SOFT ICT AND INNOVATION PERFORMANCE: AN EMPIRICAL INVESTIGATION

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Abstract

The limited number of previous empirical investigations of the effect of information and communication technologies (ICT) on innovation focus mainly on the 'hard' dimensions of ICT (i.e. firm's ICT equipment). This paper presents an empirical investigation of the effect of five important 'soft' dimensions of ICT at firm level (ICT structure, personnel, skills, strategy, processes) on firm's innovation performance (concerning both products/services and processes innovation). It is based on firm-level data collected through a survey of 271 Greek firms, which have been used for estimating regressions of product/service innovation and process innovation on measures of the hard ICT, the above five soft dimensions of ICT, and also four important 'traditional' innovation determinants identified from the long previous research in this area (demand expectation, price and non-price competition, market concentration). It is concluded that four of the examined soft dimensions of ICT (ICT personnel, skills, strategy and processes) have positive effects on firm's innovation performance. Our results indicate that the soft dimensions of ICT at firm level are strong drivers of innovation, which increase considerably the positive contribution of ICT to firms' innovation performance.

Keywords: information and communication technologies (ICT), soft ICT, hard ICT, innovation.

1 INTRODUCTION

There has been extensive theoretical literature concerning the potential of information and communication technologies (ICT) to drive not only operational improvements but also significant innovations in firms' processes, products and services (Brynjolfsson and Hitt, 2000; Bresnahan et al, 2002; Champy, 2002; Avgerou, 2003). The basic argument of this 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 fundamental assumptions of this era concerning the high costs of information processing and transfer, and the time and place constraints imposed by the manual mode of work. 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. However, limited empirical investigation of the potential of ICT to drive innovation has been conducted using large datasets, in order to find out to what extent the high expectations of this theoretical literature is realized (briefly reviewed in section 2.1). Also, these few empirical firm-level studies of the relation between ICT and innovation focus on the 'hard' dimensions of ICT (i.e. firm's ICT equipment), and neglect the 'soft' dimensions of ICT at firm level (e.g. ICT personnel, skills and ICT strategy), despite the wide recognition of their importance for firms' competitiveness and performance in previous

information systems (IS) literature (Wade and Hulland, 2004; Ravichandran and Lertwongsatien, 2005; Nevo and Wade, 2010), as explained in more detail in section 2.2.

This paper contributes to filling this research gap by presenting an empirical investigation of the effect of five important soft dimensions of ICT at firm level (ICT organizational structure, personnel, skills, strategy, processes) on firm's innovation performance (concerning both products/services and processes innovation). In particular, the research questions that this study attempts to address are: a) Do these five soft dimensions of ICT have an impact on innovation performance of firms? b) If this happens, how is this impact compared with the one of the hard ICT, c) and also with the impacts of the 'traditional' innovation determinants that previous innovation literature has identified. This study is based on firm-level data collected through a survey of 271 Greek firms, which have been used for estimating regressions of product/service innovation and process innovation on measures of hard ICT, the above five soft dimensions of ICT, and also four important 'traditional' innovation determinants (demand expectation, price and non-price competition, market concentration). It should be mentioned that the national context of our study is characterised by a culture that does not favour innovation, resulting in lower levels of firms' innovation in comparison with the other European countries. In particular, according to Geert Hofstede's studies (see http://www.geert-hofstede.com/) for Greece the score of the 'uncertainty avoidance index' (a cultural dimension associated with lower tendency for 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. Also, according to the Eurostat (http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home), 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 the more recent survey), while for the Scandinavian and the Continental European countries the corresponding average percentages of innovative firms are much higher, 45.60% and 47.90% respectively. In this 'innovation averse' national context it is quite interesting to study the relations between the ICT, and especially its soft dimensions, and innovation.

This paper consists of six sections. The following section 2 includes the background of this study, while in section 3 the research hypotheses are developed. Then, in section 4 the data and in section 5 the model specification and the estimation method are described. The results are presented and discussed in section 6, while the final section 7 summarizes the conclusions.

2 BACKGROUND

2.1 ICT and Innovation

Due to the high importance of innovation for the competitiveness and performance of firms, extensive theoretical and empirical research has been conducted for long time in order to identify factors that have positive impact on innovation, usually referred to as 'innovation determinants'; detailed reviews of this research are provided by Arvanitis and Hollenstein (1996), 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 and market structure are the most widely accepted determinants of firm's innovation activity.

More recently the emergence and growing penetration in firms of ICT gave rise to extensive theoretical research that examines and analyses the innovation potential of ICT (Hammer, 1990; Orlikowski, 1992; Hammer & Champy, 1993; Davenport, 1993; Bresnahan & Trajtenberg, 1995; Brynjolfsson and Hill, 2000; Orlikowski, 2000; Bresnahan et al, 2002; Champy, 2002; Lyytinen and Rose, 2003; Avgerou, 2003; Tavlaki and Loukis, 2005; Lyytinen and Newman, 2008). A common conclusion of this research is that ICT have a great potential to enable and drive important innovations of both processes and products/services of firms. 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 logics of the manual mode of work and high costs of and information processing and transfer. However, ICT have dramatically changed these logics and assumptions (e.g. it has reduced dramatically information processing and transfer costs), and enabled overcoming serious previous limitations (e.g. in order to co-operate and

perform a joint activity it is not any more necessary all involved individuals to be in the same place at the same time; they can have remote and asynchronous collaboration through electronic networks). For this reason ICT 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 as well, 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, controlled and coordinated, 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.

However, only a small number of empirical investigations of the relation between ICT and innovation based on large datasets have been conducted in order to find out to what extent these enthusiastic expectations of this theoretical literature concerning the innovation potential of ICT is realized, though there are several case studies analysing successful ICT-based innovations (e.g. Tarafdar and Gordon, 2007; Lindic et al., 2011). Bartel et al. (2007), based on data from a sample of 212 U.S. firms in the valve industry, found that the use of industrial ICT (CNC machines, FMS, automatic inspection sectors, 3D CAD software) a) promote product innovation (moving from commodity production based on long production runs to customized production in smaller batches), and b) lead to considerable changes in the production processes, which increase their efficiency, and at the same time the operators' skill requirements as well, leading also to changes in human resource management practices. Hempell and Zwick (2008) using data from 4,500 German firms concluded 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 they also have a direct effect on both types of innovation as well. Engelstätter and Sarbu (2010), based on data from 335 German service firms, investigated the relationship between the use of two different types of enterprise software, standardised sector-specific and customized (to fit the special needs of the firm) software, on services innovation; they found that customized software increases the probability of innovation, while there is no relationship between standardised software and innovation. Arvanitis et al. (2011), using firm-level data collected through a survey of 271 Greek firms, investigate the impact of three different types of IS (internal, e-sales and e-procurement IS) on product and process innovation performance of Greek firms. Their results show that the internal IS have a strong positive impact on both product and process innovation, and the e-sales IS only on process innovation; on the contrary, e-procurement IS are not drivers of innovation. We remark that these few empirical firm-level studies of the relation between ICT and innovation operationalize ICT using various measures of hard ICT (firm's ICT equipment), so they focus on the impact of hard ICT on innovation, and neglect the 'soft' dimensions of ICT (e.g. ICT personnel, skills and ICT strategy), despite the wide recognition of their importance in previous IS literature, as explained in more detail in the following section 2.2. This paper contributes to filling this research gap, by examining the effects of various soft dimensions of ICT at firm level on innovation, and comparing them with the impacts of hard ICT and the main traditional innovation determinants that previous innovation literature has identified.

2.2 'Soft' Dimensions of ICT

Previous IS research has revealed that it is not only the hard investments in ICT, i.e. in various types of ICT equipment, that a firm should make in order to obtain benefits from these technologies; additional soft investments are required in the development of some highly important humans-related soft dimensions of ICT (e.g. in order to create ICT skills, ICT processes, ICT strategy). This soft ICT investment constitutes an important complement of the hard ICT investment. It enables the formulation of the optimal composition of the hard ICT investment, namely the definition of the appropriate IS (hardware and software) that should be developed, and also of the exact technical and functional requirements they should fulfil, based on the needs and the strategy of the particular firm. Additionally, it enables a better monitoring and management of the corresponding IS development

projects, so that higher quality IS can be developed through them, and more benefits can be generated for the firm. Finally, it enables a more efficient operation, use and management of these IS once they have become operational. All these can increase dramatically the value that hard ICT investment generates for the firm.

It should be mentioned that there is some theoretical literature that investigates the ability of ICT, both its hard and soft dimensions, to create sustainable competitive advantages for firms, using the resource-based view (RBV) of the firm RBV of the firm (Barney, 1991) as theoretical background, assessing to what extent ICT can fulfil the four conditions proposed by RBV: value, rarity, inimitability and non-substitutability (e.g. Mata et al., 1995; Wade and Hulland, 2004; Nevo and Wade, 2010). A common conclusion of them is that hard ICT (i.e. ICT equipment) cannot create sustainable competitive advantages on its own, as it cannot fulfil two of the above conditions: rarity and inimitability (as ICT equipment is widely available, has become a commodity and can be easily purchased by competitors as well). On the contrary, some soft dimensions of ICT (e.g. ICT management, ICT cooperation and partnership with business units of the firm, ICT planning) have a much higher potential to create sustainable competitive advantages, as they can fulfil the above conditions to a much higher extent, since they cannot be directly purchased, are firm-specific, difficult to develop and have to be built and mature over a long time period. These soft dimensions of ICT are very important for the development of synergies between hard ICT and other important resources of the firm, which can lead to the creation of strong unique 'IT-enabled resources' (Nevo and Wade, 2010) that result finally to sustainable competitive advantages.

For the above reasons there has been considerable previous literature that identifies and analyses soft dimensions of ICT at firm level, so in the following paragraphs we are going to review some representative studies in this direction. Galliers and Sutherland (1991) in the early 90s proposed a model of 'stages of ICT growth', which for the assessment of the level of growth and maturity of an organization with respect to the use and management of ICT defines a comprehensive set of seven criteria that correspond to important soft dimensions of ICT at firm level: ICT strategy (=plan of related actions), (organizational) structure, systems (=formal and informal procedures), staff, skills, style (=culture and behaviour) and superordinate goals. Mata et al (1995) defined four basic 'attributes' of ICT in a firm (proprietary technologies, technical ICT skills, managerial ICT skills and access to capital) and examined them as to their potential to create sustainable competitive advantages using as theoretical foundation the RBV of the firm. They finally concluded that only the managerial ICT skills (an important soft dimension of ICT exploitation at firm level, defined as the ability of ICT management to understand the business needs of other functional units, customers and suppliers, and in cooperation with them to develop IS that cover these needs) is highly likely to provide sustainable competitive advantage; on the contrary, the ability of technologies (even proprietary ones) to provide sustainable competitive advantage was assessed as low and continuously eroding. Also, the highly influential empirical study of Brynjolfsson and Hitt (1996) examined the effect of another fundamental soft dimension of the ICT at firm level, the ICT labour, on financial performance; in their econometric models they included one ICT labour variable (in addition to the non-ICT capital, ICT capital and non-ICT labour variables), and found that it has a positive statistically significant effect on firm's output, and a marginal product higher than the one of the non-ICT labour.

This study has been followed by several empirical studies that reveal the importance and impact of various soft dimensions of ICT at firm level. Powell and Dent-Micallef (1997) from an empirical study in the retail industry found that ICT equipment alone cannot provide sustainable competitive advantages, but such advantages can be gained only by using ICT in combination with other intangible human and business resources of the firm for leveraging them; this requires strong ICT-business cooperation and partnership, which is recognised as another important soft dimension of ICT exploitation at firm level, that has been extensively investigated later by the IS Strategic Alignment research (for a review of it see Chan and Reich, 2007; Loukis et al., 2008). Bharadwaj (2000) examined empirically the effect of some soft dimensions of ICT at firm level on a variety of profit and cost-based performance measures, based also on an RBV perspective. Using a matched pair approach, he found that superior 'ICT resources', which consist of 'ICT physical infrastructure' (corresponding to the hard dimension of ICT), 'human ICT resources' (including technical and managerial ICT skills,

which are soft dimensions of ICT) and 'ICT-enabled intangibles' (including ICT-enabled knowledge assets, customer orientation, synergy between organizational divisions, which are also soft dimensions of ICT) result in superior performance in the abovementioned measures. Ravichandran and Lertwongsatien (2005) developed and estimated a model that relates basic IS resources (IS human capital (=IS personnel skills and knowledge concerning technologies and firm's operation), ICT infrastructure (firm's basic platform, network, applications and data) sophistication, and IS partnerships (both internal and external) quality with the main IS capabilities (for IS planning, development and operation), and resulting the ICT support provided for important business functions and finally the financial performance. This empirical investigation identifies and examines several soft dimensions of ICT at firm level, some of them being characterised as 'ICT resources' and some others as resulting 'ICT capabilities', and estimates statistically significant relations among them and also with the level of ICT support of the firm and its financial performance. Loukis et al. (2009) investigated empirically the effect of both 'hard' ICT investment (in ICT hardware, software and networks) and 'soft' ICT investment (in ICT human resources, skills and structure) on firm output (using firm-level data from the same national context as the current study). They found that the existence of an ICT structure having the form of a separate department has a positive and statistically significant effect on firm output, which is of considerable magnitude of about two thirds of the corresponding effect of the hard ICT investment. Recently, Mithas et al. (2011) based on an empirical investigation concluded that ICT-enabled information management plays an important role in the development of critical firm's capabilities concerning customer management, processes management, and performance management, which influence positively several aspects of performance concerning customer satisfaction, organizational effectiveness, financial results and employees satisfaction. From the review of the above empirical literature it is concluded that the effects of various soft dimensions of ICT at firm level on several aspects of firm's performance have been investigated; however, the effects of soft dimensions of ICT on innovation performance have not been examined, despite the high significance of innovation for firms' competitiveness and performance.

3 RESEARCH HYPOTHESES

The research hypotheses of this study concern the impacts of important soft dimensions of ICT at firm level on firm's innovation performance. In particular, we have focused on the soft ICT dimensions defined in the model of 'stages of ICT growth' proposed by Galliers and Sutherland (1991), since they have been based on a rich previous management literature, and also constitute a comprehensive set of fundamental soft dimensions, which are the basis for the development of higher level ICT-enabled resources and capabilities. In this study we are dealing with the first five of the seven soft dimensions of ICT defined in the above model: ICT organizational structure, staff, skills, strategy and systems (meant as procedures - processes in the model).

Our first research hypothesis concerns the organizational structure established in the firm for the exploitation of ICT, focusing on the existence of a high hierarchical level ICT department which reports directly to the Chief Executive Officer (CEO) of the firm. This structure allows a direct bi-directional communication with the CEO, which promotes the innovative use of ICT, as it contributes to both the creation and the implementation of innovative ideas. In particular, it results in a more intensive transfer of information and knowledge from the CEO to the ICT department concerning firm's operations, problems, objectives and strategic directions, which provide to the latter strong direction and motivation for innovative thought, ideas and proposals concerning innovations in processes, products and services based on ICT; such a structure reduces the risk of a techno-centric mentality in the ICT department, and exposes it to the realities and difficulties of the business departments, pushing it towards more business-centric contribution and innovation. At the same time this structure results in a more intensive transfer of information and knowledge from the ICT department to the CEO concerning new ICT that create opportunities to the firm for improvement and enrichment of its processes, or from new products and services, which can generate more interest, resources and support from the CEO for the pilot and then for the full scale implementation of ICT-based innovative ideas, and later for their institutionalisation and for overcoming resistances. There is previous literature arguing that direct reporting of the Chief Information Officer (CIO) to the CEO

promotes a shared understanding between them, and between ICT and business departments in general, on how ICT can be used strategically, and not only for operational support of existing processes, products and services (Armstrong and Sambamurthy, 1999; Chen et al, 2010; Banker et al, 2011). So, our first research hypothesis is:

Hypothesis 1: The existence of an ICT department reporting directly to the CEO has a positive impact on innovation performance.

However, a structure responsible for the exploitation of ICT in the firm in order to be effective needs to be staffed with sufficient ICT personnel. This personnel has a wide range of duties, which concern the development, modification and operation of various IS, the management of many relevant projects, and also support of numerous users of various hierarchical levels; their failures have negative impact on the firm and are widely visible inside and sometimes outside the firm. For this reason ICT personnel usually experience high levels of workload, stress and exhaustion (Moore, 2000; Shih et al, 2011). If the number of ICT personnel is too low, they will deal only with their abovementioned 'necessary' duties, and will not spend time for thinking new innovative ideas of using ICT for improving and enriching firm's processes, products and services, regarding such innovation-related tasks as undesired and unacceptable additional activities that increase further their too high workload. Therefore it is necessary to have sufficient ICT personnel, so that these 'necessary' ICT activities can be completed, and at the same time there is some time left for creative thinking, acquisition of new knowledge concerning novel ICT, experimentation with such technologies, implementation of new IS (or modifications to existing ones) which are necessary for supporting innovation, training the users of them, etc. Innovation has been traditionally associated with reasonable 'organizational slack', defined as the availability of resources above and beyond those necessary for meeting immediate business requirements and meeting explicit objectives (Cyert and March, 1963; Nohria amd Gulati, 1996; Wagner and Ettrich-Schmitt, 2009). For the above reasons our second research hypothesis is:

Hypothesis 2: The ratio of the number of ICT personnel to the number of ICT users has a positive impact on innovation performance

Our third and fourth research hypotheses concern ICT skills. It is widely recognized that in the ICT domain there is a rapid evolution, resulting in the continuous emergence of new technologies, and dramatic improvements of existing ones (Pawlowski and Robey, 2004; Shih et al, 2011), which create big opportunities for innovations in firms' processes, products and services. For this reason it is necessary to continuously enrich ICT knowledge of both ICT employees and non-ICT employees through the provision of training to them. This transfers new knowledge to both groups of employees on the capabilities of new or existing ICT, which pushes and stimulates them to think new ideas of exploiting these ICT for improving and enriching firm's processes, products and services. Also, the provision of sufficient training to ICT personnel on new ICT promotes not only the generation of innovative ideas, but also their application as well: it enables ICT personnel to create initially more efficient pilot innovative applications of these new ICT in the firm, which allow a better demonstration of their usefulness and value to the other business departments; also, this training enables ICT personnel subsequently to plan, implement and manage the large scale innovative exploitation of these new technologies in the firm. At the same time, the provision of sufficient training on new ICT to the appropriate non-ICT personnel (potential future users) results in better cooperation with the ICT personnel for devising processes, products and services innovations based on these technologies, and also their more efficient use as part of subsequent innovations' implementation, and less resistances to these innovations. In general, the transfer of new external knowledge through various mechanisms has been traditionally recognized as an important drive for innovation, in combination with relevant internal knowledge (Cassiman and Veugelers, 2006). So our third and fourth research hypotheses are:

Hypothesis 3: The provision of ICT training to ICT personnel has a positive impact on innovation performance

Hypothesis 4: The provision of ICT training to non-ICT personnel (users) has a positive impact on innovation performance

Our fifth research hypothesis concerns ICT strategic planning based on the overall strategic planning of the firm. For the development and the maintenance of such a plan there is systematic cooperation

between the ICT department and the other business departments, through mixed teams, in which intensive exchange of information takes place between the former and the latter. In particular, the business departments' representatives on one hand provide information on their processes and on the products and services they produce, together with their current problems, future plans and objectives; also, the overall strategic plan of the firm is examined, focusing on firm's strategic future directions concerning products and services to be produced, geographical areas of activity, targeted market segments and ways of achieving competitive advantage. On the other hand, the ICT department's representatives provide information on the capabilities of firm's IS and also of various emerging ICT of interest to the firm. This information exchange creates the background for a mutual understanding and a common search for opportunities of innovative uses of ICT aiming at improving firm's processes, products and services, solving its problems, supporting its future strategic actions (e.g. new products and services, new geographic areas of activity, new market segments, etc.) and for creating competitive advantages. Also, this systematic cooperation between ICT and business departments can lead to the development of innovative synergies between firm's ICT infrastructure and other important resources of the firm leading to the creation of strong unique 'IT-enabled resources' (Nevo and Wade, 2010) that can provide sustainable competitive advantages. The exchange of information and knowledge among employees of different backgrounds and roles has been widely recognised in the innovation literature as an important drive of innovation (Nerkar and Paruchuri, 2005). Also, the extensive literature on IS Strategic Alignment provides extensive evidence for the strategic benefits that can be generated through the mutual alignment between ICT direction and overall firm's strategic direction (Chan and Reich, 2007; Loukis et al, 2008). The above cooperation between ICT and business departments promotes not only the creation of innovative ideas, but also their effective implementation through a combination of appropriate coordinated IS developments (by the ICT department) and operations (by the business departments). Therefore, our fifth research hypothesis is:

Hypothesis 5: ICT strategic planning based on the overall strategic planning of the firm has a positive impact on innovation performance

Our final research hypothesis concerns ICT processes, and focuses on ICT service level management, defined as the systematic setting of goals for and measurement – monitoring of the main aspects of the quality level of the ICT services offered to firm's employees (e.g. availability, response time, problems solving time, etc.). Such a process leads to the rational definition of the required quality levels for the various ICT services offered to different employees' groups, based on the particular business needs of each (which might differ significantly), and then the adaptation of the technical and human resources used for providing these services; this results in ICT service quality that is neither below nor above users' needs (the former might result in operational problems and poor customer service, while the latter might result in waste of resources) (Hochstein et al, 2005; McNaughton et al, 2010). Taking into account that most firms' innovations today rely to a significant extent on ICT support, we expect that the establishment of ICT service level management processes will result in the provision of reliable ICT services, having the required quality level (e.g. sufficient levels of availability, response time, problems solving time, etc.), in a cost-efficient manner and avoiding waste, and this will have a positive impact on innovations implementation. Innovation projects are inherently characterized by high levels of uncertainty and risk for all stakeholders, e.g. firms, employees, customers, etc. (Goffin and Mitchell, 2010), so unreliable ICT support of low quality might increase this and result in lower adoption and success of the innovation. So our sixth research hypothesis is:

Hypothesis 6: ICT Service Level Management has a positive impact on innovation performance

4 DATA

For this study we have used firm-level data 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 (Food and Beverages, Footwear, Pulp and Paper, ICT Manufacturing, Consumer Electronics, Shipbuilding and Repair, Construction, Tourism,

Telecommunication Services and Hospital Activities). Then, two similar samples were also created with the same proportions of small, medium and large firms, and also firms from the above 27 sectors, as reserve samples, in case firms of the first sample refuse to answer. A questionnaire was developed and reviewed by three highly experienced experts from ICAP S.A.; based on their remarks the final version of the questionnaire 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). The data collection activity took about 6 months.

5 MODEL SPECIFICATION AND ESTIMATION METHOD

For testing the research hypotheses presented in section 3 using the above data the following innovation model was estimated:

$$INNOV_i = bo + b1* DEM_i + b2* PCOMP_i + b3* NPCOMP_i + b4* NUCOMP_i + b5* H\_ICT_i + b6* S\_ICT_i + b7* D\_SECT_i + b8* D\_LARGE_i + b9* D\_MED_i + e_i \quad \text{(for firm i)} \quad (1)$$

For measuring innovation performance (dependent variable) we have used two binary (Yes/No) variables (INNOV_PD, INNOV_PC) assessing whether the firm has introduced any product/service innovation or process innovation respectively in the last three years; for each of them a separate regression model has been estimated. With respect to the independent variables we have included first a set of variables corresponding to some important 'traditional' innovation determinants that previous research has identified: demand expectations, price and non-price competition, and market concentration. The demand expectations variable DEM assesses to what extent the firm expects an increase of demand on the relevant product markets in the medium-term (next three years). The two competition variables PCOMP and NPCOMP assess the intensity of price and non-price competition respectively in firm's most important market, while the market concentration variable NUCOMP measures the number of main competitors in firm's most important market. A second set of independent variables corresponds to hard and soft ICT. In particular, we have included one hard ICT variable H_ICT, which measures the extent of use by firm's employees of two basic ICT, Internet and Intranet. Also, in each model we have included one soft ICT variable S_ICT, corresponding to one of the six research hypotheses presented in section 3, so we finally estimated in total 12 regression models (2 dependent variables x 6 soft ICT variables). Our first soft ICT variable was ICT_DEP_CEO assessing whether the firm has an ICT Department reporting directly to the CEO, while our second one ICT_PERS was equal to the number of ICT personnel in the firm divided by the number of ICT users. The third and fourth variables ICT_TR_SP and ICT_TR_US assess the extent of ICT training provided to the ICT specialised personnel and the non-ICT personnel (users) respectively. The fifth soft ICT variable ICT_PLAN assesses to what extent there is an ICT plan in the firm based on its overall strategic plan, while the sixth one ICT_SLM assesses to what extent there is ICT service level management. Additionally, we included a third set of dummy variables for capturing the effects of firm size, an explanatory variable used in most innovation studies (see, e.g., Cohen 1995), and sector. In particular, we used the number of employees in full-time equivalents as a measure of firm size, and from it two dummy variables have been formed: one D_MED taking value 1 for medium-sized firms with 50 to 249 employees (and value 0 for all the others) and a second D_LARGE taking value 1 one for large firms with more than 250 employees (and value 0 for all the others). Also, we have included a sector dummy D_SECT taking value 1 for service firms and 0 for manufacturing firms. The definition of the above variables is provided in the Appendix. We used the same vector of independent variables for both innovation indicators.

The innovation models described above (see equation (1)) have been estimated using LOGIT estimation, which is the most appropriate estimation method, as recommended by the relevant econometric literature (e.g. Gujarati and Porter, 2009), if the dependent variable is binary.

6 RESULTS

The estimates are shown in the following tables. For each independent variable the exp(b) is shown, which is equal to the increase of the odds ratio of the dependent variable (process or product/service innovation) if the corresponding independent variable increases by one unit; statistically significant coefficients at the test levels of 1% and 5% are shown in bold and underlined.

In Table 1 we can see the estimated process and product/service innovation models initially without soft ICT variable. We remark that in the Greek 'innovation averse' national context the four 'traditional' innovation determinants we examined (demand expectation, price competition, non-price competition, number of competitors) have very little impact on innovation performance. In particular, we found only one statistically significant positive effect of price competition on product/service innovation, while the other three traditional determinants do not have statistically significant effects on product/service innovation; also none of these four variables has statistically significant effects on process innovation. This does not agree 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. On the contrary, we remark that hard ICT has positive statistically significant effects both on process and on product/service innovation. Therefore we can conclude that in this innovation averse national context, in which four important 'traditional' innovation determinants identified by previous literature are not drivers of innovation, this more recently emerged factor, the ICT, seems to be a strong driver of both process and product/service innovation. The discernibly larger positive and statistically significant coefficients of the dummy of large firms across estimations indicate the existence of economies of scale in innovation, as larger firms are characterized by a stronger propensity towards innovation; this is in agreement with findings of previous literature (Cohen, 1995; Arvanitis, 1997).

Independent variable	**Process Innovation**	**Prod/Serv Innovation**
Constant	.263	.198
D_Sect	**.623**	1.173
D_large	**3.977**	**2.504**
D_med	**2.453**	1.596
Demand	.910	.973
Price Competition	1.108	**1.255**
Non price competition	.986	.948
Number of Competitors	.999	1.000
H_ICT	**1.189**	**1.260**

Table 1. Process and product/service innovation models without soft ICT variable

In Tables 2, 3 and 4 we can see the estimated process and product/service innovation models with the soft ICT variables. We remark that the number of ICT personnel divided by the number of ICT users, the provision of ICT training to ICT and non-ICT personnel, the ICT strategic planning based on the overall strategic planning of the firm and the ICT service level management all have positive statistically significant effects on both process and product/service innovation; on the contrary, the existence of a high-level ICT department reporting directly to the CEO does not have statistically significant effects on either process or product/service innovation. Therefore hypotheses 2, 3, 4 and 5 are supported, but hypothesis 1 is not supported.

Independent variable	**Process Innovation**	**Prod/Serv Innovation**	**Process Innovation**	**Prod/Serv Innovation**
Constant	.263	.199	.190	.139
D_Sect	**.623**	1.172	**.634**	1.215
D_large	**3.972**	**2.486**	**4.618**	**2.878**
D_med	**2.450**	1.583	**2.714**	**1.741**
Demand	.910	.972	.934	.993
Price Competition	1.108	**1.254**	1.130	**1.289**
Non price competition	.985	.947	.977	.940
Number of Competitors	.999	1.000	.999	.999
H_ICT	**1.189**	**1.257**	**1.202**	**1.276**
ICT_DEP_CEO	1.007	1.042		
ICT_PERS			**2.608**	**2.715**

Table 2. Process and product/service innovation models for ICT department and personnel

Independent variable	**Process Innovation**	**Prod/Serv Innovation**	**Process Innovation**	**Prod/Serv Innovation**
Constant	.151	.126	.095	.099
D_Sect	**.574**	1.109	**.557**	1.097
D_large	**3.246**	**2.062**	**3.556**	**2.268**
D_med	**2.176**	1.418	**2.278**	1.487
Demand	.912	.971	.873	.946
Price Competition	1.079	1.225	1.108	1.250
Non price competition	.978	.941	.977	.942
Number of Competitors	.999	1.000	.999	1.000
H_ICT	**1.139**	**1.214**	1.129	**1.215**
ICT_TR_SP	**1.330**	**1.275**		
ICT_TR_US			**1.459**	**1.306**

Table 3. Process and product/service innovation models for ICT training of ICT and non-ICT personnel

Independent variable	**Process Innovation**	**Prod/Serv Innovation**	**Process Innovation**	**Prod/Serv Innovation**
Constant	.263	.200	.116	.104
D_Sect	**.593**	1.146	**.599**	1.146
D_large	**3.067**	**2.051**	**3.873**	**2.446**
D_med	**2.211**	1.462	**2.438**	1.587
Demand	.846	.938	.885	.952
Price Competition	1.082	1.235	1.155	**1.301**
Non price competition	.956	.925	.970	.936
Number of Competitors	.999	1.000	.999	1.000
H_ICT	1.113	**1.205**	1.115	**1.199**
ICT_PLAN	**1.217**	**1.146**		
ICT_SLM			**1.305**	**1.228**

Table 4. Process and product/service innovation models for ICT planning and ICT service level management

Our results indicate that five out of the six examined soft dimensions of ICT at firm level, which

concern ICT personnel, skills, planning and processes, can increase significantly the positive impact that ICT has on firm's innovation performance; on the contrary, the mere establishment of a high level ICT structure, having the form of an ICT department that reports directly to the CEO, will not have any positive impact on innovation performance, if it is not equipped with sufficient ICT personnel and skills, and appropriate planning and operational processes. The existence of sufficient ICT personnel is important for the innovative exploitation of ICT, allowing, in addition to the execution of everyday 'necessary' duties, as well creative thinking about ICT-based innovation, acquisition of new knowledge on novel ICT, innovative experimentation with such technologies, implementation of new IS (or modifications to existing ones) which are necessary for supporting various innovations, and training the users of them. Also, of critical importance for the innovative exploitation of ICT is the provision of training both to ICT and non-ICT personnel on existing and novel technologies, due to the very rapid evolution and development in this domain. The continuous enrichment of knowledge and skills of ICT personnel will act as stimulation for thinking new ideas of exploiting these ICT in order to improve and enrich firm's processes, products and services; also it will enable ICT personnel to develop pilot innovative applications of these new ICT in the firm and evaluate them, and subsequently to plan, implement and manage the large scale innovative exploitation of some of these new technologies. The provision of training to non-ICT personnel on existing and novel technologies will similarly stimulate creative thinking on ICT-based innovation, and also will lead to more efficient use of these technologies as part of various innovations' implementation projects. Furthermore, ICT strategic planning based on the overall strategic planning of the firm is quite important for the innovative exploitation of ICT, as it allows a systematic cooperation between the ICT department and the other business departments concerning the strategic use of ICT by the firm. This cooperation leads to intensive exchange of information from the former to the latter (concerning capabilities of firm's IS and also various emerging ICT) and inversely (concerning existing business processes, products and services, and also problems, future plans, objectives and strategic directions), which promotes the strategic use of ICT for enabling process, product and service innovation. Finally, another soft dimension of ICT that promotes innovation is the adoption of ICT service level management processes, as it contributes to the cost-efficient implementation of innovations relying on ICT through better exploitation of the existing ICT infrastructure; service level management results in the provision of reliable ICT services, having the required quality level (e.g. sufficient levels of availability, response time, problems solving time, etc.), and at the same time avoiding the waste of resources, and this has a positive impact on innovations implementation.

7 CONCLUSIONS

The innovation potential of ICT has been recognised by a rich previous theoretical literature on this topic, which argues that ICT can be strong drivers of radical innovations in firms' processes, products and services. However, these enthusiastic expectations have been empirically investigated only to a limited extent, and only a small number of empirical firm-level studies of the impact of ICT on innovation have been conducted. Also, these few empirical studies focus on the impact of the 'hard' dimensions of ICT (i.e. firm's ICT equipment) on innovation performance, and do not deal with the 'soft' dimensions of ICT at firm level (e.g. ICT personnel, skills and ICT strategy), despite the wide recognition of their importance in previous IS literature. This paper investigates empirically the effects of five important soft dimensions of ICT at firm level (ICT structure, personnel, skills, strategy, processes) on firm's products/services and processes innovation performance, and compares them with the effects of hard ICT and also four important 'traditional' innovation determinants (demand expectation, price and non-price competition, market concentration) identified from the previous innovation research. It is based on firm-level data collected through a survey of 271 Greek firms, from an innovation averse national context, characterised by a culture not favouring innovation and lower levels of firms' innovation in comparison with the other European countries.

It has been concluded that in this innovation averse national context the above four 'traditional' innovation determinants have very low impact on innovation performance. On the contrary both hard and soft ICT have strong positive impact on both process and product/service innovation. With respect to the soft dimensions of ICT we found that the number of ICT personnel divided by the number of

ICT users, the provision of ICT training to ICT and non-ICT personnel, the ICT strategic planning based on the overall strategic planning of the firm and the adoption of ICT service level management all increase significantly the positive impact of ICT on firm's innovation performance. On the contrary, the existence of a high-level ICT department reporting directly to the CEO does not have statistically significant effects on either process or product/service innovation. These findings indicate that hard and soft ICT provide a strong innovation driver even in such innovation averse national contexts, in which the traditional innovation determinants do not drive innovation of processes, products or services.

The results of this study have interesting implications for IS research and management. With respect to IS research the positive impacts of five different soft dimensions of ICT on firm's process, product and service innovation we found indicates that the extensive empirical research required in the future concerning the relation between ICT and innovation should not neglect the soft dimensions of ICT; it should take into account various both hard and soft dimensions of ICT in order to produce practically useful knowledge that can help firms exploit to the highest possible extent the innovative potential of ICT. Our study provides a useful framework for research in this direction, which combines hard and soft dimensions of ICT and at the same time traditional innovation factors. With respect to IS management our findings indicate that firms in order to maximize the exploitation of the innovation potential of ICT should place emphasis on and develop not only the hard ICT, but also the soft dimensions of it as well. In particular, they should employ sufficient ICT personnel, and train it (and also non-ICT personnel as well) extensively so that they keep up with the rapid evolutions and developments in the ICT domain, have sufficient knowledge and skills on the existing and emerging ICT, and can use them for innovations in the internal and external context of the particular firm. Also, firms should establish appropriate processes for ICT strategic planning based on the overall strategic planning of the firm, which generate fruitful interaction between ICT and business departments that generates innovation, and for ICT service level management that provide a reliable ICT infrastructure for enabling and supporting innovation. Further empirical research is required concerning the relation between ICT and innovation, in various national contexts, and also distinguishing between different types of innovations, and different hard and soft dimensions of ICT. Also, it is necessary to examine not only 'whether' but also 'how' various hard and soft ICT dimensions affect innovation, and which are the main mediators and moderators of these relations.

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APPENDIX I

Definition of model variables

Variable	Definition
Dependent variables	
INNOV_PD	Introduction of product/service innovations (yes/no)
INNOV_PC	Introduction of process innovations (yes/no)
Independent variables	
DEM	Expectations with respect to demand in the next three years; five-level ordinal variable (level 1: 'strong decrease'; level 5 'strong increase')
PCOMP	Intensity of price competition; five-level ordinal variable (level 1: 'very weak'; level 5 'very strong')
NPCOMP	Intensity of non-price competition; five-level ordinal variable (level 1: 'very weak'; level 5 'very strong')
NUCOMP	Number of main competitors
H_ICT	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 intranet 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%
ICT_DEP_CEO	Existence of ICT Department reporting directly to the CEO (Yes/No)
ICT_PERS	Number of ICT personnel in the firm divided to the number of ICT users.
ICT_TR_SP	Extent of ICT training provided to the ICT specialised personnel; five-level ordinal variable (level 1: 'not at all'; level 5: 'to a very large extent')
ICT_TR_US	Extent of ICT training provided to and the non-ICT personnel (users); five-level ordinal variable (level 1: 'not at all'; level 5 ' to a very large extent')
ICT_PLAN	Extent of having ICT plan based on the overall strategic plan; five-level ordinal variable (level 1: 'not at all'; level 5: ' to a very large extent').
ICT_SLM	Extent of having ICT Service Level Management processes (level 1: 'not all'; ; level 5: ' to a very large extent')
D_MED	Dummy variable for medium-sized firms: 50 to 249 employees
D_LARDE	Dummy variable for large firms: more than 250 employees
D_SECT	Dummy variable for service sector firms
Reference group for firm size: small firms (5 to 49 employees); for sector: manufacturing firms	