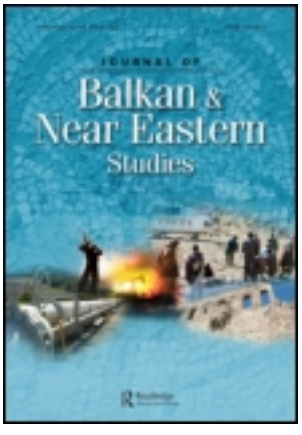

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New Technologies and Traditional Innovation Determinants in the Greek Economy

Spyros Arvanitis, Euripidis Loukis and Vasiliki Diamantopoulou

It is widely recognized that the recent economic crisis in Greece is due not only to excessive government spending and tax evasion, but also to the low competitiveness of its economy. Innovation has become of critical importance for the competitiveness of firms, sectors and countries in the modern economy. This paper presents an empirical study of the 'new' innovation determinants based on information and communication technologies (ICT) and also of the 'traditional' innovation determinants in the Greek economy. In particular, it investigates the impact of three different ICT (internal information systems (IS), e-sales and e-procurements) and also of six important traditional innovation determinants identified by previous relevant research (four 'external' ones—demand expectation, price and non-price competition, market concentration—and two 'internal' ones—investment in research and development (R&D) and firm size), on the innovation performance of Greek firms. It is based on firm-level data collected through a survey of 271 Greek firms before the start of the economic crisis, which have been used for the estimation of regression models. It is concluded that in the Greek 'innovation-averse' national context (characterized by low level of innovation and uncertainty avoidance culture) none of the examined external (market-related) traditional innovation determinants has an impact on product or process innovation of firms, while on the contrary the internal ones, R&D expenditure per employee and size, affect positively both. Furthermore, the examined new technologies seem to be important drivers of innovation: it is concluded that the internal IS have a positive impact on both product and process innovation, the e-sales only on process innovation, but the e-procurement on none. Our results indicate the high potential of ICT as innovation drivers even in such innovation-averse and lower economic development contexts, which, however, vary between different types of ICT.

1. Introduction

The recent economic crisis in Greece is due not only to excessive government spending and tax evasion, but also to the low competitiveness of its economy; as mentioned in the 'Update of the Hellenic Stability and Growth Programme',[1] in

recent years there has been a deterioration of the competitiveness of the Greek economy, which is reflected in the widening deficit of the current account balance from 6.3 per cent in 2004 to 14.7 per cent in 2008, being one of the causes of this economic crisis. In spite of the relatively high growth rates of gross domestic product (GDP) in the last decade before the crisis, Greece has suffered from low international competitiveness of its economy. This has been stated in all competitiveness surveys including the well-known World Bank Doing Business and the World Economic Forum.[2] The causes of this low competitiveness can be traced back partly to macroeconomic factors, such as the inflation differential with the Eurozone, but to a large extent also to structural determinants, such as the low productivity of the business sector of the economy.[3]

One of the most important drivers of productivity and competitiveness in the modern economy is innovation, both in the form of innovative products and innovative processes. Product innovation is defined as the introduction in the market of a product whose characteristics or intended uses differ significantly from those of previous ones, or an existing product whose performance has been significantly enhanced or upgraded; process innovation is defined as the adoption of new or significantly improved production methods.[4] It is widely recognized that innovation is of critical importance for the competitiveness and growth of firms, sectors and countries in the modern economy; 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.[5] 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 a long time; extensive theoretical and empirical research has been conducted on it in the last 30 years, which has revealed several innovation determinants, associated with both the interior and the external environment of firms (see Section 2 for more details). A second relevant research stream has been developed focusing on the innovation potential of information and communication technologies (ICT), leading to extensive mainly theoretical literature that analyses the potential of ICT to drive significant innovations in firms' processes, products and services,[6] which is briefly reviewed in Section 2. The main argument of this theoretical literature is 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; however, ICT change dramatically these assumptions, so they can lead to big transformations of existing processes, products and services. This research stream initially focused on the dominant ICT at the time, the internal information systems (IS), which aimed to support a firm's internal functions and processes, but later, after the emergence and wide penetration of the Internet, dealt extensively also with its high innovation potential.[7] The main argument of this later theoretical literature is that Internet technologies change radically the way firms communicate, collaborate and transact with their customers, vendors and business partners, and reduce dramatically the corresponding costs, so they can lead to significant changes of their processes, products and services, and even drive totally new business models.

However, despite this extensive theoretical literature on the potential of ICT (both of the internal IS and Internet technologies) to drive innovation, limited empirical investigation of this potential has been conducted based on large datasets, in order to find out to what extent the high expectations of the above theoretical literature are realized. Furthermore, as concluded from the review of this limited empirical literature (see Section 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. In addition, it is not connected with the abovementioned earlier and more mature research stream on the determinants of innovation, and does not attempt comparisons of various ICT types with the 'traditional' innovation determinants as to their impact on innovation. Furthermore, 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 characterized 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[8] and innovation,[9] 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 the three most widely used types of ICT (internal IS, and two Internet-based ones, e-sales and e-procurements) and also of six important 'traditional' innovation determinants (four external ones to the firm—demand expectation, price and non-price competition, market concentration—and two internal ones—research and development (R&D) and size), on the innovation performance of Greek firms. Therefore, the research questions of this study are:

(a) Do these three types of ICT have an impact on innovation performance of firms?
(b) If this happens, are there differences among them as to their capacity to drive innovation?
(c) How do their impacts on innovation compare with that of the abovementioned six important 'traditional' innovation determinants?

To address these research questions our study adopts a quantitative methodology. It is based on firm-level data collected through a survey of 271 Greek firms before the start of the economic crisis (so they were not affected by the distortions it may have caused in firms' innovation and technological decisions), which have been used for the estimation of regression models.

Our study has been conducted in a national context quite different from the ones of the highly developed countries where limited relevant previous studies have been conducted. According to Eurostat,[10] in Greece the GDP per capita (a basic indicator of economic development) in purchasing power standards (PPS) (with EU-27 = 100) was 89.28 before the economic crisis (average 1997–2008), while the

corresponding average values for the Scandinavian and Continental European countries were 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. In addition, according to the same Eurostat sources, in Greece the ICT expenditure was 1.23 per cent of GDP (average 2004–2006), while for the Scandinavian and Continental European countries it was on average much higher, at 3.22 and 2.85 per cent, respectively; this reflects the lower penetration and use of ICT in Greece, and therefore its lower experience in effective exploitation of ICT. With respect to innovation, according to the same Eurostat sources, in Greece 35.8 per cent of firms can be characterized 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 Continental European countries the corresponding average percentages of innovative firms are much higher, at 45.60 and 47.90 per cent, respectively. In addition, from the cultural perspective according to the highly respected Geert Hofstede's studies on the national culture 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 Continental European countries are at the much lower levels of 35.25 and 50.17, respectively.[11] These indicate that the Greek national context is characterized 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 outlines the theoretical and empirical background of the study. In Section 3 the research hypotheses of the study are formulated, while in Section 4 the methodology and the data of the study are described. The results are presented in Section 5, while the final Section 6 summarizes the conclusions.

2. Theoretical and Empirical Background

As mentioned in Section 1, numerous theoretical and empirical studies have been conducted concerning the determinants of innovation at the firm level (as the firm is the main locus of innovation decisions), motivated by the high and continuously increasing importance of innovation in the modern economy, which makes it necessary for firms, sectors and countries to become much more innovative than in the past. Comprehensive reviews of this long and mature research stream are provided by Cohen,[12] Cohen,[13] Kleinknecht,[14] Raymond *et al.*,[15] Wan *et al.*,[16] Becheikh *et al.*,[17] Van Beers *et al.*[18] and Buesa *et al.*[19] From these studies it has been concluded that there are factors associated both with the interior of the firm and with its external environment that affect positively innovation performance, which are usually referred to as 'innovation determinants'. The most important internal innovation determinants identified are demand prospects, type and intensity of competition, market structure, factors affecting the production of knowledge (such as

technological opportunities and appropriability), while the most important internal ones are R&D and firm size.

The emergence and increasing penetration of ICT lead to the gradual realization of their great innovation potential, and to the development of a new relevant mainly theoretical research stream that analyses the main sources, patterns and forms of this potential.[20] It emphasizes that most of the existing work practices, business processes and products/services of firms have been developed in the pre-ICT era, so they have been critically influenced and shaped by the dominant logics at that time of the manual mode of work and high costs of information processing and transfer. However, ICT have dramatically reduced these costs, and also changed many of the logics of the manual mode of work and the limitations it imposes, for instance, with respect to time and place; for example, cooperation between individuals is now possible from a distance (and does not require co-location as in the pre-ICT era), and also 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 can drive the design of new products/services and also substantial improvements of important intangible aspects of existing products/services, such as convenience, timeliness, quality, personalization, etc. This theoretical literature also emphasizes that 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. In addition, 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. This high potential of ICT to drive innovation is strongly associated with their nature as 'general purpose technologies', which means that they are characterized by higher flexibility and adaptability than other previous technologies utilized by firms, 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 their business processes, products and services.[21] However, a significant part of this theoretical literature[22] 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 utilized in quite different ways in different contexts, and result in quite different levels and forms of innovation and outcomes in general.

The emergence of the Internet gave rise to an enrichment of this theoretical research stream with a series of studies analysing the innovative potential of Internet technologies. This literature argues that the Internet changes dramatically 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 much more radical performance-enhancing innovations in the business processes, products and services than the internal IS, or even new business models

and value propositions.[23] In this direction Timmers[24] describes 11 new business models that can be 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. Tapscott *et al.*[25] propose a set of innovative business models based on the Internet, called 'business webs', with this term denoting '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 will 'invent new value propositions, transform the rules of competition and mobilize people and resources to unprecedented levels of performance'; five main types of business webs are proposed: agora, aggregation, distributive network, alliance and value chain. Zwass[26] identifies 11 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[27] argue that Internet e-commerce can drive extensive innovations that change both the core components of the products and the business model, which can be categorized 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 the business model). Kleis *et al.*,[28] based on a review of relevant literature, conclude that internal and Internet-based IS can significantly support the innovation production processes of firms and improve innovation performance in three ways: (a) enabling a more intensive communication and exchange of knowledge between firms' employees of different functions and locations, (b) also with external innovation partners (e.g. universities and research partners, other cooperating firms, suppliers, customers, etc.) and (c) supporting the design and production of new products (e.g. through computer-aided design (CAD) and computer-aided design manufacturing (CAM) systems).

However, despite the above extensive theoretical work, limited empirical research has been conducted concerning the impact of ICT on innovation based on large datasets, in order to find out to what extent the high expectations of this theoretical literature are realized, though there are numerous case studies analysing successful or failed ICT-based innovations.[29] Bartel *et al.*,[30] based on data from 212 US valve manufacturing firms, found that new IT promotes increased production of customized products, which is interpreted by the authors as a kind of product innovation, and also new IT embedded machines (new computer numerically controlled (CNC) machines, flexible manufacturing systems (FMS), computerized equipment inspection, etc.) improved considerably production processes increasing their efficiency. Gago and Rubalcaba[31] focused on services, and using data from 557 service firms from the region of Madrid, Spain, examined the effects of ICT investment

on the importance of firms' innovations for productivity and costs, product or market expansion, employment and required skills, services quality and fulfilment of ecological standards; they found that ICT investment has a positive impact on all these dimensions of innovations' importance and contribution. Hempell and Zwick,[32] using data from 4500 representatively chosen firms in Germany, conclude that ICT investment and share of employees working mainly on a computer have a positive impact on functional flexibility (measured through the numbers of employees working in teams, workgroups and quality circles) and through this on product and process innovation; also ICT have a direct effect on both types of innovation as well. Engelstätter,[33] based on data from 1454 German firms, investigated the effect of using three widely used types of enterprise software, enterprise resource planning (ERP), supply chain management (SCM) systems and customer relationships management (CRM), on the innovation performance of firms. He found that SCM systems have a positive effect on the likelihood of making process innovations, while ERP systems have a positive effect on the number of process innovations; also, CRM systems have a positive effect on the likelihood of making product innovations, while SCM systems have a positive effect on the number of product innovations. Kleis *et al.*,[34] using data from 201 large US manufacturing firms over the period 1987–97 including a total of 1829 observations, found that ICT investment (using the value of installed ICT capital stock as main independent variable) has a positive effect on patent output (which is used as a product innovation measure), and especially on the more 'incremental' (i.e. less radical) ones.

We remark that the empirical investigation of the impact of ICT on innovation is not only limited but also has some serious weaknesses and gaps:

(1) It views ICT as a single and homogeneous entity (the total firm's ICT investment is used as main independent variable by most of the above empirical studies), and does not discriminate between different types of IS. However, many different types of IS have been developed and are used by firms, which differ in pervasiveness in the firm and influence on its processes, products and services, so they might differ in their capacity to drive innovation.
(2) It is not connected with the earlier extensive and highly mature research stream on the determinants of innovation, and does not compare various ICT with the traditional innovation determinants identified by this research stream as to their impact on innovation.
(3) These few empirical studies have been conducted in national contexts of a small number of highly developed countries (mainly Germany and USA), which are characterized by a 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 and widely used ICT (internal information systems (IS), e-sales and e-procurements), and also, for comparison purposes, six 'traditional' innovation determinants (four 'external' ones—demand

expectation, price and non-price competition, market concentration—and two 'internal' ones—R&D intensity and size), on the innovation performance of Greek firms. This study refers to a quite different national context than that of the highly developed countries, characterized by lower levels of economic development, ICT penetration and innovation, and also an uncertainty avoidance culture.

3. Research Hypotheses

Nine research hypotheses have been formulated concerning the effects of the above three types of ICT and six traditional innovation determinants identified by previous research on innovation performance.

It is widely accepted that expectation for demand growth has a positive impact on innovation performance of firms ('demand pull' hypothesis). The hypothesis that innovation is fostered by demand growth was first proposed by Schmookler.[35] The basic idea is that the economic relevance of an innovation is measured by its acceptance on the marketplace as expressed by the existence of demand for it. The larger the (anticipated) demand potential is, for example, for a new product, the higher are also a firm's incentives for fostering product innovation. In addition, from the point of view of process innovations, the larger the demand potential is, the higher are the firm's incentives to use new cost-saving production techniques. The 'demand pull' hypothesis has been extensively tested at firm level, see, for example, Crépon *et al.*[36] for French firms, Arvanitis and Hollenstein[37] for Swiss firms, and Brouwer and Kleinknecht[38] for Dutch firms. Therefore, our first research hypothesis is

> *Hypothesis 1: Demand growth 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 pressure 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, leads to reduction of the post-entry rents, that is, 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;[39] see also the discussion in Aghion *et al.*[40]). This is the so-called 'Schumpeterian' point of view. Another line of thought argues on the contrary that it is the elasticity of demand, that is, 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[41] 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;[42] this dependence being quite complicated, most studies do not come to theoretical unambiguous results with respect to the effects of market concentration on innovation.

Aghion *et al.*[43] developed a model that predicts an inverted-U relationship between product market competition and innovation (for lower levels 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 UK 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,[44] 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.[45] 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 the firm's specific market; (b) the intensity of price competition in the firm's specific market; and (c) the intensity of non-price competition in the firm's specific market. Thus, our next three research hypotheses with respect to the influence of market conditions on innovation are as follows:

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

A firm's R&D activity is one of the most important 'internal' determinants (i.e. having to do with the interior of the firm and not with its external environment) of innovation performance according to all innovation literature reviews (such as the ones mentioned in the first paragraph of Section 2). R&D is widely recognized as an important input for generating innovation output.[46] It includes systematic scanning of the continuously created scientific knowledge relevant to a firm's products/services and processes, examination of the possibilities of exploiting it cost effectively for designing new products/services and processes (or for improvements of existing ones), building of prototypes and testing/evaluation of them, based on dedicated human and technological capital, and for these reasons it affects positively innovation performance. Therefore, our next research hypothesis is

Hypothesis 5: Research and development (R&D) activity has a positive impact on innovation performance

Another important internal determinant of innovation performance is according to the relevant literature firm size. Larger firms have more resources for the design and implementation of innovations, better access to financial markets for borrowing capital at lower interest rates in order to finance high-risk innovation projects, higher level of technical, marketing, distribution and management capabilities, while they can benefit from economies of scale and scope.[47] In larger firms the increase of the price–cost margin caused by innovation (for products/services innovations due to the higher price buyers are willing to pay for the new or significantly improved products/services, and for process innovation due to the reductions of production costs) can be spread over a higher volume of products/services, so they can have more benefits from innovation, and therefore higher motivation for being innovative.[48] There is much empirical evidence of a positive impact of a firm's size on innovation performance.[49] Therefore, our next research hypothesis is

Hypothesis 6: Size has a positive impact on innovation performance

Beyond the above traditional innovation determinants, as mentioned in Section 2, there has been an extensive theoretical literature concerning the potential of ICT to drive innovation. The earlier part of it argues that internal IS create numerous opportunities initially to transform a firm's processes (e.g. drive simplifications, improvements, abolitions of existing processes or even new horizontal interdepartmental processes), and later to improve existing products and services and to develop new ones that were not technically or economically feasible before.[50] 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 a firm's processes, products and services, and drive transformations or renewals. Furthermore, internal IS can support and improve the communication and exchange of ideas among

a firm's employees, which is of critical importance for the generation and adoption of innovations.[51] For the above reasons our next research hypothesis is

Hypothesis 7: Internal IS have a positive impact on innovation performance

However, as mentioned in Section 2 it is not only the internal IS that can drive innovations, but also the 'extrovert' Internet technologies as well. E-sales technologies change radically the way a firm communicates and transacts with its 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.[52] In particular, e-sales at a 'first level' pervade and influence the sales and customer service processes of a 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 24 hous/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. Additionally, e-sales facilitate a closer electronic interaction with existing or potential customers, which can provide valuable information on problems of current products and services, and also on unmet needs, that can be quite useful for generating innovation ideas. Therefore, our next research hypothesis is

Hypothesis 8: E-sales have a positive impact on innovation performance

Finally, e-procurement technologies change radically the way firms communicate and transact with their suppliers, and also reduce dramatically the corresponding costs, so they can lead to significant changes initially of some processes (mainly related to purchasing) and later of products and services.[53] In particular, e-procurement at a first level pervades and influences the processes of a firm associated with purchasing various raw materials, components and services it requires, so it can result in innovations concerning these processes. In addition, gradually e-procurement leads to a better understanding of the capabilities offered by the Internet 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 the development of new products and services or improvements of existing ones. Additionally, e-procurements facilitate a closer electronic interaction with existing or potential suppliers, which can provide information on new materials, components and technologies that could be useful for innovation. Therefore, our final research hypothesis is

Hypothesis 9: E-procurements have a positive impact on innovation performance

4. Methodology and Data

As mentioned in Section 2 there are many case studies analysing successful or failed ICT-based innovations, but on the contrary there is only a small number of empirical studies of the effect of ICT on firms' innovation performance based on large datasets; for this reason we adopted a quantitative methodology in this study.[54] In particular, for testing the above nine research hypotheses the following innovation model was estimated:

$$\begin{aligned}\text{INNOV} = {} & \text{b0} + \text{b1*DEM} + \text{b2*IPC} + \text{b3*INPC} + \text{b4*NCOMP} + \text{b5*D\_MED} \\ & + \text{b6*D\_LARGE} + \text{b7*RD} + \text{b8*INT\_IS} + \text{b9*E\_SAL} + \text{b10*E\_PROC} \\ & + \text{b11*D\_SECT}\end{aligned}$$

The dependent variable, innovation performance, has been measured through two binary (Yes/No) variables (INNOVPD and INNOVPC) assessing whether the firm has introduced product/services innovations and process innovations, respectively, in the last three years, which are fundamental innovation measures that have been used by many researchers in the past.[55] For each of these two variables a separate regression model has been estimated through LOGIT estimation, which is the most appropriate estimation method if the dependent variable is binary according to the relevant econometric literature.[56]

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 also included three independent variables to capture the influence of market environment, namely, a measure of the intensity of the price competition the firm faces (variable IPC), a measure of the intensity of the non-price competition (variable INPC) and a measure of the market structure/concentration as reflected by the number of main competitors in a firm's most important (worldwide) product market (variable NCOMP). For measuring firm size we used the number of employees in full-time equivalents, and from it two dummy variables have been formed: one for medium-sized firms (D_MED, taking value 1 for firms with 50–249 employees and value 0 for all the others) and a second one for large firms (D_LARGE, taking value 1 for firms with more than 250 employees and value 0 for all the others). For measuring the intensity of a firm's R&D activities, we used the logarithm of the average annual R&D expenses per employee in the last three years (variable RD). Since we do not dispose of any direct measure of appropriability in our data sample (e.g. the propensity to patent), we control for factors that are closely correlated with the propensity of patenting: firm size and sector affiliation.[57] Therefore, we have additionally included a sector dummy (D_SECT, taking value 1 for service firms and 0 for manufacturing firms).

In addition, we have included independent variables measuring the intensity of use of the three most widely used types of ICT in firms: internal IS, e-sales and e-procurements. In particular, we have used as a measure of the intensity of internal IS use, one variable reflecting the extent of use by the firm's employees of the Intranet (firm's internal network) and Internet (INT_IS, see its exact definition in the

Appendix), and also two measures of the extent of e-sales (variable E_SAL, measuring the percentage of sales conducted through the Internet) and e-procurements (variable E_PROC, measuring the percentage of procurements conducted through the Internet). The exact definition of all the above variables is provided in the Appendix.

For this study, we have used data collected through a survey among Greek firms before the start of the economic crisis, so they are not affected by the distortions this crisis may have caused in firms' innovation and technological decisions. This survey has been conducted in cooperation with ICAP (www.icap.gr), one of the largest business information and consulting companies in Greece. Initially from the database of ICAP was randomly selected a first 'balanced' sample with respect to size and sector, which included 304 Greek firms, 103 small, 103 medium and 98 large ones, from the 27 most important sectors of the Greek economy. Furthermore, two similar samples were also created, with the same proportions of small, medium and large firms, and also of firms from the above 27 sectors. A questionnaire was developed, reviewed by three highly experienced experts from ICAP 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 call was made to the firms which had not responded. Those 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 finally a balanced sample with respect to company size and industry. We received complete questionnaires from 271 firms (88 small, 105 medium and 78 large ones—147 from manufacturing sectors and 124 from services sectors).

5. Results

Initially, descriptive statistics of our dependent and independent variables were calculated, and the most important of them are shown in Table I. We remark that 41.3 per cent of the respondents had introduced one or more product/service innovations and 37.3 per cent of them had introduced one or more process innovations during the last three years; these percentages are slightly higher than the corresponding ones of Eurostat for Greece that were mentioned in Section 1 (35.8 per cent innovative firms) and lower than the corresponding average ones for Continental European and Scandinavian countries (45.60 and 47.90 per cent innovative firms, respectively). In addition, 66.4 per cent of these firms expected demand increase (since the data were collected as mentioned in Section 4 before the start of the Greek economic crisis), while 73.8 per cent faced strong or very strong price competition and 45.1 per cent faced strong or very strong non-price competition. About one-third of respondent firms' employees on average use the Intranet (firm's internal network) (35.2 per cent) and the Internet (31 per cent), while there is a very low exploitation of the Internet for sales and procurements (only 2.3 per cent of sales and 4.4 per cent of procurements on average are conducted through the Internet).

Table 1 Descriptives of Dependent and Independent Variables

Variables	Descriptives
Product innovation	41.3 per cent positive answers
Process innovation	37.3 per cent positive answers
Demand expectations	66.4 per cent expect increase
Price competition	73.8 per cent report strong or very strong
Non-price competition	45.1 per cent report strong or very strong
Number of main competitors	12.1 on average
R&D activities yes/no	35 per cent non-zero answers
Share of employees using Intranet	35.2 per cent on average
Share of employees using Internet	31 per cent on average
Percentage of sales through Internet	2.3 per cent on average
Percentage of procurements through Internet	4.4 per cent on average

Next, the two abovementioned innovation models for product innovation and for process innovation were estimated using LOGIT estimation, and the results are shown in Tables II and III, respectively. For each independent variable is shown not only its b coefficient, but also—as usual in LOGIT models—the exp(b), which is equal to the increase of the odds ratio of the dependent variable if the corresponding independent variable increases by one unit.[58] The estimated coefficients that have significance levels lower than 10 per cent, and also their standard errors and the exact level of statistical significance of these coefficients are shown in bold.

It can be seen that all four external (market-related) traditional innovation determinants we examined (demand expectation, price competition, non-price competition, number of competitors) do not show statistically significant effects on the probability of product or on process innovation in the Greek national context. Therefore, hypotheses 1–4 are not supported. This is not in agreement with the results of previous relevant empirical studies conducted in highly developed countries,[59] which have found that the above factors have a positive effect on innovation there, being the most important innovation determinants. Our results indicate that in the

Table 2 The Product Innovation Model

Independent variable	b	St. error	Sign.	Exp(b)
DEM (Demand increase expectation)	−0.033	0.302	0.912	0.967
IPC (Price competition)	0.233	0.142	0.123	1.262
INPC (Non-price competition)	−0.039	0.128	0.763	0.962
NCOMP (Number of main competitors)	−0.001	0.001	0.599	0.999
D_MED (Dummy for medium firms)	0.435	0.341	0.202	1.544
D_LARGE (Dummy for large firms)	**0.684**	**0.369**	**0.064**	**1.982**
RD (Log. of annual R&D expense per empl.)	**0.218**	**0.051**	**0.000**	**1.244**
INT_IS (Internal IS)	**0.220**	**0.081**	**0.006**	**1.246**
E_SAL (Percentage of sales through Internet)	0.420	0.388	0.279	1.522
E_PROC (Percentage of proc. through Internet)	−0.103	0.324	0.750	0.902
D_SECT (Sectoral dummy)	0.441	0.303	0.146	1.554
Constant	**−2.203**	**0.724**	**0.002**	**0.110**

Cox & Snell $R^2 = 0.162$; Nagelkerke $R^2 = 0.218$.

Table 3 The Process Innovation Model

Independent variable	b	St. error	Sign.	Exp(b)
DEM (Demand increase expectation)	− 0.057	0.308	0.853	0.944
IPC (Price competition)	0.093	0.144	0.520	1.097
INPC (Non-price competition)	− 0.033	0.132	0.802	0.967
NCOMP (Number of main competitors)	− 0.002	0.002	0.328	0.998
D_MED (Dummy for medium firms)	**0.824**	**0.357**	**0.021**	**2.279**
D_LARGE (Dummy for large firms)	**1.171**	**0.384**	**0.002**	**3.226**
RD (Log. of annual R&D expense per empl.)	**0.133**	**0.048**	**0.005**	**1.142**
INT_IS (Internal IS)	**0.144**	**0.082**	**0.079**	**1.155**
E_SAL (Percentage of sales through Internet)	**0.906**	**0.396**	**0.022**	**2.473**
E_PROC (Percentage of proc. through Internet)	0.221	0.322	0.492	1.248
D_SECT (Sectoral dummy)	**− 0.504**	**0.305**	**0.096**	**0.604**
Constant	**− 1.616**	**0.734**	**0.028**	**0.199**

Cox & Snell $R^2 = 0.156$; Nagelkerke $R^2 = 0.213$.

Greek national context, which as mentioned in Section 1 is characterized by uncertainty avoidance culture, low level of economic development and lack of innovation tradition, external environment (market-related) factors that push firms to become more innovative in the highly developed countries do not have such positive effects on innovation; Greek firms do not respond with innovation in processes, products and services to market conditions of high competition or demand increase, as the firms of highly developed countries do.

On the contrary, from Tables II and III we can see that both examined internal traditional innovation determinants, R&D and size, have statistically significant positive impacts on both process and product innovation. The size effect on product innovation is found for larger firms with more than 250 employees but not for medium-sized firms. For a country like Greece with a share of small and medium-sized enterprises (SMEs) far above the European Union (EU) average, this finding shows that product innovation performance is generated by only a small part of the Greek business sector. Therefore, hypotheses 5 and 6 are supported. These results are in agreement with the previous relevant literature mentioned in Sections 2 and 3 concerning the positive impacts of a firm's R&D and size on its innovation performance.

Furthermore, the new ICT-based technologies, mainly the internal IS, seem to be important drivers of innovation in the Greek national context. In particular, from Tables II and III we remark that internal IS have statistically significant positive impacts on both product and process innovation. Therefore, hypothesis 7 is supported. This indicates that Greek firms exploit the great innovation potential of the internal IS, which pervade and influence all a firm's processes, products and services, for making innovations at the level of both processes and also products and services.

In addition, from Tables II and III we remark that e-sales technologies (despite their limited exploitation by Greek firms, as the descriptives of Table I show) have a statistically significant positive impact on process innovation only, but not on product innovation. Therefore, hypothesis 8 is only partially supported. This

indicates that in the Greek national context 'first-level effects' of using the e-sales technologies (i.e. impact on internal processes, using the terminology introduced in the formulation of hypotheses in Section 3) are observed, but not the 'second-level effects' (i.e. impact on products and services). This finding shows that Greek firms realize that it is necessary to change their sales and customer service processes in order to exploit the new communication and transaction capabilities offered by the Internet, and also to meet the new requirements that the new e-sales channel creates. However, Greek firms do not exploit the extensive capabilities for radical innovations at the level of new products and services, or even new business models and value propositions, offered by ICT, and especially by the Internet, according to the relevant theoretical literature (outlined in Sections 2 and 3). This is due to the abovementioned innovation-averse characteristics of the Greek national context, on the one hand, and also the high inherent difficulties and complexities of the exploitation of these advanced capabilities, since it necessitates cooperation and convergence of interests among many firms (while the innovations at the level of internal processes necessitate only internal decisions within the focal firm). On the contrary, with respect to the e-procurement technologies we remark that they do not have statistically significant impacts on product or on process innovation in Greek firms. Therefore, hypothesis 9 is not supported. This indicates that the limited exploitation of e-procurement technologies by Greek firms (as the descriptives of Table I show) leads neither to process innovations (first-level effects) nor to products/services innovations (second-level effects).

Finally, we can see that the sector dummy has a statistically significant negative impact on process innovation, which indicates that Greece service firms have a lower propensity to process innovation than manufacturing firms.

6. Conclusions

Greece is in the middle of the worst economic crisis it has experienced since the end of the Second World Word, which might have quite negative long-term consequences for it and for the wider area of South-eastern Europe. The most important causes of it are regarded, on the one hand, as the excessive government spending and tax evasion and, on the other hand, the low competitiveness of the Greek economy and the structural problems behind this low performance in terms of international competitiveness. In this paper, we focus on the latter, by studying the determinants of one of its most important pre-conditions: processes, products and services innovation. We have examined for this purpose the impacts of both 'traditional' determinants, identified by previous relevant research, and also 'new' ones associated with ICT, which according to an extensive theoretical literature can be strong drivers of innovation. In particular, in the previous sections has been presented an empirical study of the impact of the three most widely used types of ICT (the internal IS, and two Internet-based ones, e-sales and e-procurements), and also six important 'traditional' innovation determinants (four external ones to the firm—demand expectation, price and non-price competition, market concentration—and two internal ones—R&D and size) on the innovation performance of Greek firms. Our

study adopted a quantitative methodology, based on firm-level data collected through a survey of 271 Greek firms before the start of the economic crisis, which have been used for the estimation of regression models.

Our study makes the following contributions:

(1) It investigates an unexplored but highly important question for Greece: innovation and its main determinants.
(2) It contributes to the quite limited empirical literature concerning the impact of ICT on innovation, by examining the impacts of three widely used types of ICT on process and product innovation, in a national context characterized by uncertainty avoidance culture, low economic development and lack of innovation tradition.
(3) It connects the earlier mature research stream on the determinants of innovation with the more recent research stream on the innovation potential of ICT (which have remained mostly unconnected).

An important conclusion drawn from our study is that Greek firms do not respond with innovation in processes, products and services to market conditions of high competition or demand increase, as the firms of highly developed countries do. Though before the start of the current economic crisis Greek firms faced increased competition (from both European firms and also firms from emerging economies, such as China) and also demand growth (due to the high growth rates of the Greek GDP at that time), as shown by the descriptive statistics of our data (which have been collected before the start of the economic crisis), they did not respond to these market conditions with innovation, and this affected negatively their competitiveness. Further, the results show that R&D investment is also for Greece an important precondition for innovation. Moreover, it appears that practically only firms with R&D activities (about 35 per cent of all firms) introduce product (about 37 per cent of all firms) or process innovations (about 41 per cent of all firms). In more advanced countries there are many more innovating firms than firms with R&D activities (e.g. in manufacturing in Germany only about 58 per cent of innovating firms also conducted R&D in 2006–2008). Finally, the expected advantages of economies of scale and scope through firm size, seem to be effective only for firms with more than 250 employees. This means that SMEs do not participate significantly in the innovation performance of the Greek economy, as it is the case, for example, in countries like Germany and Switzerland.

A second important conclusion drawn from our study is that ICT are strong innovation drivers for Greek firms. It has been concluded that especially internal IS have a strong positive impact on both product and process innovation. With respect to the more recently emerged Internet-based technologies of e-sales and e-procurement it has been concluded that there is low exploitation of them (very small percentages of firms' sales and procurements are conducted through the Internet), and only e-sales is a driver of process innovation, while e-procurement is not a driver of innovation. The above results indicate that even in such national contexts, characterized by innovation-averse attitudes, and also lower level of economic

development (which means less history, experience and tradition in introducing innovations, new advanced technologies, processes and products), in which the traditional external (market-related) innovation determinants identified in highly developed countries do not drive innovation, ICT can be a strong innovation driver. Though Greece is characterized by lower penetration and use of ICT, as mentioned in Section 1, and therefore lower experience in its effective exploitation, ICT constitutes an important innovation driver in Greek firms. This provides a strong empirical confirmation of the extensive theoretical literature concerning the innovation potential of ICT outlined in Section 2 in such an 'innovation-averse' context.

At the same time, the above results reveal that the capacity to drive innovation varies among different types of ICT, depending on the pervasiveness and influence of each on a firm's processes, products and services. 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 its products and services, and for this reason they are a strong innovation driver. E-sales are less pervasive as they support and influence mainly 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 a firm's processes associated with purchasing, so it does not drive innovation.

The results of this study have interesting implications for future research, firms' management and government policymaking. They suggest that future empirical research on innovation determinants should combine elements, factors and frameworks from both the earlier research stream on this and also the more recent one focusing on the innovation potential of ICT. The new technologies constitute an important driver of innovation that cannot be ignored by future innovation research. In addition, this research should not view ICT as a single and homogeneous entity, and differentiate between different types of ICT, since they have different impacts on innovation, as the results of this study reveal. This study provides a framework for conducting future research in this direction.

With respect to Greek firms' management, our results suggest that it is necessary that they realize the importance of innovation as an effective response to hard market conditions. Greek firms will continue having strong competition (both price competition from lower labour cost countries and also non-price competition mainly from EU countries), in combination with decreasing domestic demand, so innovation (together with increase of exports and expansion to other countries) will be the best strategy for them in order to cope with this difficult situation. In addition, Greek firms' management should exploit more the recently emerged Internet-based ICT, such as the e-sales and e-procurement technologies, for conducting more sales and procurements through the Internet, establishing better communication with suppliers, customers and business partners, and making innovations in processes, products, services, and even business models and value propositions.

Greek government policy should support firms to move in the above directions using various policy tools. In the *short and medium term*, it should use the (limited)

national development funds and also the available EU structural funds for financing cooperation projects between firms, universities and research centres aiming at the development and practical implementation of innovations in processes, products, services, business models and value propositions, especially in sectors facing strong price and non-price competition, with strong emphasis on the exploitation of the Internet for innovation purposes.

In the *long run*, government policy needs to generate a framework that makes innovation sustainable and this can only be accomplished through major institutional reforms and changes of mentality and culture in the business sector. It should use various communication channels for creating a stronger innovation culture and awareness concerning the necessity of innovation in order to cope with the current hard market conditions and the economic crisis in general, and also for spreading relevant best practices (domestic or from abroad). Furthermore, the whole educational system of Greece should place more emphasis on innovation as a means to overcome the current economic crisis, and on the exploitation of the new technologies in this direction, in order to create a stronger innovation culture among young people and to equip them with the relevant knowledge background (e.g. through specialized undergraduate and postgraduate innovation courses in various thematic university departments).

Further empirical research is required concerning the impacts of various existing and continuously emerging types of ICT on various types of innovations (both incremental and radical), in various national contexts with different levels of economic development and different cultures. In addition, further research is required for understanding the main mediating and moderating variables of these impacts, so that more knowledge can be created on how they are created and how they can be increased. With respect to Greece, since this study has been based on data collected before the start of the economic crisis, it would be useful to conduct a similar study using data collected at least one to two years after the start of the economic crisis; this will enable us to understand better whether and to what extent this economic crisis has affected the examined innovation determinants (both the traditional and the ICT-based ones), the innovation performance of firms and the impacts of the former on the latter. This knowledge will be useful also for other countries that experience (or will experience in the future) similar economic crises.

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Appendix. Definition and Measurement of Model Variables

Variable	Definition
Dependent variables	
INNOVPD	Introduction of product/service 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 main competitors
Firm size	
D_MED	Dummy variable for medium-sized firms: 50–249 employees (in full-time equivalents)
D_LARDE	Dummy variable for large firms: 250 employees (in full-time equivalents) and more
Research & development	
RD	Logarithm of the average annual R&D expenses per employee in the last three years
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 per cent; 1, 1–20 per cent; 2, 21–40 per cent; 3, 41–60 per cent; 4, 61–80 per cent; 5, 81–100 per cent; INTRANET: six-level ordinate variable for the intensity of *Intranet use*: share of employees using Intranet in daily work: 0, 0 per cent; 1, 1–20 per cent; 2, 21–40 per cent; 3, 41–60 per cent; 4, 61–80 per cent; 5, 81–100 per cent
E_SAL	Sales through the Internet (online sales) as a percentage of total sales
E_PROC	Procurements through the Internet (online procurements) as a percentage of total procurements
Sector affiliation	
D_SECT	Dummy variable for service sector firms

Reference group for firm size: small firms (5–49 employees); for sector affiliation: manufacturing firms.