THE IMPACT OF DIFFERENT TYPES OF ICT ON INNOVATION PERFORMANCE OF GREEK FIRMS

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Abstract

It is widely recognised that innovation is of critical importance for the competitiveness and growth of firms, sectors and countries, so understanding its determinants is a critical research question. Beyond the 'traditional' innovation determinants identified by previous relevant research, there has been extensive theoretical literature on the potential of information and communication technologies (ICT) to drive innovation; however limited empirical investigation of it has been conducted. This paper presents an empirical investigation of the impact of three different ICT (internal information systems (IS), e-sales and e-procurements), and also - for comparison purposes – of four important 'traditional' innovation determinants (demand expectation, price and non-price competition, market concentration), on the innovation performance of Greek firms. It is based on firm-level data collected through a survey of 271 Greek firms. The results show that in the Greek 'innovation averse' national context (characterised by low level of innovation and uncertainly avoidance culture), though none of the examined 'traditional' innovation determinants has an impact on product and process innovation of firms, the internal IS have a strong positive impact on both product and process innovation, and the e-sales only on process innovation; on the contrary, e-procurement is not a driver of innovation. Our results indicate the high potential of ICT as innovation driver even in innovation averse contexts, which however varies between different types of ICT.

Keywords: information and communication technologies, internal information systems, e-sales, e-procurement, innovation.

1 INTRODUCTION

It is widely recognised that innovation is of critical importance for the competitiveness and growth of firms, sectors and countries; not only in the advanced economies, but also in the emerging ones as well, innovation can be a very good way to enhance competitiveness, diversify activities and move towards higher value added activities (OECD 2007, 2010a and 2010b; Buesa et al, 2010). For these reasons the identification of factors affecting the innovation performance of firms, often referred to as 'determinants of innovation', has been a critical research question for long time. Previous research in the last thirty years has revealed several innovation determinants (see section 2.2). Beyond these 'traditional' innovation determinants, there has been extensive theoretical literature on the potential of information and communication technologies (ICT) to drive significant innovations in firms' processes, products and services, which is briefly reviewed in section 2.1. This literature (e.g. Brynjolfsson and Hill, 2000; Bresnahan et al, 2002; Champy, 2002) argues that most of the existing processes, products and services of firms have been designed and established in the pre-ICT era, so

they have been substantially shaped by the high costs of information processing and transfer at that time, and the time and place constraints imposed by the manual mode of work (e.g. in order to co-operate and perform a joint activity it is necessary all involved individuals to be in the same place at the same time); however, ICT change dramatically these basic assumptions, since they greatly reduce the costs of information processing and transfer, and also remove many of the above time and place constraints, so they can lead to big transformations of existing processes, products and services. Also, another stream of this theoretical literature (e.g. Amit and Zott, 2001; Zwass, 2003) argues that Internet technologies change radically the way firms communicate, collaborate and transact with their customers, vendors and business partners, reduce dramatically the corresponding costs, and this can lead to significant changes of their processes, products and services, and even drive totally new business models.

However, limited empirical investigation of the potential of ICT to drive innovation has been conducted in order to find out to what extent the high expectations of this theoretical literature are realized. Furthermore, as concluded from the review of this limited empirical literature (section 2.2), it views ICT as a single and homogeneous entity, and does not examine and compare different types of ICT as to their capacity to drive innovation, though they differ in pervasiveness in the firm and influence on its processes, products and services; also, it does not proceed to comparisons of ICT with the 'traditional' innovation determinants as to their impact on innovation. It should be noted that most of these few empirical investigations have been conducted in a small number of highly developed countries (mainly in Germany and USA), which are characterised by high penetration of ICT and long experience and maturity in using them effectively, and also higher levels of innovation. Taking into account that as concluded from previous research the national context can influence the adoption of both ICT (e.g. Hofstede and Hofstede, 2005; Leidner and Kayworth, 2006; Ali and Brooks, 2008) and innovation (e.g. Shane, 1993; Williams and McGuire, 2005; Kaasa and Vadi, 2010), it is necessary to investigate the relations between different ICT and innovation in various national contexts (with various levels of economic development, ICT penetration and innovation).

This paper contributes to filling the above research gaps by presenting an empirical investigation of the impact of three different types of ICT (internal information systems (IS), e-sales and e-procurement), and also, for comparison purposes, of four important 'traditional' innovation determinants (demand expectation, price and non-price competition, market concentration), on the innovation performance of Greek firms. So the research questions of this study are: a) Do these three ICT types have an impact on innovation performance of firms? b) If this happens, are there differences among them as to their capacity to drive innovation, and c) How their impacts on innovation compares with the ones of the abovementioned four important 'traditional' innovation determinants. Our study has been conducted in a national context quite different from the ones of previous studies on this question (see section 2.2). According to Eurostat (http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database) in Greece the Gross Domestic Product (GDP) per capita (a basic indicator of economic development) in Purchasing Power Standards (PPS) (with EU-27 = 100) is at the level of 89.28 (average 1997-2008), while the corresponding average values for the Scandinavian and the Continental European countries are 131.87 and 123.65 respectively, indicating Greece's lower level of economic development. This means less experience and tradition in introducing and exploiting effectively new advanced technologies, processes and products. Also, according to the same Eurostat sources in Greece the ICT expenditure is 1.23% of GDP (average 2004-2006), while for the Scandinavian and the Continental European countries it is on average much higher, at the levels of 3.22% and 2.85% respectively; this reflects the lower penetration and use of ICT in Greece, and therefore its lower experience in ICT effective exploitation. With respect to innovation, according to the same Eurostat sources in Greece 35.8% of firms can be characterised as 'innovative' (i.e. have made some type of product or process innovation in the time horizon of their more recent survey), while for the Scandinavian and the Continental European countries the corresponding average percentages of innovative firms are much higher, at the levels of 45.60% and 47.90% respectively. Also, from the cultural perspective according to highly respected Geert Hofstede's studies (http://www.geert-hofstede.com/) for Greece the score of the 'uncertainty avoidance index' (a cultural dimension associated with lower tendency for adoption of ICT and innovation) is 112, while the corresponding average scores for the Scandinavian and the Continental European countries are at the

much lower levels of 35.25 and 50.17 respectively. The above indicate that the Greek national context is characterised by 'innovation aversion'. In this national context of lower economic development, ICT penetration and innovation, and also uncertainty avoidance culture, it is quite interesting and useful to study the relations between the above types of ICT and innovation.

This paper consists of six sections. The following section 2 reviews previous relevant theoretical and empirical literature. In sections 3 and 4 are described the specification of the models and the data of this study. The results are presented in section 5, while the final section 6 summarizes the conclusions.

2 LITERATURE REVIEW

2.1 Theoretical Background

There has been an extensive theoretical literature concerning the innovation potential of ICT. This literature argues that ICT have a great potential to enable and drive performance enhancing innovations of both processes and products/services of firms (Hammer, 1990; Orlikowski, 1992; Hammer & Champy, 1993; Davenport, 1993; Bresnahan & Trajtenberg, 1995; Brynjolfsson and Hill, 2000; Orlikowski, 2000; Bresnahan et al, 2002; Champy, 2002; Avgerou, 2003; Lyytinen and Newman, 2008). This literature emphasizes that most of the existing work practices, business processes and products/services of firms have been developed in the past, and have been critically influenced and shaped by the dominant at that times logic of the manual mode of work and high costs of and information processing and transfer. However, ICT have dramatically reduced these costs, and removed many of the limitations that the manual mode of work imposes with respect to time and place: co-operation between individuals is now possible from a distance and asynchronously through digital networks. These can lead initially to new enhanced business processes and work practices, which result in big productivity increases, by reducing costs and increasing output quality; subsequently they drive the design of new products/services and improvements of important intangible aspects of existing products/services, such as convenience, timeliness, quality, personalization, etc. ICT can change the way that human work is performed, measured, controlled and reported, and enable significant restructuring of the work practices, through allocation of well-defined routine tasks associated with symbols processing to computers, and transformations of the tasks that require human skills. Also, ICT enable individual workers to have all the required information for completing bigger parts of the processes they are dealing with, so the existing fragmentation of many processes can be dramatically reduced, resulting in big efficiency improvements. Davenport (1993) proposes nine basic modes of using ICT for making highly beneficial process innovations: automational, informational, sequential, tracking, analytical, geographical, integrative, intellectual and disintermediating. Champy (2002) argues that ICTs can be of critical importance for improving dramatically not only the internal processes of firms, but also the processes of transaction and cooperation with their customers, suppliers and partners. This high potential of ICT to drive innovation is strongly associated with their nature as 'general purpose technologies', which means that they are characterised by high flexibility and adaptability, so they can be used in many different ways and for many different purposes in various sectors of the economy, and enable important innovations in business processes, products and services of firms (Bresnahan & Trajtenberg, 1995). However, a significant part of this theoretical literature (Orlikowski, 1992 and 2000; Avgerou, 2003; Lyytinen and Newman, 2008) warns that this innovation potential of ICT is not deterministic, but depends considerably on the context; ICT can give rise to new technology-mediated organizational practices, which are to a considerable extent shaped by the context (social, organizational, national) in which they are developed and used; so the same ICT can be used in quite different ways in different contexts, and therefore result in quite different outcomes.

The emergence of the Internet gave rise to a new stream of theoretical literature concerning its innovative potential. This literature argues that Internet changes the ways and costs of firms' communication, collaboration and transaction with their customers, vendors and business partners, and for this reason can be enablers and drivers of radical performance-enhancing innovations in the business processes, products, services, and even business models and value propositions of firms

(Timmers, 1998; Tapscott et al., 2000; Afuah and Tucci, 2001; Amit and Zott, 2001; Applegate, 2001; Zwass, 2003; Lyytinen and Rose, 2003; Wu and Hisa, 2004; Tavlaki and Loukis, 2005; Wu and Hisa, 2008). Timmers (1998) describes eleven new business models driven by the Internet: e-shop, e-procurement, e-auction, e-mall, third party marketplace, virtual community, value chain service provider, value chain integrator, collaboration platform, information brokerage and trust services. Amit and Zott (2001) developed a model of e-business value creation including four basic value sources: efficiency, novelty, complementarities and customer retention; with the exception of the first, all the other three e-business value sources are associated with innovations it can enable. Tapscott et al. (2000) proposes a set of innovative business models based on the Internet, called 'business webs', which "are inventing new value propositions, transforming the rules of competition and mobilizing people and resources to unprecedented levels of performance [...]. A b-web is a distinct system of suppliers, distributors, commerce services providers, and customers that use the Internet for their primary business communications and transactions". These business webs are grouped into five categories: agora, aggregation, distributive network, alliance and value chain. Zwass (2003) identifies eleven categories of innovation opportunities provided by the Internet, which are associated with access to and creation of marketplaces, supply-chain linkages, networks of relationships, collaboration with business partners, communities of knowledge exchange, use of interactive media, delivery of goods and services, anytime-anywhere connectivity, development platforms, telecommunications networks and computing utility. Wu and Hisa (2004 and 2008) argue that e-commerce can drive extensive innovations that change the both core components of the products and the business model, which can be categorised into four groups: incremental innovations (no significant changes in products' core components and the business model), modular innovations (considerable changes in products' core components but not in the business model), architectural innovations (considerable changes in the business model but not in products' core components) and radical innovations (considerable changes in both products' core components and business model). Tavlaki and Loukis (2005) call for a more systematic approach to the exploitation of the extensive innovation capabilities that electronic channels (such as the Internet) offer for the design of new business models, and propose a methodology for this purpose.

2.2 Empirical Literature

Numerous empirical studies have been conducted concerning the determinants of innovation at firm level; comprehensive reviews of them are provided by Cohen and Levin (1989), Cohen (1995), Kleinknecht (1996), Raymond et al. (2004), Wan et al. (2005), Van Beers et al (2008) and Buesa et al. (2010). From these studies it has been concluded that demand prospects, type and intensity of competition, market structure, factors affecting the production of knowledge (such as technological opportunities and appropriability) and firm size are the main determinants of firm's innovation activity. However, limited empirical research has been conducted on the impact of ICT on innovation, despite the above extensive theoretical background outlined in 2.1, in order to find out to what extent the high expectations of this theoretical literature are realized.

Three emprical studies have been conducted based on German firms (with two of them focusing on the services sector). In an earlier study Licht and Moch (1997) found, based on a cross-section of 1200 service firms for the period 1994-1996, that investment in information technologies per employee impacted positively some product quality dimensions (such as user friendliness, temporal and spatial availability, delivery speed, etc.), which they interpreted as indicators of product innovation. Hempell & Zwick (2008), using data from 4,500 representatively chosen firms in Germany for years 2002 and 2004, conclude that ICT investment and share of employees working mainly on a computer have a positive impact on functional flexibility (measured through numbers of employees working in teams, workgroups and quality circles) and through it on product and process innovation, while ICT has a direct effect on both types of innovation as well. Engelstätter and Sarbu (2010) investigated the relationship between the use of sector-specific and customized software on service innovation using data from 335 German firms of the period 2007-2009; their results showed that primarily customized software contributes significantly to innovation. Another study on this topic by Bartel et al. (2005) is based on quite detailed data for a sample of 212 U.S. firms in the valve industry; they found that (a) new IT promotes increased production of customized products, which is a product innovation

according to authors' interpretation, and (b) new IT embedded machines (new CNC machines, FMS, computerized equipment-inspection, etc.) improved considerably production processes increasing their efficiency.

Also, it should be mentioned that there are some other empirical studies focusing on the complementarity relation between ICT and innovation. Hempell (2005), using a production function framework and data from 1222 German service firms in the period 1994-1999, demonstrated that innovation and ICT use are complementary, i.e. mutually reinforcing, with respect to firm's productivity. In a similar study comparing German and Dutch firms from this perspective Hempell and et al. (2006) found evidence of the complementarity of innovation and ICT use in the service sector, which is of the same order of magnitude in the two countries. Similar conclusions have been drawn from the study of Loukis et al. (2008), which using data collected through a survey of 176 Greek firms estimates moderated regression models founded on the Cobb-Douglas production function and concludes that in firms following a strategy of frequent introduction of new innovative products and services there is a higher contribution of ICT to business performance (measured through firm value added). Also, Koellinger (2008), using data from a large sample of 7302 firms from 10 sectors and 25 European countries for 2003, investigated the impact of IT-enabled as compared to non-IT-enabled product and process innovations on turnover and employment growth and profitability, and found (a) positive effects of all these four types of innovation on turnover and employment growth, (b) positive effects only of product innovations on profitability, and also (c) that Internet-enabled innovations are at the very least not 'inferior' to other kinds of innovation in terms of positive correlation with performance indicators. Furthermore, from the descriptive statistics of the above variables it was concluded that a substantial amount of innovative activity in the European Union was related to or enabled by Internet-based technologies.

Therefore, it can be concluded that there are only a limited number of empirical studies that have investigated directly the impact of ICT on innovation (though there are numerous case studies investigating ICT-based innovations, e.g. Tarafdar and Gordon, 2007; Lindic et al., 2011). Furthermore, this limited empirical literature i) views ICT as a single and homogeneous entity, and does not examine and compare different types of ICT as to their capacity to drive innovation, though they differ in pervasiveness in the firm and influence on its processes, products and services, ii) does not proceed to comparisons of ICT with the 'traditional' innovation determinants as to the impact on firm's innovation activity. Also, most of these empirical studies have been conducted in a few highly developed countries (mainly Germany and USA), which are characterised by high level of economic development, high penetration of ICT and long history and experience in using them effectively, and also higher levels of innovation. This paper contributes to filling the above research gaps by presenting an empirical investigation of the impact of three different ICT (internal information systems (IS), e-sales and e-procurement), and also for comparison purposes four 'traditional' innovation determinants (price and non-price competition, market concentration and demand expectations), on the innovation performance of Greek firms.

3 HYPOTHESES FORMULATION

Our research hypotheses concern the effects of the most important 'traditional' innovation determinants according to the literature (Cohen and Levin, 1989; Cohen, 1995; Kleinknecht, 1996; Raymond et al., 2004; Wan et al., 2005; Van Beers et al., 2008; Buesa et al., 2010), and also of the three examined types of ICT (internal IS, e-sales and e-procurement), on innovation performance of Greek firms.

It is widely accepted that demand growth potential has a positive impact on innovation performanceof firms ("demand pull" hypothesis). The hypothesis that innovation is fostered by demand growth was first proposed by Schmookler (1966). The basic idea is that the economic relevance of an innovation is measured by its acceptance on the market place as expressed by the existence of demand for it. The larger the (anticipated) demand potential is, e.g., for a new product, the higher are also a firm's incentives for fostering product innovation. Also from the point of view of process innovations, the larger the demand potential is, the higher are the firm incentives to use new cost-saving production

techniques. The "demand pull" hypothesis has been extensively tested at firm level, see, e.g., Crépon et al. (1996) for French firms, Arvanitis and Hollenstein (1996) for Swiss firms, and Brouwer and Kleinknecht (1996) for Dutch firms. So our first research hypothesis is:

Hypothesis 1: Demand expectation has a positive impact on innovation performance

The (product) market conditions under which the firms are operating, particularly the competitive pressures they are exposed to, are also regarded to be of critical importance for innovation. Mostly, market concentration, a structural variable showing the market power of the largest firms in the market, is taken to reflect competitive pressures. Market concentration is measured, for example, by the market share of the largest four firms in a certain industry (concentration ratio C4). The basic idea is that the more evenly market power is distributed among the competitors in the market, the stronger is the competition pressure for each single firm. Competitive pressures can be measured also directly, separately for different dimensions of competition (price, quality, etc.).

Standard industrial organization models of product differentiation and monopolistic competition typically predict that more intense product market competition, measured by an increase in the substitutability between differentiated products, reduces post-entry rents, i.e. the profits to be gained from the innovation after entering the respective market, and therefore reduces the incentives for product innovation (see, e.g., Dixit and Stiglitz 1977; see also the discussion in Aghion et al. 2005). This is the so-called 'Schumpeterian' point of view. Another line of thought argues on the contrary that it is the elasticity of demand, i.e. the relative change of demand divided by the relative change of price causing the demand change, faced by a firm in its specific market that induces innovative activity (see Kamien and Schwartz 1970 for the original argument). In those markets where competition pressure is greater, demand elasticities can be expected to be higher because of the existence of close substitutes, thus driving firms to innovative activity. This is the so-called "free competition" point of view.

In the game-theoretic literature the impact of market structure upon the schedule of innovation is shown to depend critically on the difference of profit rates preceding and following the innovation (see, e.g., Reinganum 1981). This dependence being quite complicated, most studies do not come to theoretical unambiguous results with respect to the effects of market concentration on innovation (see Reinganum 1989 for a review of such studies). Aghion et al. (2005) developed a model that predicts an inverted-U relationship between product market competition and innovation (for lower level of competition it has a positive impact on innovation, however if the competition exceeds a threshold its effect on innovation becomes negative), and found strong evidence for this model using U.K. panel data.

In sum, whether positive "free competition effects" are stronger than negative effects according to the tradition of Schumpeter as some empirical studies find (see, e.g., Geroski 1995, Blundell et al. 1999), has to be resolved at the empirical level. Thus, we do not have an a priori expectation with respect to the effects of market concentration and price competition on innovation; positive effects would confirm the "free competition effect", negative ones the "Schumpeterian effect". As a consequence, two alternative research hypotheses have to be formulated for these two variables. Further, we expect a positive effect of the intensity of non-price competition (reflecting the influence of non-price factors such as quality, technical content, etc.) on innovation. This expectation is in accordance with models of product differentiation, in which product quality is the main dimension of competition among firms, and which are interpreted as models of incremental innovation (see, e.g., Stoneman 1983; Levin and Reiss 1988). For the above reasons, we have used three dimensions (aspects) of the market environment: (a) market structure as reflected by the number of main competitors in firm's specific market; (b) the intensity of price competition in firm's specific market; and (c) the intensity of non-price competition in firm's specific market. Thus, our next three research hypotheses with respect to the influence of market conditions on innovation are the following:

Hypothesis 2: Non-price competition has a positive impact on innovation performance

Hypothesis 3a: Price competition has a positive impact on innovation performance

Hypothesis 3b: Price competition has a negative impact on innovation performance

Hypothesis 4a: Market concentration has a positive impact on innovation performance

Hypothesis 4b: Market concentration has a negative impact on innovation performance

Firm size is a further important determinant of innovation performance. In general, larger firms have more resources for the design and implementation of innovations, a higher level of management capabilities and also the possibility to exploit economies of scale and scope. Thus, it is expected that firm size is positively related to innovation performance (see, e.g., Arvanitis 1997 for a study based on Swiss firms; Cohen 1995 for a survey on related empirical literature). So our next research hypothesis is:

Hypothesis 5: Size has a positive impact on innovation performance

Beyond the above traditional innovation determinants, there has been an extensive theoretical literature arguing for the potential of ICT to drive innovation, which has been briefly reviewed in 2.1. In particular, internal IS create numerous opportunities initially to transform processes (e.g. make processes simplifications, improvements, abolitions, or create new horizontal interdepartmental processes), and also to improve existing products and services and to develop new ones that were not feasible or economical before. As mentioned in 2.1 firms' internal processes, products and services have been developed mainly in the pre-ICT era, so they have been based on and shaped by the logic and the constraints of the manual mode of work, and the high cost of information processing and transfer at that time; the internal IS give rise to a new logic of work, overcome many of the above constraints and greatly reduce information processing and transfer costs, so they can pervade all firm's processes, products and services and transform or renew them (e.g. Brynjolfsson and Hill, 2000; Bresnahan et al, 2002; Champy, 2002). Furthermore, internal IS can support and improve the communication and exchange of ideas among firm's employees, which is of critical importance for the generation and adoption of innovations (e.g. Nonaka, 1994; Nonaka and Takeuchi, 1995; Wan et al., 2005). For the above reasons our next research hypothesis is:

Hypothesis 6: Internal IS has a positive impact on innovation performance

It is not only internal IS that can drive innovations, but also 'extrovert' ones as well. E-sales change radically the way firms communicate and transact with their customers, and also reduce dramatically the corresponding costs, so they can lead to significant changes initially of some of its processes (mainly the 'customer-facing' ones), and later of products and services, or even business models (Amit and Zott, 2001; Zwass, 2003; Wu and Hisa, 2004 and 2008). In particular, e-sales at a first level pervade and influence the sales and customer service processes of the firm, since they establish a new sales channel, which is based on a digital network (and not on physical interaction, as it happens with the other sales channels), and necessitates receiving electronic orders and payments on a 24hous/7 days basis, delivering products on time to geographically remote and dispersed customers, and offering after-sales support electronically. Furthermore, e-sales gradually lead to a better understanding of the capabilities that the digital network offers as a highly advantageous sales channel, which can result in more radical second level effects on the products and services the firm offers (e.g. improved or new products and services), or even on its business model. Therefore our next research hypothesis is:

Hypothesis 7: E-Sales have a positive impact on innovation performance

Finally, e-procurement changes radically the way firms communicate and transact with their suppliers, and also reduce dramatically the corresponding costs, so it can lead to significant changes initially of some processes (mainly related to purchasing) and later of products and services (e.g. Amit and Zott, 2001; Garrido et al., 2008; Garrido-Samaniego et al., 2010). In particular, e-procurement at a first level pervades and influences the processes of the firm associated with purchasing various raw materials, components and services it requires, so it can result in innovations concerning these processes. Also, gradually e-procurement leads to a better understanding of the capabilities offered by the digital network for finding new suppliers from a wider geographical area than before, and for transacting with them quicker and at a low cost, and this can at a second level lead to improvements of existing products and services or even development of new ones. So our final research hypothesis is:

Hypothesis 8: E-Procurement has a positive impact on innovation performance

4 DATA AND METHOD

For this study we have used data that we collected through a survey among Greek firms, which has been conducted in cooperation with ICAP S.A. (www.icap.gr), one of the largest business information and consulting companies of Greece. Initially from the database of ICAP a first sample was randomly selected, which included 304 Greek firms (103 small, 103 medium and 98 large ones) from the 27 most important sectors of Greek economy. Furthermore, two similar samples were also created with the same proportions of small, medium and large firms, and also firm from the above 27 sectors. A questionnaire was developed, reviewed by three highly experienced experts from ICAP S.A., and based on their remarks the final version of it was formulated. The questionnaire was sent by mail to the managing directors of the 304 firms of the first sample asking them to fill it in and return it by fax or mail within one month. After one month a reminder telephone was made to the firms which had not responded; the ones refusing to participate were replaced by 'similar' firms (i.e. from the same size and industry class) from the second sample, and in cases that the second sample was exhausted from the third sample. This replacement procedure allowed us to have a balanced sample concerning company size and industry. Finally we received complete questionnaires from 271 firms (88 small, 105 medium and 78 large ones).

For testing the above research hypotheses using the above data the following innovation model was estimated:

$$INNOV = bo + b1*DEM + b2*IPC + b3*INPC + b4*NCOMP + b5*INT\_IS + b6*E\_SAL + b7*E\_PROC + b8*D\_MED + b9*D\_LARGE + b10*D\_SECT$$

For measuring innovation performance (dependent variable) we have used two binary (Yes/No) variables (INNOVPD and INNOVPC) assessing whether the firm has introduced product innovations and process innovations respectively in the last three years, which have been used by many researchers in the past (e.g. Kessler, 2003; Novelli et al., 2006; Arvanitis, 2008; Soto-Acosta et al., 2009); for each of them a separate regression model has been estimated. With respect to the independent variables we have included a demand expectations variable (DEM) measuring to what extent the firm expects an increase of demand on the relevant product markets in the medium-term (next three years). We have used three variables to capture the influence of market environment, namely a measure of the intensity of price competition on a firm's specific market (variable IPC), a measure of the intensity of non-price competition (variable INPC) and a measure of the market structure/concentration as reflected by the number of main competitors on a firm's most important (worldwide) product market (variable NCOMP). With respect to the technological opportunities we have focused on the ones generated through the application of ICT. For this purpose we have used as a measure of internal IS use one variable reflecting the extent of internal use by firm's employees of two basic technologies, Internet and Intranet (INT_IS), and also two more measures of the extent of e-sales (variable E_SAL measuring the percentage of sales conducted through the Internet) and e-procurement (variable E_PROC measuring the percentage of procurement conducted through the Internet). Furthermore, firm size, an explanatory variables used in most innovation studies (see, e.g., Cohen 1995), has also been included in the present study. We use the number of employees in full-time equivalents as a measure of firm size, and from it two dummy variables have been formed: one for medium-sized firms (D_MED for firms with 50 to 249 employees) and a second one for large firms (D_LARGE for firms with more than 250employees). Since we do not dispose of any direct measure of appropriability in our data sample (e.g., the propensity to patenting) we control for factors that are closely correlated with the propensity of patenting: firm size and sector affiliation (see, e.g., Levin et al. 1987). So we have additionally included a sector dummy (D_SECT). The definition of the above variables is provided in the Appendix.

5 RESULTS

The above two models have been estimated using LOGIT estimation, which is the most appropriate estimation method, as recommended by the relevant econometric literature, if the dependent variable is binary (e.g. Gujarati, 2003). The results are shown below in Tables 1 (product innovation model)

and 2 (process innovation model) (statistically significant coefficients, having significance levels lower than 5%, are shown in bold).

Independent variable	b	St. error	Sign.	Exp(b)
D_Sect	.081	.278	.770	1.085
D_large	**.883**	**.354**	**.013**	**2.417**
D_med	.437	.328	.183	1.548
Demand	.019	.289	.948	1.019
Price Competition	.227	.137	.099	1.255
Non price competition	-.068	.124	.583	.934
Number of Competitors	-.001	.001	.562	.999
Int_IS	**.226**	**.078**	**.004**	**1.254**
E-Sales	.469	.377	.213	1.599
E-Procurement	-.017	.313	.956	.983
Constant	**-1.614**	**.683**	**.018**	**.199**

Table 1. The product innovation model

Independent variable	b	St. error	Sign.	Exp(b)
D_Sect	**-.694**	**.292**	**.018**	**.500**
D_large	**1.299**	**.377**	**.001**	**3.666**
D_med	**.813**	**.352**	**.021**	**2.255**
Demand	-.034	.302	.911	.967
Price Competition	.096	.142	.502	1.100
Non price competition	-.051	.130	.694	.950
Number of Competitors	-.002	.002	.341	.998
Int_IS	**.159**	**.081**	**.049**	**1.172**
E-Sales	**.932**	**.390**	**.017**	**2.538**
E-Procurement	.263	.317	.407	1.301
Constant	-1.285	.712	.071	.277

Table 2. The process innovation model

Initially we remark that all the four 'traditional' innovation determinants we examined (demand expectation, price competition, non-price competition, number of competitors) do not have a statistically significant effect neither on product nor on process innovation in the Greek national context. Therefore hypotheses 1, 2, 3 and 4 are not supported. This is not in agreement with the results of previous relevant empirical studies conducted in other highly developed countries (e.g. see Arvanitis, 2008), which have found that the above factors have a positive effect on innovation, being the most important innovation determinants. Our results indicate that the Greek national context, which is innovation averse as mentioned in the Introduction, characterised by lower innovation activity and uncertainty avoidance culture (the Hofstede's uncertainty avoidance index for Greece is 112, while for the Scandinavian and the Continental European countries it is on average at the much lower levels of 35.25 and 50.17 respectively), has a negative impact on firms' propensity for innovation; so firms do not respond to high competition or demand expectations with innovations in their processes, products and services, as firms of developed countries do. From the above tables we

can see that it is only size that has a positive impact in both process and product innovations, so hypothesis 5 is supported.

On the contrary, we remark that internal IS have a statistically significant positive effect on both product and process innovation, so hypothesis 6 is supported. This indicates that Greek firms exploit the great innovation potential of the internal IS, which pervade and influence all firm's processes, products and services, for making innovations both at the level of their processes and also their products and services. They have realized that their existing processes, products and services have been designed in the pre-ICT era, so they have been shaped by the dominant logic and constraints of the manual mode of work, and the concomitant high costs of information processing and transfer; at the same time, firms realize that the capabilities offered by the internal IS change radically these fundamental assumptions, so processes, products and services have to be transformed in order to exploit these valuable capabilities offered to a larger extent.

Also, we remark that e-sales have a statistically significant positive effect on process innovation only, but not on product innovation, so hypothesis 7 is only partially supported. This indicates in the Greek national context are observed the 'first level effects' of using the e-sales ICT (i.e. impact on internal processes, as mentioned in hypotheses formulation in section 3), but not the 'second level effects' (i.e. impact on products and services). This seems that as e-sales pervade and influence the sales and customer service processes of the firm, Greek firms realize that it is necessary to change them in order to meet the new requirements that this new sales channel creates (e.g. receiving electronic orders and payments on a 24hous/7 days basis, delivering products on time to geographically remote and dispersed customers, offering after-sales support electronically). However, in this innovation averse national context are not observed the 'second level effects' of using the e-sales ICT (i.e. impact on products, services or even business models). It seems that Greek firms do not exploit the extensive capabilities for radical innovations at the level of new products and services, or even new business models, offered by ICT, and especially the Internet, according to the relevant theoretical literature (outlined in 2.1). It should be noted that the exploitation of these advanced capabilities is much more difficult and complex than process innovation, as it should take into account seriously many factors not controlled by their firm and associated with the external environment of it (e.g. markets, customers, legislation, etc.).

Finally, we remark that e-procurement does not have statistically significant effects neither on product nor on process innovation, so hypothesis 8 is supported. This indicates that though e-procurement pervade and influence some processes of the firm (however a much smaller range of processes than the internal IS and the e-sales, mainly processes associated with purchasing various raw materials, components and services the firm requires), this does not drive Greek firms neither to process innovations (first level effects) nor to products/services innovations (second level effects).

The above results indicate that even in such national contexts, characterised by innovation averse attitudes, and also lower level of economic development (which means less history, experience and tradition in introducing new advanced technologies, processes and products), in which the traditional innovation determinants identified in relevant literature do not drive innovation, the ICT can be a strong innovation drive. Though Greece is characterised by lower penetration and use of ICT, as mentioned in the Introduction, and therefore lower experience in its effective exploitation, we can see that ICT is an important innovation driver. This provides a strong empirical confirmation of the extensive theoretical background concerning the innovation potential of ICT outlined in 2.1 in such an 'innovation averse' context; also it is in agreement with and expands the limited relevant empirical literature reviewed in 2.2.

Furthermore, our results indicate that different types of ICT may show different capacity to drive innovation. In particular, internal IS pervade, support and influence to a large extent all the processes of a firm, and also the design and production of all products and services, so they are a strong innovation drive. E-sales are less pervasive as they support and influence only the customer-facing processes of the firm associated with selling goods and services and providing customer support, but not much the design and production of products and services, so they drive mainly process

innovations. E-procurement is even less pervasive, as it supports and influences a smaller subset of firm's processes associated with purchasing, so it does not drive innovation.

6 CONCLUSIONS

There has been an extensive theoretical literature on the innovation potential of ICT, which concludes that ICT are strong drivers of radical and disruptive innovations in firms' processes, products and services. However, only limited empirical research has been conducted concerning the impact of ICT on innovation in order to examine to what extent the high and enthusiastic expectations of this theoretical literature are realised. For filling this research gap in the previous sections has been presented an empirical investigation of the impact of three different and widely used types of ICT (internal information systems (IS), e-sales and e-procurement), and also - for comparison purposes- of four 'traditional' innovation determinants (demand expectation, price and non-price competition, market concentration), on the innovation performance of Greek firms. It is based on the estimation of two innovation models for product and process innovation using firm-level data from 271 Greek firms collected through a survey.

The results show that none of the examined 'traditional' innovation determinants has an impact on product and process innovation of Greek firms. On the contrary internal IS have a strong positive impact on both product and process innovation, and e-sales only on process innovation, while e-procurement is not a driver of innovation in Greek firms. These indicate that ICT provide a strong innovation drive even in such innovation averse national contexts, in which the traditional innovation determinants do not drive innovation of processes, products or services. At the same time our results reveal that the capacity to drive innovation varies among different types of ICT, depending on the pervasiveness and influence of each on firm's processes, products and services. This has an interesting research implication: the extensive empirical research required in the future concerning the relation between ICT and innovation should not be generic, but should discriminate among particular types of ICT. Further empirical research is required in this direction, in various national contexts, and also distinguishing between different types of innovations, which might have different relations with different types of ICT. Also, it is necessary to examine not only 'whether' but also 'how' ICT affects innovation, and which are the main mediators and moderators of this critical relation.

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APPENDIX

Definition and measurement of model variables

Variable	Definition
Dependent variables	
INNOVPD	Introduction of product innovations (yes/no)
INNOVPC	Introduction of process innovations (yes/no)
Independent variables	
DEM	Expectations with respect to demand development in the next three years; five-level ordinal variable (level 1: 'strong decrease'; level 5 'strong increase')
Market environment:	
IPC	Intensity of price competition; five-level ordinal variable (level 1: 'very weak'; level 5 'very strong')
INPC	Intensity of non-price competition; five-level ordinal variable (level 1: 'very weak'; level 5 'very strong')
NCOMP	Number of principal competitors
Technological opportunities	
INT_IS	Sum of the standardized values of the variables INTERNET and INTRANET; where: INTERNET: six-level ordinate variable for the intensity of *internet use*: share of employees using internet in daily work: 0: 0%; 1: 1-20%; 2: 21-40%; 3: 41-60%; 4: 61-80%; 5: 81-100%; INTRANET: six-level ordinate variable for the intensity of i*ntranet use*: share of employees using internet in daily work: 0: 0%; 1: 1-20%; 2: 21-40%; 3: 41-60%; 4: 61-80%; 5: 81-100%
E_SAL	Sales through the Internet (on-line sales) as a percentage of total sales
E_PROC	Procurement through the Internet as a percentage of total procurement
Firm size	
D_MED	Dummy variable for medium-sized firms: 50 to 249 employees (in full-time equivalents)
D_LARDE	Dummy variable for large firms: 250 employees (in full-time equivalents) and more
D_SECT	Dummy variable for service sector firms
Reference group for firm size: small firms (5 to 49 employees); for sector: manufacturing firms	