

# An Empirical Investigation of the Effect of Hard and Soft ICT Investment on Innovation Performance of Greek Firms

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**Abstract** — Firms have been making big investments in information and communication technologies (ICT) in the last twenty years. Therefore the investigation of their effect on various aspects of business performance is necessary. This paper presents an empirical investigation and comparison of the effects of hard and soft ICT investment, and also of four ‘traditional’ innovation drivers (demand expectation, price and non-price competition, market concentration), on the innovation performance of Greek firms. In particular, we examine from this perspective four different types of soft ICT investment in ICT structures, personnel, skills and processes. Our results indicate that while in the innovation averse Greek national context none of the examined traditional innovation drivers have a statistically significant impact on the innovation performance of Greek firms, both hard ICT investment, and three of the examined types of soft ICT investment, have such positive impacts. Our results provide empirical evidence that both hard and soft ICT investment can be strong drivers of innovation, even in such innovation averse contexts, in which the classical innovation drivers do not affect innovation performance.

**Keywords:** *innovation, ICT investment, soft ICT, hard ICT, innovation*

## I. INTRODUCTION

Firms have been making big investments in information and communication technologies (ICT) in the last twenty years. According to OECD (<http://www.oecd-ilibrary.org/sites/factbook-2011-en>) the ICT investment has grown to about 20% on average of the total non-residential investment in its member countries, and is expected to increase further in the near future; at the same time it is noted that this varies considerably among its member countries, reaching as high as 31.4% in USA and 29.4% in Finland, but 10.1% and 11.4% in Spain and Portugal respectively. Therefore the investigation of the effect of ICT investment on various aspects of business performance is necessary. Most of previous literature in this area has examined the effect of ICT investment on the firms’ financial performance (comprehensive reviews of this literature are provided in [1]-[2]). However, it is widely recognized that other aspects of firms’ business performance should be examined as well, and one of them is definitely innovation performance, which is regarded as a critical determinant of firm’s financial performance, or even survival, in the near future. For

instance, the extensive literature on balanced scorecard [3-5] argues that it is not sufficient to examine only firm’s financial performance, but it is necessary to examine three other important aspects of firms’ business performance: customers’ satisfaction, business processes efficiency and innovation performance; also, the same literature argues that innovation performance is a critical determinant of the other three main aspects of business performance (business processes efficiency, customers’ satisfaction and financial performance). For this reason the present study focuses on firm’s innovation performance, and examines the effects of both ‘hard’ and ‘soft’ ICT investment on it.

There has been extensive theoretical literature concerning the potential of ICT to drive significant innovations in firms’ processes, products and services [6-13]. However, only a very small number of empirical investigations of this potential have been conducted based on large datasets [16-19]; they are briefly reviewed in the following section. Furthermore, these few empirical studies of the effect of ICT on innovation focus on the ‘hard’ ICT investment (i.e. firm’s ICT equipment), and neglect the large ‘soft’ ICT investments that firms make on ICT structures, personnel, skills and processes [20-25]. It is therefore interesting and practically useful to examine and compare to what extent these hard and soft ICT investments of firms are drivers of innovation. This is going to help firms to optimize the composition of their ICT investment.

This paper contributes to filling the above research gaps. It presents an empirical investigation and comparison of hard and soft ICT investment, and also of four ‘traditional’ innovation drivers according to previous literature (demand expectation, price and non-price competition, market concentration), on the innovation performance of Greek firms. In particular, it examines from this perspective four different types of soft ICT investment in ICT structures, personnel, skills and processes. This study is based on firm-level data collected through a survey of 271 Greek firms. It should be noted that the Greek national context of our study is characterised by a lower level of ICT investment than the highly developed countries; according to OECD (<http://www.oecd-ilibrary.org/sites/factbook-2011-en>) in Greece the ICT investment is 15.7% of the total non-residential investment, which is much lower than most of the highly developed countries. In general Greece does not have a tradition of adopting and using advanced technologies in its

economy. Also, the Greek national context is characterized by a culture that does not favour innovation, resulting in lower levels of firms' innovation activity in comparison with the other European countries. According to Geert Hofstede (see <http://www.geert-hofstede.com/>) the score of the 'uncertainty avoidance index' (a national cultural dimension associated with lower tendency for innovation) for Greece is 112, while for the Scandinavian and the Continental European countries it is at the much lower levels of 35.25 and 50.17 respectively. For this reason the percentage of innovative firms in Greece is lower in comparison to the highly developed European countries according to the relevant Eurostat statistics (<http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat>).

This paper is organized in six sections. The following section II includes the background of this study, while in section III the research hypotheses are developed. Then, in section IV the data and method of the study are described. The results are presented and discussed in section V, while the final section VI summarizes the conclusions.

## II. BACKGROUND

As mentioned in the introduction there is a large body of previous literature that discuss theoretically the big innovation potential that ICT, which concludes based on theoretical arguments that ICT can drive important process, product and service innovations, which can substantially improve firms' performance [6-13]. 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, so they can lead to big transformations of existing processes, products and services. By using ICT work can be significantly restructured, so that routine, well-defined tasks associated with symbols processing are performed by computers, and only the more sophisticated tasks that require human skills are performed by humans, but with substantial support of computers and in different ways than before. ICTs can be very useful for simplifying most business process and reducing considerably the number of their activities, and for achieving cross-functional process level optimization rather than departmental level optimization. Also, ICTs enable an individual worker to have all the required information for completing a bigger part of a process, so historical fragmentation of many processes can be dramatically reduced resulting in large efficiency gains. Furthermore, ICT can be enablers of new products and services, which were not possible, or were too costly, previously.

However, these theoretical arguments have been only to a very limited extent empirically investigated. Though in the literature are reported several case studies of successful ICT-based innovations (e.g. [14-15]), only a small number of empirical investigations of the effect of ICT on innovation based on large datasets have been conducted. One of them is

presented in [16], based on data from a sample of 212 U.S. firms in the valve industry; it concludes that the use of industrial ICT promote product innovation, and lead to considerable changes in the production processes, which increase their efficiency. Another empirical study is described in [17], which uses data from 4,500 German firms, and concludes that ICT investment and share of employees working mainly on a computer have a positive impact on functional flexibility and through it on product and process innovation, and have also additional direct effects on both types of innovation. [18] based on data from 335 German service firms found that customized software increases the probability of innovation, while there is no relationship between standardised software and innovation. In [19] using firm-level data collected through a survey of 271 Greek firms it is concluded that the internal IS have a strong positive impact on both product and process innovation, while the e-sales IS only on process innovation, and e-procurement IS are not drivers of innovation. We remark that these few empirical firm-level studies of the relation between ICT and innovation use as independent variables various measures of hard ICT investment (usually firm's ICT equipment, and only [18] ICT software). So they really examine the impact of hard ICT investment on innovation; on the contrary, they do not examine the impact of the large soft ICT investments that firms make on ICT structures, personnel, skills and processes.

However, the importance of the latter has been widely recognised in previous IS literature as a complementary investment to the hard ICT investment [20-25]. This soft ICT investment constitutes an important complement of the hard ICT investment, as it enables the formulation of the optimal composition of the hard ICT investment. Additionally, it enables a better monitoring and management of the corresponding IS development projects. Finally, it enables a more efficient operation, use and management of these IS. In [20], based on the resource-based view (RBV) of the firm [26], it is examined to what extent ICT can create unique valuable capabilities and sustainable competitive advantages for firms; for this purpose it is assessed to what extent ICT can fulfil the four conditions proposed by RBV: value, rarity, inimitability and non-substitutability. It is concluded that hard ICT investment cannot create unique valuable capabilities and sustainable competitive advantages on its own, as it cannot fulfil two of the above conditions: rarity and inimitability (ICT equipment has become a commodity and can be easily purchased by competitors as well). On the contrary, some types of soft ICT investment (e.g. ICT personnel and skills, processes for cooperation and partnership of ICT unit with business units of the firm and ICT planning) have a much higher potential to create sustainable competitive advantages; they can fulfil the above conditions to a much higher extent, since they cannot be directly purchased, are firm-specific, are difficult to develop and have to be built and mature over a long time period. The above indicate that soft ICT investment on ICT structures, personnel, skills and processes has the potential to lead to the development of new unique processes, products and services, driving important innovations in these directions.

This paper contributes to filling the above empirical research gap, by examining and comparing the effects of various types of soft ICT investment, and also hard ICT investment, on innovation performance of firms; furthermore, it compares these effects with the ones of main traditional innovation drivers that previous innovation literature has identified.

### III. RESEARCH HYPOTHESES

Our first research hypothesis concerns the effect of hard ICT investment on innovation performance. As mentioned in previous section hard ICT investment in hardware and software creates opportunities to transform firm's business processes, to improve existing products and services and to develop new ones that were not feasible before. These ICT infrastructures reduce dramatically information processing and transfer costs, so they can pervade all firm's processes, products and services and improve or transform them. Also, ICT provide an infrastructure for designing, producing and delivering improved or new products and services in an efficient manner, which would not be feasible without ICT support. Furthermore, IS can support the communication and exchange of ideas among firm's employees, and also with customers, suppliers and business partners, and this is recognized by previous literature [27-28] to be of critical importance for the generation and adoption of innovations. Therefore our first research hypothesis is:

*Hypothesis 1: Hard ICT investment has a positive effect on innovation performance*

Our second research hypothesis concerns the organizational structure established in the firm for the exploitation of ICT. It focusing on the effect of a high hierarchical level ICT department, which reports directly to the Chief Executive Officer (CEO) of the firm, on innovation performance. 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. 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. At the same time this structure results in a more intensive transfer of information and knowledge from the ICT department to the CEO on the capabilities of ICT, which results in more CEO's interest in and support for ICT-based innovations. So, our second research hypothesis is:

*Hypothesis 2: The existence of an ICT department reporting directly to the CEO has a positive effect 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 'obligatory' 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. It is necessary to have sufficient ICT personnel, so that these obligatory 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. For the above reasons our third research hypothesis is:

*Hypothesis 3: The ratio of the number of ICT personnel to the number of ICT users has a positive effect on innovation performance*

It is widely recognized that there is a rapid evolution in the ICT domain, resulting in the continuous emergence of new technologies, and dramatic improvements of existing ones, which creates big opportunities for innovations in firms' processes, products and services. For this reason it is necessary to continuously enrich ICT knowledge and skills 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 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 enables them to create initially more efficient pilot innovative applications of these new ICT in the firm, which allow a better demonstration of their 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. So our fourth and fifth research hypotheses are:

*Hypothesis 4: The provision of ICT training to ICT personnel has a positive effect on innovation performance*

*Hypothesis 5: The provision of ICT training to non-ICT personnel (users) has a positive effect on innovation performance*

Our final research hypothesis concerns the effect of ICT strategic planning on innovation performance. For the development and the maintenance of an ICT strategic 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 direction. 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. Therefore, our sixth research hypothesis is:

*Hypothesis 5: ICT strategic planning has a positive impact on innovation performance*

#### IV. DATA AND METHOD

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). 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. 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. Finally, we received complete questionnaires from 271 firms (88 small, 105 medium and 78 large ones). The data collection activity took about 6 months.

For testing our research hypotheses we used the above data for estimating the following innovation model:

$$\text{INNOV} = \text{bo} + b1*\text{DEM} + b2*\text{IPC} + b3*\text{INPC} + b4*\text{NCOMP} + b5*\text{D\_SECT} + b6*\text{D\_LARGE} + b7*\text{D\_MED} + b8*\text{HARD\_ICT} + b9*\text{SOFT\_ICT}_i \quad (1)$$

The dependent variable is innovation performance (INNOV). For measuring it a composite index was formed, which is equal to the sum of the standardized values (having zero average and unity standard deviation) of three variables: product innovation in the last 3 years (Y/N), process innovation in the last 3 years (Y/N), and percentage of sales coming from new of significantly improved products.

With respect to the independent variables we have included first a set of variables corresponding to some important 'traditional' innovation drivers that previous research [29-33] has identified: 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 medium-term (next three years). The two competition variables IPC and INPC assess the intensity of price and non-price competition respectively in firm's most important market, while the market concentration variable NCOMP measures the number of main competitors in firm's most important market.

A second set of independent variables concern hard and soft ICT investment. In particular, we have included one hard ICT investment variable HARD ICT, which is equal to the sum of the standardized values of two variables measuring the intensity of use of (i.e. the percentage of firm employees using) two basic ICT, Internet and Intranet (both in a six levels scale: 0: 0%; 1: 1-20%; 2: 21-40%; 3: 41-60%;

4: 61-80%; 5: 81-100%). Also, in each model we have included one soft ICT investment variable, measuring a different type of soft ICT investment, and corresponding to one of the abovementioned research hypotheses 2 to 6. Our first soft ICT investment variable was ICT\_STR assessing whether the firm has an ICT Department reporting directly to the CEO (for testing hypothesis 2). The second variable was ICT\_PERS equal to the number of ICT personnel in the firm divided by the number of ICT users (for testing hypothesis 3). Then we had variables ICT\_TR\_SP and ICT\_TR\_US assessing (in a five points scale) the extent of ICT training provided to the ICT specialized personnel and the non-ICT personnel (users) respectively (for testing hypotheses 4 and 5). The last soft ICT investment variable was ICT\_PLAN assessing (in a five points scale) to what extent there is ICT planning in the firm based on its overall strategic plan.

Additionally, we included a third set of dummy variables for capturing the effects of firm size, which according to previous innovation literature impacts innovation, 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: variable D\_MED taking value 1 for medium-sized firms with 50 to 249 employees (and value 0 for all the others) and variable 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.

#### V. RESULTS

The results from the estimation of the innovation model of equation (1) are shown below in Table 1 (the statistically significant independent variables, with significance levels lower than 5%, are shown in bold).

TABLE I. INNOVATION ACTIVITY MODEL

Independent Variable	Skills(Specialists)	Skills (Users)	Structure	Planning	Process	Personnel
DEM	-0.014	-0.019	-0.012	-0.022	-0.024	-0.007
IPC	.031	.044	.048	.036	.037	.059
INPC	-0.012	-0.015	-0.008	-0.019	-0.025	-0.013
NCOMP	-0.045	-0.039	-0.037	-0.033	-0.033	-0.057
D_SECT	<b>-.113</b>	<b>-.118</b>	<b>-.099</b>	<b>-.106</b>	<b>-.107</b>	<b>-.090</b>
D_LARGE	<b>.276</b>	<b>.301</b>	<b>.332</b>	<b>.277</b>	<b>.276</b>	<b>.356</b>
D_MED	<b>.134</b>	<b>.147</b>	<b>.172</b>	<b>.147</b>	<b>.144</b>	<b>.190</b>
HARD ICT	<b>.139</b>	<b>.142</b>	<b>.183</b>	<b>.143</b>	<b>.133</b>	<b>.188</b>
ICT_TR_SP	<b>.174</b>					
ICT_TR_US		<b>.144</b>				
ICT_STR			-0.007			
ICT_PLAN				<b>.147</b>		
<b>ICT_PROC</b>					<b>.168</b>	
ICT_PERS						<b>.129</b>
Constant						

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. 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 and the ICT strategic planning based on the overall strategic planning of the firm 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 innovation activity. 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.

## VI. 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 driver 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 skills, organizational structure, planning, processes and personnel) on firm's innovation activity 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.

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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