

Arvanitis, Spyros; Loukis, Euripidis N.; Diamantopoulou, Vasiliki

**Working Paper**

## Are ICT, workplace organization and human capital relevant for innovation? A comparative study based on Swiss and Greek micro data

KOF Working Papers, No. 333

**Provided in Cooperation with:**

KOF Swiss Economic Institute, ETH Zurich

Suggested Citation: Arvanitis, Spyros; Loukis, Euripidis N.; Diamantopoulou, Vasiliki (2013) : Are ICT, workplace organization and human capital relevant for innovation? A comparative study based on Swiss and Greek micro data, KOF Working Papers, No. 333, ETH Zurich, KOF Swiss Economic Institute, Zurich, <http://dx.doi.org/10.3929/ethz-a-007632303>

This Version is available at:

<http://hdl.handle.net/10419/80827>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*

# KOF Working Papers

Are ICT, Workplace Organization and Human Capital Relevant for Innovation?  
A Comparative Study Based on Swiss and Greek Micro Data

Spyros Arvanitis, Euripidis N. Loukis and Vasiliki Diamantopoulou

# KOF

ETH Zurich  
KOF Swiss Economic Institute  
WEH D 4  
Weinbergstrasse 35  
8092 Zurich  
Switzerland

Phone +41 44 632 42 39  
Fax +41 44 632 12 18  
[www.kof.ethz.ch](http://www.kof.ethz.ch)  
[kof@kof.ethz.ch](mailto:kof@kof.ethz.ch)

# Are ICT, Workplace Organization and Human Capital Relevant for Innovation? A Comparative Study Based on Swiss and Greek Micro Data

Spyros Arvanitis

ETH Zurich, KOF Swiss Economic Institute

8092 Zurich, Switzerland

Phone: +41 44 632 51 68

Fax: +41 44 632 13 52

E-mail: arvanitis@kof.ethz.ch

Euripidis N. Loukis

University of the Aegean, Department of Information and Communication Systems

Engineering

83200 Karlovassi/Samos, Greece

Phone: +30 22730 82221

Fax: +30 22730 82009

E-mail: eloukis@aegean.gr

Vasiliki Diamantopoulou

University of the Aegean Department of Information and Communication Systems

Engineering,

83200 Karlovassi/Samos, Greece

E-mail: vdiamant@aegean.gr

## **Abstract**

This paper investigates the relationship between indicators for the intensity of use of ICT (examining three different types of ICT widely used in firms: internal, e-sales, e-procurement IS), several forms of workplace organization, and human capital on one hand, and several measures of innovation performance at firm level on the other hand, in an innovation equation framework, in which was also controlled for standard innovation determinants such as demand, competition and firm size. The empirical part is based on data of Swiss and Greek firms. This paper contributes to literature in three ways: first, it analyzes three important factors, i.e. information technology, workplace organization and human capital, which are considered to be drivers of innovation performance particularly in the last fifteen to twenty years, in the same setting, it uses several innovation indicators that cover both the input and the output side of the innovation process and, third, it does the analysis in a comparative setting for two countries, Greece and Switzerland, with quite different levels of technological and economic development.

**Key words:** ICT; workplace organization; product innovation; process innovation

**JEL Classification:** O31

## 1. Introduction

Much theoretical and empirical literature both in economic and in business administration domains has been dedicated in the last fifteen years to the investigation of the contribution of modern information and communication technologies (ICT) to economic performance at country, industry and firm level (Wan et al., 2007; Kretschmer, 2012). In economics much attention has been paid to the specific character of ICT as “general purpose technology” that is spread and used in many different forms across all sectors of the economy (Bresnahan and Trajtenberg, 1995). In management literature the focus is on the specific attributes of ICT with respect, e.g., ICT capital assets, ICT human resources, ICT technical and managerial skills, that enable firms to develop a sustained competitive advantage (Mata et al., 1995; Powell and Dent-Micaleff, 1995; Bharadai, 2000; Mithas, Ramasubbu and Sambamurthy, 2011). Also, there is a tendency to examine organizational issues in the context of ICT, particularly the direct and indirect (in combination with ICT) impact of workplace organization on firm performance (Brynjolfsson et al., 2000, 2002; Black and Lynch, 2001; Arvanitis, 2005; Moshiri and Simpson, 2011). The organizational issues are primarily a concern for the microeconomic point of view and is mostly in more management-oriented literature. The third factor that interest here, human capital, plays also a prominent role – being regarded as the fuel of the “growth machine” – in both branches of literature (see Bresnahan et al., 2002 for a seminal micro-study; Vandebussche et al., 2006 for a seminal macro-study in this issue).

This paper investigated the relationship between indicators for the intensity of use of ICT (examining three different types of ICT widely used in firms: internal, e-sales, e-procurement IS), several forms of workplace organization, and human capital and several measures of an important aspect of firm’s business performance, the innovation performance, in an innovation equation framework, in which was also controlled for standard innovation determinants such as demand, competition and firm size. For our empirical analysis we have used firm level data that were collected by a survey was based on the same questionnaire for both countries..

This paper contributes to literature in three ways: i) it analyzes the three most important factors, i.e. information technology, organization, human capital, which are considered to be important drivers of innovation performance in the last fifteen to twenty years, in the same setting, ii) it uses several innovation indicators that cover both the input and the output side of the innovation process, and, iii) it does the analysis in a comparative setting for two countries, Greece and Switzerland, with quite different levels of technological and economic development.

The paper is structured as follows: in section 2 we present the conceptual framework and related empirical literature. Section 3 describes the data used in the study. Section 4 refers to

the model specification and the econometric procedure. In section 5 the results are presented. The final section 6 contains a summary and conclusions.

## **2. Conceptual framework and related empirical literature**

### **2.1 The “new firm” paradigm**

The last twenty years have witnessed a constellation of important changes of the production process, as associated with the extensive use of computer-aided production technologies, the advances in information and communication technologies, the emerging of new ideas on how to organize firms, changes in the skill requirements of labour and changes in employee preferences toward more flexible working conditions. On this ground, many authors even postulated a shift to a new „firm paradigm“. Some of them focus their attention mainly to technological changes (e.g., Milgrom and Roberts, 1990), some find the introduction of new organizational practices a central characteristic of this „paradigm change“ (e.g., Lindbeck and Snower, 2000), while a third group concentrates primarily on the shift of firm demand to high-skilled labour in the last twenty years and analyzes the determinants of this shift (e.g., Bresnahan et al., 2002). Related empirical literature based on firm level data focused mainly on the *direct effects* of such changes on firms’ economic performance, mostly measured by average labour productivity (e.g., Black and Lynch, 2001 and Besnahan et al., 2002 for U.S. firms; Hempell, 2003 for German firms; Caroli and Van Reenen 2001, for French firms; Crespi et al., 2006 for U.K. firms; Arvanitis, 2005 for Swiss firms; Loukis et al., 2009 for Greek firms; Arvanitis and Loukis, 2009 for Greek and Swiss firms in a comparative study; Badescu and Garcés-Ayerbe, 2009 for Spanish firms; Moshiri and Simpson, 2011 for Canadian firms).

However, less attention was given until now in literature to possible *indirect effects* of ICT, workplace organization and human capital on economic performance through the enhancement of *innovation*.

### **2.2 ICT and innovation**

Following Kleis et al. (2012) we posit that the use of ICT contributes to firms’ innovation activities through three main channels. The first channel goes through the improvement of the management of the knowledge used in the innovation process. This knowledge might be internally created or externally acquired. Information technology enables an efficient storage and a high accessibility of this knowledge throughout an enterprise. Internal networks, e-mail systems, and electronic databases all facilitate the transfer of knowledge and the communication between innovation participants. This is particularly the case for external information, which is critical for successful innovation (Klevorick et al., 1995; Laursen and Salter 2006).

Second, ICT enables a more efficient cooperation in innovation with external partners. The creation of new knowledge through collaboration with other firms has become more and more important in the last twenty years (Enkel et al. 2009). Information technology facilitates the exchange of information with external partners that are located far away from the focal firm.

Third, ICT contributes directly to the innovation production in several ways. Kleis et al. (2010) identified three main stages of the innovation process, for which the application of ICT has proved to be useful. First, the stage of the generation of ideas for new products can benefit from information systems (e.g., Customer Relationship Management CRM) that enable a firm to analyze customers' communication and transaction data and identify needs that can be covered by new products or significant modifications of existing products. Further, information technology enables the development of efficient design capabilities for new products. For example, technologies such as computer-aided design (CAD) and computer-aided manufacturing (CAM) help to digitize a new product's design, make it available throughout the innovation process. Finally, ICT helps integrate design and production systems, so that errors of information transfer and translation are reduced and, as a consequence, the efficiency of this last stage of the innovation process is increased.

Furthermore, ICT can also directly drive ICT-based innovations in firms' processes and products and services, and even business models (Tapscot et al., 2000; Bresnahan et al., 2002; Brynjolfsson and Saunders, 2010). It can enable new products and services, and also existing products' and services' variety and personalization, which were not operationally and economically feasible before without ICT.

In sum, we expect a positive impact of ICT through these four channels on innovation performance.

The existing empirical literature on the impact of ICT on innovation is quite heterogeneous with respect of the sectors of the economy and the time periods covered, the measures of ICT and innovation as well as the methods of analysis used. Most of them are based on firm level data from only one country, and only two are multi-country studies. The different points of time of these studies have to be taken into consideration when assessing ICT effects on innovation and/or economic performance at firm level, because of the newness of these technologies and the different diffusion rates of them among sectors and countries in the last decade. In particular, Han and Ravichandran (2006) examined the relationship between IT investment and firm innovation outcome based on data for 450 US firms; they found that IT investment did not have a direct effect on innovation outcomes measured by patent counts, but the interaction between IT investment and R&D expenditure positively affected innovation. Gago and Rubalcaba (2007) focused on the service sector, and investigated the impact of ICT on service innovation based on data from 557 Spanish service firms; they found that ICT correlated positively with the importance of firm's innovations for



productivity and costs, product or market expansion, employment and required skills, services quality and fulfilment of ecological standards.

There are also two German studies focusing on the effects of different types of enterprise software on innovation. Engelstätter and Sarbu (2010) investigated the relationship between the use of sector-specific standardized/package enterprise software and customized enterprise software on service innovation (335 German firms; 2007-2009); the results showed that primarily customized enterprise software contributes significantly to innovation. Engelstätter (2012) examined the relationship between three types of enterprise software systems offering different types of functionality - enterprise resource planning ERP, supply chain management SCM and customer relationship management CRM - and firms' innovation performance. The results showed that (a) the likelihood of introducing process innovations is correlated positively with ERP systems, while the likelihood of introducing product innovations correlated with the use of CRM ones; and also (b) that the number of process innovations a firm realized is correlated positively with ERP systems, whereas the number of product innovations is correlated with the use of SCM ones.

In a study based on 2,500 UK SMES in the year 2004 Higon (2011) found that ICT enhance mainly process innovation, while only specific market-oriented ICT applications (such as websites, or ICT supporting R&D) favour product innovation. Kleis et al. (2012), analyzing data from 201 large U.S. manufacturing firms over the period 1987 to 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.

Finally, there exist two multi-country studies. Spiezia (2011) reported the findings of separate investigations of the effects of ICT on the firms' capabilities to innovate that was performed under the coordination of the OECD. The investigation teams used large datasets for firms from seven European countries (Italy, Ireland, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland and UK) and Canada. The findings support the hypothesis that ICT as an enabler of innovation, particularly for product and marketing innovations, in both manufacturing and services. However, no evidence could be found that the use of ICT increases the capability of a firm to develop innovation in-house or to introduce products new-to-the market. Ollo-Lopez and Aramendia-Muneta (2012) examined the impact of ICT on innovation in the glass, ceramics and cement industries based on data for 676 firms in 2009 from Germany, Spain, France, Italy, Poland and the U.K. The results for the pooled data for all 6 countries showed that some ICT elements favoured product (ERP, CAD, services on line) and/or process innovations (CAD).

### **2.3 Workplace organization and innovation**

Some theories have been developed to explain why new high-skill and high-involvement workplaces may be more effective (see, e.g., Ichniowski et al., 2000, Black and Lynch 2001). These can be divided, first, into theories that focus on the effort and motivation of workers and work groups, and suggest that due to the positive worker incentives created by new organizational forms the worker performance increases (see Mookherjee, 2006 for a survey of the theoretical literature on decentralization, hierarchies and incentives). A second group of theories focuses on changes of the structure of organizations that improve efficiency (see also Aghion et al., 1999, p. 1650 for a discussion of the characteristics of developments in the structure of European and US companies). These theories imply that some new arrangements can make organizational structures more efficient. For example, decentralizing decision-making to self-directed teams can reduce the number of supervisors and middle-level managers required while improving communication; employee involvement can eliminate or reduce grievances and other sources of conflict within the firm, thus improving performance.

Similarly, it can be argued that decentralized decision-making, information sharing and collaborative workplace arrangements might enhance the knowledge creation process (Lee and Choi, 2003; Zoghi et al., 2010). Increased delegation of decision-making to employees and increased use of teams may allow better for the discovery and utilization of knowledge in the organization, particularly when there are incentives that foster such behaviour (Laursen and Foss, 2003). From a more general point of view, Acemoglu et al. (2007) derived theoretically the empirical prediction that firms closer to technological frontier (i.e. potentially innovative firms) are more likely to choose decentralization.

A series of empirical studies covering a number of European countries, the USA, Canada, Australia and Korea investigated the relationship between innovation performance and organizational characteristics and management practices.

The study of Michie and Sheehan (1999) based on data for 487 firms in the year 1990 found a positive correlation between investment in R&D and new technology on one hand and “high-commitment” organizational practices (teamwork, information sharing between workers and managers, increased assignment flexibility, innovative incentive pay plans, etc.) on the other.

Acemoglu et al. (2007) investigated, besides their abovementioned theoretical analysis, also empirically - based on large datasets of British and French manufacturing firms in the nineties - the relationship between several indicators of organizational decentralization (e.g., decentralization in profit centers) and measures of the distance from the technological frontier. They showed among other things that firms closer to the technological frontier are more likely to choose decentralization.

In a further study, based on data from 1995 UK SMEs in the nineties, Cosh et al. (2012) found that decentralized decision-making in combination with a formal structure and written plans is positively correlated with innovation performance, and is superior to other structures.

Using data for 1,900 Danish firms Laursen and Foss (2003) investigated the relationship between systems of human resource management containing organizational practices such as interdisciplinary workgroups, quality circles, job rotation, delegation of responsibility, etc. and the probability of introducing of an innovation with a certain degree of novelty. Of the total nine sectors they considered, they found that innovation performance correlated positively with an organizational measure of the intensity of use of the above practices for the four manufacturing sectors. In a subsequent study, the same authors examined based on data for 1000 Danish firms the relation between delegation of responsibility and innovation and found a significantly positive correlation between them (Foss and Laursen, 2005). This finding was confirmed also by a further study with data for 1544 Danish firms coming from both manufacturing and service sectors (Vinding, 2006).

Hempell and Zwick (2008) investigated the effects of two organizational practices, employee participation and outsourcing, on the likelihood of the introduction of products and/or process innovations. The results, based on data for 900 German firms in the years 2002 and 2004, showed that employee participation is positively associated with product and process innovations, while outsourcing favours innovations in the short run, but reduces innovation performance in the long run.

Lee and Choi (2003) found in a study based on data for 58 Korean firms a positive effect of collaboration (among a firm's employees), a negative effect of centralization (of organizational structure) but no effect of formalization on a measure of the degree of development of "knowledge creation processes".

In a study based on panel data for 3,200 Canadian firms in the years 1999, 2001 and 2003 Zoghi et al. (2010) explored the relationship between workplace organization – in particular decentralization, information-sharing, and incentive pay schemes – and innovation. They showed that the positive correlation between workplace organization and innovation holds for all these organizational factors but is stronger for information-sharing than for decentralized decision-making or incentive pay programmes. The use of lagged variables gave no clear evidence that organizational changes have an impact on innovation.

Finally, in a study for 112 Taiwanese firms Chang et al. (2012) found a positive relationship between organizational capabilities (openness capability, autonomy capability, integration capability and experimentation capability) and radical innovation performance.

In sum, given the heterogeneity of the reviewed studies with respect to data structure and model specification there exists a remarkably stable finding that refers to the positive

relationship between decentralization of decision-making, delegation of responsibility and information-sharing (between managers and employees) and innovation performance.

## **2.4 Human capital and innovation**

The relationship between human capital and innovation has been intensively investigated both theoretically and empirically already in the first generation models of endogenous growth (Romer, 1990; Aghion and Howitt, 1998; Barro, 1999). Besides being the “engine of innovation”, human capital is also a key determinant of knowledge absorptive capacity that enables firms not only to generate new knowledge but also to understand and adopt external new knowledge and technology (Vandenbussche et al., 2006). The abovementioned study of Vinding (2006), based on a review of previous relevant literature, argues that highly educated employees through their daily tasks increase the stock of knowledge of the organization; also, through their relationships with other individuals with similar competencies outside the firm they facilitate access to external networks of knowledge, and through their high levels of knowledge they recognize and value useful new external knowledge. Furthermore, the empirical part of this study found that the share of highly educated employees is positively correlated with firm’s ability to innovate. In a further study, Lopez-Garcia and Montero (2012) argue that firm’s knowledge, which is of critical importance for its innovation activity, is embedded in its human capital; also the latter is a critical determinant of firm’s ability to absorb and assimilate knowledge spillovers. The empirical part of this study, based on data from 769 both manufacturing and services Spanish firms during the period 2003–2007 (3682 observations in total), came to the conclusion that the share of skilled labour and provision of on-the-job training affect the innovative capacity of a firm through their impact on a firm’s spillover knowledge absorptive capacity

## **2.5 Research hypotheses**

The above discussion of the literature shows that there are some common testable hypotheses with respect to the direct effects of ICT, new organizational practices and human capital on innovation performance:

- *Hypothesis 1*: There are direct positive effects of ICT (of both the internal IS, and the e-sales and e-procurement IS) on innovation performance;
- *Hypothesis 2*: There are direct positive effects of organizational factors on innovation performance;
- *Hypothesis 3*: There are direct positive effects of human capital on innovation performance.

### 3. Data

Both surveys were conducted in autumn 2005. The reference period for the qualitative data is the period 2003-2005 unless otherwise mentioned (see Table 1). The reference year for the quantitative variable is 2004. Differences with respect to the composition of the data by industry in Table A.1 appear to reflect the structural difference between the two countries. For example, the share of textile and clothing firms, hotels and catering firms is significantly higher in Greece. On the other hand, metal working, machinery, electrical machinery and electronics/instruments are much stronger represented in Switzerland. In both surveys we used the same questionnaire in different languages, which included questions on the incidence and within-firm diffusion of several ICT technologies (e-mail, Internet, intranet, extranet, e-sales, e-procurement) and new organizational practices (team-work, job rotation, employees' involvement, decentralization), employees' formal education, and also on basic economic data (sales, value of intermediate inputs, investment expenditure, number of employees, etc.).<sup>1</sup>

#### 3.1 Swiss data

The data used in the Swiss part of this study were collected in the course of a survey among Swiss enterprises. The survey was based on a disproportionately stratified (with respect to firm size) random sample of firms with at least 20 employees, covering all relevant industries of the business sector as well as firm size classes (on the whole 27 industries, and within each industry three industry-specific firm size classes with full coverage of the upper class of large firms)<sup>2</sup>. Answers were received from 1803 firms, i.e. 38.7% of the firms in the underlying sample. The response rates do not vary much across industries and size classes with a few exceptions (over-representation of paper and energy industry, under-representation of hotels, catering and retail trade). In Table A.1 in the appendix in columns 3 and 4 we can see the structure of the data set we used for the Swiss part of this study by industry and firm size class. The non-response analysis (based on a follow-up survey of a sample of the non-respondents) did not indicate any serious selectivity bias with respect to the use of ICT and new organizational practices (team-work, job rotation). A careful examination of the data of these 1803 firms led to the exclusion of 93 cases with contradictory or non-plausible answers. However, missing values for certain variables allowed the utilization of 1591 observations.

---

<sup>1</sup> The questionnaire was based to a considerable extent on similar questionnaires used in earlier surveys (see EPOC, 1997; Francois et al., 1999, Vickery and Wurzburg, 1998; and Canada Statistics, 1999). Versions of the questionnaire in German, French and Italian are available in [www.kof.ethz.ch](http://www.kof.ethz.ch).

<sup>2</sup> Table A.1 contains only 26 industries; the Swiss sample has „watches“, „telecommunication“ and „computer services“ as separate industries that were put together with „electronics/instruments“, „transport“ and „other business services“ respectively to make the industry classification comparable to that of the Greek data.

## **3.2 Greek data**

The data we used in the Greek part of this study were collected similarly through a survey among Greek enterprises. Three samples of 300 Greek firms each were randomly selected from the database of ICAP, one of the largest business information and consulting companies of Greece, which consists of approximately 135,000 Greek firms from all industries. All these three samples included firms from the same industries and sizes as in the Swiss sample. Firms that definitely refused to participate in this survey were replaced by similar firms (i.e. from the same industry and size class) from the second sample, while in a few cases, in which the firms of the second sample were exhausted, we had to proceed to the third sample. Following the above procedure, which aimed to maintain the proportions of industry and size classes, we finally received responses from 281 firms; after an examination of the returned completed questionnaires we excluded 10 cases with contradictory or non-plausible answers, and the remaining 271 valid responses were used for our analyses. In Table A.1 of the appendix in columns 1 and 2 we can see the structure of the final data set we used for the Greek part of the by industry and firm size class. A non-response analysis was performed (survey of a sample of the non-respondents), which did not indicate any serious selectivity bias with respect to the use of ICT, new organizational practices, vocational education and job-related training. For these 271 firms we also retrieved from the database of ICAP some economic data for 2004 that were not collected through the questionnaire. So we finally obtained for all these Greek firms all the economic data that were collected for the firms of the above Swiss data set through the Swiss questionnaire. However, due to missing values for certain variables only 265 observations could be effectively used in the econometric estimations.

## **4. Model specification and econometric method**

### **4.1 Model specification**

#### **4.1.1 Dependent variables**

In view of the complexity of innovation process, which are characterized by several stages, ranging from basic research to the penetration of the market with new products, an approach relying on a single measure of innovation may leave out important relationships and produce results that are not robust (see, e.g., Kleinknecht et al., 2002). For this reason we used several innovation variables. First, we investigated two binary (yes/no) variables (INNOPD, INNOVPC) for innovation output assessing whether the firm has introduced any product/service innovation or process innovation respectively in the last three years. Second, we also used two metric variables, the R&D expenditures per employee (LRDL) and the sales coming from innovative products (new or significantly improved ones) per employee (LINNL). For each of these four dependent variables a separate model has been estimated.

### 4.1.2 Independent variables

As measures for the internal use of ICT for supporting firm's internal functions and processes we used the intensity of use of two important technologies, Internet (linking to the outside world) and Intranet (linking within the firm), quantified by the share of employees using Internet and intranet respectively in their daily work. The firms were asked to report this share not by a precise figure but within a range of twenty percentage points in a six-level scale: 0%, 1% to 20%, 21% to 40%, 41% to 60%, 61% to 80% and 81% to 100%. Based on these data we constructed two ordinal variables, i.e. one for Internet and one for Intranet, taking the values 0 to 5, thus covering the whole range from 0% to 100% (see Table 1). The idea behind this variable was that a measure of the diffusion of a certain technology within a firm would be a more precise proxy for the use of ICT' than the mere incidence of this technology or some kind of simple hardware measure (e.g., number of installed personal computers). We expected in general (for the reasons explained in 2.2) a positive correlation of these technology variables with the innovation indicators. In order to be able to measure an overall effect of internal ICT, we constructed a composite indicator for ICT that was calculated as the sum of the standardized values (average 0; standard deviation 1) of the underlying variables for Internet and Intranet. In addition, we used also two variables that measured the intensity of use of two important external environment oriented applications of ICT associated with E-commerce: E-sales (quantified through the percentage of firm's sales conducted through the Internet) and E-procurement (quantified through the percentage of firm's sales conducted through the Internet) (see Table 1).

The measurement of organizational inputs, here restricted to inputs related to workplace organization, is an issue still open to discussion, since there is not yet a definite agreement among applied economists to the exact definition of "organizational capital" (see Black and Lynch, 2005 and Lev, 2003 for a discussion of this matter; see also Appelbaum et al., 2000, Ch. 7 for definitions of high-performance work system variables). In order to choose the variables related to the use of new organizational practices at the workplace level we draw on the definition offered by Black and Lynch (2002), who distinguish three components of organizational capital: "work design", "employee voice" and "workforce training". The first component "work design" includes practices that involve changing the occupational structure of the workplace, the number of levels of management within the firm, the existence and diffusion of job rotation, the job share arrangements and the level of cross-functional cooperation. The second component "employee voice" is associated with practices that give employees, especially non-managerial ones, greater autonomy and discretion in the structure of their work, such as individual job enrichment schemes, decentralization of decision competencies that give to employees more decision competences, etc. Based on the above definitions in this study we regard "organizational capital" as consisting of the first two of these components, "work design" and "employee voice", while we view the third component "workforce training" as part of the human capital of the firm. In this direction we constructed

the following three- or five-level ordinate variables covering most of the above-discussed aspects of organisational capital (see Table 1):

i) For measuring “work design” practices: intensity of use of team-work (project groups, quality circles, semi-autonomous teams), intensity of use of job rotation, change of the number of management levels;

ii) For measuring “employee voice”: overall shift of decision competencies from managers to employees inside a firm and distribution of decision competencies between managers and employees inside the firm with respect to: (a) work pace, (b) sequence of the tasks to be performed, (c) the assignment of tasks, (d) the way of performing tasks, (e) solving emerging production problem, (f) contacts to customers and (g) solving emerging problems with customers. For empirical testing we constructed two composite indicators, one for the three organizational variables measuring “work design” (ORG1) and one for the eight organizational variables measuring “employee voice” (ORG2). These composite indices were calculated as the sum of the standardized values (average 0; standard deviation 1) of the underlying variables (see Table 1). We expected positive correlation of the above two composite organizational variables with innovation indicators (for the reasons explained in 2.3).

Finally, for measuring human capital we used the share of employees with vocational education at the tertiary level (universities, business and technical colleges, etc.) (HQUAL). We expected a positive correlation of these variables to innovation indicators (for the reasons explained in 2.3).

We also included a set of variables corresponding to some important innovation determinants that previous research has identified: demand expectations, price and non-price competition, market concentration (see, e.g., Kleinknecht, 1996; Van Beers et al., 2008, Cohen, 2010). The demand expectations variable (DEM) assesses to what extent the firm expects an increase of demand on the relevant product markets in the medium-term (next three years). The two competition variables (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. Finally, we controlled for firm size and sector affiliation. We expected positive effects for the demand variable, the two variables measuring the intensity of competition, the variable that measures the number of principal competitors and firm size (see Arvanitis, 2008 for Switzerland and Arvanitis et al., 2011 for Greece).

## **4.2 Econometric issues**

For testing the research hypotheses that were presented in section 2.5 the following innovation model was estimated for each of the four innovation variables we used (see 4.1.1):



$$\begin{aligned}
INNOV_i = & b_0 + b_1 DEM_i + b_2 IPC_i + b_3 INPC_i + b_4 NCOMP_i + b_5 HQUAL_i + b_6 ICT_i + \\
& b_7 ORG1_i + b_8 ORG2_i + b_9 E\_P_i + b_{10} E\_S_i + controls + e_i \quad (for\ firm\ i) \quad (1)
\end{aligned}$$

#### 4.2.1 Testing for endogeneity of the right-hand variables

There was a potential endogeneity problem with respect to the determinants of innovation performance in equation (1) above, due to the fact that both the dependent and the independent variables are cross-section data with almost complete overlapping. We concentrated our testing of endogeneity to those right-hand variables that are relevant for the investigation of our research questions. These are the variables for technology (ICT, E\_P and E\_S), workplace organization (ORG1, ORG2) and human capital use (HQUAL). Even after testing for endogeneity the question of causality still remains open. As a consequence, our estimates of the innovation equations have to be seen primarily as an extensive analysis of the correlations between the determinants (that are considered as structural characteristics that change only slowly over time) and the innovation indicators. Nevertheless, some robust regularities came out, which if interpreted in view of our hypotheses presented in section 2.5, and their theoretical and empirical support outlined in sections 2.2, 2.3 and 2.4, could possibly indicate the direction of causal links.

We tested endogeneity by applying the procedure by Rivers and Vuong (1988). Instrument equations were estimated separately for each of the relevant right-hand variables mentioned above for all innovation indicators and for each country. The instrument choice was based on 3 criteria: significant correlation to the instrumented variables, insignificant correlation to the dependent variables and insignificant correlation to the error term of the innovation equation. The residuals (predicted instrumented variables minus original variable) of the first stage instrument equations were inserted in the innovation equation as additional right-hand variables. Bootstrapping was used in order to correct the standard errors of the estimated parameters. If the coefficient of the residuals was statistically significant (at the 10%-test level), we have assumed that endogeneity is a problem and consequently based our inference on instrumented variables; also in this case standard errors were estimated by bootstrapping. In cases in which the coefficient of the residual was not statistically significant, we have assumed exogeneity of the innovation variables and the estimates were based on the original variables.

On the whole, we tested 24 estimates (six different right-hand variables for four innovation indicators) for each country. The search for appropriate instruments was not successful in every case. For the Swiss data we could not find an instrument for the variable E\_P. For the Greek data no instruments could be found for ORG2 and partly for HQUAL (1 case) and E\_P (2 cases). In 16 out of 20 cases that could be effectively tested for the Swiss data the coefficients of the residuals (predicted instrumented variables minus original variable) were

statistically insignificant at the 10% test level. Therefore, for these cases we could not find any evidence for endogeneity in our estimates. In 4 cases, all referring to the variable LRDS with respect to ICT, ORG1, ORG2 and E\_S, the coefficient of the residual was statistically significant. In all 17 cases that could be effectively for the Greek data no evidence for endogeneity could be found. Table A.4 in the appendix shows an overview of the results of the performed endogeneity tests. The detailed results were not included in the paper in order to keep it shorter, but they are available upon request.

#### **4.2.2 Interdependence of INNOPD and INNOPC**

Many firms reported both the introduction of product and process innovations, other only product or process innovations. Thus, there might exist an interdependency of firms' decisions to introduce product and process innovation. For this reason we estimated a bivariate probit model in order to test the influence of potential interdependency on our estimates. We found no significant differences to the estimates of separate probits that are presented below.

### **5. Empirical results**

#### **5.1 Swiss results**

The estimates of the models for the Swiss data are presented in Table 2a and Table 2b.<sup>3</sup> The composite indicator for the internal use of ICT correlates significantly positive only with the likelihood of the introduction of process innovation. There is no significant effect with respect to the introduction of product innovation and the sales share of innovative products that reflects the intensity of product innovation. A positive effect is also found for the innovation input variable R&D expenditures per employee (column 2 in Table 2b). We conclude that ICT contribute to innovation activities of Swiss firms (a) as enabler of innovative practices that increase a firm's overall efficiency and/or (b) as means for increasing the efficiency of the R&D process, for example, through more efficient storage and higher accessibility of knowledge and more efficient R&D cooperation with external partners (Kleis et al., 2010). The evidence does not support the assumption of ICT as enabler of product innovation through the identification of customers' needs and development of efficient design capabilities for new products (Kleis et al., 2010).

Further, we could not find any effect for the E-commerce variables. The main reason might have been that in 2005 both e-sales and e-procedure were not widespread in the Swiss business sector. The average share of e-sales in 2005 manufacturing was 5% in manufacturing

---

<sup>3</sup> Descriptive statistics for all variables are found in Table A.2 in the appendix. The correlations between the model variables are found in the Tables A.3a and A.3b, respectively.

and 3% in business services; the respective figures for e-procurement were 2% and 4% respectively (Arvanitis et al., 2007). Therefore hypothesis 1 is only partially supported for the internal IS by Swiss results, and not supported for the e-sales and e-procurement IS.

The organizational variables for “work design” (ORG1) and “employee voice” (ORG2) show significant positive marginal effects for all innovation indicators. The marginal effect of “work design” (reduction of formal hierarchy, increase of work flexibility through workgroups and job rotation) is significantly larger than that for “employee voice” (delegation of responsibility from managers to employees). The positive delegation effect is also in accordance with a large part of empirical literature (see section 2.3). Therefore hypothesis 2 is supported by Swiss results.

Human capital matters primarily for R&D activities (column 1 in Table 2b) and product innovation (INNOPD; LINNL).<sup>4</sup> Therefore hypothesis 3 is partially supported by Swiss results.

As indicated by the magnitude of the marginal effects ORG1 shows the largest effect – among the three examined factors (technology, organization, human capital) that we focus on in this study – on innovation performance for all four innovation indicators; the extensive capabilities for exchange of information, knowledge and ideas among firm employees of different business functions (e.g., sales, marketing, manufacturing, R&D) offered by the teamwork, job rotation and reduction of managerial levels that the new work designs include constitute important drivers of innovation. The internal ICT effect seems to be the second-strongest for process innovation and R&D activities; the ORG2 effect is the second-strongest for product innovation (for the binary as well as the metric indicator).

In (partial) accordance with earlier results we find a positive effect for the intensity of non-price competition for all innovation indicators, and also a positive effect for the intensity of price competition with the exception of the variable LRDL, what does not astonish (Arvanitis, 2008). Contrary to our expectation (positive effect of “free competition”) the variable for the number of competitors that measures the effect of market concentration shows in the estimates for product innovation (INNOPD; LINNL) a negative sign, which means that the more competitors a firm has, the smaller the likelihood or the intensity of product innovation (dominance of the Schumpeterian effect). As in earlier work we found also in this study positive effects for demand perspectives and for large firms.

---

<sup>4</sup> Due to multicollinearity with ICT ( $r=0.490$ ; see Table A3a in the Appendix) is the effect of HQUAL statistically insignificant in the equation for INNOPD in column 1 in Table 2a. After dropping ICT the marginal effect of HQUAL becomes significant at the 10%-test level (column 2 in Table 2a).

## 5.2 Greek results

The results of the estimates for the Greek firms are found in Table 3. The variable for internal ICT has a statistically significant positive effect on both product and process innovation, also on the sales share of innovative products, but not on the R&D expenditure per employee, which is quite low in Greece. This finding indicates that Greek firms exploit the innovation potential of the internal IS, which pervade and influence all firm's processes, products and services, for making innovations both at the level of their processes and also their products and services. They have realized that they have inefficient processes, and also weak products and services that have been designed in the pre-ICT era, which have been strongly influenced by the dominant logic and constraints of the manual mode of work, and the concomitant high costs of information processing and transfer; Greek firms realize that the capabilities offered by the internal IS change radically these fundamental assumptions, so they offer important opportunities for overcoming traditional fundamental inefficiencies and weaknesses in their processes, products and services can be transformed. These effects are in contrast to the developments in Swiss firms, which being already highly innovative in the pre-ICT era, and not having so strong traditional fundamental inefficiencies and weaknesses, could not hold so much benefits out of ICT as Greek firms(at least with respect to product innovation).

As in the Swiss case we found no effects for e-commerce (both for e-sales and e-procurement), presumably for the same reasons as in Switzerland. Therefore in Greece hypothesis 1 is only partially supported for internal IS, and not supported for e-sales and e-procurement IS.

A further interesting finding refers to the effect of the organizational variable ORG1 (associated with new work designs), which is significantly positive correlated with the propensity to introduce product and process innovation as well as with the R&D expenditures per employee. Greek firms seem to realize that organizational means, such as team work, job rotation and reduction of the number of management levels can be conducive for innovation. There is a tendency also for a positive effect of ORG2 (delegation of responsibility from managers to employees) but this effect is not robust.<sup>5</sup> ICT effects and organizational effects (referring to work design) as measured by the marginal effects are of similar magnitudes for product and process innovations.

Human capital seems to be of no relevance for the innovation activities of Greek firms, which is a further hint for the relative backwardness of Greek firms with respect to innovation.

Therefore on the whole, hypothesis 1 and hypothesis 2 are partially supported by the Greek results, while hypothesis 3 is not supported.

---

<sup>5</sup> The possibility of multicollinearity of ICT and ORG2 ( $r=0.286$ ; see Table A3b in the Appendix) was examined by dropping ICT and observing eventual changes of the estimates for ORG2 (columns 2 and 6 in Table 3). The negative sign of ORG2 in column 5 is caused by multicollinearity with ICT.

Finally, we remark that all four ‘traditional’ innovation determinants we examined (demand expectation, price competition, non-price competition, number of competitors) do not have statistically significant effects on the product and process innovation and R&D expenditure variables. Our results indicate that the Greek national context, which is innovation averse, characterised by lower innovation activity and uncertainty avoidance culture<sup>6</sup>, has a negative impact on firms’ propensity for innovation; firms do not respond to high competition or demand expectations with innovations in their processes, products and services, as firms of developed countries do. Finally, we found a positive effect for large firms, in accordance with standard evidence from other studies.

## **6. Summary and conclusions**

Our main conclusions concerning the effects of the examined factors on innovation in Switzerland and Greece are summarized in Table 4. We concentrate on the results referring to ICT, organization and human capital.

### **6.1 Results for the Swiss economy**

For the Swiss firms we have concluded that ICT contribute to innovation activities (a) as enabler of innovative practices that increase a firm’s overall efficiency and/or (b) as means for increasing the efficiency of the R&D process, for example, through more efficient storage and higher accessibility of knowledge and more efficient R&D cooperation with external partners. On the contrary, the evidence does not support the assumption of ICT as enabler of product innovation. Further, we could not find any effect for the variables for E-commerce. The main reason might have been that at the time of data collection both e-sales and e-procurement were not widespread in the Swiss business sector. The organizational variables for “work design” (ORG1) and “employee voice” (ORG2) show significant positive marginal effects for all innovation indicators. Human capital matters primarily for R&D activities and product innovation.

### **6.2 Results for the Greek economy**

For the Greek firms the finding indicates that Greek firms exploit the innovation potential of the internal IS, which pervade and influence all firm’s processes, products and services, for making innovations both at the level of their processes and their products and services, in order to overcome traditional fundamental weaknesses and inefficiencies. These effects are in a way in contrast to the development in Swiss firms, which being already highly innovative in the pre-ICT era, and not having so strong traditional fundamental inefficiencies and weaknesses, could not hold so much benefits out of ICT as Greek firms (at least with respect to product innovation). As in the Swiss case we found no effects for e-commerce, presumably

---

<sup>6</sup> The Hofstede’s uncertainty avoidance index for Greece is 112, while for the Scandinavian and the Continental European countries it is on average at the much lower levels of 35.25 and 50.17 respectively.

for the same reasons as in Switzerland. A further interesting finding refers to the effect of the examined new work designs (variable ORG1). Greek firms seem to realize that organizational means such as team work, job rotation and reduction of the number of management levels can be conducive for innovation. There is a tendency also for a positive effect of decentralization - delegation of responsibility (variable ORG2) but this effect is not robust.

### **6.3 Comparison of the two economies**

A comparison of the two countries (see Table 4) reveals less similarities and more differences. In both countries ICT have positive impacts on innovation but of different nature: in Switzerland ICT affect positively process innovation – but not product innovation – and R&D activity, while in Greece ICT affect positively both process and product innovation (and also the percentage of sales coming from innovative products) – but not R&D activity. In both countries new workplace designs including teamwork, job rotation and reduction of managerial levels have positive impacts on innovation. The same happens with the decentralization - delegation of responsibility practices, however in Switzerland there is positive impact of them on all examined innovation variables, while in Greece only on product innovation and R&D activity – but not on process innovation. Another similarity can be identified with respect to firm's size, which in both countries has positive impact on innovation. On the contrary, with respect to the widely debated human capital, there is a notable difference: while in Greece it does not have any impact on innovation, in Switzerland it affects positively R&D activity and product innovation (and also the percentage of sales coming from innovative products). In general in Switzerland there is a much wider range of innovation drivers than in Greece.

The above differences indicate that national context characteristics (e.g., level of economic and technological development, culture) shape considerably the innovation drivers that affect positively firms' innovation performance. Moreover, the above results indicate that even in national contexts that are characterised by innovation averse attitudes and lower level of economic development (which means less tradition and experience in introducing new advanced technologies, processes and products), and in which standard innovation determinants such as competition and demand do not drive innovation, the ICT can be a strong innovation driver. Though Greece is characterized by lower penetration and use of ICT and therefore lower experience in its effective exploitation, we can see that ICT is an important innovation driver.

### **6.4 Implications for research and practice**

The results of our study have interesting implications for research and practice. Future research on innovation determinants should take into account both the 'traditional' determinants and the more recently emerged ones, which are associated with various ICT that are continuously developed, new forms of workplace organization characterized by more teamwork, job rotation and decisions' decentralization, and also with firms' increasingly

important human capital. Also, this research should not treat ICT as a single and homogeneous entity (using variables like total ICT investment per employee), but differentiate between different ICT, since they might have different impacts on innovation, as the results of this study show, and place much emphasis on the continuously emerging new ICT. Finally research on innovation determinants should take seriously into account the national context as an important factor influencing them. With respect to firms' management practice, our results indicate that decisions on the introduction of ICT, new forms of workplace organization and on human capital improvement should be based not only on efficiency criteria, but also on their innovation driving potential; also, in innovation-averse national contexts firms should think more of innovation in processes, products and services as a possible response to increasing competition or demand. Finally, governments in order to design their policies and practices for promoting innovation should not 'copy' solutions from other countries, since the effects of various factors on innovation might vary significantly among countries; it is important to exploit relevant knowledge of other countries, but at the same time appropriate adaptations should be made taking into account country's particular characteristics and specificities.

## References

- Aghion, P., Caroli, E. and Garcia-Penalosa, C., 1999. Inequality and economic Growth: The perspectives of the new growth theories. *Journal of Economic Literature* 37(4), 1615-1660.
- Agion, P. and Howitt, P., 1998. *Endogenous Growth Theory*, MIT Press, Cambridge, Mass.
- Acemoglu, D, Aghion, P., Lelarge, C., Van Reenen, J. and P. Zilibothi, P., 2007. Technology, information, and the decentralization of the firm. *Quarterly Journal of Economics* 122(4), 1759-1799.
- Appelbaum, E., Bailey, T., Berg, P. and Kalleberg, A.L., 2000. *Manufacturing Advantage. Why High-Performance Work Systems Pay Off*. Cornell University Press, Ithaca.
- Arvanitis, S., 2005. Computerization, workplace organization, skilled labour and productivity: Evidence for the Swiss business sector. *Economics of Innovation and New Technology* 14(4), 225-249.
- Arvanitis, S., 2008. Innovation and labour Productivity in the Swiss manufacturing sector: An Analysis Based on Firm panel Data, in: C. van Beers, A. Kleinknecht, R. Ortt and R. Verburg (Eds.), *Determinants of Innovative Behaviour: A Firm's Internal Practices and Its External Environment*. Palgrave, London, pp. 188-216.

- Arvanitis, S., Hollenstein, H., Sydow, N. und M. Wörter, M., 2007. Innovationsaktivitäten in der Schweizer Wirtschaft - Eine Analyse der Ergebnisse der Innovationserhebung 2005, Strukturberichterstattung Nr. 34. Staatssekretariat für Wirtschaft, Bern.
- Arvanitis, S. and Loukis, E., 2009. Information and communication technologies, human capital, workplace organization and labour productivity in Greece and Switzerland: A comparative study based on firm-level data. *Information Economics and Policy* 21, 43-61.
- Arvanitis, S., Loukis, E. and Diamantopoulou, V., 2011. The impact of different types of ICT on the innovation performance of Greek firms. *European, Mediterranean & Middle Eastern Conference on Information Systems 2011 (EMCIS2011)*, May 30-31 2011, Athens, Greece.
- Badescu, M., and Garcés-Ayerbe, C., 2009. The impact of information technologies on firm productivity: Empirical evidence from Spain. *Technovation* 29(2), 122-129.
- Barro, R.J., 1999. Human capital and growth in cross-Country regressions. *Swedish Economic Policy Review* 6, 237-277.
- Bharadwaj, A., 2000. A resource based perspective on information technology capability and firm performance: An empirical investigation. *MIS Quarterly* 24(1), 169-196.
- Black, S.E. and Lynch, L.M., 2001. How to compete: the impact of workplace practices and information technology on productivity. *Review of Economics and Statistics* 83(3), 434-445.
- Black, S.E. and Lynch, L.M., 2005. Measuring organizational capital in the New Economy. University of Chicago Press, in: Corrado, C., Haltwanger, J. and Sichel, D. (Eds.), *Measuring Capital in the New Economy*, Chicago University Press, Chicago.
- Bresnahan, T. F. and Trajtenberg, M., 1995. General purpose technologies: engines of growth. *Journal of Econometrics* 65, 83-108.
- Bresnahan, T. F., Brynjolfsson, E. and Hitt, L.M., 2002. Information technology, workplace organisation, and the demand for skilled Labour: firm-level evidence. *Quarterly Journal of Economics* 112(1), 339-376.
- Brynjolfsson, E. and Hitt, L.M., 2000. Beyond computation: information technology, organizational transformation and business performance. *Journal of Economic Perspectives*. 14(4), 23-48.
- Brynjolfsson, E., Hitt, L.M. and Yang, S., 2002. Intangible assets: computers and organizational capital. *Brookings Papers on Economic Activity* 1, 37-199.
- Brynjolfsson, E. and Saunders, A., 2010. *Wired for Innovation: How Information Technology Is Reshaping the Economy*. MIT Press, Cambridge, Massachusetts.



- Canada Statistics, 1999. Information and communications technologies and electronic commerce, Survey. Canada Statistics, Ottawa.
- Caroli, E. and Van Reenen, J., 2001. Skill biased organizational change? Evidence from a panel of British and French establishments. *Quarterly Journal of Economics* 116(4), 1449-1492.
- Chang, Y.-C., Chang, H.-T., Chi, H.-R, Chen, M.-H. and Deng, L.L., 2012. How do established firms improve radical innovation performance? The organizational capabilities view. *Technovation* 32(7-8), 441-451.
- Cosh, A., Fu, X. and Hughes, A., 2012. Organization structure and innovation performance in different environments. *Small Business Economics* 39, 301-317.
- Cohen, W. M., 2010. Fifty years of empirical studies of innovative activity and performance, in: B.H. Hall and N. Rosenberg (Eds.), *Handbook of the Economics of Innovation*, Volume 1, Elsevier B.V., Amsterdam, pp. 129-213.
- Crespi, G., Criscuolo, C. and Haskel, J., 2006. Information technology, organizational change and productivity growth: Evidence from UK firms. Queen Mary College, University of London Working Paper No. 558, London.
- Engelstätter, B. and Sarbu, M., 2010. Enterprise and service innovation: standardization versus customization. ZEW Discussion Paper No. 10-100, Mannheim.
- Engelstätter, B., 2012. It is not all about performance gains – Enterprise software and innovations. *Economics of Innovation and New Technology* 21(3), 223-245.
- Enkel, E., Gassmann, O. and Chesbrough, H., 2009. Open R&D and Open Innovation: Exploring the Phenomenon. *R&D Management Journal* 39 (4), 311-316.
- EPOC, 1997. New Forms of Work Organization. Can Europe Realize its Potential? Results of A Survey of Direct Employee Participation in Europe. European Foundation for the Improvement of Living and Working Conditions, Dublin.
- Foss, N.J. and Laursen, K., 2005. Performance pay, delegation and multitasking under uncertainty and innovativeness: An empirical investigation. *Journal of Economic Behavior and Organization* 58, 246-276.
- Francois, J.-P., Favre, F. and Greenan, N., 1999. Organizational Changes in Industrial Firms and Computerization of Industrial Enterprises. OECD, Paris.
- Gago, D. and Rubalcaba, L., 2007. Innovation and ICT service firms: Towards a multidimensional approach for impact assessment. *Journal of Evolutionary Economics* 17, 25-44.
- Han, S. and Ravichandran, T., 2006. Does IT impact firm innovativeness? An empirical examination of complementary and direct effects. *AMCIS 2006 Proceedings Paper* 91.

- Hempell, T., 2003. Do computers call for training? Firm-level evidence on complementarities between ICT and human capital investments. ZEW Discussion Paper No. 03-20, Mannheim.
- Hempell, T. and Zwick, T., 2008. New technology, work organisation, and innovation. *Economics of Innovation and New Technology* 17(4), 331-354.
- Higon, D.A., 2011. The impact of ICT on innovation activities: Evidence for UK SMEs, *International Small Business Journal* 20(10), 1-16.
- Ichniowski, C., Kochan, T.A., Levine, D.I., Olson, C. and Strauss, G., 2000. What works at work: Overview and assessment, in: Ichniowski, C., Levine, D.I., Olson, C. and Strauss, G. (Eds.), *The American Workplace. Skills, Compensation and Employee Involvement*. Cambridge University Press, Cambridge, pp. 1-37.
- Kleinknecht, A. (Ed.), 1996. *Determinants of Innovation and Diffusion. The Message from New Indicators*. Macmillan Press, London.
- Kleinknecht, A., van Montfort, K. and Brower, E., 2002. The non-trivial choice between innovation indicators. *Economics of Innovation and New Technology* 11(2), 109-205.
- Kleis, L., Chwelos, P., Ramirez, R. and Cockburn, I., 2012. Information technology and intangible output: The impact of IT investment on innovation productivity. *Information Systems Research* 23(1), 42-59.
- Klevorick, A.K., Levin, R.C., Nelson, R.R. and Winter, S.G., 1995. On the sources and significance of interindustry differences in technological opportunities. *Research Policy* 24, 185-205.
- Kretschmer, T., 2012. Information and communication technologies and productivity growth: a survey of the literature. *OECD Digital Economy Papers*, No. 195, OECD Publishing, Paris.
- Laursen, K. and Foss, N.J., 2003. New human resource management practices, complementarities and the impact on innovation performance. *Cambridge Journal of Economics* 27, 243-263.
- Laursen, K. and Salter, A., 2006. Open for innovation: the role of openness in explaining innovation performance among U.K. manufacturing firms, *Strategic Management Journal*, 27, 131-150.
- Lee, H. and Choi, B. 2003. Knowledge management enablers, processes, and organizational performance: An integrative view and empirical examination. *Journal of Management Information Systems* 20(1), 179-228.
- Lev, B., 2003. The measurement of firm-specific organizational capital. NBER Working Paper No. 9581, Cambridge, Mass.

- Lindbeck, A. and Snower, D.J., 2000. Multi-task learning and the reorganization of work: From tayloristic to holistic organization. *Journal of Labor Economics* 18, 353-376.
- Lopez-Garcia, P. and Montero, J. M., 2012. Spillovers and absorptive capacity in the decision to innovate of Spanish firms: the role of human capital. *Economics of Innovation and New Technology* 21(7), 589-612.
- Loukis, E., Sapounas, I. and Milionis, A., 2009. The effect of hard and soft information and communication technologies investment on manufacturing business performance in Greece - A preliminary econometric study. *Telematics and Informatics* 26(2), 193-210.
- Mata, F. J., Fuerst, W. L. and Barney, J. B., 1995. Information technology and sustained competitive advantage: A resource-based analysis. *MIS Quarterly* 19(4), 487-505.
- Mithas, S., Ramasubbu, N. and Sambamurthy, V., 2011. How Information Management Capability Influences Firm Performance. *MIS Quarterly* 35(1), 237-256
- Michie, J. and Sheehan, M., 1999. HRM practices, R&D expenditure and innovative investment: Evidence from the UK's 1990 Workplace Industrial Relations Survey (WIRS). *Industrial and Corporate Change* 8(2), 211-233.
- Milgrom, P. and Roberts, J., 1990. The economics of modern manufacturing. *American Economic Review* 80 (3), 511-528.
- Moshiri, S. and Simpson, W., 2011. Information technology and the changing workplace in Canada: firm-level evidence. *Industrial and Corporate Change* 20(6), 1601-1636.
- Mookherjee, D., 2006. Decentralization, hierarchies, and incentives: A mechanism design perspective. *Journal of Economic Literature* 44, 367-390.
- Olló-Lopez and Aramenda-Muneta. M.E., 2012. ICT impact on competitiveness, innovation and environment. *Telematics and Informatics* 20, 204-210.
- Powell, T. C. and Dent-Micallef, A., 1997. Information technology as competitive advantage: The role of human, business, and technology resources. *Strategic Management Journal* (18)5, 375-405.
- Rivers, D. and Vuong, Q.H., 1988. Limited information estimators and exogeneity tests for simultaneous Probit models. *Journal of Econometrics* 39, 347-366.
- Romer, P.M., 1990. Endogenous technological change, Part II. *Journal of Political Economy* 98(5), 71-102.
- Spiezia, V., 2011. Are ICT users more innovative. *OECD Journal: Economic Studies*, Volume 2011, pp.
- Tapscott, D., Ticoll, D. and Lowi, A., (2000). *Digital Capital – Harnessing the Power of Business Webs*. Harvard Business School Press, Boston.

- Van Beers, C., Kleinknecht, A., Ortt, R. and Verburg, R. (Eds.), 2008. *Determinants of Innovative Behaviour: A Firm's Internal Practices and its External Environment*. Palgrave Macmillan, London.
- Vandenbussche, J., Aghion, P., and Meghir, C., 2006. Growth, distance to frontier and composition of human capital. *Journal of Economic Growth* 11(2), 97-127.
- Vickery, G. and Wurzburg, G., 1998. *The challenge of measuring and evaluating organizational change in enterprises*. OECD, Paris.
- Vinding, A.L., 2006. Absorptive capacity and innovative performance: A human capital approach. *Economics of Innovation and New Technology* 15(4-5), 507-517.
- Zoghi, C., Mohr, R.D. and Meyer, P.B., 2010. Workplace organization and innovation. *Canadian Journal of Economics* 43(2), 622-639.
- Wan, Z., Fang, Y. and Wade, M., 2007. A ten-year odyssey of the 'IS productivity paradox' - A citation analysis (1996-2006). *Proceedings of the Americas Conference on Information Systems (AMCIS) 2007*, Keystone, Colorado, USA.

Table 1: Definition of variables

Variable	Definition
<i>Dependent variables</i>	
INNOPD	Introduction of product innovations (yes/no)
INNOPC	Introduction of process innovations (yes/no)
RD	R&D expenditures yes/no
LRDL	Natural logarithm of R&D expenditures per employee
LINNL	Natural logarithm of sales of innovative products (new and considerably modified products) per employee
<i>Independent variables</i>	
DEM	Expectations with respect to demand development in the next three years; five-level ordinal variable (level 1: 'strong decrease'; level 5 'strong increase')
HQUAL	Share of employees with tertiary-level formal education
<i>Market environment:</i>	
IPC	Intensity of price competition; five-level ordinal variable (level 1: 'very weak'; level 5 'very strong')
INPC	Intensity of non-price competition; five-level ordinal variable (level 1: 'very weak'; level 5 'very strong')
NCOMP	Switzerland: Interval variable: up to 5 competitors; 6 to 10; 11 to 15; 16 to 50; more than 50; Greece: number of main competitors
<i>Use of ICT:</i>	
ICT	Sum of the standardized values of the variables INTERNET and INTRANET; where: INTERNET: six-level ordinate variable for the intensity of <i>internet use</i> : share of employees using internet in daily work: 0: 0%; 1: 1-20%; 2: 21-40%; 3: 41-60%; 4: 61-80%; 5: 81-100%; INTRANET: six-level ordinate variable for the intensity of <i>intranet use</i> : share of employees using internet in daily work: 0: 0%; 1: 1-20%; 2: 21-40%; 3: 41-60%; 4: 61-80%; 5: 81-100%
E_S	Sales through the Internet (on-line sales) as a percentage of total sales
E_P	Procurement through the Internet as a percentage of total procurement
<i>Workplace organization:</i>	
ORG1	Sum of the standardized values of the 3 variables ORG1_1, ORG1_2 and ORG1_3
ORG1_1	Ordinate variable measuring how widespread is <i>team-work</i> inside a firm on a five-point Likert scale (1: 'very weakly widespread'; 5: 'very strongly widespread'); team work: project groups, quality circles, semi-autonomous teams, etc.
ORG1_2	Ordinate variable measuring how widespread is <i>job rotation</i> inside a firm on a five-point Likert scale (1: 'very weakly widespread'; 5: 'very strongly widespread'); team work: project groups, quality circles, semi-autonomous teams, etc.
ORG1_3	Three-level ordinate variable for the change of the number of <i>managerial levels</i> in the period 2000-2005: 1: increase; 2: no change; 3: decrease
ORG2	Sum of the standardized values of the 8 variables ORG2_1 to ORG2_8
ORG2_1	Three-level ordinate variable measuring the <i>change</i> of the distribution of

	decision competences between managers and employees inside a firm in the period 2000-2005: 1: shift towards managers; 2. no shift; 3: shift towards employees
ORG2_2	Ordinate variable measuring the distribution of decision competences to determine work <i>pace</i> (1: 'primarily managers'; 5: 'primarily employees')
ORG2_3	Ordinate variable measuring the distribution of decision competences to determine the <i>sequence</i> of the tasks to be performed (1: 'primarily managers'; 5: 'primarily employees')
ORG2_4	Ordinate variable measuring the distribution of decision <i>competences to assign tasks</i> to the employees (1: 'primarily managers'; 5: 'primarily employees')
ORG2_5	Ordinate variable measuring the distribution of decision competences to determine the way of performing tasks (1: 'primarily managers'; 5: 'primarily employees')
ORG2_6	Ordinate variable measuring the distribution of decision competences to solve emerging production problems (1: 'primarily managers'; 5: 'primarily employees')
ORG2_7	Ordinate variable measuring the distribution of decision competences to contact customers (1: 'primarily managers'; 5: 'primarily employees')
ORG2_8	Ordinate variable measuring the distribution of decision competences to solve emerging problems with customers (1: 'primarily managers'; 5: 'primarily employees')
<i>Controls</i>	
Medium-sized firms	Dummy variable for medium-sized firms: 50 to 249 employees (in full-time equivalents)
Large firms	Dummy variable for large firms: 250 employees (in full-time equivalents) and more
Manufacturing / services	Greece: Dummy variable for manufacturing and service sector
High-tech manufacturing	NACE 24; 25; 29; 30; 31; 32; 33; 34; 35
Low-tech manufacturing	NACE: 15; 16; 17; 18; 19; 20; 21; 22; 23; 26; 27; 28; 36; 40; 41
Knowledge-intensive services	NACE 65; 66; 67; 72; 73; 74
Traditional services	NACE 50; 51; 52; 55; 60; 61; 62; 63; 64; 70; 71; 93
RES_ICT	Residuals of the instrument equations for ICT
RES_ORG1	Residuals of the instrument equations for ORG1
RES_ORG2	Residuals of the instrument equations for ORG2
RES_HQUAL	Residuals of the instrument equations for HQUAL
RES_E_S	Residuals of the instrument equations for E_S
RES_E_P	Residuals of the instrument equations for E_P
Reference group for firm size: small firms (5 to 49 employees); reference group for sector: construction	

Table 2a: The impact of ICT and E-sales, E-procurement, human capital and workplace organization on innovation input and innovation output; Swiss firms

	INNOPD Probit estimates	INNOPD Probit Estimates	INNOPC Probit estimates	LINNL Tobit estimates
DEM	0.038*** (0.014)	0.038*** (0.014)	0.028* (0.015)	0.917*** (0.277)
IPC	0.028*** (0.011)	0.029*** (0.011)	0.027** (0.012)	0.795*** (0.231)
INPC	0.053*** (0.011)	0.053*** (0.011)	0.026** (0.012)	1.034*** (0.230)
NCOMP	-0.027*** (0.008)	-0.027*** (0.008)	0.001 (0.009)	-0.556*** (0.168)
HQUAL	0.001 (0.001)	0.001* (0.000)	0.000 (0.001)	0.030** (0.015)
ICT	0.004 (0.008)		0.021*** (0.009)	0.139 (0.161)
ORG1	0.031*** (0.006)	0.031*** (0.006)	0.034*** (0.007)	0.628*** (0.120)
ORG2	0.009*** (0.002)	0.009*** (0.002)	0.006** (0.003)	0.168*** (0.051)
E_P	-0.001 (0.001)	-0.001 (0.001)	0.001 (0.001)	0.042* (0.022)
E_S	0.002 (0.002)	0.002 (0.002)	0.003 (0.003)	-0.017 (0.043)
Medium-sized firms	0.012 (0.026)	0.013 (0.026)	0.041 (0.028)	0.395 (0.533)
Large firms	0.144*** (0.033)	0.146*** (0.033)	0.180*** (0.035)	2.586*** (0.663)
High-tech manufacturing	0.387*** (0.040)	0.390*** (0.040)	0.214*** (0.044)	7.944*** (0.0893)
Low-tech manufacturing	0.251*** (0.039)	0.252*** (0.039)	0.212*** (0.042)	6.265*** (0.863)
Knowledge-intensive services	0.072 (0.050)	0.079* (0.048)	0.087* (0.053)	2.151** (1.067)
Traditional services	0.064 (0.043)	0.067 (0.042)	0.022 (0.046)	2.030** (0.915)
Const.	-1.642*** (0.264)	-1.663*** (0.260)	-1.431*** (0.252)	-10.392*** (1.766)
N	1591	1591	1591	1591
N left-censored at zero				692
Pseudo R2	0.170	0.170	0.098	0.051
Wald chi2	318.6***	318.9***	182.1***	
LR chi2				387.1***

Note: Average marginal effects; heteroskedasticity-robust standard errors in brackets (for INNOPD and INNOPC); \*\*\*, \*\*, \* denote statistical significance at the 1, 5 and 10% test level resp.; reference sub-sector: construction; reference firm size class: small firms (5-49 employees).

Table 2b: The impact of ICT and E-sales, E-procurement, human capital and workplace organization on innovation input; Swiss firms

	LRDL Tobit	LRDL Tobit IV two step ICT instrumented	LRDL Tobit IV two step ORG1 instrumented	LRDL Tobit IV two step ORG2 instrumented	LRDL Tobit IV two step E_S instrumented
DEM	0.527** (0.237)	0.507* (0.262)	0.117 (0.349)	0.316 (0.268)	0.472** (0.222)
IPC	0.304 (0.200)	0.233 (0.211)	0.013 (0.012)	0.316 (0.199)	0.289 (0.204)
INPC	0.731*** (0.198)	0.684*** (0.194)	0.830*** (0.211)	0.498** (0.245)	0.811*** (0.219)
NCOMP	-0.230 (0.145)	-0.139 (0.159)	-0.187 (0.142)	-0.064 (0.158)	-0.247* (0.150)
HQUAL	0.039*** (0.012)	-0.010 (0.032)	0.026* (0.014)	0.022 (0.016)	0.061*** (0.017)
ICT	0.285** (0.139)	1.974** (0.991)	0.108 (0.177)	-0.273 (0.335)	0.015 (0.221)
ORG1	0.416*** (0.102)	0.359*** (0.119)	3.649* (1.901)	0.229* (0.139)	0.511*** (0.111)
ORG2	0.117*** (0.044)	0.017 (0.071)	0.008 (0.078)	1.049** (0.520)	0.134*** (0.044)
E_P	0.002 (0.021)	-0.033 (0.030)	-0.030 (0.031)	0.021 (0.022)	-0.064 (0.051)
E_S	-0.036 (0.046)	-0.067 (0.053)	-0.002 (0.056)	-0.024 (0.053)	0.961 (0.662)
Medium-sized firms	0.674 (0.464)	0.028 (0.630)	-0.662 (0.958)	0.782 (0.518)	0.602 (0.488)
Large firms	2.384*** (0.567)	1.107 (0.981)	0.192 (1.461)	1.872*** (0.723)	1.797** (0.771)
High-tech manufacturing	8.330*** (0.783)	6.908*** (1.145)	5.721*** (1.756)	7.966*** (0.862)	8.563*** (0.809)
Low-tech manufacturing	5.039*** (0.760)	4.427*** (0.920)	2.677* (1.611)	4.879*** (0.792)	5.092*** (0.805)
Knowledge-intensive services	1.975** (0.923)	-0.968 (1.182)	0.191 (1.489)	1.950* (1.039)	1.318 (1.057)
Traditional services	-2.277*** (0.853)	-3.628 (1.223)	-3.469*** (1.213)	-3.681* (1.202)	-3.864*** (1.524)
Const.	-9.799** (1.548)	-6.832*** (2.346)	-4.499 (3.444)	-7.965*** (1.902)	-10.428*** (1.550)
N	1591	1591	1591	1591	1591
N left-censored at 0	899	899	899	899	899
Pseudo R2	0.097	0.098	0.095	0.097	0.098
LR chi2	587.4***	590.4***	825.3***	876.6***	956.9***

Note: Standard errors in brackets; \*\*\*, \*\*, \* denote statistical significance at the 1, 5 and 10% test level resp.; reference sub-sector: construction; reference firm size class: small firms (5-49 employees).



Table 3: The impact of ICT, E-sales, E-procurement, human capital and workplace organization on innovation input and innovation output; Greek firms

	INNODP Probit estimates	INNODP Probit estimates	INNOPC Probit estimates	LRDL Tobit estimates	LINNL Tobit estimates	LINNL Tobit estimates
DEM	0.003 (0.032)	0.010 (0.032)	0.010 (0.032)	0.668 (0.651)	1.189*** (0.390)	1.280*** (0.391)
IPC	0.039 (0.030)	0.038 (0.030)	0.020 (0.028)	-0.087 (0.597)	0.747** (0.360)	0.743** (0.362)
INPC	-0.016 (0.027)	-0.017 (0.027)	-0.008 (0.026)	-0.375 (0.560)	-0.051 (0.329)	-0.088 (0.331)
NCOMP	0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.001 (0.002)	-0.003 (0.002)	-0.003* (0.002)
HQUAL	0.001 (0.002)	0.002 (0.002)	-0.000 (0.001)	0.018 (0.030)	0.006 (0.018)	0.023 (0.016)
ICT	0.032* (0.019)		0.033* (0.019)	0.112 (0.379)	0.531** (0.243)	
ORG1	0.037** (0.015)	0.039** (0.016)	0.027* (0.015)	0.645** (0.308)	-0.014 (0.191)	0.012 (0.019)
ORG2	0.011 (0.007)	0.014** (0.006)	0.002 (0.006)	0.249* (0.131)	-0.175** (0.081)	-0.123 (0.078)
E_P	0.002 (0.002)	0.002 (0.002)	0.001 (0.002)	0.066 (0.061)	0.029 (0.025)	0.034 (0.025)
E_S	0.001 (0.004)	0.001 (0.004)	0.006 (0.004)	-0.002 (0.043)	0.006 (0.039)	0.008 (0.040)
Medium-sized firms	0.083 (0.069)	0.096 (0.069)	0.154** (0.068)	1.459 (1.479)	0.489 (0.840)	0.681 (0.843)
Large firms	0.187*** (0.072)	0.206*** (0.071)	0.272*** (0.069)	5.059*** (1.539)	1.524* (0.914)	1.892** (0.909)
Manufacturing / services	0.023 (0.060)	0.024 (0.060)	-0.112** (0.057)	-4.325*** (1.241)	-0.226 (0.725)	-0.240 (0.730)
Const.	-0.882** (0.448)	-0.921** (0.445)	-0.682 (0.454)	-1.019 (2.994)	6.869*** (1.839)	6.551*** (1.839)
N	265	265	265	265	261	261
N left-censored at 0				187	59	59
Pseudo R2	0.098	0.091	0.114	0.058	0.024	0.021
R2						
Wald chi2	33.9***	33.3***	37.3***			
LR chi2				42.7***	34.0***	29.2***

Note: Average marginal effects; heteroskedasticity-robust standard errors in brackets; \*\*\*, \*\*, \* denote statistical significance at the 1%, 5% and 10% test level resp.; reference sub-sector: construction; reference firm size class: small firms (5-49 employees).

Table 4: Summary of results concerning the effects of the examined factors on innovation in Switzerland and Greece

	Switzerland	Greece
Internal IS	positive on process innovation and R&D activity	positive on products and process innovation
E-sales IS	non-significant	non-significant
E-procurement IS	non-significant	non-significant
New work design	positive	positive on products - process innovation and R&D activity
Decentralisation	positive	positive on products innovation and R&D activity
Human capital	positive on products innovation and R&D activity	non-significant
Demand expectations	positive	non-significant
Price competition	positive	non-significant
Non-price competition	positive	non-significant
Number of competitors	negative	non-significant
Firm size	positive	positive

Appendix:

Table A.1: Composition of the data sets by industries and firm size classes

	Greece		Switzerland	
	N	Percentage	N	Percentage
<i>Industry:</i>				
Food, beverage	25	9.2	77	4.5
Textiles	6	2.2	24	1.4
Clothing, leather	7	2.6	6	0.3
Wood processing	3	1.1	27	1.6
Paper	3	1.1	24	1.4
Printing	12	4.4	52	3.0
Chemicals	12	4.4	66	3.8
Plastics, rubber	6	2.2	38	2.2
Glass, stone, clay	9	3.3	28	1.7
Metal	4	1.5	24	1.4
Metal working	7	2.6	106	6.2
Machinery	1	0.4	165	9.7
Electrical machinery	2	0.7	50	2.9
Electronics, instruments	3	1.1	122	7.1
Vehicles	2	0.7	20	1.1
Other manufacturing	5	1.8	30	1.8
Energy	3	1.1	33	1.9
Construction	14	5.2	179	10.5
Wholesale trade	52	19.2	142	8.3
Retail trade	21	7.7	102	6.0
Hotels, catering	27	10.0	56	3.3
Transport,	15	5.2	91	5.3
Telecommunication				
Banks, insurances	5	1.8	73	4.3
Real estate, leasing	2	0.7	11	0.6
Business services	16	5.9	151	8.8
Personal services	10	3.7	11	0.6
<i>Firm size:</i>				
20-49 employees	88	32.5	474	27.7
50-249 employees	105	38.7	875	51.2
250 employees and more	78	28.8	361	21.1
Total	281	100.0	1710	100.0

Table A.2: Descriptive statistics

	Greece		Switzerland	
	Mean (N=265)	Standard deviation	Mean (N=1591)	Standard deviation
INNOPD	0.413	0.493	0.493	0.500
INNOPC	0.373	0.484	0.422	0.494
RD	0.353	0.479	0.381	0.486
LRDL	1.798	2.961	3.936	3.702
LINNL	8.068	4.619	5.622	5.613
DEM	2.355	0.057	3.308	0.021
IPC	3.967	1.052	3.933	1.056
INPC	3.177	1.141	3.064	1.003
NCOMP <sup>(*)</sup>	44.306	19.947	2.490	0.035
HQUAL	26.181	23.690	20.816	20.306
ICT	-0.006	1.808	0.000	1.788
ORG1	-0.003	1.833	0.012	1.867
ORG2	0.020	4.785	-0.001	4.693
E_P	4.478	0.882	2.774	0.248
E_S	2.343	0.560	0.974	0.137
Medium-sized firms	0.387	0.488	0.358	0.479
Large firms	0.288	0.454	0.149	0.356

(\*): Greece: number of competitors; Switzerland: interval variable.

Table A.3a: Independent variables: correlation matrix; Switzerland

	DEM	IPC	INPC	NCOMP	HQUAL	ICT	ORG1	ORG2	E-P	E-S	Medium-sized firms	Large firms
DEM	1.000											
IPC	-0.081	1.000										
INPC	0.099	0.041	1.000									
NCOMP	-0.077	0.171	-0.019	1.000								
HQUAL	0.127	-0.060	0.064	-0.036	1.000							
ICT	0.125	-0.008	0.011	-0.085	0.490	1.000						
ORG1	0.102	0.038	0.046	-0.060	0.111	0.154	1.000					
ORG2	0.097	-0.019	0.107	-0.095	0.183	0.292	0.133	1.000				
E-P	0.030	0.058	0.027	0.036	0.076	0.172	0.053	0.009	1.000			
E-S	0.007	0.008	-0.003	0.011	-0.031	0.084	-0.027	0.010	0.140	1.000		
Medium-sized firms	0.002	-0.021	0.014	-0.021	-0.051	-0.029	0.035	-0.043	-0.030	-0.030	1.000	
Large firms	0.113	0.037	0.099	-0.105	0.085	0.203	0.123	0.130	-0.025	0.043	-0.509	1.000

Table A.3b: Independent variables: correlation matrix; Greece

	DEM	IPC	INPC	NCOMP	HQUAL	ICT	ORG1	ORG2	E-P	E-S	Medium-sized firms	Large firms
DEM	1.000											
IPC	0.082	1.000										
INPC	0.093	0.349	1.000									
NCOMP	-0.011	0.002	0.034	1.000								
HQUAL	-0.066	0.003	0.159	-0.047	1.000							
ICT	-0.153	0.036	0.070	-0.042	0.524	1.000						
ORG1	-0.047	0.054	0.033	0.006	0.026	0.066	1.000					
ORG2	-0.166	0.150	0.101	-0.012	0.286	0.377	-0.038	1.000				
E-P	-0.056	-0.020	0.103	0.046	0.013	0.060	0.032	0.002	1.000			
E-S	-0.024	-0.002	0.092	-0.024	0.114	0.169	0.041	0.085	0.256	1.000		
Medium-sized firms	0.046	-0.082	-0.011	-0.056	0.124	0.072	0.079	-0.014	0.087	0.011	1.000	
Large firms	-0.123	0.028	0.040	-0.059	-0.005	0.140	0.044	0.077	0.003	0.038	-0.501	1.000

Table A.4: Results of endogeneity tests (Rivers-Vuong-Test)

	Switzerland				Greece			
	INNOPD-eq.	INNOPC-eq.	LRDL-eq.	LINNS-eq.	INNOPD-eq.	INNOPC-eq.	LRDL-eq.	LINNS-eq.
	stat. sign.	stat. sign.	stat. sign.	stat. sign.	stat. sign.	stat. sign.	stat. sign.	stat. sign.
RES_ICT	no	no	yes	no	no	no	no	no
RES_ORG1	no	no	yes	no	no	no	no	no
RES_ORG2	no	no	yes	no	na	na	na	na
RES_HQUAL	no	no	yo	no	no	na	no	no
RES_E_P	na	na	na	na	na	na	no	no
RES_E_S	no	no	yes	no	no	no	no	no

*Note:* Statistical significance (at the 10% test level) refers to the coefficients of the residuals of the instrument equations for ICT, ORG1, ORG2 and E\_S (RES\_ICT, etc.) that were inserted as additional right-hand variables in the respective innovation equations; na: no valid instruments could be found for HQUAL and E\_P for the Swiss firms.