat these computations conditional on the observed data set. The final step is to choose a test statistic to investigate the compatibility of the null hypothesis with the observed data. Like many previous studies (e.g., Barlow et al., 1972; Robertson et al., 1988, Silvapulle and Sen, 2004), we use the LRT for evaluating the hypotheses at hand.

This procedure is conducted for all type of hypothesis testing previously described. For each couple of complementarity constraints, we estimate the constrained model and test them by bootstrapping. It is also checked the presence of substitutable innovation practices by replacing the ≥ sign by the ≤ sign in all inequalities. As to Model 4 with multiple market destinations, the same methodology is applied for each exporting strategy. Results and comments are presented in section 3.3.

2.3 Endogeneity of binary innovation variables

With reference to logit models presented in the previous sections (Models 1-2), three key aspects of the estimation problem are recognized. First, the innovation choice is potentially endogenous. Since we expect that exporting firms are more likely to be involved in innovation activities, the un-weighted regression gives excessive importance to exporting firms. Thus, we are asked to control for potential endogeneity of the different types of innovation. Second, the dependent variable – the exporting choice - is binomial, when export propensity is evaluated without specifying the destination markets, or multinomial if EU market alone and both EU and extra-EU markets strategies are separately studied. In both cases, the true underlying regression specification is likely to be non-linear. Third, as a whole the innovation strategy is multinomial in the complementarity testing strategy. Specifically, an unordered multinomial innovation variable MD can be easily constructed considering all dichotomous variables D_i from equation (7), with $i \in I$ (*j* suppressed for simplicity), that is MD=0 if D_{000}=1, MD=1 if D_{100}=1, MD=2 if D_{010}=1, MD=3 if D_{001}=1, MD=4 if D_{101}=1, MD=5 if D_{110}=1, MD=6 if D_{011}=1 and MD=7 if D_{111}=1.

To address the issue of endogeneity in non-linear models for export propensity, we can interpret innovators as a treatment group and non-innovators as the control group.[13] If innovations were assigned completely at random, we could just compare treatment and control group. However, this is likely not to be the case. When the regression of the outcome of interest **(**y**)** on a potentially endogenous multinomial variable (x) is not linear, applications of the standard two-stage least square (2SLS) estimator, in which nonlinearity is ignored, can lead to a consistent but biased estimate of the causal effect of x on y. In this context, some methods are designed to deal with endogeneity: propensity score matching methods; IV models, such as bivariate probit and maximum simulated likelihood methods.

In the econometric literature, several approaches estimate treatment-effects models that consider an endogenous binary treatment on another binary outcome, which can be used for our purposes. Given that our treatment is multinomial we propose to simplify the problem into a pair-wise comparison of innovation strategies. This is possible by recognizing that all innovation strategies can be classified into two groups: complex innovation strategies and simple innovation strategies. In this view, we may construct a bivariate treatment from the multinomial innovation one (MD) to compare a situation where the firm introduces a simple innovation strategy to a situation where the firm chooses a complex innovation strategy from each couple of the three basic product, process and organizational innovation decisions. A complex strategy requires the simultaneous adoption of (at least) two types of innovation. Specifically, to evaluate complementarity between product and process innovation, we consider the following dummy

$$d_{12} = \begin{cases} =1 \quad if \quad D_{110}=1 \; or \; D_{111}=1 \\ =0 \quad otherwise \end{cases}$$

to evaluate complementarity between product and organizational innovation, we consider the following dummy

$$d_{13} = \begin{cases} =1 \quad if \quad D_{101}=1 \; or \; D_{111}=1 \\ =0 \quad otherwise \end{cases}$$

to evaluate complementarity between process and organizational innovation, we consider the following dummy

$$d_{23} = \begin{cases} =1 \quad if \quad D_{011}=1 \; or \; D_{111}=1 \\ =0 \quad otherwise \end{cases}$$

From a methodological point of view, we first consider the propensity score matching (PSM) approach, which compares exporters and non-exporters with a very similar probability of receiving

[13] For an extensive econometric and statistical analysis of causal effects, see Imbens and Wooldridge (2009).

innovation treatment (propensity score) based on observables (Rosenbaum and Rubin, 1983, 1985:Heckman et al., 1998). Our objective is to estimate the average treatment effect (ATE) as the difference between the probability of exporting, conditional on having received a treatment, and the probability of exporting of the untreated (or control) group, that is the exporting probability conditional on having received no treatment, both calculated over the entire population. The idea is to compare two alternatives: one with all units exposed to the treatment and one with none exposed, where the treatment is defined as the introduction of complex innovation policies.

Alternatively, among all possible IV models the maximum-likelihood bivariate probit approach is the simplest way to deal with endogeneity in complex non linear models, as suggested by Freedman and Sekhon (2010)[14]. However, convergence issues emerge in some cases and bootstrap standard errors calculated for ATE estimates are very small[15]. These problems are known in the literature (Nichols, 2011). Then, another IV model employing a maximum simulated likelihood (MSL) approach is used to estimate treatment-effects models (Bratti and Miranda, 2011).

A simultaneous model for export propensity and innovation strategy is considered. We present MSL estimates, by assuming that the outcome variable and the treatment are modeled via logit models.

The choice of the instruments used in PSM and MSL approaches has been driven by the application of under-identification LM tests (to verify that the excluded instruments are relevant) and Hansen-Sargan tests of over-identifying restrictions.

To test the existence of endogeneity in non-linear models for export propensity, two methodologies have been applied: Rivers-Vuong two stage test and the test on coefficients of the latent factors in MSL estimates. The Rivers-Vuong test is carried out as follows. At the first stage, a logit model of innovation is estimated by using the instruments identified by LM and Hansen-Sargan tests. At the second stage, a logit regression for export propensity includes the predicted error term from the first stage among other regressors. Under the null hypothesis of exogeneity, the coefficient of the error term is zero[16]. The effect of latent factors is captured by the estimated value of ρ parameter, The exogeneity hypothesis is not rejected when ρ is not statistically different from zero. A positive (negative) ρ means that unobserved characteristics that increase the probability of a complex innovation strategy relative to the control also lead to a higher (lower) probability of exporting for treated individuals.

Finally, the PSM method is a balancing method, so covariate imbalance after propensity score matching is a concern. In this view, we have checked the presence of imbalance. Indeed, the PSM is very sensitive to the choice of conditioning variables and robustness can be missing in the case of misspecification of such conditioning variables (Nichols, 2007; Heckman and Navarro-Lozano, 2004). Specifically, we calculate the reduction of the median absolute standardized bias in the observables between the treated firms and all control units versus the treated and the matched control units. Literature suggests that the remaining bias should be smaller than 20 percent (Rosenbaum and Rubin, 1985). Similarly, comparing the pseudo-R^2 of the propensity score estimation before and after matching, a drop in the explanatory power is required, indicating that there is no remaining systematic difference in observables between treated and control firms in the matched sample.

3. INNOVATION AND EXPORTING OF GERMAN FIRMS

3.1 Data description

[14] For a survey see Nichols (2007).
[15] Results are available upon request.
[16] Detailed results are available upon request.

Our analysis of the relationship between exporting and innovation activities is performed by using firm-level data for Germany given by the Community Innovation Survey 2005 (CIS4). The CIS4 dataset is a survey of innovation covering the 2002-2004 period for all sectors of the economy. Data on turnover, exports, dimension, etc., are also available. Table 1 reports export and innovation data description by sector.

For what concerns innovation the CIS4 consider the distinction made by the Oslo manual in its 2005 revision and data are collected on three forms of innovations: product innovations; process innovations; organizational and marketing innovations.

Product innovations involve the introduction of new goods or services or significant improvement of the existing ones. Process innovations include the implementation of a new or the improvement of already existing production or delivery methods. Organizational and marketing innovations consist of the implementation of new organizational or marketing methods[17].

As for any cross-sectional dataset also CIS4 one suffers from the problems highlighted by Mairesse-Mohnen (2010). In fact, analysis about direction of causalities with innovation issues and the treatment of econometric endogenous matters should involve dynamic setting and the availability of panel data. As already depicted in the previous section, we overcome this difficulty by adequately treating the endogeneity issue with appropriate econometric techniques dealing with discrete endogenous variables. On the other hand, the sample we consider fits very well the purpose of our analysis since a great deal of firms is involved in exporting and innovation activities. As shown in table 2 about one half of the firms (48,79%) exports, with a percentage increasing in the size from 36,2% of the small firms up to 51,42% of the medium and to 62,24% of the large firms. Even a greater share of firms innovate. In fact, 82,4% of them adopts at least one of the three innovation activities (table 3). Also in this case size plays a relevant role, since large firms are more involved than medium and small firms in innovation. For both exporting and innovation some differences are evident between manufacturing firms and firms belonging to services. As expected, among manufacturing firms exporters are more than non-exporters (68,13%), as for service firms the reverse is true, since exporters are only a quarter (25,08%) (tables 4 and 5). This is not a surprising fact, since trade barriers for services, as professional associations or special national certifications, are still high (Breinlich and Criscuolo, 2011). For what concerns innovation tables 6 and 7 show that it is significant for both the sub samples, in fact 86,32% of manufacturing firms and 76,66% of service firms adopt at least one of the three activities, but different firms' attitude towards innovation is also evident. Manufacturing firms are quite homogenously distributed among the three innovation activities, whereas service firms are more concentrated in organizational and marketing innovation activities (64,24%). This is consistent with the importance that the creation and diffusion of advanced knowledge in intangible activities have in the innovative activities of service firms. In services sector, investments in organizational innovations are more essential than the accumulation of physical capital and tangible assets.

3.2 Exporters, non-exporters and innovation

This section is devoted to the analysis of the differences between exporters and non-exporters with respect to their innovation activities and to other characteristics. Moreover the analysis goes into details of the two sub-samples: exporters to EU markets (henceforth E_{EU}) and exporters to both EU and extra EU markets (henceforth E_B).

We first analyze the productivity levels of exporters versus non-exporters. We consider a measure of firm's relative profitability (®$_j$), proposed by Aw et al. (2008), given by the log of firm's revenue share. It is calculated as the deviation from the mean log market share in the 5-digit level

[17] New organizational methods involve changes in workplace organizations, external relations and business practices. New marketing methods concern changes in product promotion or pricing, product design or packaging and product placement.

industry[18]. Specifically, $\text{®}_j = \ln\left(\frac{r_j}{I}\right) - \frac{1}{n}\sum_j \ln\left(\frac{r_j}{I}\right)$ where r_j is firm *j*'s revenue in a reference time period and *I* is total market size measured in terms of total industry revenues.

Table 8 shows that exporting firms are more productive than non-exporting ones, and this remains true for firms belonging to different sectors. These results are in line with trade literature (Bernard et al., 2003; Bernard et al., 2007; Melitz, 2003; Yeaple, 2005) that is the more productive firms may afford the fixed costs of exporting better than the less productive ones. Moreover, the analysis on productivity levels of innovators versus non-innovators confirms what already stated by the economic literature (Griliches, 1998), since productivity is higher for innovating firms than for non-innovating ones: only more productive firms may afford the fixed costs of innovating.

We want now to explore if it is reasonable to infer a positive correlation between innovation practices and exporting at firm-level. In fact, trade-literature (Caldera, 2010; Cassiman et al., 2010; Wagner, 2007) has recognized the positive effect of innovation activities on exporting. In particular, through product innovation firms adequate their products to the foreign demand preferences or to foreign market regulations and conditions. Instead through process or organizational innovations firms receive cost advantages and can charge lower prices becoming more competitive on the foreign markets of their products.

In table 9 exporters and non-exporters are compared in terms of innovation practices. Exporters are more innovative than non-exporters and the relative weight of all three forms of innovation is greater in exporters than in non-exporters. More specifically the relative weight of process innovation is 25,66% greater in exporters than in non-exporters, for process innovation the relative weight is 14,86% bigger in exporters than in non-exporters and for organizational and marketing innovation the relative weight is 10,69%. Exporters adopt all types of innovation activities.

In the sample we analyze three different destinations for firms' exports: EU markets, other foreign markets and both destinations (EU and extra EU markets). We are particularly interested in analysing the two subsets of firms: the ones that export to EU markets (E_{EU}) and the ones that export to both markets (E_B). The main reason is in line with what highlighted above in section 2.1 and concerns the higher fixed costs of exporting borne by firms with larger foreign markets to serve (Melitz, 2003). We want to scrutinize whether this element of heterogeneity implies different behaviour of exporters with respect to their attitude to innovate.

Data in table 9 support our intuition, since the share of E_B that do not innovate are almost half the share of E_{EU} firms that do not innovate (7,89% versus 14,30%) and the percentages of E_B that adopts each of the three kinds of innovation are always larger than the percentages of E_{EU}.

As a first step of the analysis of the relationship among firms' innovation activities and exporting, we estimate a logit model to identify exporting determinants.

Given the unobservable intensity of exporting E_j^* for any firm *j*, we can model it as follows:

(9) $$\ln \Pr\left(E_j = 1 \middle| \bar{}_j\right) = a_0 + a_1 C_j + a_2 \text{®}_j + \sum_{s \in S} a_s D_{sj} + b_1 I_{1j} + b_2 I_{2j} + b_3 I_{3j} + \text{£}_j$$

where C_j is a dummy indicating which firms are part of a group, D_{sj} are sector dummies and I_{kj} , k = 1, 2, 3, are innovation dummies reported by firm *j* and related to product, process and

[18] Aw et al. (2008) show that the firm's observable revenue share $\bar{}_i$ is strictly linked to a theoretical measure of firm's relative profitability in a dynamic model of exporting, which shares many features with Melitz (2003) and Costantini and Melitz (2007). Such relative profitability depends on firm's productivity level, capital stock, mark-up and return to scale parameters.

organizational/marketing practices, respectively. Again, ®_j is a measure of firm's relative profitability as in Aw *et al*. (2008). It is calculated as the deviation of the log of the firm's revenue share from the mean log market share in the industry. Table 10 reports the list of variables we use in this study and descriptive statistics.

In order to evaluate the effects of environmental conditions on innovation strategies, a different framework is asked for. When a firm chooses between exporting toward EU countries only or selling to all (both EU and extra EU) countries, it takes into account different trade costs connected to all exporting alternatives, as suggested by Melitz (2003). Then it is interesting to investigate whether the incentives of innovation practices change or not when comparing these different environments. Thus, let consider a multinomial logit model:

$$(10)\quad \ln \frac{\Pr\left(E_j = m \,|\!\vdash_j\right)}{\Pr\left(E_j = No\ \exp \,|\!\vdash_j\right)} = a_{0m} + a_{1m}C_j + a_{2m}\text{®}_j + \sum_{s\in S} a_{sm}D_{sj} + b_{1m}I_{1j} + b_{2m}I_{2j} + b_{3m}I_{3j} + \text{£}_{jm}$$

where m = {EU only, extra EU only, both EU and extra EU} and each outcome is compared to the no exporting group.

Before applying our methodology of complementarity testing to Model 1 and Model 2, exogenous logit estimates for both specifications (9) and (10) are presented in table 11. First of all, the positive link between productivity and exporting is confirmed. The coefficients on the productivity are positive and highly significant. More productive firms are more likely to export. For what concerns innovations the coefficient on the product innovation is for all firms positive and highly significant at the 1 percent. Firms that adopt product innovations are more likely to export. Going into details, the coefficient on product innovation is still positive and strongly significant for manufacturing and services firms and for firms of small and medium size.. Process and organizational innovations, instead, don't seem to have effects on the likelihood of firms' exporting. In fact, results show a positive significant coefficient only on process innovation for large firms[19]. The negative and peculiar result concerning organizational innovation for service (negative and highly significant at the 1 percent) is not robust, since it is not confirmed when sub-samples of exporters by size and macro sectors are considered.

Results on innovations are quite in line with what already emphasized by the literature (Becker and Egger, 2013; Caldera, 2010; Cassiman et al., 2010) that the effects of product innovations appear to weight more on exporting than those of other kinds of innovation. The stronger effects of product innovation may be explained as a necessary step which a firm has to deal with in order to serve foreign markets. Actually, firms do have to adjust their products to foreign markets regulations or to meet foreign demand and to differentiate from foreign competitors. On the other hand, process and organizational innovations imply firms' cost advantages that can have effects not so much on the likelihood of exporting but rather on the probability of surviving in foreign markets.

However, as previously highlighted (table 9), large percentages of exporters (both E_B and E_{EU}) adopt also process and organizational innovations in our sample. Moreover, data in table 9a show that the largest share of exporters (both E_B and E_{EU}) adopt all three forms of innovation jointly. We believe that the relationship between innovation and export deserves a deeper analysis.

More specifically, we next scrutinize if a relationship of complementarity among the three kinds of innovation exists when exporting is the firm's objective function.

3.3 Results on testing complementarity among innovation practices

[19] Results on the two subsets of exporters (E_{EU} and E_B), available upon request, do not appear significantly different.

In this section, we apply the testing procedure explained in sections 2.2-2.3 with the objective of evaluating the presence of complementarity among innovative activities for German firms.
Some preliminary checks have been performed. Data are heteroskedastic, therefore robust estimates have been calculated for all methods. To test the existence of endogeneity in non-linear models for export propensity, two methodologies have been applied as detailed in section 2.3: Rivers-Vuong two stage test and the test on coefficients of the latent factors in MSL estimates. Endogeneity of innovation variables is supported in many cases by both methods. The choice of the instruments used in PSM and MSL approaches has been driven by the application of under-identification LM and Hansen-Sargan tests. All instruments come from the CIS4 data set.
When assuming exogenous innovation practices, for each couple of complementarity constraints, we estimate the constrained (exogenous) logit model (Model 1) and test them by bootstrapping. It is also checked the presence of substitutable innovation practices by replacing the ≥ sign by the ≤ sign in all inequalities. As to Model 2 with multiple market destinations (exogenous multinomial logit model), the same methodology is applied for each exporting strategy. Summary results are reported in table 11.
When assuming endogenous innovation practices, complementarity results are obtained by propensity score matching (PSM) and maximum simulated likelihood (MSL) methods. They are calculated in terms of average treatment effects (ATE), that is differences between the probability of exporting, conditional on having received a complex innovation treatment, and the probability of exporting of the untreated group. As to the PSM approach, we apply radius matching, where each treated firm is compared to all firms within a radius equal to 0.05 around its propensity score. Robustness of the method is checked by considering a smaller radius and alternative matching estimators (nearest-neighbor and kernel matching) in the sensitivity analysis. Imbalance is also tested. Results for PSM effects are reported in table 13 and for MSL in table 14.
Our analysis confirms what already emphasized by the literature (Caldera, 2010; Cassiman et al., 2010): the adoption of innovation strategies by a firm improves its probability of exporting. Moreover, while previous works have identified product innovation as the main driver of firms' probability of exporting, our analysis gives more details of the relationship between firms' innovation and exporting. In fact our results confirm our preliminary intuition that the coexistence of different innovation strategies in exporting firms suggests the presence of various complementarities: exporters tend to adopt two or more practices together because their joint adoption leads to a higher probability of exporting than the sum of the probability from their individual adoptions.
This result is particularly robust with respect to all the three methods used in the econometric analysis for what concerns large manufacturing firms that export to both EU and extra EU markets. As shown in table 12, for this subset of firms complementarities is found, through the bootstrapping method, between product and process innovations, between product and organizational innovations and between process and organizational innovations These results are then confirmed also by the analysis conducted through PSM and MSL methods (see tables 13 and 14), which consider the endogeneity of innovation variables, but that are less direct than the bootstrapping, since the comparison is made between the two alternatives: complex innovation versus simple innovation options.
The robust result confirms also our second intuition, that is firms that bear higher fixed costs of exporting, because of the higher number of foreign markets they serve (Melitz, 2003), exploit complementarities among innovation strategies in a deeper way than the other firms. In fact, as relationships of complementarities are frequent for manufacturing firms exporting two both EU and extra EU markets[20], it is almost absent for manufacturing firms exporting to EU markets only, for

[20] For manufacturing firms exporting to both EU and extra EU markets, besides the one already mentioned of the large firms, another case of complementarity is found through the bootstrapping method and confirmed by MSL estimates, and concerns process and organizational innovations in small firms.

which complementarity arises, through bootstrapping and confirmed by MSL average treatment effect estimates, only between product and process innovations in large firms (see tables 12 and 14). Still dealing with manufacturing firms relationships of substitutability arise more frequently for firms exporting to EU markets only than for firms exporting to both EU and extra EU markets, and concern product/process innovations and product/organizational innovations in small firms[21]. For this subset of firm the two kinds of innovation are maybe considered as substitute pathways for investment spending and small manufacturing exporters to EU markets channel their investment spending into only one of the innovation strategies.

4. Conclusions

The main message of our study is that product, process and organizational-marketing innovations jointly matter for firms' export propensity. The issue of complementarity is addressed theoretically by studying the properties of supermodular functions and exploring firms' heterogeneity by export destinations.

Using data from CIS4, we show that heterogeneous incentives of exploiting complementarity among German firms' innovation practices emerge by export destinations and when size and sector specific conditions are satisfied. Specifically, large firms belonging to manufacturing sector (which are the most) exploit complementarity among all three forms of innovation. Furthermore, export strategies oriented to multiple market destinations require a stronger coordination among innovation activities. In fact evidence of complementarity relationship is found particularly for firms that export in both intra and extra EU markets.

Our proposed econometric strategy considers either exogenous or endogenous innovations variables in the model specification of export propensity. The main advantage of using bootstrapping hypothesis testing in the former case and PSM/MSL average treatment effects in the latter one is the possibility to apply it to large data sets. As a further step of our future research, we are interested in considering other approaches for the treatment of endogenous discrete regressors in non linear models, such as Deb and Trivedi (2006) and Information Theory estimators.

[21] These results are obtained through the bootstrapping method and do not suffer from endogeneity problems.

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Table 1: Export and Innovation data description

		Exporters		*Product innovation*		*Process innovation*		*Organiz/marketing innovation*	
	Nace rev. 1.1 sectors	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
	C	33	0.81	18	0.44	18	0.44	26	0.64
Manufacturing	DA	77	1.90	84	2.07	69	1.70	100	2.47
	DB	30	0.74	60	1.48	47	1.16	68	1.68
	DC	7	0.17	11	0.27	9	0.22	8	0.20
	DF_DG	59	1.46	160	3.95	123	3.03	153	3.77
	DH	41	1.01	92	2.27	74	1.83	108	2.66
	DI	39	0.96	59	1.46	40	0.99	57	1.41
	DK	39	0.96	215	5.30	149	3.68	205	5.06
	DL	111	2.74	358	8.83	230	5.67	310	7.65
	DM	24	0.59	108	2.66	95	2.34	124	3.06
	DN	38	0.94	58	1.43	46	1.13	64	1.58
	20_21	59	1.46	64	1.58	66	1.63	76	1.87
	22	86	2.12	64	1.58	75	1.85	99	2.44
	27	17	0.42	50	1.23	64	1.58	64	1.58
	28	121	2.98	141	3.48	141	3.48	161	3.97
	E	155	3.82	41	1.01	64	1.58	108	2.66
Services	51	132	3.26	66	1.63	56	1.38	111	2.74
	60_61_62	133	3.28	62	1.53	63	1.55	100	2.47
	63	67	1.65	47	1.16	44	1.09	66	1.63
	64	64	1.58	36	0.89	35	0.86	49	1.21
	72	97	2.39	125	3.08	83	2.05	118	2.91
	73_74	454	11.20	244	6.02	211	5.20	368	9.08
	J	193	4.76	143	3.53	140	3.45	170	4.19
	Total	**2,076**	**51.21**	**2,306**	**56.88**	**1,942**	**47.90**	**2,713**	**66.92**

Sector description is reported in table A1 in Appendix

Table 2: Export data, all sectors

	total sample		*size04=0*		*size04=1*		*size04=2*	
	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Exporting firms	1978	48.79%	567	36.18%	651	51.42%	760	62.24%
Non exporting firms	2076	51.21%	1000	63.82%	615	48.58%	461	37.76%
Total	4054	100%	1567	100%	1266	100%	1221	100%

Table 3: Innovation data, all sectors

	total sample		*size04=0*		*size04=1*		*size04=2*	
	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Product	2306	56.88%	707	45.12%	678	53.55%	921	75.43%
Process	1942	47.90%	528	33.69%	559	44.15%	855	70.02%
Organizational and marketing	2713	66.92%	871	55.58%	826	65.24%	1016	83.21%
At least one of the 3	3341	82.41%	1163	74.22%	1037	81.91%	1141	93.45%

Table 4: Export data, manufacturing

	total sample		*size04=0*		*size04=1*		*size04=2*	
	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Exporting firms	1599	68.13%	384	47.23%	552	72.06%	663	86.33%
Non exporting firms	748	31.87%	429	52.77%	214	27.94%	105	13.67%
Total	2347	100%	813	100%	766	100%	768	100%

Table 5: Export data, services

	total sample		*size04=0*		*size04=1*		*size04=2*	
	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Exporting firms	317	25.08%	164	26.28%	81	22.50%	72	25.71%
Non exporting firms	947	74.92%	460	73.72%	279	77.50%	208	74.29%
Total	1264	100%	624	100%	360	100%	280	100%

Table 6: Innovation data, manufacturing

	total sample		*size04=0*		*size04=1*		*size04=2*	
	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Product	1524	64.93%	420	51.66%	462	60.31%	642	83.59%
Process	1228	52.32%	294	36.16%	361	47.13%	573	74.61%
Organizational and marketing	1597	68.04%	452	55.60%	503	65.67%	642	83.59%
At least one of the 3	2026	86.32%	633	77.86%	654	85.38%	739	96.22%

Table 7: Innovation data, services

	total sample		*size04=0*		*size04=1*		*size04=2*	
	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)	Frequency	Percentage (%)
Product	580	45.89%	251	40.22%	157	43.61%	172	61.43%
Process	492	38.92%	197	31.57%	133	36.94%	162	57.86%
Organizational and marketing	812	64.24%	354	56.73%	228	63.33%	230	82.14%
At least one of the 3	969	76.66%	450	72.12%	273	75.83%	246	87.86%

Table 8: Productivity levels of exporters and innovators, by sectors

	All sectors		**Manufacturing**		**Services**	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Exporters	0.47	2.09	0.48	2.07	0.32	2.00
Non-exporters	-0.45	2.01	-1.03	1.79	-0.11	1.99
Innovators	0.35	2.17	0.31	2.12	0.40	2.17
Non-innovators	-0.78	1.70	-0.99	1.72	-0.55	1.59
All firms	0	2.10	0	2.11	0	2.00

Table 9: Innovation and exporting by market destination (frequency and percentage)

	Total	**No innovation**	**Product**	**Process**	**Org/marketing**
All firms	4054	713	2306	1942	2713
Exporters	1978	211	1385	1098	1432
EU only	*748*	*107*	*456*	*373*	*505*
Extra-EU only	*115*	*16*	*75*	*50*	*77*
Both	*1115*	*88*	*854*	*675*	*850*
Non-exporters	2076	502	921	844	1281
All firms	100%	17.59%	56.88%	47.90%	66.92%
Exporters	100%	10.67%	70.02%	55.51%	72.40%
EU only	*100%*	*14.30%*	*60.96%*	*49.87%*	*67.51%*
Extra-EU only	*100%*	*13.91%*	*65.22%*	*43.48%*	*66.96%*
Both	*100%*	*7.89%*	*76.59%*	*60.54%*	*76.23%*
Non-exporters	100%	24.18%	44.36%	40.66%	61.71%
Difference between Exp and Non-exp		*-13.51%*	*25.66%*	*14.86%*	*10.69%*

Table 10: Innovation strategies (frequency in numbers and %), (rif. Table 2 Mohnen-Roller 2005 EER)

	Total	000	001	010	100	110	101	011	111
All firms	4054	713	551	132	283	213	565	352	1245
Exporters	1978	211	186	59	159	117	324	137	785
EU only	*748*	*107*	*92*	*26*	*55*	*55*	*121*	*67*	*225*
Extra-EU only	*115*	*16*	*16*	*4*	*10*	*8*	*23*	*4*	*34*
Both	*1115*	*88*	*78*	*29*	*94*	*54*	*180*	*66*	*526*
All firms	100.00%	17.59%	13.59%	3.26%	6.98%	5.25%	13.94%	8.68%	30.71%
Exporters	100.00%	10.67%	9.40%	2.98%	8.04%	5.92%	16.38%	6.93%	39.69%
EU only		*14.30%*	*12.30%*	*3.48%*	*7.35%*	*7.35%*	*16.18%*	*8.96%*	*30.08%*
Extra-EU only	*100.00%*	*13.91%*	*13.91%*	*3.48%*	*8.70%*	*6.96%*	*20.00%*	*3.48%*	*29.57%*
Both	*100.00%*	*7.89%*	*7.00%*	*2.60%*	*8.43%*	*4.84%*	*16.14%*	*5.92%*	*47.17%*

Table 11: Marginal effects of product, process and organizational/marketing innovations

		Export			EU market only (E_{EU})			EU and extra EU markets (E_B)		
		product	process	organiz	product	process	organiz	product	process	organiz
All data		0.120***	-0.009	0.008	0.053**	-0.004	0.005	0.056***	-0.0003	0.004
		0.032	*0.031*	*0.032*	*0.024*	*0.023*	*0.024*	*0.018*	*0.017*	*0.018*
Manufacturing		0.130***	-0.010	0.034	0.023	-0.005	0.021	0.110***	0.001	0.004
		0.037	*0.037*	*0.038*	*0.032*	*0.031*	*0.032*	*0.031*	*0.029*	*0.032*
Services		0.099**	-0.010	-0.003***	0.057*	-0.008	0.0003	0.027	0.002	0.004
		0.044	*0.041*	*0.039*	*0.034*	*0.030*	*0.029*	*0.027*	*0.025*	*0.023*
Manufacturing										
	small firms	0.142***	-0.024	0.031	0.051	-0.008	0.036	0.094***	-0.017	-0.025
		0.049	*0.051*	*0.049*	*0.040*	*0.041*	*0.038*	*0.035*	*0.033*	*0.033*
	medium firms	0.115**	-0.016	0.017	0.008	-0.038	-0.002	0.110**	0.028	0.028
		0.045	*0.045*	*0.047*	*0.045*	*0.045*	*0.051*	*0.052*	*0.052*	*0.057*
	large firms	0.010	0.080**	-0.016	-0.067	0.039	-0.126*	0.083	0.052	0.110
		0.034	*0.034*	*0.032*	*0.064*	*0.051*	*0.067*	*0.068*	*0.058*	*0.069*
Services										
	small firms	0.099*	0.003	-0.008	0.061	-0.001	-0.001	0.027	0.009	0.005
		0.055	*0.051*	*0.047*	*0.043*	*0.038*	*0.034*	*0.031*	*0.031*	*0.026*
	medium firms	0.095	-0.051	-0.019	0.059	-0.019	-0.014	0.016	-0.028	-0.009
		0.063	*0.052*	*0.056*	*0.050*	*0.040*	*0.044*	*0.039*	*0.032*	*0.033*
	large firms	0.016	0.011	0.082*	-0.001	-0.001	0.003	0.002	-0.006	0.026*
		0.053	*0.055*	*0.045*	*0.004*	*0.004*	*0.003*	*0.019*	*0.019*	*0.015*

Logit estimates; *** 1%, ** 5%, * 10% significant coefficients; standard errors in italics

Table 12: Tests on complementarity/substitutability, bootstrapping for exogenous logit

		Exports			EU market only (E_{EU})			EU and extra EU markets (E_B)		
		product &process	product &organiz	process &organiz	product &process	product &organiz	process &organiz	product &process	product &organiz	process &organiz
Manufacturing										
	small firms	x			x	x		x		x
	medium firms									
	large firms	x		x	x			x	x	x
Services										
	small firms	x			x					x
	medium firms	x			x		x	x		
	large firms	x				x	x		x	x

Substitutability	x (5%)
Complementarity	x (5%)
No significant relationship	

Table 13: Tests on complementarity/substitutability, propensity score matching results

		Exports			EU market only (E_{EU})			EU and extra EU markets (E_B)		
		product &process	product &organiz	process &organiz	product &process	product &organiz	process &organiz	product &process	product &organiz	process &organiz
Manufacturing										
	small firms		10%	x			x			
	medium firms	10%	10%	x			x	10%	x	
	large firms	x		x		10%		x	x	x
Services										
	small firms								x	
	medium firms						x			
	large firms									

Table 14: Tests on complementarity/substitutability, MSL results

	Exports			**EU market only (E_{EU})**			**EU and extra EU markets (E_B)**		
	product &process	product &organiz	process &organiz	product &process	product &organiz	process &organiz	product &process	product &organiz	process &organiz
Manufacturing									
small firms	x	x	x	x			x		x
medium firms	x	x	x	x	x	x		x	x
large firms	x	x	x	x	x	x	x	x	x
Services									
small firms	x	x	x	x		x		x	
medium firms			x		x	x		no conv	x
large firms	no conv	no conv		x			x		

Appendix

Table A1: Description of NACE rev. 1.1 sectors

	Sectors	Description
	C	Mining and quarrying
Manufacturing	DA	Food products, beverages and tobacco
	DB	Textiles and textile products
	DC	Leather and leather products
	DF-DG	Coke, refined petroleum products and nuclear fuel; chemicals, chemical products and man-made fibres
	DH	Rubber and plastic products
	DI	Other non-metallic mineral products
	DK	Machinery and equipment n.e.c.
	DL	Electrical and optical equipment
	DM	Transport equipment
	DN	Manufacturing n.e.c.
	20-21	Wood and of products of wood and cork, except furniture; articles of straw and plaiting materials; pulp, paper and paper products
	22	Publishing, printing and reproduction of recorded media
	27	Basic metals
	28	Fabricated metal products, except machinery and equipment
	E	Electricity, gas and water supply
Services	51	Wholesale trade and commission trade, except of motor vehicles and motorcycles
	60-61-62	Land transport; transport via pipelines; water transport; air transport
	63	Supporting and auxiliary transport activities; activities of travel agencies
	64	Post and telecommunications
	72	Computer and related activities
	73-74	Research and development; other business activities
	J	Financial intermediation