Knowledge Base, Exporting Activities, Innovation Openness and Innovation Performance: A SEM approach towards a unifying framework

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Abstract

In this paper we demonstrate that the role of innovation openness ought to be highlighted within a unified framework, as it is considered an additional activity of firms' knowledge creation strategy. In this line, innovation and exporting orientation are ruled by the firms' strategic mix comprised of internal knowledge creation processes and the diversity of innovation openness. Theoretical and empirical links between these major components are identified and measured employing a Structural Equation Modelling (SEM) approach on a sample of Greek R&D active manufacturing firms. Empirical findings corroborate the complexity of relationships and indicate that the firms' knowledge base and open innovation strategy regulate via complementary and substitution relationships firms' innovation and export performance.

Keywords: SEM, latent variables, endogeneity, open innovation strategy, knowledge base, innovation performance, export performance

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1. Introduction

The relevant literature has established that knowledge creation processes and internationalization are interrelated (Love and Ganotakis, 2013). One key finding has been that indeed export and knowledge creation are endogenously related (Harris and Li, 2009; Gkypali et al, 2012) and that R&D active firms endogenously self select into international markets. The mechanism upon which this endogenous relationship is based, relates with the creation and expansion of the firms' technological capabilities and in extension their knowledge base. In other words, internationalization activities as they are captured by exporting activities positively affect the firms' processes of creating and acquiring new technological competencies and capabilities.

At the same time, another parallel strand of research is interested in investigating the relationship between firms' external sources of knowledge and innovation performance (Laursen and Salter, 2006). In particular, empirical findings suggest that the decision to cooperate and the intensity of collaborations in R&D activities, exerts a positive influence on innovation performance (Cassiman and Veugeleurs, 2002; Belderbos et al, 2004; Abramovsky et al., 2009). However, researchers have been mostly focused in investigating one way this relationship, and as a result, the findings so far may not have captured the complete framework in which this relationship operates. *In particular, and provided that innovation openness contributes both in building the firm's knowledge base as well as in extending the international orientation of the firm, it could be argued that there may be complex a relationship between innovation openness, knowledge base, internationalization and innovation performance*. More specifically, external sources of knowledge may complement the already existing knowledge base and influence positively the outcome of innovation process itself. In turn, successful innovation outcomes may reinforce the search for external search for knowledge sources (Becker and Dietz, 2004) by making the firm more attractive to potential R&D collaborators.

Furthermore, innovation openness may be related to firms' knowledge in the sense that it results in an increase of the incoming knowledge spillovers and the required investments for the successful implementation of R&D collaborations. However, such a knowledge base expansion increases the likelihood to adopt a more

extensive search strategy for external knowledge sources that are either complementary and/or substitutes to the already existing internally to the firm. On the other hand, innovation openness could be related with internationalization-of-production activities, since potential R&D collaborators may either be found outside domestic markets and/or be directly or indirectly linked with firm's exporting activities.

This paper is concerned *with investigating reciprocal relationships by incorporating them in a unifying conceptual framework which would include firm's (i) knowledge base formation, (ii) export performance, (iii) innovation openness and (iv) innovation performance.* The development and empirical analysis of this unifying conceptual framework is the main contribution to literature of this paper. Theoretical and empirical links between these major components are identified and measured. More specifically, the knowledge creation processes as they have been captured by firms' knowledge base components and their external search strategy for R&D collaborations have been 'paired' with the firms' internationalization performance and innovation performance respectively. Another level of complexity is added when the dual role of innovation openness as both a means of knowledge creation and internationalization is considered. In other words, innovation openness may also be linked with internationalization performance, while knowledge base may very well be linked with innovation performance. *Therefore, it is argued that these relationships are all part of the firms' complex strategy for living up to the challenges of the regional, national and global business interface, and as such they are interrelated.* This complexity translates into a non-recursive system of equations which are modeled with the use of the Structural Equation Modeling (SEM) approach. In order to identify the relationships between these four key variables, a sample of Greek R&D active manufacturing firms that came as a result of a field research, is employed.

The rest of this paper is organized as follows; Section 2 reviews the relevant literature on the relationships between R&D active firms' knowledge base, innovation openness, export orientation and innovation performance, formulating testable hypotheses in the context of an extended structural model of the four abovementioned entrepreneurial modules. Section 3 presents data employed for the approximation of latent variables as well as the control variables in the regression equations. Section 4 is devoted in presenting and discussing the estimation results and Section 5 concludes this paper.

2. Literature Review and Hypotheses Formulation

2.1. Framing the relations between knowledge base, open innovation strategy (R&D collaboration) and innovation performance

2.1.1 Open innovation (R&D collaboration) affecting knowledge base

The discussion about the sources from which business entities draw valuable insights in the context of their innovative activities dates since the famous demand pull – technology push hypotheses (Schmookler, 1966; Dosi, 1988). These hypotheses acknowledge two major pools capable of providing the required potential for innovation, that of the demand side and that of technological advancement itself. In this line, a multidimensional research direction has emerged aiming at identifying more precise sources of innovation. In 1988, Eric von Hippel published the book '*Sources of Innovation*' which was the first systematic effort to document the influence of external factors in the innovation process. Based on several case studies, von Hippel identified three main categories within the innovation process i.e. the *users*, the *manufacturers* and the *suppliers*, and each firm can belong simultaneously in more than one category. A further acknowledged important source of innovation-relevant knowledge is public research done in institutions of higher education and public research organizations (e.g., Cohen et al. 2002).

In this context, innovation process is perceived as a process that the case, where a firm seeks for stimuli outside its boundaries, is usually the norm rather than the exception (Drucker, 1985). More recently, Chesbrough (2003), coined the notion of innovation openness which is defined as *"…. a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as firms look to advance their technology…"*. Since then, research has spurred on the subject of identifying sources and partners for innovation and has showcased that firms' innovation activities entail cooperation with Universities, suppliers, consumers and even with competitor firms (Belderbos, 2004a, 2004b; 2006). R&D collaborations have been the primary object of research investigation in a number of estimable research outputs either investigating the determinants of the decision to cooperate in R&D or the impact of such cooperation on innovation performance. In other occasions, the research focus was shifted towards distinguishing external and internal factors that influence R&D activities and their outputs.

More relevant for the research question, which is our concern in this section, namely the influence of R&D collaborations on a firm's knowledge base, is the literature on the *knowledge-oriented motives* of R&D collaborations that considers R&D cooperation as an important knowledge acquisition strategy. A first strand of this literature, namely the industrial organization approach, is primarily of theoretical nature. One of the most influential papers in this field is that of D'Aspremont and Jacquemin (1988). According to this approach, the main motive for R&D cooperation is the internalization and better utilization of knowledge that is easily leaking out to competitors in the framework of a cooperation contract. A generalization of them framework of D'Aspremont and Jacquemin (1988) is found in Kamien et al. (1992) and Kamien and Zang (2000), but the main motive of collaboration remains the same as in the original paper, namely the internalization of knowledge externalities.

The second strand of literature dealing with the motives of R&D collaboration is part of management literature. A particular approach in this literature emphasizes resources and capabilities building on the resource-based view of the firm originally developed by Penrose (1959) and further developed by Teece (1982; dynamic capabilities approach) and Prahalad and Hamel (1990; core competences concept). In this view, technological alliances are effective organizational modes for gaining access to new and/or complex technologies as additional resources. Hagedoorn (1993) in a survey of management literature on technology partnering, develops a taxonomy of cooperation motives distinguishing between (a) motives related to basic and applied research, (b) motives related to concrete innovation projects in a joint activity of firms, and (c) motives related to market access and search of opportunities. Groups of motives (a) and (b) are closely associated with our research question because they refer primarily to the increased complexity of new technologies, monitoring of evolution of technologies and technology synergies.

In sum, it can be argued that R&D collaborations are part of the overall innovation strategy of the firm which aims at augmenting its internal competencies and capabilities, i.e. its knowledge base, by creating pathways outside its boundaries to other knowledge and innovation stimuli (Gassmann and Enkel, 2004). Based on the above the following hypothesis is formed:

H_1: Firm's open innovation strategy (R&D collaborations) positively affects its knowledge base

2.1.2 Open innovation strategy (R&D collaboration) and innovation performance: a two-way relationship

A complementary strand of research in R&D cooperation is occupied with investigating the impact of R&D collaborations, which is also referred as innovation openness, on firms' innovation performance. In this sense, an open attitude towards innovative activities essentially depicts a search strategy for external sources that complement internal competencies and capabilities (Dahlander and Gann, 2010). The importance of complementarities with respect to innovation performance between internal and external sources, whether they refer to strategies (Belderbos et al. 2004a; Laursen and Salter, 2006), products (Roller et al., 1997) or technological knowledge sourcing (Piga and Vivarelli, 2003; Cassiman and Veugelers, 2006) is particularly emphasized in this literature strand.

In this respect, the existing empirical literature refers primarily to European countries. The research setting consists mostly of an innovation equation, which contains, among other innovation-relevant variables, measures of innovation cooperation, often differentiated by partner category. A number of studies have found a positive impact of R&D collaboration on innovation performance usually measured by the sales share of innovative products (e.g., Lööf and Heshmati, 2002; Belderbos et al., 2004). Further studies with positive effects of innovation cooperation on innovation performance measured by different indicators can be found in Czarnitzki et al. (2007) for German and Finnish firms, and Simonen and McCann (2008) for Finnish firms. Other studies have found little or no evidence for a significant correlation between cooperation and innovation performance as measured by output indicators (e.g., Kemp et al. 2003; Okamuro 2007; Aschhoff and Schmidt 2008).In addition, there is a tendency for cooperation propensity to correlate positively with input but not with output innovation indicators (e.g., Klomp and Van Leeuwen 2001). Overall, there is a relatively large heterogeneity of results, but nevertheless a general tendency for positive effects of cooperation on innovation performance is also discernible. It should be noted that the relationship between innovation performance and innovation openness has been mainly explored under the scope of one way causality and more specifically, it has been hypothesized that innovation openness influences -exogenously and positively- the firm's innovation performance. In line with this finding we aim at testing the following hypothesis:

H_{2a}: Firms' open innovation strategy (R&D collaborations) positively affects their innovation performance

However, it is not highly unlikely to assume that there might be lurking a two way relationship between innovation openness and innovation performance. In particular, Tether (2002) finds in a study based on British CIS-2 data that firms that engage in R&D and attempt to introduce higher level innovation are much more likely to engage in cooperative arrangements for innovation than other firms. Becker and Dietz (2004) empirically investigate the role of innovation openness, as captured by R&D collaborations, in the innovation process both with respect to the input and the output side in a simultaneous equation framework. They find empirical evidence based on German firm data that R&D cooperation significantly enhances both in-house R&D and innovation output (as measured by the realization of product innovations), but also that the other causality works, at least with respect to the intensity of in-house R&D, which seems to significantly stimulate the probability (and the number) of joint R&D activities with other firms and institutions. Therefore, it can be assumed that the relationship between innovation openness and performance has a two way causality which forms the next testable hypothesis:

H_{2b}: Firm's innovation performance positively affects open innovation strategy (R&D collaborations)

With respect to the rest of the determinants of innovation performance, special attention has been given to the influence of the firm's knowledge base on its innovative output, as the latter is composed from both internal capabilities and external knowledge sources (Klevorick et al., 1995; Lööf and Heshmati, 2002). More specifically, in a detailed empirical investigation of seven European Countries, Caloghirou et al. (2004) demonstrate that internal capabilities in conjunction with external sources of knowledge affect innovation performance of European firms. In the same line, Vega-Jurado et al. (2008) provide empirical evidence that the firm's competencies and capabilities pose as the most important determinants of its innovative performance. In line with the previous empirical findings we test the following hypothesis:

H_3: Firm's knowledge base positively affects their innovation performance.

2.2. The role of internationalization in shaping the firm's knowledge base, open innovation strategy (R&D collaboration) and innovation performance

The role of exporting performance has been highlighted as an important determinant throughout firms' innovation process. It has been found to contribute in firms' knowledge base expansion (Harris and Li, 2009; Gkypali et al., 2012) but also in firms' innovation performance (Kafouros et al., 2008; Aw et al., 2008; Ganotakis and Love, 2011).

2.2.1 Exporting performance and knowledge base: a two-way relationship

With respect to the innovation input side, the empirical findings have been closely associated with the two well-known hypotheses of '*self selection*' and '*learning by exporting*' and in some cases the existence of a two-way (endogenous) relationship between exporting and innovation activities has been highlighted (Harris and Li, 2009; Gkypali et al., 2012). The presence of endogeneity suggests that exporting activities do not only serve as a proxy for the international competition and the firm's competitiveness but also as a channel for knowledge and technology transfer. In other words, exporting activities offer the firm the ability to expand its knowledge base by expanding its market share. Hence, following the empirical findings which suggest that export performance is endogenously related with the firms' internal knowledge base, as the latter is comprised by competencies and capabilities, we test the following hypotheses

H_{4a}: Firms' knowledge base positively affects their exporting performance

H_{4b}: Firms' exporting performance positively affects their knowledge base.

2.2.2 Exporting performance and innovation performance: a two way relationship

Shifting the attention towards the relationship between innovation outputs and exporting activities, the empirical literature also suggests that exporting activities are related with firms' innovation performance. More specifically, export performance and other internationalization modes are perceived as another component in firm's strategy that entrepreneurs should pursue, in the case they seek for augmenting their returns from innovation and experience growth (Kylaheiko et al. 2011). More specifically, exposure to the international markets extends the pool of new ideas, know-how and other important resources from which the firm can draw the necessary elements for its innovation process (Korbin, 1991; Kafouros et al., 2008). Furthermore, as Kotabe et al. (2002) note, selling to more than one geographical locations allows firms to charge premium prices for their products thus, spreading the costs and allowing the firm to expand its appropriating returns over innovation investments. It could also be suggested that innovation performance influences export performance since it is the outcome of firms' efforts to diversify, compete and distinguish themselves from competitors and create or sustain their competitive advantage. Hence the following hypotheses are formed:

H_{5a}: Firms' innovation performance positively affects their exporting performance

H_{5b}: Firms' exporting performance positively affects their innovation performance

2.2.3 Exporting performance and open innovation strategy (R&D collaboration)

Interestingly enough, the relationship between firms' open innovation and internationalization strategies has been less investigated. Within this context, export performance and other internationalization modes are treated as another component in firms' strategy which is complementary to their open innovation strategy (Haathi et al., 2005). Recently, Johanson and Vahlne (2009) provided an extension of their early theoretical framework analyzing firms' internationalization process, adopting a network view on international markets. More specifically, international markets are perceived as networks of relationships where business entities are linked to each other with several paths and modes. Thus, being an active member of this network of relationships offers the potential for learning from various sources (Dyer and Singh,

1998) and at the same time serves as a necessary condition for implementing a successful internationalization strategy. Therefore, firms that are open to innovative ideas are likely to perform well in exporting (Leonidou, 1998; Stottinger and Holzmuller, 2001; Calantone et al., 2006). On the other hand, it might be the case that firms' exporting activities influence positively firms' open innovation strategy since they act as an antecedent of the capability of learning to exploiting knowledge sources from the external environment. Towards the same direction, the reduction of coordination, search and transaction costs, on the basis of exploiting exporting competencies and networking for R&D collaborations purposes may are in operation. Thus,

H_6: Firms' exporting performance positively affects their open innovation strategy.

3. Data and method

3.1. Sample and Field Research

It needs to be made clear from the beginning that statistical data for Greek firms regarding innovation and exporting activities are not available either by the European Statistical authority (EUROSTAT) or by the National General Secretary for Research and Technology (GSRT). Hence, the adopted methodological strategy entailed firstly the identification of the target population and then the realization of a national level field research. The identification of the reference population was made based on published accounts of the Greek Manufacturing R&D active (GRD) firms for the period 2001-2010. More specifically, and for the ten-year reference period, the electronic database "i-mentor" has been employed in order to locate nationwide GRD firms that have included in their published financial accounts expenditures on R&D either as part of their assets and/or as part of their income statements. After data cleaning twenty four firms were excluded (3.35% in the total population) thus, leaving a population of 740 firms.

The field research was carried out during the second half of 2011. Members of the research team have come in contact with all the firms included in the population. Eventually, 316 firms replied reaching a response rate of 45%. All firms identified in the sample were called to complete a specially designed questionnaire which is composed of four sections. The first section was interested in depicting the general

economic environment within which the GRD firm operated. The second section involved questions regarding the GRD firms' exporting activities. More specifically, departing from the key question of export decision, a series of following questions regarding first year of export, export intensity, export volume growth, means of exporting, barriers to exporting as well as other means of internationalization were included. The third section entailed a series of thorough questions surrounding the Greek firms' R&D activities. In particular, it involved, among others, questions regarding the internal organization of R&D activities, as well as information about the innovative outcomes of these activities, along with potential barriers encountered in the process of conducting R&D. The fourth and final section of the questionnaire involved information about domestic and international cooperation in the context of the Greek firm's R&D activities.

Especially with respect to the third and fourth section of the questionnaire, and for the gathered information to be comparable with other European surveys on Innovation and in particular with Community Innovation Survey (CIS), the design of the questions was primarily based on the CIS standards. It should be mentioned that regarding the data (i) on R&D expenditures and other financial indicators from the electronic database for the period 2001-2010 and (iii) from the field research, provide comprehensive and up-to-date information about both R&D and exporting activities at the firm level for the entire Greek Manufacturing sector.

3.2. The measurement model and variables employed

In Structural Equation Modelling (SEM) analysis the main interest lies in testing the hypothesized causal relationships among structural parameters that are quite often *latent*. In this line, the measurement of the structural parameters plays a crucial role since a potential misspecification of the latent variables can affect the estimation of the structural model.

In order to 'construct' the latent variables an appropriate methodology is employed and specifically the confirmatory factor analysis (CFA) method. This method is used to study the dimensionality of a set of variables. In factor analysis, latent variables represent unobserved constructs which are comprised by a set of observed or response variables. With respect to Structural Equation Modeling, the CFA approach is more commonly employed because it is perceived as an inextricable part of building and testing a theoretical framework. The selection of the latent

variables indicators was carefully made based not only on what the relevant literature dictates as to what the appropriate indicators and proxies in each of the occasions may be but also on the availability of information. Table 1 below outlines the measurement model. Each of the latent variables is comprised of at least two observed variables.

Table 1. Operationalization of the measurement model

Latent Constructs	**Indicators** (y_i)	**Scale**	**Descriptive Statistics** **Average (St. Dev.)**	**Min (Max)**
Export Performance				
	Export Intensity	Ordinal (0-4)	1.433 (1.240)	-
	Export Growth (5yr)	Ordinal (0-2)	1,060 (0,912)	-
Knowledge Base				
	R&D stock	Continuous	0.115 (0.237)	0.000* (2.067)
	R&D Training	Binary	0.567 (0.496)	-
	In-house R&D	Binary	0.793 (0.406)	-
	External Knowledge acquisition	Binary	0.200 (0.401)	-
	R&D equipment purchase	Binary	0.767 (0.424)	-
Openness				
	R&D Collaborations within Greece	Continuous	0.340 (0.234)	0.000 (0.857)
	R&D Collaborations outside Greece	Continuous	0.124 (0.130)	0.000 (1.036)
Innovation Performance				
	Percentage of innovative Sales over total Sales	Continuous	0.422 (0.310)	0.000 (1.000)
	Percentage of innovative products over total range of products	Continuous	0.414 (0.313)	0.000 (1.000)

*actually smaller than 0.001

For constructing exporting performance, two economic measures have been opted as indicators, that of export intensity and export growth (Haathi et al., 2005). Export intensity is the most frequently employed variable in measuring export performance (Papadopoulos and Martin Martin, 2010) as it captures firm sales from its foreign activities as a percentage of its total sales. In addition, in order to include

an implicit dimension of time a categorical indicator of a five year export growth status has been also included.

For the approximation of the Greek R&D manufacturing firms' *knowledge base*, the framework of the 'knowledge based view of the firm' (Grant, 1996) has been a driving guide in this process. This framework is quite generic and argues that firms sustain their competitive advantage from their ability to learn. This premise is based on the firms' ability to identify and exploit knowledge sources. However, there is not a generally accepted approach to the measurement of knowledge intensity (Autio et al., 2000) and a consensus is yet to emerge (Toften and Olsen, 2003). Spender and Grant (1996) argue that traditional measures of knowledge creation such as R&D investments and patenting are problematic in capturing the heterogeneous sources of knowledge. For instance not all SMEs have distinct R&D departments and specially designated funds in conducting R&D. Furthermore, patents held by a firm may reflect a strategic stance rather than knowledge or innovation (Spender and Grant, 1996). Besides, patents may have an innovation output character confusing the analysis (Nagaoka et al., 2010). Based on these arguments, the latent construct of knowledge base is comprised of the traditional indicator of R&D stock indicator (Dierickx and Cool, 1989) but we have also included a set of binary variables intending to capture other potential knowledge sources. In particular, training activities, capital equipment, external knowledge and knowhow acquisition as well as the existence of in-house R&D activities (Caloghirou et al., 2004) serve as firms' knowledge sources in the context of their innovation activities.

The most common approximation method of R&D collaborations has been the use of a binary variable regarding firms' decision to cooperate (Abramovsky et al. 2009). Some other studies have adopted an index of the number of R&D collaborations thus, measuring the intensity of such activities (Becker and Dietz, 2004). Following Haathi et al. (2005) the latent variable is composed by two indices measuring the intensity of collaborations within Greece and outside Greece as the ratio of the number of cooperations within (outside) Greece to the total number of R&D collaborations. This geographical distinction further elevates the relationship between innovation openness and firm's internationalization performance.

Furthermore, innovation performance is composed of two main indicators of innovation outputs the first one being the ratio of sales of innovative products to the total firm sales; and the second one being the ration of innovative products to the total

range of firm products. These two indicators are in accordance with Oslo Manual (2005).

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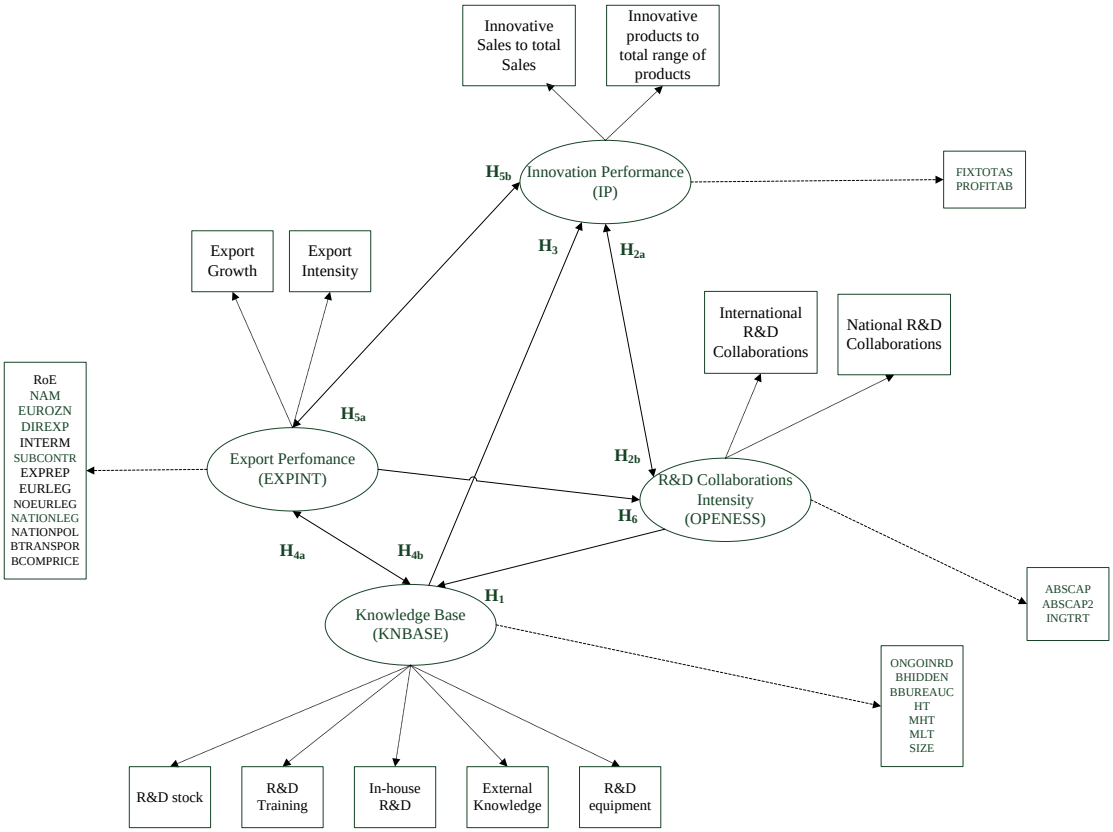
3.3 Model identification and heterogeneity

At this point it is worth mentioning that the complexity of the proposed structural relations among the latent variables demands additional covariates to be taken under consideration in the estimation process otherwise the model is not identified. In this line, a meaningful set of covariates have been included in each of the four equations to be estimated. In figure 2 below the full the-model is graphically depicted and summarized.

Fig. 2 The full model representing the measurement and structural model along with covariates



Regarding the determinants of *export performance,* the relevant literature has identified that the means of exporting influence the intensity of exports since direct and indirect modes of exporting are both associated with different kinds of benefits and risks (Salomon and Shaver, 2005; Acs and Terjesen, 2006). More specifically,

indirect export methods are associated with benefits such as reduction of risk and uncertainty whereas, they also include risks such as certain costs of operating abroad and lack of control of local representatives or intermediaries (Hessels and Terjesen, 2010). On the other hand, firms could benefit of direct exports in terms of increased profits from selling their products abroad and better control over the entire process, though this process takes up quite significant amount of firms' resources. In addition to the means of exporting, market destination of exports has been found to positively influence firms' export performance (Barrios et al., 2003; Gkypali et al., 2012). The decision of how many and which foreign markets the firm plans to penetrate is by far a lighthearted decision. On the contrary, it is a crucial part of its internationalization strategy and it is expected to affect its exporting performance (Cooper and Kleinschmidt, 1985; Beleska-Spasova et al., 2012). Last but not least, institutional and market barriers are expected to affect firms' export performance (Hessels and Terjessen, 2010; Moini, 1997).

In order to control for the heterogeneity among firms' *knowledge base* the sectoral technological intensity needs to be primarily taken into consideration (Clark and Griliches, 1984; Malerba, 2002). In addition, the effect of firm size (Cohen and Klepper, 1996) and has been found to exert mixed effects on firms' investment in knowledge base augmentation. It may also be the case that during the process of the knowledge base formation and augmentation, firms come across barriers that may disrupt or hamper their innovative activities (Skuras et al. 2008; D'Este et al., 2012). Therefore, barriers related to the innovation process itself may impact the ultimate knowledge base formation. Furthermore, firm specific characteristics related to profitability, internal distribution between tangible and intangible assets may control for heterogeneity related to operational business aspects (Skuras et al. 2008).

Turning to the determinants of *open innovation strategy*, firms' absorptive capacity has been considered widely from the relevant literature as an important determinant of firms' open innovation strategy (Laursen and Salter, 2006). In addition, the firm's degree of participation in foreign affiliates, is expected to play a role in determining an open attitude in R&D collaboration (De Faria et al., 2010). Finally, GRD firms' *innovation performance* is expected to be determined by its financial performance as well as the internal composition of assets employed in the production process (Skuras et al., 2008). In the appendix section a more detailed presentation of the employed covariates is provided.

4. Results and Discussion

4.1. The measurement model

The first step in SEM analysis is the construction of latent variables which is accomplished via the Confirmatory Factor Analysis (CFA). Table 2 below presents the estimation results of CFA. We have opted for weighted least squares with mean and variance adjusted (WLSMV) estimator (Muthen 1984, Muthen and Muthen, 1998-2014). This estimator is available only with the MPlus software. WLSMV is a limited information estimator and is considered to be the most appropriate for factor analytic models in which indicators are categorical since it allows for non-normality and it is asymptotically efficient (Browne, 1984)[1]. Table 2 is divided in four columns. Column (2) presents the unstandardized coefficients which represent the indicator loading on the Latent Variable (LV) factor. Column (3) in turn, presents the standardized loadings and column (4) presents the Latent Variables mean scores.

Table 2. Results on the measurement model with WLSMV and MLR estimator.

Latent variable /Indicators	Unstandardized loadings (WLSMV)	Standardized loadings (WLSMV)	LV mean (WLSMV)
(1)	(2)	(3)	(4)
Export Performance			*3.547*
EXPINT	1.000[2]	0.915	
	(0.000)	(0.030)*	
EXPGR	0.380*	0.653	
	(0.101)	(0.055)*	
Knowledge Base			*0.676*
TRAIN	1.000	0.658	
	(0.000)	(0.057)*	
RDSTOCK	0.089*	0.392	
	(0.021)	(0.053)*	

[1] As a robustness check the model has also been estimated with Maximum Likelihood with robust standard errors (MLR). Even though the ML estimator with Huber-White covariance adjustment provides robustness in the presence of non-normality and non-independence of observation, it treats all variables as continuous. Despite the fact that MLR is a full information approach (FIML) with the analogous computational burden, WLSMV estimator is a limited information method which allows it to avoid the computational burden of FIML. However, MLR supersedes WLMSV in terms of efficiency; nevertheless, the gains are quite small (Muthen and Muthen, 1998-2014). Empirical results are available upon request.

[2] By default the first indicator is set to one due to the fact that the CFA analysis needs to set a variance for the latent variable since the size of the loadings is scaled from the size of the variance.

INHOUSE	0.759*	0.595	
	(0.196)	(0.079)*	
EXTERNKN	0.449*	0.401	
	(0.124)	(0.079)*	
RDEQUIP	0.993*	0.695	
	(0.234)	(0.065)*	
Innovation Openness			*0.097*
RDCOOPFOR	1.000	0.993	
	(0.000)	(0.070)*	
RDCOOPGR	0.938*	0.517	
	(0.185)	(0.051)*	
Innovation Performance			*0.008*
INNSALES	1.000	0.821	
	(0.000)	(0.078)*	
INNPROD	0.878*	0.734	
	(0.181)	(0.072)*	

- One and two asterisks denote level of significance at 1% and 5% respectively.
- Standard errors are reported in parentheses

In order to examine the relationships among latent variables in the proposed structural model, firstly it is imperative to examine the fit of the measurement model. It becomes easily understood that a misspecification of the measurement model harms the validity of the subsequent structural relationships (Jarvis et al, 2003). For this purpose, the relevant literature has suggested the criteria of convergent and divergent validity using the Average Variance Extracted (AVE; Fornell and Lacker, 1981).

The value of AVE essentially indicates the variability of the set of the observed indicators within the latent variable and for the convergent validity criterion to be satisfied its value must be greater than 0.50. If the value of AVE is less than 0.50 then the set of observed indicators do not correlate with each other and thus the latent variable is not adequately explained by its observed indicators. For the examination of the divergent validity criterion, the AVE scores should be placed next to the latent variables correlation matrix as it is presented in Table 3.

Table 3. WLSMV results on intercorrelations between latent variables and convergent and divergent validity criteria

	AVE	*Export Performance*	*Innovation Performance*	*Innovation Openness*	*Knowledge Base*
Export Performance	**0.795**	-			
Innovation Performance	**0.779**	0.171	-		
Innovation Openness	**0.792**	0.427	0.028	-	
Knowledge Base	**0.572**	0.409	0.251	0.669	-

The divergent validity criterion is satisfied when the AVE score is greater than the correlations between latent variables. If this criterion is not satisfied then the latent variables indicators correlate more highly with indicators 'outside' the latent variable construct they are placed. In other words, it may be the case that the latent factor is better explained by some other indicators from a different latent variable than its own observed variables.

Results on the convergent and divergent validity criteria indicate that on the one hand the convergent criterion is easily fulfilled for all latent variables. With respect to the divergent validity criterion, results from Table 3 indicate that the criterion fails in the case of the latent variable capturing knowledge base since it is quite highly correlated with the latent variable capturing innovation openness $(r_{WLSMV} = 0.669)$.This may be due to the fact that R&D collaborations may be considered as a relative means for the firms' to sustain and augment their knowledge base (Grant, 1996). However, none of the correlations reached the benchmark limit of 0.85 for viably distinct factors (Kline, 2005) providing further evidence of divergent validity.

4.2. The structural model

The measurement model presented analytically above was extended in forming and estimating the structural model which was theoretically expressed in section two in the form of hypotheses and is summarized below in Table 4 while in Table 5 estimation results for the structural relationships are presented.

Table 4. Recapitulation of the hypothesized structural model

Independent Variables / Dependent Variables	*Knowledge Base*	*Innovation Openness*	*Innovation Performance*	*Export Performance*
Knowledge Base		**H_1**		**H_{4b}**
Innovation Openness			**H_{2b}**	**H_6**
Innovation Performance	**H_3**	**H_{2a}**		**H_{5b}**
Export Performance	**H_{4a}**		**H_{5a}**	

Table 5. Estimation results of the structural model

	Unstandardized coefficients (1)	Standardized coefficients (2)
Knowledge Base		
Innovation Openness **(H_1)**	3.237*	0.403*
	(1.252)	(0.123)
Export Performance **(H_{4b})**	0.012	0.029
	(0.048)	(0.112)
Innovation Openness		
Innovation Performance **(H_{2b})**	0.377	0.797
	(0.166)**	(0.324)**
Export Performance **(H_6)**	0.012***	0.221**
	(0.006)	(0.110)
Innovation Performance		
Innovation Openness **(H_{2a})**	-2.612*	-1.236*
	(0.960)	(0.408)
Knowledge Base **(H_3)**	0.176**	0.668*
	(0.072)	(0.236)
Export Performance **(H_{5b})**	0.036***	0.322***
	(0.022)	(0.180)
Export Performance		
Knowledge Base **(H_{4a})**	0.557*	0.239*
	(0.170)	(0.055)
Innovation Performance **(H_{5a})**	0.429	0.048
	(0.418)	(0.046)
Goodness of Fit Statistics		
χ^2, df	304.082, 285	
CFI	0.957	
TLI	0.950	
$RMSEA$	0.015	
$WRMR$	0.898	

- One and two asterisks denote level of significance at 1% and 5% respectively.
- Standard errors are reported in parentheses

In terms of the model fit indices provided the χ^2 test is considered the traditional measure for evaluating overall model fit and '*assesses the magnitude of discrepancy between the sample and fitted covariance matrices'* (Hu and Bentler, 1999). However, the χ^2 statistic has some explicit limitations. First of all, it is very sensitive to sample size. The larger size the more likely it is to accept the null hypothesis. Secondly, χ^2 is very sensitive to violations of the assumption of multivariate normality with its values increasing the more skewed variables are inserted into the model. Thirdly, it is not invariant to the number of parameters inserted into the model (Wang and Wang, 2012; p. 18). For these reasons other indices are preferable and specifically, CFI , TLI and $RMSEA$. The results on CFI , TLI and $RMSEA$ presented in Table 5 above provide further indications of goodness of fit of the estimated model.

Turning to the estimation of the structural relationships as they have been presented in section 2, it seems that most of the hypothesized structural relationships are confirmed. More specifically, it is evident that the latent construct of knowledge base mainly captures sources of learning with respect to R&D activities. Hence, it is not unreasonable to argue that for the case of Greek R&D manufacturing firms' their stimuli for knowledge base augmentation is driven by their search strategy for external sources of knowledge as they have been captured by the innovation openness variable used in this study (R&D collaborations). This relationship is expressed in *Hypothesis 1* and estimation results indicate that indeed innovation openness exerts positive and statistically significant on knowledge base. In this context, the importance of R&D collaborations is highlighted as a pivotal tool for the sustainability of firms' knowledge base which in turn is considered as the cornerstone of its competitive advantage (Grant, 1996). In other words, knowledge flows resulting from R&D collaborations augment GRD firms' knowledge base. In addition, collaboration in the context of R&D activities may further stimulate GRD firms' investments in knowledge creation in order to be in a position to exploit incoming knowledge flows.

Furthermore, in terms of the reciprocal relationship between Greek R&D manufacturing firms' innovation openness and innovation performance – *Hypotheses 2a and 2b* – estimation results confirm the existence of a two-way causality. This

endogenous relationship has not been previously reported in the relevant literature and it may be an interesting insight as to how R&D collaborations which are embedded in the firms' open innovation strategy affect its innovation performance and vice versa. More specifically, while innovation performance exerts a positive influence on innovation openness, the opposite seems to apply with respect to the influence of innovation openness on innovation performance. The interpretation of this somewhat startling empirical finding requires to be placed within the appropriate context. First of all, and even though the relevant literature has implicitly hypothesized that pursuing an open innovation strategy is a must-pursue strategy due to, among others, shorter product life cycles (Chesbrough, 2003; Dahlander and Gann, 2010, onnly recently scarce empirical evidence has surfaced claiming that it may not be exactly the case. More specifically, Knudsen et al. (2011) perform an exploratory analysis on a sample of Danish firms and find that open innovation strategy and internal mechanisms of knowledge creation act as substitutes and that open innovation strategies may bare a negative effect on innovation performance due to high costs, of the transaction, search and coordination type, in integrating external knowledge into the internal forming blocks of knowledge.

Turning to this particular case, the majority of the employed sample consists of SMEs and firms' belonging to the low and medium-low tech industries but most importantly they are all engaged in R&D activities. This characteristic on its own implies that firms have already developed an internal mechanism of knowledge and innovation production. Therefore, the negative influence of R&D collaborations intensity on innovation performance may indicate a high adjustment cost of knowledge derived from external partners that needs to be integrated in the firms' knowledge creation routines. This may be further supported by the fact that the standardized loading of the number of foreign partners in R&D activities has a huge influence in shaping the latent variable of innovation openness. Thus, problems related to cultural, institutional and other difference may also be in place.

At the other end of this reciprocal interaction, innovation performance positively affects the intensity of external collaborations. It could be argued that both firms' knowledge and their relationships with external partners are developed in parallel and gradually. With respect to partnerships and cooperation as a part of business operation, issues of establishing a 'common language', trust and fruitful cooperation environment become of the utmost importance (Boschma, 2005). This

empirical finding may suggest that successful innovation projects signify a successful learning outcome and result in a higher demand for external knowledge partners. In other words, increased innovation performance may act as a signal for enhancing technological capabilities (Iammarino et al, 2012) which in turn may signal an improved predisposition for exploration and exploitation of external sources of knowledge. Furthermore, the successful in terms of innovation performance GRD firms may be more attractive partners in a potential R&D collaboration. Hence, it may be more likely that already collaborating firms may engage more easily in a new collaboration relative to those that are less successful in implementing innovation project and engaging in R&D partnerships.

Turning to the statistically significant and positive relationship between innovation performance and knowledge base –*Hypothesis 3*– it should be recalled that the latent construct of knowledge base represents the internal mechanism for knowledge creation and assimilation (Cohen and Levinthal, 1989) which enhances the innovation performance of Greek R&D manufacturing firms. This finding, taken together with the negative effect of the external knowledge search strategy discussed above, strengthens the argument that internal knowledge creation processes also exhibit a substitution character with innovation openness and that firms' innovation performance is heavily dependent on their internal resources to codify and transform knowledge into commercially valuable products and/or services.

The proposed structural framework entails the examination of another reciprocal relationship and particularly between Greek R&D manufacturing firms' export performance and knowledge base –*Hypotheses 4a and 4b.* Estimation results do not confirm the existence of an endogenous relationship. Greek R&D manufacturing firms' knowledge base positively and significantly influences their exporting performance. However, the opposite direction of this relationship does not seem to hold. In other words, the 'learning by exporting hypothesis' (Love and Ganotakis, 2013) is not confirmed for this particular framework.

Moving forward to examine the reciprocal relationship between GRD firms' innovation and export performance (*Hypotheses* 5_a *and* 5_b) empirical results do not confirm the existence of a reciprocal relationship. However, export performance positively and statistically significantly determine GRD firms' innovation performance, a finding which is in accordance with the relevant literature (Kafouros

et al. 2008) which considers export performance to be positively related with innovation performance.

The effect of export performance on innovation openness (*Hypothesis 6*) may be seen as an additional strategy in the context of the firms' open innovation mode. More specifically, exporting activities may serve as an additional knot in the firms' networking efforts and through such activities relationships with domestic and foreign customers may serve as a valuable external source of knowledge which is formed in R&D collaborations. In other words, as Simard and West (2006, p. 222) argue *"...in open innovation, some firms need to identify external knowledge and incoroporate it into the firm; others seek external markets for their existing innovations"* exports is the means to reach out external markets.

5. Conclusions

The main goal of this paper has been the investigation of the relationship among knowledge base, R&D collaborations, and innovation and exporting performance of GRD firms. Hence, firms' innovation and internationalization activities have been incorporated into a unifying framework specifying the underlying relationships between internal and external sourcing of knowledge and internationalization and innovation performance respectively. GRD firms' innovation openness is related with their knowledge base since not only it contributes in the increase of incoming knowledge flows and the required level of R&D investments in order to successfully engage in R&D collaborations; also, knowledge base augmentation further intensifies the open innovation strategy since GRD firms' seek for complementary or substitute external knowledge sources to their own. On the other hand, innovation openness as considered here is related with GRD firms' internationalization strategy since R&D collaboration partners may be found outside the domestic environment and may directly or indirectly be linked with GRD firms' exporting activities.

The line of argumentation adopted supports the existence of reciprocal relationships between *(i)* firms' internal knowledge base and export performance, *(ii)* their external search strategy for R&D collaborations and innovation performance as well as between *(iii)* firms' export and innovation performance. As a result a four module framework is developed where two-way relationships is multifaceted and dominant. The four conceptual variables, namely firms' *knowledge base, innovation*

openness, *export performance* and *innovation performance* play a central role in developing the framework depicting structural relationships *among* them.

In this line, six hypotheses have been formulated regarding the effects of each one of the above on the remaining three and thus, a non recursive structural system of equations has been developed. In order to test the validity of the developed structural framework, the information from the field research on the sample of Greek R&D manufacturing firms is employed. Structural Equation Modeling (SEM) approach has enabled both the approximation of the key conceptual variables but also the simultaneous estimation of a non recursive system of equations. More specifically, in order to measure the four conceptual variables a set of indicators have been employed and with the use of Confirmatory Factor Analysis (CFA) four latent variables have been creating capturing the above key concepts. We employed as a more appropriate estimator Weighted Least Squares with adjusted mean and corrected variance (WLSMV).

Based on estimation findings, it is argued that with respect to the reciprocal relationship between, Greek R&D manufacturing firms' knowledge base and their export performance are partially confirmed. In more detail, firms' knowledge base positively and significantly affects export performance whereas the opposite is not confirmed by empirical estimations. Furthermore, and with respect to the formulated hypotheses about the reciprocal relationship between innovation openness and innovation performance empirical results support the existence of a two-way causality relationship. Interestingly though and while innovation performance exerts a positive and statistically significant influence on innovation openness, innovation openness in turn exerts a negative and significant influence on innovation performance. This startling empirical result is interpreted on the grounds of associated costs in internalizing external knowledge which negatively impact innovation performance but as the firms' innovative performance increases, internal sources of knowledge creation do not suffice and thus, alternative means of knowledge sourcing are needed.

Towards this direction, standardized estimates indicate that innovation openness and Greek R&D manufacturing firms' knowledge base present substitution effects on innovation performance. In other words, knowledge base, in contrast to innovation openness, enhances innovation performance. In addition, R&D collaborations intensity influences positively firms' knowledge base providing thus,

another indication of their multidimensional interrelationship where feedback mechanisms may be in place.

Regarding the hypothesized reciprocal relationship between export and innovation performance, empirical results confirm only the one-way causality and specifically, the positive influence of export performance on innovation performance. Confirmation is also provided for the dual role of innovation openness acting also as an internationalization channel since it is positively influenced by export performance

A set of independent observed variables have been also employed in the regression of the structural model mainly for reasons of model identification and controlling for heterogeneity. However, further research is needed in this direction. More specifically, it should be further investigated the mediating role of knowledge base and innovation openness with respect to innovation and internationalization performance. In addition, the potential substitutional or complementary relationship between knowledge base and innovation openness as a means of sustaining firms' competitive advantage may be an interesting future research path.

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Appendix

The last thing remaining to complete the picture of the model is to present the control variables employed to determine each one of the structural parameters. Tables I, II and III present the determining factors of export performance, knowledge base, innovation openness and innovation performance.

Table I. Definition, Descriptive Statistics and Empirical Results of covariates determining Export Performance

	Name	Definition	Descriptive statistics Average (St. Dev.)	Min (Max)	Empirical Results Unstandardized Coefficients	Standardized Coefficients
Export Market Destination	RoE	The percentage of exports destinted to European Countries outside Eurozone	0.168 (0.247)	0.000 (1.000)	1.430** (0.627)	0.155* (0.061)
	NAM	The percentage of exports destined to the Region of North America (including Canada)	0.045 (0.116)	0.000 (0.775)	0.187 (0.210)	0.061 (0.068)
	EURO	The percentage of exports destined to the Eurozone	0.340 (0.340)	0.000 (1.000)	1.489* (0.501)	0.223 (0.063)*
Means of Exporting	DIREXP	Dummy variable which takes the value 1 if the firm is engaged in direct exports and 0 otherwise	0.617 (0.487)	-	1.806* (0.426)	0.795* (0.115)
	INTERM	Dummy variable which takes the value 1 if the firm uses an intermediary for its exporting activities and 0 otherwise	0.173 (0.379)	-	0.836* (0.267)	0.368* (0.100)
	SUBCONTR	Dummy variable which takes the value 1 if the firm uses a subcontractor for its exporting activities and 0 otherwise	0.097 (0.296)	-	0.685*** (0.378)	0.302** (0.158)
	EXPREPR	Dummy variable which takes the value 1 if the firm uses an export representative and 0 otherwise	0.307 (0.462)	-	1.072* (0.300)	0.472* (0.102)
Export Barriers	EURLEG	Exporting barrier which concerns the difficulties generated by the European legislation	-0.344*** (0.650)	-1.957 (2.207)	-0.296 (0.183)	-0.085*** (0.050)
	NOEURLEG	Exporting barrier which concerns the difficulties generated	-0.143 (0.738)	-1.620 (2.173)	0.622* (0.173)	0.202* (0.048)

	by the Non-European legislation				
NATIONLEG	Exporting barrier which concerns the difficulties generated by the National (Greek) legislation	0.135 (0.787)	-1.478 (2.526)	0.396* (0.148)	0.137* (0.046)
NATIONPOL	Exporting barrier which concerns the difficulties generated by the National (Greek) policies	0.741 (0.951)	-1.348 (3.242)	0.366* (0.138)	0.153* (0.053)
BTRANSPOR	Exporting barrier which concerns transport difficulties	0.573 (0.837)	-1.620 (4.007)	0.510* (0.170)	0.188* (0.053)
BCOMPRICE	Exporting barrier which concerns the difficulties generated by the firms' competitive product prices	0.663 (0.903)	-1.620 (4.007)	0.183 (0.129)	0.073 (0.049)

Table II. Definition, Descriptive Statistics and Empirical Results of covariates determining Knowledge Base

Name	Definition	Descriptive statistics		Empirical Results	
		Average (St. Dev.)	Min (Max)	Unstandardized Coefficients	Standardized Coefficients
ONGOINGRD	Dummy variable which takes the value 1 if the firm has had ongoing R&D activities at the time of the survey and 0 otherwise	0.313 (0.465)	-	0.405* (0.156)	0.415* (0.145)
BHIDDEN	R&D barrier which concerns the difficulties generated by miscalculation of hidden costs	-0.205 (0.808)	0.349 (1.065)	0.218* (0.087)	0.181* (0.065)
BBURAUC	R&D barrier which concerns the difficulties generated by bureaucratic procedures	-3.615 (1.775)	-2.214 (3.615)	0.160* (0.061)	0.175* (0.062)
HT	Dummy variable which takes the value 1 if the firm belongs to High tech sectors and 0 otherwise	0.113 (0.318)	-	0.831* (0.326)	0.853* (0.286)
MHT	Dummy variable which takes the value 1 if the firm belongs to Medium High tech sectors and 0 otherwise	0.200 (0.401)	-	0.328*** (0.190)	0.336*** (0.188)
MLT	Dummy variable which takes the value 1 if the firm belongs to Medium Low tech sectors and 0 otherwise	0.293 (0.456)	-	0.111 (0.162)	0.114 (0.164)
SIZE	Firm's size: annual gross total sales	64.172 (414.351)	0.025 (5851.898)	0.000 (0.000)	-0.075 (0.058)

Table III. Definition, Descriptive Statistics and Empirical Results of covariates determining Innovation Openness and Innovation Performance

Name	Definition	Descriptive statistics Average (St. Dev.)	Min (Max)	Empirical Results Unstandardized Coefficients	Standardized Coefficients
	INNOVATION OPENNESS				
ABSCAP	Firm's absorptive capacity defined as the ratio of employees with tertiary education to total number of employees	0.265 (0.206)	0.000 (1.000)	0.151 (0.166)	0.257 (0.281)
ABSCAP2	The square of ABSVCAP variable	0.113 (0.190)	0.000 (1.000)	-0.104 (0.173)	-0.163 (0.270)
INTGRT	Firm's degree of internalization (integration) defined as the ratio of expenditures on affiliated undertakings to total assets	0.048 (0.124)	0.000 (0.776)	0.485* (0.136)	0.495* (0.137)
	INNOVATION PERFORMANCE				
FIXTOTAS	The ratio of fixed assets (for the yr 2010) to total assets (for the year 2010)	0.408 (0.203)	0.001 0.960	0.050 (0.145)	0.039 (0.114)
PROFITAB	The ratio of firms' 3year averaged gross profits to 3year averaged total assets	0.245 (1.054)	-0.133 (18.192)	-0.029 (0.126)	-0.120 (0.517)