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

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Abstract

This paper examined the relationship between indicators for the intensity of use of ICT, several forms of workplace organization, and human capital and several measures of innovation performance at firm level 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. based on the same questionnaire for both countries and took place in 2005. This paper contributes to literature in three ways: first, it analyzes the three most important factors, i.e. information technology, organization, human capita, that are considered to be drivers of innovation performance 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 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. In economics much attention has been paid to the specific character of ICT as "general purpose technology" that is spread and used 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., to capital requirements, technical and managerial skills that enable firms to develop a sustained competitive advantage (Mata et al., 1995; Powell and Dent-Micaleff, 1995). Recently, there is a tendency to examine organizational issues in the context of ICT, particularly the direct and indirect (in combination with ICCT) impact of workplace organization on firm performance (Brynjolfsson et al., 2000; 2002). The Organizational issues is primarily a concern for themicroeconomic point of view and is mostly in more management-oriented literature. The third factor that interest here, human capital, plays also a prominent role – say the fuel of the "growth machine" – in both branches of literature (see Bresnahan et al., 2002 for a seminal micro-study; Vandenbusschee et al., 2006 for a seminal macro-study in this issue).

This paper examined the relationship between indicators for the intensity of use of ICT, several forms of workplace organization, and human capital and several measures of innovation performance at firm level in an innovation equation framework, in which was also controlled for standard innovation determinants such as demand, competition and firm size.

For the empirical analysis we used data at firm level that were collected by a survey that was based on the same questionnaire for both countries and took place in 2005.

This paper contributes to literature in three ways: first, it analyzes the three most important factors, i.e. information technology, organization, human capita, that are considered to be drivers of innovation performance 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.

The paper is structured as follows: in section 2 we present the conceptual frame work and related empirical literature. Section 3 describes the data used in the study. Section 4 refers to the model specification and the econometric procedure. Section 5 the results are presented. Section 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, such as the extensive use of computer-aided production technologies, the advances in information and communication technologies, the emerging of new ideas how to organize firms, changes in the skill requirements of labour and changes in employee preferences toward more flexible working conditions. On this ground, recently 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 data focused mainly on the *direct effects* of such changes on firms’ economic performance, mostly measured by average labour productivity (e.g., 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 and Arvanitis and Loukis, 2009 for Greek and Swiss firms in a comparative study; Badescu and Garcés-Ayerbe, 2009 for Spanish firms).

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

2.2 ICT and innovation

Following Kleis et al. (2010) we posit that the use of ICT contributes to firms’ innovation activities through three main channels. The first channel goes through the management of knowledge used in the innovation process. This knowledge might be internally crated or externally acquired. Information technology enables an efficient storage and a high accessibility of 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).

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. 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 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 computed-aided manufacturing CAM help to digitize a new product's design and make it available throughout the innovation process. Finally, information technology 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.

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

The existing empirical economic 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. Especially, the different points of time 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 twenty years.

Four of the studies reviewed here refer to German service firms. In an earlier study Licht and Moch (1997) found based on a cross-section of 1,200 service firms for the period 1994-1996 that investment in information technologies per employee impacted positively five different measures of dimensions of product quality (user friendliness, temporal and spatial availability, delivery speed, etc.), which they interpreted as indicators of product innovation. Engelstätter and Sarbu (2010) investigated the relationship between the use of sector-specific and customized software on service innovation (335 German firms; 2007-2009). The results showed as expected that primarily customized software contributes significantly to innovation. Engelstätter (2011) examined the relationship between three business software systems (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 correlated positively with ERP, while the likelihood of introducing product innovations correlated with the use of CRM; and (b) that the number of process innovations a firm realized correlated positively with ERP, whereas the number of expected product innovations correlated with the use of SCM.

In a fourth third German study also for service firms in the period 1994-1999 Hempell (2005) demonstrated using a production function framework that innovation and ICT use are complementary, i.e. mutually reinforcing, with respect to productivity. On the whole, German studies find mostly that ICT use is innovation-enabling, at least in the service sector. In a further study comparing German and Dutch firms, which is similar to that of Hempell (2005), Hempell and et al. (2006) found evidence of the complementarity of innovation and ICT use in the service sector at the same order of magnitude in the two countries.

In a study based on 2,500 UK SMES in the year 2004 Higon (2011) found that ICT enhances process innovation, while specific market-oriented applications of ICT (website development) favour product innovation.

Gago and Rubalcaba (2007) investigated based on data for 557 Spanish service firms in the year 2002 the impact of ICT on service innovation and found that ICT correlated positively with service innovation as measured by higher variety of services provide by the firms.

Arvanitis et al. (2011), using firm-level data collected through a survey of 271 Greek firms, investigate the impact of three different types of IS (internal, e-sales and e-procurement IS) on product and process innovation performance of Greek firms. Their results showed that the internal IS had a strong positive impact on both product and process innovation, and the e-sales IS only on process innovation; on the contrary, e-procurement IS were not drivers of innovation.

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. In a further study based on quite detailed data for 212 US firms in the valve industry Bartel et al. (2007) found that (a) new IT promotes increased production of customized products (i.e. product innovation according to the authors' interpretation) and (b) new IT embedded machines (new CNC machines, FMS, computerized equipment-inspection, etc.) improved considerably production process efficiency.

Finally, there exist also some multi-country studies. Koellinger (2008) investigated for a large sample of 7'000 firms from 10 sectors and 25 European countries for 2003 the impact of IT-enabled as compared to non-IT-enabled product and process innovations on profitability and found (a) positive effects only for product innovations and (b) larger differences of the profitability effects between product and process innovations than between IT-enables and non-IT-enabled product innovations. The author concluded that "internet-enabled innovations are at the very least not 'inferior' to other kinds of innovation" with respect to profitability.

Spieza (2111) 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 industry 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 recently to explain why new high-skill and high-involvement workplaces may be more effective (see, e.g., Ichniowski et al., 2000). 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 recent developments in the structure of European and US companies). These theories imply that 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.

In an older literature review Damanpour (1991) performed a meta-analysis of the relationship between innovation and a series of potential organizational determinants. He concluded that organization structure is in general a significant determinant of innovation performance.

More recently, 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 appositive correlation between investment in R&D and new technology and "high.-commitment" organizational practices (teamwork, information sharing between workers and managers, increased assignment flexibility, innovative incentive pay plans, etc.).

Acemoglu et al. (2007) investigated besides their theoretical analysis also empirically for 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 measure 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 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 the organizational measure 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 Danish firms (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 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 effects of centralization (of organizational structure) but no effect of formalization (of organizational structure) on the on a measure of the "knowledge creation process".

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 technology (Vandenbussche et al., 2006).

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 considerable direct positive effects of ICT, eventually also of ICT applications such as e-sales and e-procurement, on innovation performance;
- *Hypothesis 2*: There are considerable direct positive effects of organizational factors on innovation performance;
- *Hypothesis 3*: There are considerable 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 much 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) and new organizational practices (team-work, job rotation, employees‘ involvement), employees' formal education, and also on basic economic data (sales, value of intermediate inputs, investment expenditure, number of employees, etc.).[1]

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 29 industries, and within each industry three industry-specific firm size classes with full coverage of the upper class of large firms)[2]. 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 of 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 only 1591 observations.

3.2 Greek data

[1] 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.

[2] 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.

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, and the proportions of all the industry and size classes were the same 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, that exhausted the firms of the second sample, 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 the 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 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, 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 tat are not robust (see, for example, 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 and a further binary variable for conducting R&D (R&D) in the same time period. Second, we also used (b) two metric variables, the R&D expenditures per employee (LRDL) and the sales of innovative products per employee (LINNL). For each of the dependent variables a separate model has been estimated.

4.1.2 Independent variables

As measures for ICT 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 a positive correlation of these technology variables with the innovation indicators. In order to be able to measure an overall effect of 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 applications of ICT in E-commerce: E-sales and E-procurement.

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 changes and/or introduction and 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 co-operation. 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 manages and employees inside a 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. We expected an overall positive correlation of organizational variables with innovation indicators, but we do not have sign expectations for every single variable. 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).

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

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., Cohen, 1995; Kleinknecht, 1996; Raymond et al., 2006; Van Beers et al., 2008). The demand expectations variable DEM assesses to what extent the firm expects an increase of demand on the relevant product markets in the medium-term (next three years). The two competition variables PCOMP and NPCOMP assess the intensity of price and non-price competition respectively in firm's most important market, while the market concentration variable NUCOMP measures the number of main competitors in firm's most important market. 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 concentration variable and firm size (see Arvanitis, 2008 for Switzerland and Arvanitis et al., 2011 for Greece).

For testing the research hypotheses that were presented in section 2.5 the following innovation model was estimated:

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

4.2 Econometric issues

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 outsourcing 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 2.6 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 already 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 outsourcing variables and the estimates were based on the original variables.

On the whole, we tested 30 estimates (six different right-hand variables for five 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 21 out of 25 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 the10% 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 LRDL with respect to ICT, ORG1, ORG2 and E_S, was the coefficient of the residual statistical significant. In all 22 cases that could be effectively for the Greek data no evidence for endogeneity could be found. Table A.3 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. 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 model for the Swiss data are presented in Table 2a and Table 2b. The composite indicator for technology (ICT) correlates significantly positive only with the likelihood of the introduction of that 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 variables for E-commerce. 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 and 3% in business services; the respective figures for e-procurement were 2% and 4% respectively (Arvanitis et al., 2007).

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 that 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).

Human capital matters primarily for R&D activities (column 1 in Table 2b) and product innovation (INNOPD; LINNS).[3]

As indicated by the magnitude of the marginal effects ORG1 shows the largest effect on innovation performance. In sum, all three hypotheses are supported by the empirical findings for the Swiss firms.

In (partial) accordance with earlier results we find a positive effect for the intensity of non-price competition for all innovation indicators, 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; LINNS) 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.

5.2 Greek results

The results of the estimates for the Greek firms are found in Table 3. The variable for 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 great 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 their existing processes, products and services have been designed in the pre-ICT era, so they have been shaped by the dominant logic and constraints of the manual mode of work, and the concomitant high costs of information processing and transfer; at the same time, firms realize that the capabilities offered by the internal IS change radically these fundamental assumptions, so processes, products and services have to be transformed in order to exploit these valuable capabilities offered to a larger extent. These effects are in contrast to the development in Swiss firms, which being already highly innovative in the pre-ICT era 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 for the same reasons as in Switzerland.

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[3] Due to multicollinearity with ICT (r=0.490; see Table A2a 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 HQAL becomes significant at the 10%-test level (column 2 in Table 2a).

A further interesting finding refers to the effect of the variable ORG1, 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) but this effect is not robust.[4] ICT effects and organizational effects (referring to work design) as measured by the marginal effects are of the same magnitude.

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.

On the whole, hypothesis 1 and partly hypothesis 2 are confirmed by the Greek results.

Finally, we remark that all four 'traditional' innovation determinants we examined (demand expectation, price competition, non-price competition, number of competitors) do not have a statistically significant effect for any innovation indicator. Our results indicate that the Greek national context, which is innovation averse, characterised by lower innovation activity and uncertainty avoidance culture[5], has a negative impact on firms' propensity for innovation; so firms do not respond to high competition or demand expectations with innovations in their processes, products and services, as firms of developed countries do. We found a positive effect for large firms, in accordance with standard evidence from other studies.

6. Summary and conclusions

We concentrate here on the results referring to ICT, organization and human capital. For the Swiss firms we conclude 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. 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. Further, we could not find any effect for the variables for E-commerce. The main reason might have been that in 2005 both e-sales and e-procedure 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

[4] The possibility of multicollinearity of ICT and ORG2 (r=0.286; seeTable A2b 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.

[5] 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.

innovation. In sum, all three hypotheses are supported by the empirical findings for the Swiss firms.

For the Greek firms the variable for 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 great 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. These effects are in a way in contrast to the development in Swiss firms, which being already highly innovative in the pre-ICT era 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 for the same reasons as in Switzerland. A further interesting finding refers to the effect of the variable ORG1, 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) but this effect is not robust.

The above results indicate that even in national contexts that are characterised by innovation averse attitudes and also lower level of economic development (which means less history, experience and tradition 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 drive. 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.

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Table 1: Definition of variables

Variable	Definition
Dependent variables	
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
Independent variables	
DEM	Expectations with respect to demand development in the next three years; five-level ordinal variable (level 1: 'strong decrease'; level 5 'strong increase')
HQUAL	Share of employees with tertiary-level formal education
Market environment:	
IPC	Intensity of price competition; five-level ordinal variable (level 1: 'very weak'; level 5 'very strong')
INPC	Intensity of non-price competition; five-level ordinal variable (level 1: 'very weak'; level 5 'very strong')
NCOMP	Switzerland: Interval variable: up to 5 competitors; 6 to 10; 11 to 15; 16 to 50; more than 50; Greece: number of main competitors
Use of ICT:	
ICT	Sum of the standardized values of the variables INTERNET and INTRANET; where: INTERNET: six-level ordinate variable for the intensity of *internet use*: share of employees using internet in daily work: 0: 0%; 1: 1-20%; 2: 21-40%; 3: 41-60%; 4: 61-80%; 5: 81-100%; INTRANET: six-level ordinate variable for the intensity of i*ntranet use*: share of employees using internet in daily work: 0: 0%; 1: 1-20%; 2: 21-40%; 3: 41-60%; 4: 61-80%; 5: 81-100%
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
Workplace organization:	
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 *team-work* 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 *job rotation* 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 *managerial levels* 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 *change* 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 *pace* (1: 'primarily managers'; 5: 'primarily employees')
ORG2_3	Ordinate variable measuring the distribution of decision competences to determine the *sequence* of the tasks to be performed (1: 'primarily managers'; 5: 'primarily employees')
ORG2_4	Ordinate variable measuring the distribution of decision *competences to assign tasks* 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')
Controls	
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
Reference group for firm size: small firms (5 to 49 employees); reference group for sector: construction	

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

	INNOPD Probit estimates	INNOPD Probit Estimates	INNOPC Probit estimates	LINNSL Tobit estimates
DEM	0.038***	0.038***	0.028*	0.917***
	(0.014)	(0.014)	(0.015)	(0.277)
IPC	0.028***	0.029***	0.027**	0.795***
	(0.011)	(0.011)	(0.012)	(0.231)
INPC	0.053***	0.053***	0.026**	1.034***
	(0.011)	(0.011)	(0.012)	(0.230)
NCOMP	-0.027***	-0.027***	0.001	-0.556***
	(0.008)	(0.008)	(0.009)	(0.168)
HQUAL	0.001	0.001*	0.000	0.030**
	(0.001)	(0.000)	(0.001)	(0.015)
ICT	0.004		0.021***	0.139
	(0.008)		(0.009)	(0.161)
ORG1	0.031***	0.031***	0.034***	0.628***
	(0.006)	(0.006)	(0.007)	(0.120)
ORG2	0.009***	0.009***	0.006**	0.168***
	(0.002)	(0.002)	(0.003)	(0.051)
E_P	-0.001	-0.001	0.001	0.042*
	(0.001)	(0.001)	(0.001)	(0.022)
E_S	0.002	0.002	0.003	-0.017
	(0.002)	(0.002)	(0.003)	(0.043)
Medium-sized firms	0.012	0.013	0.041	0.395
	(0.026)	(0.026)	(0.028)	(0.533)
Large firms	0.144***	0.146***	0.180***	2.586***
	(0.033)	(0.033)	(0.035)	(0.663)
High-tech manufacturing	0.387***	0.390***	0.214***	7.944***
	(0.040)	(0.040)	(0.044)	(0.0893)
Low-tech manufacturing	0.251***	0.252***	0.212***	6.265***
	(0.039)	(0.039)	(0.042)	(0.863)
Knowledge-intensive services	0.072	0.079*	0.087*	2.151**
	(0.050)	(0.048)	(0.053)	(1.067)
Traditional services	0.064	0.067	0.022	2.030**
	(0.043)	(0.042)	(0.046)	(0.915)
Const.	-1.642***	-1.663***	-1.431***	-10.392***
	(0.264)	(0.260)	(0.252)	(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-commerce, 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**	0.507*	0.117	0.316	0.472**
	(0.237)	(0.262)	(0.349)	(0.268)	(0.222)
IPC	0.304	0.233	0.013	0.316	0.289
	(0.200)	(0.211)	(0.012)	(0.199)	(0.204)
INPC	0.731***	0.684***	0.830***	0.498**	0.811***
	(0.198)	(0.194)	(0.211)	(0.245)	(0.219)
NCOMP	-0.230	-0.139	-0.187	-0.064	-0.247*
	(0.145)	(0.159)	(0.142)	(0.158)	(0.150)
HQUAL	0.039***	-0.010	0.026*	0.022	0.061***
	(0.012)	(0.032)	(0.014)	(0.016)	(0.017)
ICT	*0.285***	*1.974***	0.108	-0.273	0.015
	(0.139)	*(0.991)*	(0.177)	(0.335	(0.221)
ORG1	*0.416****	0.359***	*3.649**	0.229*	0.511***
	(0.102)	(0.119)	*(1.901)*	(0.139)	(0.111)
ORG2	*0.117****	0.017	0.008	*1.049***	0.134***
	(0.044)	(0.071)	(0.078)	*(0.520)*	(0.044)
E_P	0.002	-0.033	-0.030	0.021	-0.064
	(0.021)	(0.030)	(0.031)	(0.022)	(0.051)
E_S	*-0.036*	-0.067	-0.002	-0.024	*0.961*
	(0.046)	(0.053)	(0.056)	(0.053)	*(0.662)*
Medium-sized firms	0.674	0.028	-0.662	0.782	0.602
	(0.464)	(0.630)	(0.958)	(0.518)	(0.488)
Large firms	2.384***	1.107	0.192	1.872***	1.797**
	(0.567)	(0.981)	(1.461)	(0.723)	(0.771)
High-tech manufacturing	8.330***	6.908***	5.721***	7.966***	8.563***
	(0.783)	(1.145)	(1.756)	(0.862)	(0.809)
Low-tech manufacturing	5.039***	4.427***	2.677*	4.879***	5.092***
	(0.760)	(0.920)	(1.611)	(0.792)	(0.805)
Knowledge-intensive services	1.975**	-0.968	0.191	1.950*	1.318
	(0.923)	(1.182)	(1.489)	(1.039)	(1.057)
Traditional services	-2.277***	-3.628	-3.469***	-3.681*	-3.864***
	(0.853)	(1.223)	(1.213)	(1.202)	(1.524)
Const.	-9.799**	-6.832***	-4.499	-7.965***	-10.428***
	(1.548)	(2.346)	(3.444)	(1.902)	(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-commerce and workplace organization on innovation input and innovation output; Greek firms

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

Appendix:

Table A.1: 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
LINNSL	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(*)	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.2a: 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.2b: 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.3: Results of endogeneity tests (Rivers-Vuong-Test)

	Switzerland					Greece				
	INNOPD-eq.	INNOPC-eq.	R&D-eq.	LRDL-eq.	LINNSL-eq.	INNOPD-eq	INNOPC-eq	LRDL-eq.	R&D-eq.	LINNSL-eq.
	stat. sign.	stat. sign.	stat.sign.	stat. sign.	stat. sign.	stat. sign.	stat. sign.	stat. sign.	stat.sign.	stat. sign.
RES_ICT	No	No	No	Yes	No	No	No	No	No	No
RES_ORG1	No	No	No	Yes	No	No	No	No	No	No
RES_ORG2	No	No	No	Yes	No	na	na	na	na	na
RES_HQUAL	No	No	No	No	No	No	na	No	No	No
RES_E_P	na	na	na	na	na	na	na	No	No	No
RES_E_S	No	No	No	Yes	No	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.