



# The effect of soft ICT capital on innovation performance of Greek firms

Innovation  
performance of  
Greek firms

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## Abstract

**Purpose** – The purpose of this paper is to investigate the effects of four types of “soft” information and communication technologies (ICT) capital related to ICT knowledge and skills (ICT personnel, ICT training of ICT personnel and users, ICT unit) on the innovation performance of Greek firms. Furthermore, the paper compares these effects with the ones of the hard ICT capital and also of four important “traditional” innovation determinants identified from previous research in this area (demand expectation, price and non-price competition, market concentration).

**Design/methodology/approach** – A quantitative methodology has been adopted for investigating the above effects, based on the estimation of regression models. Using data collected through a survey based on a structured questionnaire from 271 Greek firms, innovation models have been estimated, having as independent variables measures of hard ICT capital, the examined four types of soft ICT capital and also the above traditional innovation determinants.

**Findings** – The paper has been concluded that in the innovation averse Greek national context the examined traditional innovation determinants have very low impact on firms’ innovation performance, however, on the contrary both hard ICT capital, and three out of the four examined types of soft ICT capital (ICT personnel, ICT training of ICT personnel and users) have positive impact on both process and product/services innovation. Furthermore, it has been found that the total effect of these three knowledge and skills related types of soft ICT capital on innovation performance is stronger than the effect of the hard ICT capital.

**Research limitations/implications** – The main limitations of the paper are that it uses simple innovation performance measures (not distinguishing between different types of innovations), and also is based on firm-level data collected from a single country. The paper has interesting implications for future research on the impact of the relation between ICT and innovation, which should not any more neglect the soft ICT capital, but consider various types of both hard and soft ICT capital.

**Practical implications** – The results of the paper can be useful to firms’ chief information officers and chief executive officers and also to consultants and practitioners interested in maximizing the exploitation of the innovation potential of ICT, in order to understand the hard and soft aspects of ICT that have to be developed for this purpose and optimize firms’ ICT-related investment.

**Originality/value** – The limited previous empirical literature concerning the effect of ICT on innovation focus on the hard ICT capital (mainly on ICT equipment) and neglect the role of the soft ICT capital. The paper contributes to fill this research gap, by examining the effects of three types of ICT capital, and also – for comparison and regression models’ completeness purposes – of hard ICT capital and of four traditional innovation determinants, on firms’ innovation performance.

**Keywords** Innovation, Hard ICT, Information and communication technologies (ICT), Innovation drivers, Soft ICT

**Paper type** Research paper



## 1. Introduction

It has been widely recognized that information and communication technologies (ICT) have a great potential not only to improve the efficiency of the established business processes of firms, through which their usual products and services are produced, but also to facilitate and drive innovations both in their processes, and in the products and services. This can be highly beneficial, as innovation has become a critical element of modern economy, which is highly important for the prosperity of firms, industries and nations (Organization for Economic Co-operation and Development, 2010). Products/services innovations can enable a firm to achieve differentiation over competitors, or even create new markets in which it has a dominant position, as well as provide an avenue for expansion into other industries, resulting finally in higher levels of profits. Process innovations create new methods of performing firm activities, which have lower costs and higher efficiency or generate new revenue, having also a positive impact on profitability. Especially in highly dynamic sectors, the capability of a firm to “renew” itself is critical for its survival.

There has been extensive theoretical literature analyzing the innovation potential of ICT (e.g. Davenport, 1993; Bresnahan *et al.*, 2002; Thomke, 2006; Wu and Hisa, 2008). The basic argument of this literature (briefly reviewed in Section 2.1) is that many of the current processes, products and services of firms have been designed and established in the pre-ICT era, so they have been shaped to a large extent by the basic characteristics and limitations of the manual mode of work and the high costs of information processing and transfer at that time. Since ICT overcome these limitations (e.g. individuals cooperating for completing a task and documents used need not be located at the same place, cooperation can be asynchronous, a higher degree of tasks’ parallelism can be achieved) and reduce information processing and transfer costs (Davenport, 1993), they offer huge capabilities and opportunities for dramatic innovations in the processes, products and services of firms. Also, ICT have the potential to support and enhance significantly the collection and management of innovation-related knowledge, the innovation production and the external innovation collaborations, increasing the productivity of firms’ innovation creation processes (Thomke, 2006).

However, limited empirical investigation of this potential of ICT to drive innovation has been conducted using large data sets, in order to find out to what extent the high expectations of this theoretical literature are realized. Furthermore, these few previous empirical firm-level studies of the effect of ICT on innovation performance (briefly reviewed in Section 2.2) focus on the “hard” ICT capital (mainly on ICT equipment) and neglect the role of the “soft” ICT capital (e.g. ICT knowledge and skills), though its importance for the exploitation of the potential of the hard ICT capital has been widely recognized in information systems (IS) research (Wade and Hulland, 2004; Ravichandran and Lertwongsatien, 2005; Liang *et al.*, 2010). Also, this limited empirical research is restricted to the national contexts of a few highly developed countries, as explained in more detail in Section 2.2. Therefore it is important to investigate empirically the effect of various types of soft ICT capital on firms’ innovation performance in various national contexts.

This study contributes to filling these research gaps, by making the following four contributions:

- (1) It empirically investigates the effects of four types of soft ICT capital related to ICT knowledge and skills (ICT personnel, ICT training of ICT personnel and users, existence of ICT unit) on firm’s innovation performance.

- (2) It compares these effects with the ones of the hard ICT capital.
- (3) It also compares these effects with the ones of four important “traditional” innovation determinants identified from previous research in this area: demand expectation, price and non-price competition, market concentration.
- (4) It investigates the above effects in the national context of Greece, which is quite different from the ones of the highly developed countries where most similar previous empirical studies (e.g. concerning the effects of ICT on various aspects of business performance) have been conducted, with respect to the level of economic development, the use of ICT and the propensity to innovation. In particular, according to the European Central Bank (<http://sdw.ecb.europa.eu>) the gross domestic product per capita of Greece (which is a basic indicator of economic development) is 19,000 euro, which is much lower than the ones of the highly developed European countries (e.g. for Germany it is 31,400 euro, for UK it is 27,800 euro, etc.). So, Greece has a much lower level of economic development than the highly developed countries, and therefore a weaker tradition of adopting and using advanced technologies in its economy, and introducing technological innovations. Also, Greece is characterized by a lower level of ICT use in its economy than the highly developed countries; according to OECD ([www.oecd-ilibrary.org/sites/factbook-2011-en](http://www.oecd-ilibrary.org/sites/factbook-2011-en)) in Greece the ICT investment is 15.7 per cent of the total non-residential investment, which is much lower in comparison with most of the highly developed countries (e.g. for the USA it is over 30 per cent, while for Sweden and Denmark it is about 25 per cent). Furthermore, Greece is characterized by a culture of lower propensity to innovation; according to the studies of Geert Hofstede (see [www.geert-hofstede.com/](http://www.geert-hofstede.com/)) the score of the “uncertainty avoidance index” (a national cultural dimension associated with lower propensity to innovation) for Greece is 112, while on the Scandinavian and the continental European countries it is at the much lower levels of 35.25 and 50.17, respectively. In this quite different and “innovation averse” national context from the ones of the highly developed countries it is interesting to study the relations between hard and soft ICT capital and innovation.

A quantitative methodology has been adopted for investigating the above effects, based on the estimation of regression models. Based on data collected through a survey based on a structured questionnaire from 271 Greek firms, innovation models have been estimated, having as independent variables measures of hard ICT capital, the examined four types of soft ICT capital and also the above traditional innovation determinants.

This paper is structured in six sections. The following Section 2 includes the background of this study, while in Section 3 the research hypotheses are developed. Then, the methodology and data of this study are described in Section 4, followed by the results presented and discussed in Section 5. The final section includes the conclusion and implications of this study, and also future research directions.

## 2. Background

### 2.1 Theoretical research

The emergence and growing penetration of ICT lead to the gradual realization of its great potential not only to improve the efficiency of established business processes of firms, through which their usual products and services are produced, but also to facilitate and drive important innovations in their processes, and also in their products

and services. This gave rise to extensive theoretical research that examines and analyses the innovation potential of ICT, its sources, forms and possible impacts (Hammer, 1990; Hammer and Champy, 1993; Davenport, 1993; Bresnahan and Trajtenberg, 1995; Brynjolfsson and Hitt, 2000; Bresnahan *et al.*, 2002; Champy, 2002; Lyytinen and Rose, 2003; Avgerou, 2003; Lyytinen and Newman, 2008; Brynjolfsson and Saunders, 2010). This theoretical literature argues that ICT differ considerably in this sense from the other “traditional” types of capital that firms use, as they are “general purpose technologies” (Bresnahan and Trajtenberg, 1995), characterized by higher levels of flexibility and adaptability, so they can be used in numerous different ways by firms and for many different purposes, enabling important innovations in business processes, products and services. This literature also emphasizes that most of the existing work practices, business processes and products/services of firms have their roots in the pre-ICT era, and have been critically influenced and shaped by the dominant at these times logics and limitations of the manual mode of work. For instance, the manual work necessitates extensive human labour (since all tasks have to be performed by humans), colocation of cooperating persons and documents used, and synchronous human interaction; also it provides limited capabilities for tasks parallelism (since documents can be used only by one person at each specific time) and is characterized by high costs of information processing and transfer (Davenport, 1993). However, ICT have dramatically changed these logics and assumptions, have reduced dramatically information processing and transfer costs, and enable overcoming previous limitations of manual work (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, since they can have remote and asynchronous co-operation through electronic networks; a higher degree of tasks parallelism can be achieved, since an electronic document can be accessed by many persons at the same time). For these reasons 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, and significant improvements of important intangible aspects of existing products/services, such as convenience, timeliness, quality, personalization, etc. ICT can be enablers of new products and services, which were not feasible, or were too costly, previously. The 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, it can change the geographic allocation of tasks, leading in some cases to more centralization and in some others to more decentralization, according to the specific characteristics of each task and its context.

Another theoretical research stream examines and analyses the innovation potential offered by the internet, concluding that it can enable dramatic innovations in the way firms do business, and new value propositions and business models (Timmers, 1998; Afuah and Tucci, 2001; Zwass, 2003; Wu and Hisa, 2004, 2008; Tavlaki and Loukis, 2005). Wu and Hisa (2004, 2008) conclude that internet commerce can facilitate and drive extensive innovations that change both products’ core components and business model, which can be categorized into four groups: incremental innovations (small changes in products’ core components and 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

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in both products' core components and business model). Timmers (1998) describes some new business models, which are emerging based on 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. Zwass (2003) identified some categories of innovation opportunities that the www/internet compound provides, which are associated with marketplaces, universal supply-chain linkages, networks of relationships, external collaborations, use of forums for setting up private groups spaces and public discussion spaces, interactive media, goods and services delivery, any-time any-place connectivity, interconnection of enterprise IS with the ones of business partners, integration of previous telecommunications networks and computing utility.

Finally, there is another more recent theoretical research stream dealing with the potential of ICT to increase the productivity of firms' research and development (R&D) and innovation creation processes, which can result in higher innovation performance (Thomke, 2006; Dodgson *et al.*, 2006; Kafouros, 2006; Gordon *et al.*, 2008; Kleis *et al.*, 2012). This theoretical literature concludes that ICT can significantly help improving the collection, management and exchange of innovation-related knowledge. They enable researchers distributed in different research centres of a firm to easily and rapidly share knowledge assets. Furthermore, ICT allow a better communication and exchange of knowledge among firm's employees from different functions and disciplines, and this facilitates the combination of scientific and operational knowledge from different domains, which according to the relevant literature (e.g. Rogers, 2003; Nerkar and Paruchuri, 2005) is of critical importance for innovation. Also, innovation production itself can be improved through ICT-based methods of designing, prototyping and testing new products (e.g. using computer-aided design (CAD) and computer-aided design manufacturing technologies). At the same time electronic networks can support and improve external innovation collaborations (e.g. with universities, research centres, other firms, etc.), through which a firm gains access to specialized knowledge that can be used for designing new products, services and processes. The application of ICT provide the required links for effective research partner monitoring and information sharing, as well as reduce the transaction costs of working with multiple innovation partners. In general, ICT are becoming an increasingly important infrastructure of innovation due to the gradual move from the "closed innovation" paradigm, in which firms generate internally ideas for innovative products and services, and then develop, manufacture, market and distribute them on their own, to a new and more productive "open innovation" paradigm (Chesbrough, 2003; Chesbrough and Crowther, 2006); in this paradigm internal and external ideas, skills and knowledge (i.e. from both firm employees and suppliers, customers, partners) are combined in order to create better innovations in a shorter time and promote them in various markets.

### *2.2 Empirical research*

However, limited empirical investigation of this potential of ICT to facilitate and drive innovation has been conducted in order to find out to what extent the high expectations of the above three theoretical research streams are realized. It is small the number of empirical studies that have been conducted concerning the effect of ICT on innovation performance of firms based on large data sets, especially in comparison with the number of studies conducted on the effects of ICT on other aspects of business performance, though there are many case studies analyzing successful ICT-based innovations (e.g. Tarafdar and Gordon, 2007; Lindic *et al.*, 2011).

Gera and Gu (2004), using data from 5,501 Canadian firms, found that the share of workers using computers at work and ICT investment per worker have positive effects on both process and product innovation. Bartel *et al.* (2007), based on data from a sample of 212 US firms from the valve manufacturing industry, found that the use of industrial ICT (computer numerically controlled machines, flexible manufacturing system, automatic inspection sectors, 3D CAD software) on one hand promote product innovation (moving from commodity production based on long production runs to customized production in smaller batches), and on the other hand lead to considerable changes in the production processes, which increase their efficiency. 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 the 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 kinds of innovation as well. Engelstätter (2012), based on data from 1,454 German firms, investigated the effect of using three different 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 positive effect on the likelihood of proceeding to process innovation, while ERP systems have a positive effect on the number of process innovations; also, CRM systems have positive effect on the likelihood of proceeding to product innovation, while SCM systems have a positive effect on the number of product innovations. Kleis *et al.* (2012), analyzing data from 201 large US manufacturing firms over the period 1987-1997 including a total of 1,829 observations, found that ICT capital has a positive effect on patents output (which is used as a product innovation measure), and especially on the more “incremental” (i.e. less radical) ones.

In conclusion, the following research gaps can be identified in this area:

- (1) Only a small number of empirical studies that have been conducted concerning the effect of ICT on innovation performance of firms based on large data sets;
- (2) these few empirical studies focus on the effect of the “hard” ICT capital (and mainly of ICT equipment, with only one of the above empirical studies focusing on software) on innovation, and neglect the role of the “soft” ICT capital, though its importance has been widely recognized in IS research as discussed in more detail in the next Section 2.3; and
- (3) this limited empirical research has been conducted in the national contexts of a few highly developed countries, characterized by high levels of economic development, ICT use and innovation culture, while there is a lack of empirical studies concerning the effect of ICT on innovation in other types of national contexts.

### *2.3 Soft ICT capital*

Previous IS research has revealed that firms in order to exploit the potential of ICT it is critical to develop not only “hard” ICT capital (i.e. ICT equipment and software), but also “soft” humans related ICT capital as well. There has been considerable previous literature that identifies, analyses and examines the impact of various types of soft ICT capital of high importance for firms. In this section we are going to review some representative theoretical and empirical studies in this direction.

Mata *et al.* (1995) in order to investigate the potential of ICT to create sustainable competitive advantages examine four basic “attributes” of ICT at firm level: proprietary technologies, technical ICT skills, managerial ICT skills and access to capital. From an extensive theoretical analysis based on the resource-based view (RBV) of the firm (Barney, 1991) they finally concluded that only the managerial ICT skills 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) examines the effect on financial performance of not only the ICT capital and the non-ICT capital (which were the usual independent variables of previous similar ICT business value studies), but also the ICT labour and the non-ICT labour as well; they found that the ICT labour has a positive statistically significant effect on firm’s output, and a marginal product higher than the one of the non-ICT labour. Bharadwaj (2000) investigates empirically the effect of hard ICT capital and also of some types of soft capital on a variety of profit and cost-based performance measures, based also on an RBV perspective. He found that superior “ICT resources”, which consist of “ICT physical infrastructure”, “human ICT resources” and “ICT-enabled intangibles” (including ICT-enabled knowledge assets, customer orientation, synergy between organizational divisions) result in superior performance in the above-mentioned measures.

Wade and Hulland (2004) from a literature review identified eight types of ICT resources and capabilities that firms require in order to exploit the potential of ICT, from which one corresponds to hard ICT capital (IS infrastructure), while the other seven correspond to soft ICT capital (IS technical, development and operations skills, IS-business partnerships and planning, and market responsiveness and external relationships management). Ravichandran and Lertwongsatien (2005) developed and estimated a model that relates ICT infrastructure (firm’s basic platform, network, applications and data) sophistication, IS human capital (= IS personnel skills and knowledge concerning technologies and firm’s operation) and IS partnerships (both internal and external) quality at a first layer, with some important IS capabilities (for IS planning, development and operation) at a second layer, the resulting ICT support provided for the main business functions at a third layer and finally the financial performance; they found that all first layer IS resources have positive effects on the second layer IS capabilities, with the effect of the IS human capital being the strongest. Liang *et al.* (2010) from a meta-analysis of empirical studies of ICT on firm performance conclude that there is a set of “technology resources” (corresponding to hard ICT capital) and a set of “organizational resources” (corresponding to soft ICT capital) that have a positive impact on various aspects of business performance; the most important elements of the second set are the ICT human and knowledge resources.

From the review of the whole body of this literature it can be concluded that ICT knowledge and skills are the most widely mentioned and examined type of soft ICT capital. Another interesting conclusion is that there have been many empirical studies of the effects of various types of soft ICT capital (including ICT knowledge and skills) on various aspects of firm’s performance. However, a major research gap identified is that there is a lack of empirical studies of the effects of soft ICT capital on innovation performance of firms, despite the wide recognition of the high significance of innovation for firms’ competitiveness and performance. This paper contributes to filling this research gap, by examining the effects of four types of firms’ soft ICT capital related to ICT knowledge and skills on product and process innovation,

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and comparing them with the effects of the hard ICT capital and four important traditional innovation determinants that previous innovation literature has identified.

### 3. Research hypotheses

Our research hypotheses concern the effects of the main types of firm's ICT knowledge and skills soft capital on its innovation performance. Due to the high complexity of ICT (which are a large and continuously increasing set of technologies with rich capabilities and adaptability) the formation and maintenance of ICT knowledge and skills soft capital at firm level necessitates sufficient both "quantity" (number) and "quality" (achieved through continuous training) of ICT personnel. The first mechanism for a firm to acquire ICT knowledge and skills is to employ ICT personnel, so this is the first type of soft ICT capital we examined (*H1*). The second mechanism is definitely to provide ICT training to its ICT personnel, and this has to be combined with the provision of training to the non-ICT personnel (ICT users), so these are the second and third types of soft ICT capital we examined (*H2* and *H3*). Finally, the best way of channelling this ICT knowledge to the other parts of the firm, and combining it with other types of firm's knowledge (e.g. on operations, sales and marketing, etc.), in order to facilitate innovations, is through the establishment of a high hierarchical level ICT department reporting directly to the chief executive officer (CEO) of the firm, so this is the fourth type of soft ICT capital we examined (*H4*).

In particular, our first research hypothesis concerns the effects of ICT personnel on innovation performance. According to previous innovation literature the combination of knowledge from various functional domains of the firm can be a highly productive source of innovations ideas (Rogers, 2003; Nerkar and Paruchuri, 2005). The ICT personnel possesses highly valuable knowledge on the capabilities of firm's hard ICT capital (equipment, software, networks), and of ICT in general. The combination of this knowledge with the knowledge of production and operations personnel (e.g. concerning problems and inefficiencies of current production and operations processes) can lead to ideas for ICT-based process innovations exploiting the capabilities offered by ICT. Also, the combination of this ICT knowledge with the knowledge of sales and marketing personnel (e.g. concerning customers' complaints and preferences, competitors' offerings, market trends) can lead to ideas for ICT-based new products and services, or improvements of existing ones. Furthermore, the combination of this ICT knowledge with the knowledge of R&D personnel can lead to valuable ideas for using ICT in order to increase the productivity of firms' R&D and innovation creation processes (e.g. for supporting and enhancing the collection and management of innovation-related knowledge, the external innovation collaborations and the innovation production). Therefore the knowledge and skills of the ICT personnel are highly important for innovation. Furthermore, with respect to the ICT-based innovations (i.e. processes, products and services innovations directly based on the use of ICT), the knowledge and skills of the ICT personnel are critical not only for their conception, but also for their implementation, initially at a small scale (through pilot applications), and then (for the ones evaluated from the pilots as beneficial) at a larger scale.

However, it should be taken into account that the ICT personnel of a firm has a wide range of other more urgent and pressing duties, which concern the operation and administration of various firm's IS, the support of numerous users, the development of new IS or the maintenance and modification of existing ones and the management of many relevant projects and external providers; failures in these tasks are widely visible



inside and sometimes outside the firm and usually have quite negative impact on the it. For this reason ICT personnel usually experience high levels of workload, stress and exhaustion, as highlighted by the relevant academic (Moore, 2000; Shih *et al.*, 2011). So if the number of ICT personnel is too small, they will deal exclusively with these urgent and pressing duties, and have no time to think of and deal with innovation. It is necessary to have a sufficient number of ICT personnel, so that these necessary and urgent 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, co-operation with personnel from other functional domains of the firm, implementation of new IS (or modifications to existing ones) which are necessary for supporting innovations, 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 (Cyert and March, 1992; Nohria and Gulati, 1996; Wagner and Ettrich-Schmitt, 2009).

For the above reasons, our first research hypothesis is:

*H1.* The number of firm’s ICT personnel has a positive effect on its innovation performance.

Our second and third research hypotheses concern the effects of ICT training provision to ICT personnel and non-ICT personnel (users) on innovation performance. 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 capabilities and flexibility 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 the ICT knowledge and skills of both ICT and non-ICT employees (ICT users) 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 stimulates them to think new ideas of exploiting these ICT for processes and products/services innovations, and for increasing the productivity of firms’ R&D and innovation creation processes.

The provision of sufficient training to ICT personnel 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 the above 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 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 second and third research hypotheses are:

*H2.* The provision of ICT training to firm’s ICT personnel has a positive effect on its innovation performance.

*H3.* The provision of ICT training to firm's non-ICT personnel (ICT users) has a positive effect on its innovation performance.

Finally, our fourth research hypothesis concerns the effect of the existence of a high hierarchical level ICT department reporting directly to the CEO of the firm on its innovation performance. This ICT structure enables on one hand a better organization of the acquisition, management and exploitation of ICT knowledge and skills, and on the other hand a better channelling and flow of them to the other functions of the firm, in order to be combined with their own knowledge and facilitate innovations. It allows direct bi-directional communication with the CEO and the managers of the other functional domains of the firm, which promotes the mutual understanding among them, and the creation and the implementation of ICT-based innovation ideas.

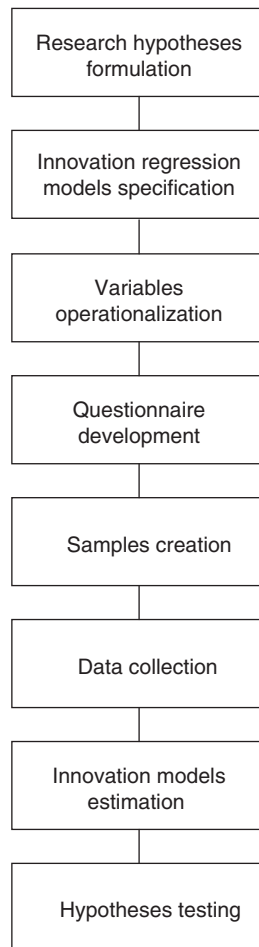
In particular, a high hierarchical level ICT department reporting directly to the CEO of the firm allows a more intensive transfer of information and knowledge from the ICT department to the CEO and the other departments concerning ICT that create opportunities to the firm for improvement and enrichment of its processes, for new products and services or substantial improvements of existing ones, and for enhancements of R&D and innovation creation processes. This can generate more interest, resources and support from the CEO and the other departments for the pilot and then for the full scale implementation of ICT-based innovation ideas, and later for their institutionalization and for overcoming inertia and resistances. At the same time, a more intensive transfer of information and knowledge to the ICT department from the CEO and the other departments can take place, concerning firm's operations, problems, objectives and strategic directions, which provide to the ICT department strong direction and motivation for innovative thought, ideas and proposals concerning innovations in processes, products and services based on ICT. 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 fourth research hypothesis is:

*H4.* The existence of an ICT department reporting directly to firm's CEO has a positive effect on its innovation performance.

#### **4. Methodology and data**

Taking into account that as mentioned in Section 2.2 there are many case studies analyzing successful ICT-based innovations, but on the contrary there is only a small number of empirical studies of the effect of ICT (mainly ICT equipment) on firms' innovation performance based on large data sets, we have adopted a quantitative methodology in our study (Maylor and Blackmon, 2005; Ragin and Amoroso, 2011); it is based on the estimation of regression innovation models (Gujarati and Porter, 2009; Greene, 2011), which have as independent variables measures of hard and soft ICT capital, and also of four important "traditional" innovation determinants. All the steps of our research methodology are shown diagrammatically in Figure 1.



**Figure 1.**  
Research  
methodology diagram

In particular, for testing our research hypotheses presented in Section 3, the following innovation model was estimated:

$$\begin{aligned}
 \text{INNOV}_i = & b_0 + b_1 \times \text{DEM}_i + b_2 \times \text{PCOMP}_i \\
 & + b_3 \times \text{NPCOMP}_i + b_4 \times \text{NUCOMP}_i \\
 & + b_5 \times \text{HARD\_ICT}_i + b_6 \times \text{SOFT\_ICT}_i \\
 & + b_7 \times \text{D\_SECT}_i + b_8 \times \text{D\_LARGE}_i \\
 & + b_9 \times \text{D\_MED}_i + e_i \quad (\text{for firm } i)
 \end{aligned} \tag{1}$$

The dependent variable is innovation performance (INNOV). For measuring it, we have used two binary (yes/no) variables (INNOV\_PC, INNOV\_PDS) assessing whether the firm has introduced any process innovation or product/service 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 the most important “traditional” innovation determinants (= factors having a positive impact on innovation) according to previous research (detailed reviews of this research are provided by Arvanitis and Hollenstein, 1996; Raymond *et al.*, 2006; Van Beers *et al.*, 2008; Buesa *et al.*, 2010): demand expectation, price and non-price competition, and market concentration. The demand expectation variable (DEM) assesses to what extent the firm expects an increase of demand on the relevant product markets in the next three years. The two competition variables (PCOMP and NPCOMP) assess (in a five-level scale) 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 this market.

A second set of independent variables correspond to the hard and soft ICT capital. In particular, we have included one hard ICT capital variable (HARD\_ICT), which is equal to the sum of the standardized values of two variables measuring the intensity of use of (= the percentage of firm employees using) two basic ICT, internet and intranet (both in a six-level scale: 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). We estimated four models with the specification of Equation (1), each of which included a different soft ICT capital variable (SOFT\_ICT) measuring a different type of soft ICT capital, and corresponding to one of the above-mentioned research *H1-H4* (we did not include all soft ICT investment variables in the same model due to the high correlations between these variables, in order to avoid multi-collinearity problems). Our first soft ICT capital variable was ICT\_PERS equal to the number of ICT personnel in the firm divided by the number of ICT users (for testing *H1*). Then we had variables ICT\_TR\_SP and ICT\_TR\_US assessing (in a five-level scale) the extent of providing ICT training to the ICT specialized personnel and to the non-ICT personnel (users), respectively (for testing *H2* and *H3*). The fourth soft ICT capital variable was ICT\_DEPT assessing whether the firm has an ICT department reporting directly to the CEO (for testing *H4*).

Also, we included a third set of dummy variables for capturing the effects of firm size, which according to previous innovation literature has a positive impact on innovation (e.g. Arvanitis, 1997), and sector. 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: D\_MED, taking value 1 for medium-sized firms with 50-249 employees and 0 for all the others, and D\_LARGE, taking value 1 one for large firms with 250 employees or more and 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 detailed definitions of models’ variables are shown in the Appendix.

These eight “basic” innovation models described above (with the specification of the Equation (1)) – 2 dependent variables  $\times$  4 soft ICT capital variables – have been estimated using LOGIT estimation, which is the most appropriate estimation method if the dependent variable is binary, as recommended by the relevant econometric literature (Gujarati and Porter, 2009; Greene, 2011). For validation purposes we calculated for each of them the values of the “pseudo”  $R^2$  of Cox & Snell and the one of Nagelkerke (Scott Long, 1997), which are analogous to the  $R^2$  calculated in the ordinary least squares (OLS) estimation (Gujarati and Porter, 2009; Greene, 2011).

Furthermore, in order to examine the total effect of the examined types of ICT knowledge and skill-related soft capital on the total firms’ innovation performance (i.e. concerning both process and products innovation), we estimated an additional “compact” model with a similar specification. Its dependent variable is the total

innovation performance (INNOV\_TOT), which is equal to the sum of the standardized values of the two above-mentioned binary process and product/service variables (INNOV\_PC, INNOV\_PDS). Also, it includes a total soft ICT capital variable (SOFT ICT\_TOT), which is equal to the sum of the standardized values of subset of the above four soft ICT variables that have statistically significant effects on process and products/services innovation. In order to check the robustness of the findings from this compact model, a second compact model was estimated as well, differing only in the dependent variable, but having the same independent variables; its dependent variable (INNOV\_TOTA) is equal to the sum of the standardized values of the above binary process innovation variable (INNOV\_PC) and a different product/service innovation variable equal to the percentage of firms' sales coming from new products/services introduced in the last three years (INNOV\_PDSA). These two compact models have been estimated using OLS estimation; for validation purposes for each of them we calculated the value of the  $R^2$  (Gujarati and Porter, 2009; Greene, 2011).

For estimating the above models 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 ten important sectors (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 ten 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 with respect to company size and industry. Finally, we received complete questionnaires from 271 firms (88 small, 105 medium and 78 large ones).

## 5. Results

The estimates of the above eight "basic" innovation models are shown in Tables I and II. For each independent variable the  $\exp(b)$  is shown, which is equal to the increase of the odds ratio of the dependent (process or product/service innovation) if the corresponding independent variable increases by one unit; therefore values greater than one correspond to positive  $b$  coefficients and effects, while values less than one correspond to negative  $b$  coefficients and effects (the statistically significant ones at the test levels of 1 and 5 per cent are shown in italics). Also, for each model are shown the values of the "pseudo"  $R^2$  of Cox & Snell and the one of Nagelkerke (Scott Long, 1997), which are at similar levels with the ones of previous innovation empirical studies (Arvanitis, 1997, 2008).

We remark that in the Greek national context the four "traditional" innovation determinants we examined (demand expectation, price competition, non-price

**Table I.**  
Process and product/  
service innovation  
models for ICT  
department and  
personnel (exp(*b*) values)

Independent variables	Process innovation	Product/service innovation	Process innovation	Product/service innovation
Constant	0.263	0.199	0.190	0.139
D_Sect	<i>0.623</i>	1.172	<i>0.634</i>	1.215
D_large	<i>3.972</i>	<i>2.486</i>	<i>4.618</i>	<i>2.878</i>
D_med	<i>2.450</i>	1.583	<i>2.714</i>	<i>1.741</i>
Demand	0.910	0.972	0.934	0.993
Price competition	1.108	<i>1.254</i>	1.130	<i>1.289</i>
Non-price competition	0.985	0.947	0.977	0.940
Number of competitors	0.999	1.000	0.999	0.999
Hard ICT capital	<i>1.189</i>	<i>1.257</i>	<i>1.202</i>	<i>1.276</i>
ICT_Department	1.007	1.042		
ICT_Personnel			<i>2.608</i>	<i>2.715</i>
Cox & Snell $R^2$	0.109	0.902	0.116	0.102
Nagelkerke $R^2$	0.149	0.104	0.159	0.137

**Table II.**  
Process and product/  
service innovation  
models for ICT training  
of ICT and non-ICT  
personnel (exp(*b*) values)

Independent variables	Process innovation	Product/service innovation	Process innovation	Product/service innovation
Constant	0.151	0.126	0.095	0.099
D_Sect	<i>0.574</i>	1.109	<i>0.557</i>	1.097
D_large	<i>3.246</i>	<i>2.062</i>	<i>3.556</i>	<i>2.268</i>
D_med	<i>2.176</i>	1.418	<i>2.278</i>	1.487
Demand	0.912	0.971	0.873	0.946
Price competition	1.079	1.225	1.108	1.250
Non price competition	0.978	0.941	0.977	0.942
Number of competitors	0.999	1.000	0.999	1.000
Hard ICT capital	<i>1.139</i>	<i>1.214</i>	1.129	<i>1.215</i>
ICT_Training_Specialists	<i>1.330</i>	<i>1.275</i>		
ICT_Training_Users			<i>1.459</i>	<i>1.306</i>
Cox & Snell $R^2$	0.127	0.106	0.127	0.102
Nagelkerke $R^2$	0.173	0.142	0.173	0.137

competition, number of competitors) have very little impact on innovation performance. In particular, we found only statistically significant positive effects of price competition on product/service innovation in two out of the four product/service innovation models, 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 in all models. Therefore we can conclude that in this innovation averse national context, characterized by lower level of economic development, ICT use and innovation culture than the highly developed countries where most similar studies have been conducted, these four important “traditional” innovation determinants identified by previous literature are not drivers of innovation, however, a more

recently emerged factor, the ICT, seems to be a strong driver of both process and product/service innovation.

With respect to the soft ICT capital variables, we remark that the number of ICT personnel divided by the number of ICT users, and the provision of ICT training to the ICT specialized personnel and to the non-ICT personnel (users), all have statistically significant positive effects (since the corresponding  $\exp(b)$  values are greater than one) 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 *H1-H3* are supported, while *H4* is not supported. These results indicate that the development of soft ICT capital related to ICT knowledge and skills through the employment of ICT personnel and the provision of ICT training to both the ICT personnel and the non-ICT personnel can increase further the positive impact of the hard ICT capital 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 staffed with sufficient ICT personnel and equipped with sufficient and continuously updated knowledge and skills. Our results show that ICT personnel possesses highly valuable knowledge on the capabilities of firm's hard ICT capital, and ICT in general, which if combined with the knowledge of personnel from other functional domains (e.g. operations, sales and marketing, R&D, etc.) can lead to valuable ideas for exploiting ICT for processes and products/services innovations, and for increasing the productivity of firms' R&D and innovation creation processes. The knowledge and skills of the ICT personnel are also highly important also for the implementation of these ICT-based innovation ideas, initially at a small pilot scale, and then at a larger scale. Furthermore, our results show that it is of critical importance for the innovative exploitation of ICT to provide 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 for 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.

It is interesting to compare the above findings with the ones of the few previous empirical studies of the effect of ICT on innovation performance, which have been reviewed in Section 2.2. Our findings concerning the positive effect of hard ICT capital on innovation performance are in agreement with the ones of these studies. However, our study reveals that additional positive effects on firm's innovation performance can be achieved by developing an ICT knowledge and skills soft capital.

The statistically significant and positive effects of the large firms' dummy variable across estimations (since all the corresponding  $\exp(b)$  values are greater than one) indicate that large firms are characterized by a stronger propensity to innovation, probably due to the existence of economies of scale; this is in agreement with findings of previous literature (Cohen, 1995; Arvanitis, 1997). Also, we can see that the effect of the sector dummy on process innovation is statistically significant and negative in all

models (since all the corresponding  $\exp(b)$  values are less than one), which indicates that service firms have a lower stronger propensity to process innovation than the manufacturing firms.

Finally in Table III we can see the estimates of the above two “compact” innovation models. For each independent variable the  $b$  coefficient is shown and also the standardized one in parent (the statistically significant coefficients at the test levels of 1 and 5 per cent are shown in italics). It is noted that, as described in Section 4, the total soft ICT capital variable (SOFT\_ICT\_TOT) has been calculated as the sum of the standardized values of the three soft ICT variables that have been found from the above basic models to have statistically significant effects on process and products/services innovation (ICT personnel as percentage of ICT users, extent of ICT training provided to the ICT personnel and the non-ICT personnel (users)).

We remark that, in both these compact models, the hard ICT capital, this ICT knowledge and skills-related soft capital, and also firm size have positive impact on firms’ total innovation performance, while all four examined traditional innovation determinants do not. The standardized  $b$  coefficients shown in parentheses allow us a comparison of the effects of these factors on the total innovation performance. From them it can be concluded that firm size has the largest effect, followed by the soft ICT capital, and then the hard ICT capital. Also, the total effect of these three ICT knowledge and skills related types of soft ICT capital on total innovation performance is about 30 per cent stronger than the effect of the hard ICT capital (in the first compact model we have  $0.179/0.137 = 1.30$ , while in the second compact model we have  $0.149/0.111 = 1.34$ ). The above results indicate that the positive impact of ICT on firms’ innovation can be roughly divided into two parts: a smaller part generated through simple and straightforward ICT-based process and products/services innovations, exploiting basic capabilities of the hard ICT capital, and a larger part generated through more sophisticated and difficult to design and implement ICT-based process and products/services innovations, exploiting more advanced capabilities of the hard ICT capital, which relies critically on firm’s ICT knowledge and skills soft capital, developed through the employment of ICT personnel and the provision of ICT training to both the ICT personnel and the non-ICT personnel (users).

## 6. Conclusions

The innovation potential of ICT has been recognized and analyzed by a rich previous theoretical literature, which argues that ICT can facilitate and drive important

Independent variables	INNOV_TOT	INNOV_TOTA
Constant	-1.628	-1.541
D_Sect	-0.195 (-0.055)	-0.196 (-0.063)
D_large	<i>0.835 (0.213)</i>	<i>0.695 (0.200)</i>
D_med	<i>0.459 (0.126)</i>	<i>0.465 (0.146)</i>
Demand	-0.053 (-0.014)	0.155 (0.048)
Price competition	0.130 (0.076)	0.039 (0.026)
Non price competition	-0.039 (-0.025)	0.058 (0.043)
Number of competitors	0.000 (-0.049)	0.000 (-0.068)
Hard ICT capital	<i>0.135 (0.137)</i>	<i>0.097 (0.111)</i>
Soft ICT capital	<i>0.158 (0.179)</i>	<i>0.116 (0.149)</i>
$R^2$	0.139	0.134

**Table III.**  
Compact innovation  
models



innovations in firms' processes, products and services. However, these enthusiastic expectations have been empirically investigated only to a limited extent. Furthermore the few previous empirical firm-level studies of the effect of ICT on innovation performance focus on the "hard" ICT capital (mainly on ICT equipment) and neglect the role of the "soft" ICT capital (e.g. ICT knowledge and skills), though its importance has been widely recognized in previous IS research. This study contributes to filling these research gaps; in particular it makes the following four contributions: it investigates empirically the effects of four types of soft ICT capital, which are related to ICT knowledge and skills (ICT personnel, ICT training of ICT personnel and users, ICT unit), on firms' innovation performance; it compares these effects with the ones of the hard ICT capital; also with the ones of four important "traditional" innovation determinants identified from previous research in this area (demand expectation, price and non-price competition, market concentration); and it investigates the above effects in the national context of Greece, which is quite different from the ones of the highly developed countries where most similar previous empirical studies (e.g. concerning the effects of ICT on various aspects of business performance) have been conducted, with respect to the level of economic development, the use of ICT and the propensity to innovation. Our study has adopted a quantitative approach, based on the estimation of innovation models, using firm-level data collected through a survey of 271 Greek firms.

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 capital and three out of the four examined types of soft ICT capital (ICT personnel, provision of ICT training to ICT personnel and non-ICT personnel (users)) have strong positive impact on both process and product/service innovation. These findings indicate that hard and soft ICT capital provide a strong innovation drive even in such innovation averse national contexts, in which the traditional innovation determinants do not drive innovation of processes, products or services. Furthermore, it has been found that the total effect of these three knowledge and skills related types of soft ICT capital on innovation performance is stronger than the effect of the hard ICT capital. Therefore the exploitation of the largest part of the innovation potential of ICT is not straightforward, but necessitates the development of sufficient ICT knowledge and skills-related soft capital, through the employment of ICT personnel and the provision of ICT training to them and to the ICT users.

The results of this study have interesting implications for IS research and practice. With respect to IS research, the strong positive effects of three different types soft ICT capital on firm's process, product and service innovation that we found provides empirical evidence of the high importance of the soft ICT capital for innovation production. Therefore the extensive future empirical research required concerning the relation between ICT and innovation should not focus on the hard ICT capital and neglect the soft ICT capital, as it did so far. It should consider various types of both hard and soft ICT capital, and combine them with the innovation determinants identified by the research conducted in the innovation domain, in order to produce reliable and 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 is based on the estimation of innovation models and combines hard and soft ICT capital and at the same time traditional innovation determinants, enabling an interconnection of the ICT and innovation research domains. With respect to IS practice, the results of this study can be useful to firms' CIOs and CEOs and also to consultants and practitioners interested in maximizing the

exploitation of the innovation potential of ICT, in order to understand the hard and soft aspects of ICT that have to be developed for this purpose and optimize firms' ICT-related investment. 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 their hard ICT capital, but also their soft ICT capital with respect to ICT knowledge and skills. For this purpose they should employ sufficient ICT personnel, and train it, and also the ICT users as well, so that they keep up with the rapid evolutions and developments in the ICT domain, have sufficient knowledge and skills on existing and emerging ICT relevant to the firm's activities, and can use them for innovations in processes, products and services. On the contrary, the reductions of spending on ICT personnel and training that many firms decide as a response to the current economic crisis might have negative impact on their innovation capability, and therefore on their medium-term financial performance.

It should be recognized that this study has three main limitations. First, it examines only soft ICT capital related to ICT knowledge and skills; so future research should investigate the effects of other types of soft ICT capital (e.g. organizational, relational, etc.) on firms' innovation performance. Second, it uses simple innovation performance measures, and does not distinguish between different types of innovations (e.g. incremental and radical); so future research on the relation between ICT and innovation should use more sophisticated measures of innovation performance, and distinguish between different types of processes, products and services innovations. Third, the firm-level data we have used for this study has all been collected from a single country; so, it is necessary to investigate empirically the above questions in other countries as well, with different levels of economic development, ICT use, propensity to innovation and culture. In general, extensive further empirical research is required concerning the impact of different types of hard and soft ICT capital on the creation of various types of innovations, in various national contexts, and also concerning the main mediators and moderators of these relations.

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(The Appendix follows overleaf.)

Variables	Definitions
<i>Dependent variables</i>	
INNOV_PD	Introduction of product/service innovations (yes/no)
INNOV_PC	Introduction of process innovations (yes/no)
<i>Independent variables</i>	
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
HARD_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")
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

**Table A1.**  
Definition of models' variables

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