# THE IMPACT OF INFORMATION SYSTEMS INVESTMENT AND MANAGEMENT ON BUSINESS PERFORMANCE IN GREECE[1]

Loukis, Euripidis, University of the Aegean, Gorgiras Street, 83200 Karlovassi, Samos, Greece, eloukis@aegean.gr

Sapounas, Ioakim, University of the Aegean, Gorgiras Street, 83200 Karlovassi, Samos, Greece, isapounas@aegean.gr

## Abstract

*The impact of information and communication technologies (ICT) investment on business performance has been a major research subject for long time. Until the mid 1990s there was little empirical evidence of a positive and statistically significant relation between ICT investment and business performance (ICT Productivity Paradox). Subsequent research, conducted mainly in a few highly developed countries, provided some empirical evidence of a statistically significant positive contribution of ICT investment to some measures of business performance, which increases if ICT investment is complemented by 'co-investments' that create some complementary 'intangible assets', such as new work practices, business processes, organizational structures and skills. In this paper is presented the first study of the impact of information systems (IS) investments on business performance in Greece, based on firm-level data collected through a questionnaire-based survey in cooperation with the Federation of Greek Industries. In this study we also examine whether there is complementarity between IS investment and a set of IS management factors. It is concluded that in Greece IS spending by firms as a percentage of their sales revenue is lower than in the highly developed countries. Also, using econometric models based on the Cobb Douglas production function, we conclude that IS investments in Greece make a positive and statistically significant contribution to firm output and labour productivity, but not to the return on assets. Moreover it was found that the average marginal productivities of ICT capital and ICT labour expenses in Greece are higher than in the highly developed countries; also they are much higher than the average marginal productivities of the non-ICT capital and the non-ICT labour expenses respectively. Finally it was found that there is complementarity between IS investment and the examined set of IS management factors with respect to firm output and labour productivity; therefore the combination of IS investment with these IS management factors results in additional increase of firm output and labour productivity beyond the individual effect of IS investment.*

*Keywords: information systems (or information and communication technologies) investment, productivity paradox, business performance, information systems (or information and communication technologies) management*

## 1    INTRODUCTION

Businesses have been making significant investments in information and communication technologies (ICT) in the last 25 years. According to OECD (2003) the investment in ICT in its member countries

---

has risen from less than 15% of the total non-residential investment in the early 1980s, to between 15% and 30% in 2001. However, in the same report it is mentioned that there are marked differences in the diffusion of ICT across OECD countries: in some of them ICT investment is particularly high, e.g. in USA it is about 28% of the total non-residential investment, while in some others it is much lower (although it constitutes a considerable percentage of the total non-residential investment). Given the high level of ICT investment it is of critical importance to investigate the benefits and the value they create, and also their impact on business performance. For this reason the study of the relation between ICT investment and business performance has been extensively researched and debated for long time.

This research can be divided into two periods. The first period of this research, from the mid 1980s until the mid 1990s, contrary to theoretical arguments and professional beliefs, provided very little empirical evidence of a positive and statistically significant relation between ICT investment and business performance (Roach 1987, Strassman 1990, Yosri 1992, Loveman 1994, Hitt & Brynjolfsson 1996, Rai & Patnayakuni R. & Patnayakuni N. 1996, Rai & Patnayakuni R. & Patnayakuni N. 1997, Strassman 1997). These early results posed critical questions concerning the productivity of the huge investments in ICT: do they really contribute to the productivity of firms, or not? And if they do, how much they contribute? This problematic is usually referred to as the 'ICT Productivity Paradox' (Brynjolfsson 1993). The Productivity Paradox, summed up in R. Solow's statement that 'you can see the computer age everywhere but in the productivity statistics' (Solow 1987), alarmed managers, puzzled researchers, because firms were spending huge amounts of money for ICT; if the returns of these huge ICT investments and their contribution to the productivity and performance of firms are small, then firms should reconsider and reduce their ICT investment, and admit that they had overestimated the value that ICT can create.

On the contrary, the second period of this research, from the mid 1990s until today, provided empirical evidence of positive and statistically significant relation between ICT investment and some measures of business performance, such as output, labour productivity, etc. (Lichtenberg 1995, Brynjolfsson & Hitt 1996, Dewan & Min 1997, Gurbaxani & Melville & Kraemer 1998, Lehr & Lichtenberg 1999, Gilchrist & Gurbaxani & Towne 2001, Devaraj & Kohli 2003). These positive results reflect the improvements in ICT management, and also the adjustment and the restructuring that had taken place at the firm level between the mid 1980s until the mid 1990s, which enabled a higher level of benefits from ICT; also they reflect improvements in the research methodology (e.g. in data collection and analysis). However firms continue to experience situations where the returns to ICT investment fall short of expectations (Hartman 2002). During this second period extensive research has also been conducted in order to understand better and maximise the contribution of ICT investment to business performance. An important conclusion of this research is that the benefits from ICT investments can increase significantly if they are combined with some complementary actions and 'co-investments' aiming at the development of new work practices, business processes, organisational structures, skills, etc. (Black & Lynch 1997, Francalanci & Galal 1998, Tallon & Kraemer & Gurbaxani 2000, Devaraj & Kohli 2000, Brynjolfsson & Hitt 2000, Brynjolfsson & Hitt & Yang 2000, Ramirez 2003, Arvanitis 2003, OECD 2003).

However, most of the empirical studies on the impact of ICT investment on business performance in both periods have been conducted in the context of only a few countries, which are characterised by high levels of economic development and ICT diffusion, and have been based mainly on data from quite big firms (many of these studies have been based on data from firms belonging to the 'Fortune 1000'). Therefore the results of these studies are conditional on the characteristics of the particular contexts. OECD in its recent report on this subject warns that the impact of ICT investment can differ markedly across countries due to differences in 'the regulatory framework, the availability of appropriate skills, the ability to change organisational set-ups as well as the strength of accompanying innovations in ICT applications' (OECD 2003). Also Melville, Kraemer and Gurbaxani (2004) in their recent literature review stressed that one of the most important deficiencies of the research conducted in this area is its 'emphasis on U.S. firms' and 'lack of cross-country studies', so its 'results are

conditional on the characteristics of the U.S. business environment'. Therefore it is necessary to investigate the above research questions also in contexts of other countries, which are characterised by different levels of economic development, ICT diffusion and ICT skills, different sizes of firms and different regulatory frameworks and business culture.

In this direction the present study contributes to the empirical firm level literature on this subject by being the first study of the impact of information systems (IS) investments on business performance in Greece, based on firm-level data collected via a questionnaire-based survey in cooperation with the Federation of Greek Industries. It is quite interesting to study the abovementioned research issues in Greece, given the its significant differences from the highly developed countries in which most of the empirical studies on this subject have been conducted. Greece does not belong to the highly developed countries, though it has made considerable economic progress in the last decade and has become a full member of the European Economic and Monetary Union. It is characterised by smaller size of internal market, smaller average firm size and lower level of ICT diffusion; according to the European Information Technology Observatory (EITO – www.eito.gr) the per capita ICT expenditure in Greece during 2003 was 689 Euro, while in the highly developed countries it was much higher, e.g. in USA it was 2430 Euro, in Sweden it was 2369 Euro, etc. Also, from a study that has been conducted on the exploitation of ICT by Greek firms (Sirigos 2001), it has been concluded not only that the level of their ICT investment is low, but also that in many firms there are basic weaknesses in ICT management: there is not sufficient ICT personnel, there is not sufficient training of the users in ICT, and the ICT organisational unit has a low hierarchical level (usually it is a part of the financial or the production department), so it cannot have adequate intraorganisational power and influence; moreover, in many firms there is a very narrow focus of the ICT investment only on a few organisational units/functions, usually on the ones having big intraorganisational power and/or massive calculations-intensive operations ('islands of automation' approach), while the others have minimal or even no ICT support. For these reasons in the present study we also examine whether there is complementarity between IS investment and the above IS management factors; we expect that these IS management factors are not only in Greece but also in many other countries, which are not highly developed and are characterised by similar context. These IS management factors (with the only exception of IS users training) have not been adequately studied as a complement of IS investment in the relevant literature.

The structure of the paper is as follows: initially in section 2 is presented a review of the literature on the impact of ICT investment on business performance. Then in section 3 are described the methodology and the data of the present study, while in section 4 the results are presented and discussed. Finally section 5 contains the conclusions and also directions for further research.


## 2       LITERATURE REVIEW


Extensive research has been conducted in the last 20 years on the business benefits and value generated by ICT investments, and on their impact on business performance. Many empirical studies are reported in the relevant literature, which differ in the level of analysis (there are studies at the national economy, sectoral and firm level), the dependent variables (business performance measures), the independent variables, the methodology, the data and the context. In this section we focus on the firm level research in this area; as mentioned in the introduction this research can be divided into two periods. In its first period, from the mid 1980s until the mid 1990s, was found very little empirical evidence of a positive and statistically significant relation between ICT investment and business performance. One of the first studies in this area was conducted by Roach (1987), who measured the productivity of information workers against that of production workers; he found that during the 1970s through the mid 1980s the productivity of production workers increased by 16,9%, while the productivity of information workers decreased by 6,9%, despite the big ICT investments. Strassman (1990 and 1997), in three relevant studies he conducted in 1985, 1990 and 1994, found no evidence of

relation between ICT investment and profitability, and also between ICT investment and productivity. Weill (1992) examined the effect of three categories of ICT investment (in transactional, informational and strategic IS) on various measures of business performance in 33 valve manufacturing firms; he concluded that only the investment in transactional IS is positively associated with some measures of business performance (return on assets and sales per employee), while the investment on informational and strategic IS has no impact on business performance. Yosri (1992), based on data from 31 major food firms, found that ICT investment is not associated with sales growth, market share gain, new market penetration, productivity and various measures of quality improvement. Loveman (1994) examined the benefits of ICT investment in 60 business units of 20 manufacturing firms between 1978 and 1984 using production function estimates. He found no evidence of a positive contribution of ICT investment to firm output; however he found that non-ICT inputs are contributing positively to firm output. Hitt and Brynjolfsson (1996), based on data from 370 firms between 1988 and 1992, found no evidence of correlation between ICT spending and return on assets, return on equity and total shareholder return. Rai, Patnayakuni R. and Patnayakuni N. (1996, 1997) found that the total IS budget (including both IS capital and operating expenses) makes a positive contribution to firm output and labour productivity, but not to the return on assets and the return on equity; also they found that different components of the IS budget have different effects on the various business performance measures. Similar conclusions were drawn by Barua, Kriebel and Mukhopadhyay (1995), who found that intermediate level business processes, such as inventory turnover, etc., benefit from ICT investment; however, they found no evidence of benefits at the level of the returns on assets. Brynjolfsson (1993), based on a review of the relevant literature of this first period, summarises the 'Productivity Paradox' issue as follows: 'Delivered computing power in the U.S. has increased by more than two orders of magnitude since 1970, yet productivity, especially in the service sector, seems to to have stagnated'; also he remarks that the Productivity Paradox is at least to some extent due to mismeasurement of outputs and inputs, mismanagement of ICT, redistribution of ICT benefits to the consumers (via an increase of consumer surplus) and also due to lags in learning, adjustment and restructuring of firms, which are necessary in order to reap the full benefits from ICT investments.

The studies of Brynjolfsson and Hitt (1996) and Lichtenberg (1995) can be regarded as the starting point of a second period of research in this area, from the mid 1990s until today, which provided some first empirical evidence of positive and statistically significant relation between ICT investment and some measures of business performance, such as output, labour productivity, etc. Brynjolfsson and Hitt (1996), using an extensive data set on IS spending by large U.S. firms compiled by the International Data Group (IDG) and a Cobb Douglas production function framework, found that the contributions of computer capital and IS staff labour expenses to firm output are not only positive and statistically significant, but also much higher than the contributions of the non-computer capital and the non-IS labour expenses respectively; they also found that the return to computer capital and IS staff labour expenses differs across industries and depends on the type of firm and the type of computer equipment (centralised or decentralised computing). Lichtenberg (1995) and Lehr and Lichtenberg (1999), using estimates of Cobb Douglas production functions, came to similar conclusions: ICT investment contributes significantly to firm output and generates high levels of returns, which are much higher than the returns of the non-ICT investment. Dewan and Min (1997), using multiple econometric models (CES, Translog, CES-Translog), provide consistent and confirmatory evidence of a positive relation between ICT investment and firm output. Gurbaxani, Melville and Kraemer (1998), based on data from 400 firms belonging to the 'Fortune 1000' between 1987 and 1994, examine the returns to different kinds of computer hardware investments; using estimates of a Cobb Douglas production function they found that investments in mainframe and PC hardware are positively associated with firm output. Devaraj and Kohli (2000) provide evidence of positive effect of ICT capital and labour on two important output measures in hospitals: net patient revenue per day and net patient revenue per admission. Gilchrist, Gurbaxani and Towne (2001) examine the effect of ICT on the performance of manufacturing firms between 1987 and 1994; their analysis shows that ICT contribute to productivity, and this contribution is higher than what would be expected given the share of ICT capital in the overall capital investment; also they found that the

contribution of decentralised computing (e.g. PC technology) is higher than the contribution of centralised computing (e.g. mainframe technology). The positive evidence found in this second period concerning the impact of ICT investment on several measures of business performance reflects the improvements in ICT management, and also the adjustments and the restructuring that had taken place at the firm level between the mid 1980s and the mid 1990s, which enabled a higher level of value and benefits from ICT; also it reflects the significant improvements in research methodology (e.g. in data collection and analysis). However firms continue to experience situations where the returns to ICT investment fall short of expectations (Hartman 2002).

In this second period there was also considerable research effort focused on understanding better and maximising the contribution of ICT investment to business performance; most of this research concerns the identification of complementary actions and factors, which should accompany ICT investment, in order to maximise its contribution to business performance. In this direction Black and Lynch (1997) examine the effect of ICT and new human resource management practices associated with total quality management, performance benchmarking and recruitment policies on productivity in 600 manufacturing firms between 1987 and 1993. Their analysis indicates that these new human resource management practices make a positive contribution to productivity; also they found the investment in ICT and the usage of ICT by non-managers (e.g. workers) contribute positively to productivity. However, in this study the ICT investment and the above new human resource management practices are considered as separate independent variables, and their complementarity and interaction is not examined. Francalanci & Galal (1998), based on data from insurance companies, examine the effect of ICT investment, employees composition and the interaction between them on firm productivity; they conclude that increase in ICT spending combined with changes in employees composition (more 'information and knowledge workers') results in higher overall productivity. Devaraj and Kohli (2000) in their abovementioned study concluded also that the combination of ICT investment with business processes reengineering increases the positive effects on output. Tallon, Kraemer and Gurbaxani (2000), based on a survey of business executives, found that the strategic alignment of ICT investment with business strategy results in higher business value from the ICT investment; also they found that systematic post-implementation review and evaluation of the IS projects enhances the business value they generate. Stratopoulos and Dehning (2000) conclude that the 'successful users' of ICT have a higher financial performance than the 'less successful users'; they reach this conclusion by comparing the financial performances of 100 companies, which have been selected by the Computerworld/IDG Company as being 'successful users' of ICT (based on four criteria: percentage of revenue spent on ICT, suitability of IS for meeting business needs, profitability growth rate and evaluation by other companies), with the financial performances of 100 similar companies, which are 'less successful users' of ICT. Bharadwaj (2000), adopting a resource-based view of the firm, found that it is not simply the investment in ICT infrastructure, but the creation of unique ICT capabilities, that leads to higher firm performance. Brynjolfsson, Hitt and Yang (2000) found that the combination of decentralisation practices (allocation of more decision authority, self managed teams, increase of worker responsibilities) with ICT has a disproportionately large positive effect on firm market value. Devaraj and Kohli (2003) from a longitudinal study in hospitals conclude that the main driver of the impact of ICT on financial and non-financial performance is not the investment in technology, but the actual usage of technology. Ramirez (2003) investigated the impact of ICT and three sets of organisational work practices: employee involvement, total quality management and reengineering; his results indicate that ICT is a key enabler of employee involvement and total quality management, and also that their combination with ICT contributes positively to the performance of firms. Arvanitis (2003), based on data from Swiss firms, constructed three composite indices for ICT capital, new organisational practices and human capital respectively, and examined their impact on labour productivity and their complementarity. His results indicate that ICT capital, new organisational practices and human capital all contribute positively to labour productivity; also provide evidence of complementarity between ICT capital and human capital: the combined use of ICT and human capital results in additional labour productivity increase beyond the individual effects of these two factors. Important is contribution of the recent OECD report on 'ICT and Economic

Growth' (OECD 2003) to this research; it provides statistics on ICT diffusion and evidence on the positive impact of ICT at macroeconomic, sectoral and firm level across OECD countries, concluding that 'ICT is part of a broader range of changes that help enhance performance', but 'the impacts of ICT depend on complementary investments, e.g. in appropriate skills, and on organisational changes, such as new strategies, new business processes and new organisational structures'. Brynjolfsson and Hitt (2000) reach similar conclusions: '..both case studies and econometric work point to organisational complements such as new business processes, new skills and new organisational and industry structures as a major driver of the contribution of information technology. These complementary investments, and the resulting assets, may be as much as an order of magnitude larger than the investments in the computer technology itself'.

However, as mentioned in the introduction, most of the research about the impact of ICT investment on business performance and about its complementary actions and factors has been conducted in the context of only a few countries, which are characterised by high levels of economic development and ICT diffusion, and has been based mainly on data from big firms. Therefore the results of these studies are conditional on the characteristics of the particular contexts, so it is it is necessary to investigate these critical research questions also in contexts of other countries with different characteristics (OECD 2003, Melville & Kraemer & Gurbaxani 2004).

# 3 METHODOLOGY AND DATA

In this direction the first objective of the present study is to examine the impact of IS investment on business performance in Greece. For this purpose three business performance measures were selected and used as dependent variables:

- firm output (total sales revenue), as a basic business performance measure,

- labour productivity (total sales revenue per employee), as an intermediate business performance measure,

- return on assets (profits before taxation divided by total assets) as financial business performance measure.

In this direction we tested the following hypotheses H1 to H3:

<u>H1</u>: IS investment makes a positive contribution to firm output

<u>H2</u>: IS investment makes a positive contribution to labour productivity

<u>H3</u>: IS investment makes a positive contribution to the return on assets

Our basic model for firm output was based on microeconomic production theory and in particular on the Cobb Douglas production function, which has been extensively used in the past in economic studies for the estimation of the contribution of various firm inputs to firm output; we used an extended form of the Cobb Douglas production function, which has been used in the past in many relevant studies of the business impact of ICT investments for the estimation of the contribution of ICT capital and labour inputs to firm output (Brynjolfsson & Hitt 1996, OECD 2003, Melville & Kraemer & Gurbaxani 2004):

$$Q = e^{\beta_0} \, CK^{\beta_1} \, K^{\beta_2} \, ISL^{\beta_3} \, L^{\beta_4}$$

where Q is the firm output and CK, K, ISL and L are computer capital, non-computer capital, IS labour and non-IS labour respectively (firm inputs), while the β1 – β4 are the (partial) output elasticities with respect to these four inputs. By log-transforming this model, we obtained the following linear regression model:

$$\ln Q = \beta_0 + \beta_1 \ln CK + \beta_2 \ln K + \beta_3 \ln ISL + \beta_4 \ln L + u_i$$

where ui is the error term. For the other two business performance measures (labour productivity LP and return on assets ROA) we used similar models, but we normalised the independent variables (CK, K, ISL, L) by dividing them by the number of firm employees N. In order to collect these data from Greek firms a survey questionnaire was designed; based on the above models it included questions concerning the yearly sales revenue, profits before taxation, average assets, computer capital depreciation (including hardware, software and networks), non-computer capital depreciation, IS labour expenses and non-IS labour expenses, and also the number of employees.

The second objective of this study is to examine whether there is complementarity between IS investment and a set of IS management factors, which have been reported to be of critical importance in Greece, in a study conducted by Sirigos (2001) on the exploitation of ICT by Greek firms. One of the most important conclusions of this study is that many Greek firms have some basic weaknesses in ICT management, which reduce the benefits they have from their IS investments:

- there is not sufficient IS personnel, so there is inadequate support of the existing IS and their users,

- there is not sufficient training of the users in ICT, so they cannot use efficiently the existing IS,

- the ICT organisational unit has a low hierarchical level; usually it is not a separate department, but it is a part of the financial or the production department, so it is dealing mainly with the department it belongs to, and can have neither a complete view of the whole firm and all its computerisation needs, nor adequate power and influence,

- there is a very narrow focus of the ICT investment only on a few organisational units/functions, usually on the ones having big internal power and/or massive calculations-intensive operations, adopting an 'islands of automation' approach, while the other organisational units/functions have minimal or even no ICT support; having only a few tasks performed manually and all the other tasks performed electronically results in significant integration problems, which increase the data entry and in general the operating costs and reduce considerably the benefits from ICT investment.

In order to collect data about the above four IS management factors we included in the above survey questionnaire four corresponding questions concerning respectively the number of IS employees, the extent of the ICT training provided to the users (in a 5 points scale), the hierarchical level of the ICT organisational unit (whether it is a separate department or a part of another department) and the number of ICT users in the firm (as a measure of the width of ICT coverage of the organisational units/functions). Also we added one more question concerning the overall satisfaction from IS organisation and management in the firm (in a 5 points scale).

We normalised the first and the fourth of these five variables (number of IS employees, number of ICT users) by dividing them by the number of firm employees. Also we standardised these five variables: from each of them was subtracted its average and then it was divided by its standard deviation, so that finally it has zero average and unit standard deviation. Then we calculated a composite IS management index ISM as the sum of these five standardised variables, and we used this index to test the following hypotheses H4 to H6:

*H4: The interaction of IS investment and IS management makes a positive contribution to firm output*

*H5: The interaction of IS investment and IS management makes a positive contribution to labour productivity*

*H6: The interaction of IS investment and IS management makes a positive contribution to the return on assets*

For this purpose we used enriched versions of the three models described above; to each model we added two more terms: one for the composite IS management index and one for its interaction with the computer capital.

The data used in this study were collected through a survey among Greek industrial firms in cooperation with the Federation of Greek Industries (FGI). The FGI selected the 250 biggest firms among its members, sent to them by mail the above questionnaire accompanied by a cover letter explaining them the objectives of this survey, and then contacted them by phone in order to inform them orally about the survey. The recipients were asked to fill in the questionnaire with data for the year 2002 and return it by fax or mail within one month. After one month were contacted by phone again all the recipients who had not responded. Finally were received answered questionnaires from 137 firms, so the response rate was 54.8%. The respondents were big firms for the Greek context: their average number of employees was 362, while for the year 2002 their average sales revenue was 23.3 billion drachmas; however they were much smaller than the big firms that most studies on this subject (e.g. in U.S.A. or other highly developed countries) were based on.

## 4    RESULTS

Initially we calculated the average ICT spending of the respondents during 2002, consisting of the yearly computer capital depreciation (hardware, software and networks) and IS labour expenses, as percentage of sales revenue; we found that during 2002 the amount spent for ICT was 1.2% of sales revenue. It is lower than in the highly developed countries, where ICT spending has been reported (e.g. Willcocks 1996, Robson 1997) to be 2-3% (depending on the industry) of sales revenue. A possible explanation of this lower ICT spending by Greek firms is that the competition they face, even though it has increased since the entry of Greece in the European Union, is not as high as the competition faced by the firms in the developed countries. Therefore the market pressure on the Greek firms for more ICT investment and use is lower than in the highly developed countries; however, due to the growing globalisation of economic activity, the competition faced by the Greek firms is expected to increase in the near future, therefore there will be more market pressure on them for more ICT investment and usage. Another possible explanation of this lower ICT spending by Greek firms is the smaller size of Greek firms, which results in a lower level of economies of scale in using high fixed cost ICT capital and specialised labour.

In Table 1 we can see the regression results for the first of the above models described in the previous section, with the output Q as the dependent variable, and the computer capital CK, the non-computer capital K, the IS labour expenses ISL and the non-IS labour expenses L as independent variables (all variables in this model, and in all the other models that will be presented in the remaining of this section, are log-transformed). For each independent variable in Table 1 we can see the corresponding $\beta$ coefficient (elasticity), its significance and also the average marginal productivity MP of the corresponding input, which has been calculated as $MP_i = \beta_i * [average(Q)/average(i)]$ (where i is the input).

| Dependent variable : ln (Q) | | | |
|---|---|---|---|
| Independent variable | Coefficient | Significance | Marginal productivity |
| constant | 0.819 | 0.000 | |
| ln (CK) | 0.049 | 0.005 | 10.79 |
| ln (K) | 0.198 | 0.000 | 1.7 |
| ln (ISL) | 0.048 | 0.005 | 3.86 |
| ln (L) | 0.734 | 0.000 | 0.96 |
| R-squared : 0.89 | | | |
| Durbin-Watson Statistic : 1.77 | | | |

*Table 1.        Regression results for the impact of computer capital, non-computer capital, IS labour and non-IS labour on output*

We remark that the coefficients of both computer capital and IS labour are positive and statistically significant, therefore it is concluded that they both make a positive contribution to firm output. This finding supports hypothesis H1. We also remark that the average marginal productivity of the computer capital is 10.79, being much higher than the average marginal productivity of the non-computer capital (1.7). Similarly the average marginal productivity of the IS labour expenses is 3.83, being much higher than the average marginal productivity of the non-IS labour expense (0.96). Both these estimated average marginal productivity values of computer capital and IS labour expenses are higher than those estimated by other similar studies conducted in highly developed countries (e.g. Brynjolfsson & Hitt 1996). Taking into account that in general by using larger quantities of an input in the production process its marginal productivity decreases, a possible explanation of the above high marginal productivities is that Greek firms use computer capital and labour to a much lower extent than the optimum, limiting themselves to quite basic and fundamental IS, which are essential for their operations and give them big and obvious benefits (e.g. basic office automation systems resulting in big cost reductions); on the other hand they probably do not invest in more sophisticated systems, which would take more time and require more complentary 'co-investments' (e.g. in the development of new work practices, business processes, organizational structures, skills, etc.) in order to give high levels of benefits.

In Table 2 we can see the regression results for the second of the models described in the previous section, with the labour productivity LP as the dependent variable, and the normalised (divided by the number of firm employees) computer capital CK, the normalised non-computer capital K and the normalised total labour expenses LT as independent variables (all variables are log-transformed). In this model, and in all the other models that will be presented in the remaining of this section, because of the small size of our data set we merge IS labour and non-IS labour variables into one total labour variable in order to increase the estimations accuracy; only in the previous model shown in Table 1 we had both the IS labour and the non-IS labour variables, in order to estimate and compare the corresponding marginal productivities. From Table 2 we remark that the coefficient of the normalised computer capital is positive and statistically significant, therefore it is concluded that computer capital makes a positive contribution to labour productivity. This finding supports hypothesis H2.

| Dependent variable : ln (LP = Q/N) | | |
|---|---|---|
| Independent variable | Coefficient | Significance |
| constant | 0.243 | 0.544 |
| ln (CK/N) | 0.109 | 0.000 |
| ln (K/N) | 0.206 | 0.000 |
| ln (LT/N) | 0.728 | 0.000 |
| R-squared : 0.83 | | |
| Durbin-Watson Statistic : 1.75 | | |

*Table 2.        Regression results for the impact of normalised computer capital, normalised non-computer capital and normalised  labour on labour productivity*

The regression results for the third of the models described in the previous section, with the return on assets ROA as the dependent variable, and the normalised (divided by the number of firm employees) computer capital CK, the normalised non-computer capital K and the normalised total labour expenses LT as independent variables, has a low R-squared value and statistically non-significant coefficients. Therefore there is no evidence that computer capital affects the return on assets. This finding provides no support for hypothesis H3. A possible explanation is that ICT investment in Greek firms, even though it makes a positive contribution to output and labour productivity, is too small to affect the return on assets.

Next we examined whether there is complementarity between IS investment and the IS management factors described in the previous section. In Table 3 we can see the regression results for the first of the models described in the previous section, enriched with two more terms: one for the composite IS

management index ISM and one for its interaction with the computer capital. We remark that the coefficients of both the computer capital and its interaction with the composite IS management index are positive and statistically significant. Therefore it is concluded that the combination of IS investment with these IS management factors make an additional positive contribution to firm output beyond the individual positive contribution of the IS investment. This finding supports hypothesis H4 and indicates that there is complementarity between IS investment and these IS management factors with respect to firm output. Also we remark that the coefficient of the ISM is negative and statistically significant, reflecting the fact that in the imaginary case that these IS management factors were not combined with investment in developing IS, they would create only costs and no benefits, therefore their contribution to the output would be negative.

| Εξαρτημένη μεταβλητή : ln (Q) | | |
|---|---|---|
| Independent variable | Coefficient | Significance |
| constant | 0.682 | 0.113 |
| ln (CK) | 0.071 | 0.003 |
| ln (K) | 0.183 | 0.000 |
| ln (LT) | 0.736 | 0.000 |
| ISM | -0.349 | 0.035 |
| ln (CK) * ISM | 0.016 | 0.035 |
| R-squared : 0.93 | | |
| Durbin-Watson Statistic : 1.94 | | |

*Table 3.*　　　*Regression results for the impact of computer capital, non-computer capital, labour, IS management and the interaction of computer capital and IS management on output*

In Table 4 we can see the regression results for the second of the models described in the previous section, enriched with two more terms: one for the composite IS management index ISM and one for its interaction with the normalised computer capital. We remark that the coefficients of both the normalised computer capital and its interaction with the composite IS management index are positive and statistically significant. Therefore it is concluded that the combination of IS investment with these IS management factors make an additional positive contribution to labour productivity, beyond the individual positive contribution of the IS investment. This finding supports hypothesis H5 and indicates that there is complementarity between IS investment and these IS management factors with respect to labour productivity. The regression results for the third of the models described in the previous section, with the return on assets ROA as the dependent variable, enriched with two more terms, one for the composite IS management index ISM and one for its interaction with the normalised computer capital, has a low R-squared value and statistically non-significant coefficients. This finding provides no support for hypothesis H6.

| Dependent variable : ln (LP=Q/N) | | |
|---|---|---|
| Independent variable | Coefficient | Significance |
| constant | 0.240 | 0.561 |
| ln (CK/N) | 0.102 | 0.001 |
| ln (K/N) | 0.205 | 0.000 |
| ln (LT/N) | 0.734 | 0.000 |
| ISM | -0.319 | 0.050 |
| ln (CK/N) * ISM | 0.015 | 0.053 |
| R-squared : 0.90 | | |
| Durbin-Watson Statistic : 1.92 | | |

*Table 4.*　　　*Regression results for the impact of normalised computer capital, normalised non-computer capital, normalised labour, IS management and the interaction of normalised computer capital and IS management on labour productivity*

This complementarity we found between IS investment and the above IS management factors can be explained based on information systems theory. Sub-optimal use of specialised IS labour results in sub-optimal effort for IS planning and development, and also in inadequate support of IS and their users, leading to reduced benefits from IS investment. Also sub-optimal training of the users results in inefficient use of IS and sub-optimal exploitation of their functionality and capabilities, resulting in reduction of the benefits from IS investment. If the ICT organisational unit has a low hierarchical level, being part of another department and not a separate department, then it is dealing mainly with the department it belongs to, and can have neither a complete view of the whole firm and all its computerisation needs, nor adequate power and influence; in this case the ICT organisational unit cannot assume a leading role in coordinating IS development and use throughout the firm and ensuring technological homegeneity and interoperability. For these reasons the value from IS investment will be reduced. Finally, a very narrow focus of the ICT investment only on a few organisational units/functions, results in the development of some 'islands of automation': a few tasks will be performed manually and all the other tasks will be performed electronically, resulting in significant integration problems, which increase the data entry and in general the operating costs and reduce considerably the benefits from IS investment.


## 5        CONCLUSIONS

In this paper is presented the first study of the impact of IS investments on business performance in Greece. It is based on data from Greek industrial firms, which have been collected via a questionnaire-based survey conducted in cooperation with the Federation of Greek Industries. It is concluded that IS spending by Greek firms is lower than in the highly developed countries; the lower level of competition faced by the Greek firms, and also their smaller size (allowing a lower level of economies of scale), in comparison with the firms of the highly developed countries, are possible explanations. However the return to this IS spending is quite high: using econometric modelling, based on the Cobb Douglas production function, we found that IS investment Greece make a positive and statistically significant contribution to firm output and labour productivity; however, IS investment is not big enough to affect the return on assets. An interesting finding is that the ICT capital and ICT labour expenses have high average marginal productivities, which are much higher than those of the non-ICT capital and the non-ICT labour expenses respectively; also the estimated average marginal productivities of the ICT capital and ICT labour expenses are much higher than those estimated by other similar studies conducted in highly developed countries. These findings indicate sub-optimal use of ICTs by Greek firms.

We also examined whether there is complementarity between IS investment and a set of IS management factors, which concern the number of IS employees, the ICT training provided to the users, the hierarchical level of the ICT organisational unit and the number of ICT users in the firm (which is a measure of the width of ICT coverage of the firm organisational units/functions). It was concluded that there is complementarity between IS investment and the above set of IS management factors with respect to firm output and labour productivity. Therefore the combination of IS investment with these IS management factors results in additional increase of firm output and labour productivity beyond the individual effect of IS investment.

The above conclusions enable a better understanding of the basic characteristics of IS investment in a national context different from the ones of the highly developed countries, which is characterised by lower level of economic development and smaller size of internal market and firms. We found that in such a context IS investment is lower than in the contexts of the highly developed countries, because the level of competition and economies of scale are lower; however, this IS investment has high marginal productivity, being focused mainly on quite basic and fundamental IS, which are essential for the operations of firms and give them big and obvious benefits. Also in such contexts there are basic

weaknesses in IS management; if IS investment is combined with overcoming these weaknesses, then much higher benefits can be achieved.

Further research is in progress by the authors concerning IS investment in Greece and other complements of IS investment, associated with new work practices and business processes, total quality, knowledge management and reorganization.

## References

Arvanitis, S. (2003). Information Technology, Workplace Organization, Human Capital and Firm Productivity: Evidence for the Swiss Economy. Working Paper 74, Swiss Federal Institute of Technology Zurich.

Barua, A., Kriebel, C. and Mukhopadhyay, T. (1995). Information technology and business value: an analytic and empirical investigation. Information Systems Research, 6(1), 3-23.

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. and Lynch, L. (1997). How to Compete: The Impact of Workplace Practices and Information Technology on Productivity. National Bureau of Economic Research (NBER) Working Paper 6120.

Brynjolfsson, E. (1993). The productivity paradox of information technology: review and assessment. Communications of the ACM, 36(12), 67-77.

Brynjolfsson, E. and Hitt, L. (1996). Paradox lost? Firm-level evidence on the returns to information systems. Management Science, 42(4), 541-558.

Brynjolfsson, E. and Hitt, L. (2000). Beyond Computation: Information Technology, Organizational Transformation and Business Performance. Journal of Economic Perspectives, 14(4), 23-48.

Brynjolfsson, E., Hitt, L. and Yang S. (2000). Intangible assets: How the interaction of information technology and organizational structure affects stock market valuations. MIT Working Paper.

Devaraj, S. and Kohli, R. (2000). Information technology payoff in the health care industry: A longitudinal study. Journal of Management Information Systems, 16(4), 41-67.

Devaraj, S. and Kohli, R. (2003). Performance Impacts of Information Technology: Is Actual Usage the Missing Link? Management Science, 49(3), 273-289.

Dewan, S. and Min, C. (1997). The Substitution of Information Technology for Other Factors of Production: A Firm Level Analysis. Management Science, 43(12), 1660-1675.

Francalanci, C. and Galal, H. (1998). Information technology and Worker Composition: Determinants of Productivity in the Life Insurance Industry. MIS Quarterly, 22(2), 227-241.

Gilchrist, S., Gurbaxani, V. and Towne R. (2001). Productivity and the PC revolution. UC Irvine Working Paper.

Gurbaxani V., Melville N. and Kraemer K. (1998). Disaggregating the Return on Investment to IT Capital. Proceeding of ICIS Conference.

Hartman, A. (2002). Why tech falls short of expectations. Optimize, Issue November-July 2002, 20-27.

Hitt, L. and Brynjolfsson E. (1996). Productivity, profit and consumer welfare: three different measures of information technology value. MIS Quarterly, 20(2), 121-142.

Lehr, B. and F. Lichtenberg (1999). Information Technology and its Impact on Productivity: Firm-Level Evidence from Government and Private Data Sources, 1977-1993. Canadian Journal of Economics, 32(2), 335-362.

Lichtenberg, F. (1995). The output contributions of computer equipment and personnel: A firm-level analysis. Economics Innovations and New Technology, 3(4), 210-217.

Loveman, G. (1994). Information Technology and the Corporation in the 1990s. MIT Press, Cambridge, MA.

Melville, N., Kraemer, K. and Gurbaxani, V. (2004). Information technology and organizational performance: An integrative model of IT business value. MIS Quarterly, 28(2), 283-322.

Organisation for Economic Co-operation and Development (OECD) (2003). ICT and Economic Growth – Evidence from OECD Countries, Industries and Firms. Paris.

Rai, A., Patnayakuni, R. and Patnayakuni, N. (1996). Refocusing where and how IT value is realized. Omega, 24(4), 399-407.

Rai, A., Patnayakuni, R. and Patnayakuni, N. (1997). Technology investment and business performance. Communications of the ACM, 40(7), 89-97.

Ramirez, R. (2003). The Influence of Information Technology and Organizational Improvement Efforts on the Performance of Firms. Doctoral Dissertation, University of California.

Roach, S. (1987). America's technology dilemma: A profile of the information economy. Morgan Stanley Special Economic Study, New York, USA.

Robson, W. (1997). Strategic Management of Information Systems. 2nd edition. Prentice Hall – Financial Times, Great Britain.

Sirigos, N. (2001). Measurement of ICT exploitation in the Greek Industry using a multidimensional indexes set. Degree Thesis, University of the Aegean.

Solow, R. (1987). We'd better watch out. New York Times Books Review, 36.

Strassman, P. (1990). The Business Value of Computers: An Executive's Guide. The Information Economic Press, New Canaan, Connecticut.

Strassman, P. (1997). The Squandered Computer. The Information Economic Press, New Canaan, Connecticut.

Stratopoulos, Th. and Dehning, B. (2000). Does successful investment in information technology solve the productivity paradox? Information & Management, 38, 103-117.

Tallon, P., Kraemer, K. and Gurbaxani, V. (2000). Executives' perception of the Business Value of Information Technology: A Process Oriented Approach. Journal of Management Information Systems, 16(4), 145-173.

Weill, P. (1992). The relationship between investment in information technology and firm performance: a study of the valve manufacturing sector. Information Systems Research, 3(4), 307-333.

Willcocks, L. (1996). Introduction: Beyond the productivity paradox. In Investing in Information Systems – Evaluation and Management, (Willcocks, L. Ed.), Chapman and Hall, 1-12.

Yosri, A. (1992). The relation between information technology expenditures and revenue contributing factors in large corporations. Doctoral Dissertation, Walden University.