The Intervening Role of BPR in the ICT - Business Performance Relationship

Loukis Euripidis, Pazalos Konstantinos

University of the Aegean, Department of Information and Communication Systems Engineering, Karlovassi, 83200, Samos

Abstract— ***The critical importance of information and communication technologies (ICT) for the firms nowadays, and the big ICT investments they make, necessitate a deeper understanding of 'how' ICT affects business performance, through identification of the intervening mechanisms and variables in the relationship between ICT and business performance. This paper describes an empirical investigation of whether and to what extent Business Process Reengineering (BPR) has an intervening role in the relationship between ICT investment and business performance, based on firm-level data from 271 Greek firms. Using this data a Structural Equation Model (SEM), founded on the Cobb-Douglas production function, is constructed, which includes a multi-item construct for measuring the extent of BPR with high level of reliability. From this model it is concluded that BPR mediates partially the relationship between ICT investment and business performance. On the contrary, it is concluded that BPR does not have such an intervening role in the relationship between the non-ICT investment (in 'traditional' assets) and business performance.***

***Index Terms*— ICT (or IS) Asset (or capital), ICT (or IS) Investment, Business Process Reengineering (BPR), Business Performance, Intervening Role, Mediation Effect, Structural Equation Modeling (SEM).**

I. Introduction

During the last three decades a rapid diffusion of information and communication technologies (ICT) in firms of most sectors has taken place (OECD 2004). Firms have made big investments in ICTs with high expectations of various kinds of benefits from them. For this reason one of the most important research topics in the area of information systems (IS) has been for long time the contribution of firms' ICT investment to their business performance. The conclusions of this research have been mixed and inconsistent (Dedrick et al 2003, Lim et al 2004, Melville et al 2004, Wan et al 2007). Some of the studies that have been conducted on this topic, mainly during the 80s and the 90s, did not find evidence of an association between ICT investment and business performance (Roach 1987, Strassman 1990, Brynjolfsson 1993, Loveman 1994, Strassman 1997). On the contrary, some other studies, mainly more recent ones, found some evidence of a positive association between ICT investment and business performance (Brynjolfsson & Hitt 1996, Stolarick 1999, Devaraj & Kohli 2000, Preslac 2003, OECD 2004, Arvanitis 2005). One of the explanations proposed by the relevant literature (e.g. Brynjolfsson & Hitt 1996, Brynjolfsson & Hitt 1998, Brynjolfsson & Hitt 2002, Bresnahan et al 2002) for this inconsistency is that the full potential of ICTs is exploited not by simply automating existing business processes, but by adjusting and improving them based on the capabilities that ICTs offer, which takes time and requires extensive effort and specialized expertise. The same literature argues that the most beneficial aspect of modern ICTs is that they are catalysts and enablers of big improvements of existing business processes and work practices, which, in turn, lead to high levels of benefits; for this reason they expect that the main business value from ICT will be generated not through simple automation of existing business processes, but through an ICT-enabled change and improvement of them. It is therefore necessary to test empirically these arguments and expectations, and investigate the intervening role of business process change in the relationship between ICT and business performance empirically using large datasets.

One of the most widely used and debated paradigms of business process change is the 'Business Process Reengineering' (BPR). It was first presented in two articles written by Hammer (1990) and Davenport & Short (1990), though it incorporates theories and tools that were not new and already existed in management science and practice. BPR is defined as "the fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical measures of performance such as cost, quality, service, job satisfaction, and speed" (Hammer and Champy, 1993). It remains a highly interesting topic for long time for both researchers and practitioners. Recently there is a growing interest in ICT-based BPR as a response to the high competitive pressures that firms face in most countries. In the most recent survey of the key IS management issues conducted by the Society for Information Management (SIM) of USA (www.simnet.org) BPR has been ranked as the fifth most important issue that IS managers face (Luftman et al 2006).

Although the role of BPR as mediator in the relationship between ICT and business performance has been extensively discussed and emphasized by the relevant literature (e.g. Brynjolfsson & Hitt 1996, Brynjolfsson & Hitt 1998,

Brynjolfsson & Hitt 2002, Bresnahan et al 2002), it has only to a very small extent been empirically investigated using large datasets (Grover et al 1998, Albadvi 2007). Also, even these very few empirical studies are based not on objective, but on subjective measures of business performance (managers' perceptions) as dependent variables; furthermore, they are not based on theoretically sound models and omit important independent variables, such as non-ICT assets, labor, etc.

This study contributes to filling the abovementioned research gaps. It investigates empirically using a large dataset whether and to what extent BPR has an intervening role in the relationship between firm ICT investment and business performance as a complete or partial mediator, based on objective measures of both. Also, in order to contribute to a better understanding of the similarities and differences of the ICT capital from the non-ICT capital (traditional assets), this study addresses the same question for the non-ICT capital as well: it investigates empirically whether and to what extent BPR has an intervening role in the relationship between firm non-ICT investment (traditional assets) and business performance (as a complete or partial mediator). For addressing the above questions a theoretically sound structural equation model (SEM) that includes all the fundamental variables is constructed, based on firm-level data from 271 Greek firms. This model is based on the Cobb-Douglas production function, which constitutes a sound foundation from the area of microeconomics that has been extensively used in the past for estimating the contribution to firm output of various firm inputs, including the ICT investment (e.g. Brynjolfsson & Hitt 1996, Stolarick 1999, OECD 2003, etc.). In this model the extent of BPR is measured through a multi-item construct in order to achieve a high level of measurement reliability.

In the following Section II the relevant literature is briefly reviewed. Then in Section III the research methodology and data are described, while in Section IV the results of this study are presented and discussed. Finally in section V the main conclusions and the limitations of this study are discussed.

II. Literature Review

There is considerable literature emphasizing the innovative capabilities that ICTs offer as catalysts and enablers of big improvements of existing business processes and work practices, which, in turn, can lead to the highest level of benefits (e.g. Brynjolfsson & Hitt 1996, Brynjolfsson & Hitt 1998, Brynjolfsson & Hitt 2000, Bresnahan et al 2002, OECD 2004, Melville et al 2004). Brynjolfsson and Hitt (1996) regard as one possible explanation for the "ICT Productivity Paradox" that a period of learning how to utilize and exploit ICTs and how to make the appropriate process adjustment and restructuring was necessary for the firms, before they can reap the full benefits that ICTs can offer, adding also that 'Apparently, an analogous period of organizational redesign was necessary to unleash the benefits of electronic motors'. Bresnahan et al (2002) emphasize that ICTs will generally change the way that human work is measured, controlled and reported; also work may be restructured in order to allocate routine, well-defined tasks associated with symbols processing to computers and separate and redesign tasks that require human skills; furthermore, they argue that ICTs enable an individual worker to have all the required information for completing a bigger part of a process, so historical fragmentation of many processes can be dramatically reduced resulting in large efficiency gains. Brynjolfsson and Hitt (2000) argue that modern ICTs can lead to big productivity increases initially by reducing costs and subsequently by enabling firms to increase output quality. In the same direction OECD (2004), based on many studies conducted in its member states, conclude that achieving benefits from ICT investments is not straightforward, but requires 'complementary investments' and changes in business processes, organization and human capital.

Moreover, the relevant literature includes numerous case studies reporting creative and innovative usage of ICTs for supporting BPR, which resulted in significant business-level benefits (Lucas et al 1996, Rangan & Dell 1998, Hunter et al 2000, Attaran 2003, Attaran 2004), though BPR failures have been reported as well (Altinkemer et al 1998, Al Mashari and Zairi 2000, Al Mashari et al 2001). Other studies investigate the role of ICTs in BPR. Davenport (1993) propose nine basic modes of using ICT for supporting BPR: automational, informational, sequential, tracking, analytical, geographical, integrative, intellectual and disintermediating. Gunasekaran and Nath (1997) they propose a conceptual model illustrating the role of ICT in BPR; they argue that ICT can be very useful for simplifying business process, reducing considerably the number of their activities and achieving cross-functional process level optimization. Attaran (2004) analyzes the key role that ICT can play before, during and after any BPR implementation project as enablers, facilitators and implementors of BPR and provides useful gudelines.

Research has also been conducted on the relationship between reengineering and performance (e.g. Altinkemer et al 1998, Arvanitis 2005, Altinkemer et al 2007) with mixed results. Altinkemer et al (1998) present a longitudinal empirical analysis of the effect of BPR on various measures of business performance; the findings show that BPR is positively correlated with the productivity measure sales per employee, but not with the financial performance measures. Arvanitis (2005) from an empirical investigation draws the conclusion that the extent of adopting 'new organizational practices' (this term denoting a subset of the BPR practices, which includes team-work, job rotation and decentralization of competences from managers to employees) has a positive effect on labor productivity, which is further increased if these new organizational practices are combined with ICT (positive complementarity effect). Altinkemer et al (2007) investigate empirically the productivity and performance effects of IT-enabled BPR using econometric modelling; they conclude that there a positive effect of BPR on the return on assets, the

return on equity and the profit margin, but not on labour productivity and inventory turnover.

However, only a very small number of empirical investigations using large datasets have been conducted concerning the intervening role of BPR in the relationship between ICT and business performance. Grover et al (1998) investigated whether the relationship between ICT diffusion and perceived ICT-related productivity improvement is mediated by the perceived extent of ICT-related process change; by constructing regression models they concluded that only for some types of ICTs the perceived extent of the process change they cause mediates the relationship between ICT diffusion and perceived ICT-related productivity improvement. Albadvi et al (2007) empirically tested the hypothesis that the relationship between ICT and perceived firm performance is mediated by the extent of ICT-based BPR of the basic business processes identified by Gunasekaran and Nath (1997); the regression models they constructed finally provided support to this hypothesis.

It should be noted that even these few empirical studies on this topic are based not on objective, but on subjective measures of business performance (managers' perceptions) as dependent variables. Furthermore, they are not based on theoretically sound models that include all the fundamental variables, and omit important independent variables (such as non-ICT assets, labor, etc.), which may affect substantially their selected measures of business performance; this can be problematic, since the omission of important independent variables introduces biases in the estimation of the coefficients of the constructed models, especially in cases where the omitted variables are correlated to some extent with the included ones (Gujarati 2003). It should also be noted that in the literature there has been no empirical investigation of whether and to what extent BPR has an intervening role in the relationship between firm non-ICT investment (traditional assets) and business performance

III. Research Methodology and Data

This study aims to contribute to filling the abovementioned research gaps. It investigates empirically using a large dataset whether and to what extent BPR - measured in a highly reliable manner - has an intervening role (i.e. as a complete or partial mediator) in the relationship between ICT investment and business performance, using objective measures of both; also, it investigates empirically the same question for the non-ICT capital as well, and makes a comparison between ICT capital and non-ICT capital from this viewpoint. In this direction the main foundation of this study is a fundamental production function from the area of microeconomics, which connects a basic firm performance variable, firm value added, with the basic variables affecting it, labor and capital: the Cobb-Douglas production function (Nicholson, 1998). It constitutes a sound and mature foundation, since it has been extensively used in the past for estimating the contribution of various types of firm inputs, including ICT capital (e.g. see Brynjolfsson & Hitt 1996, Stolarick 1999, Preslac 2003), to firm output. In particular, we have used an extended form of the Cobb-Douglas production function, in which the capital is divided into computer capital and non-computer capital:

$$VA = e^{\beta_0} L^{\beta_1} K^{\beta_2} CK^{\beta_3} \quad (1)$$

where VA is the yearly firm value added (=yearly sales revenue minus yearly expenses for buying materials and services), L, K and CK are the yearly labor expenses, the value of firm non-computer capital and the value of firm computer capital respectively; ß$_1$, ß$_2$ and ß$_3$ are the corresponding output elasticities, while ß$_0$ incorporates all the factors associated with firm organization and management, including the extent of BPR, which affect firm's capability to combine inputs and produced value from them. By log-transforming (1) and dividing-normalizing both sides of it by the number of firm employees it is inferred that the log-transformed firm value added per employee (a fundamental objective measure of business performance), is a linear function of the log-transformed value of the firm ICT capital per employee (an objective measure of the magnitude of ICT investment), the log-transformed value of the firm non-ICT capital per employee (an objective measure of the magnitude of non-ICT investment), the extent of BPR and other organization and management factors. This leads to our research model, which also includes hypothesized relations between ICT investment and BPR and also between non-ICT investment and BPR, in order to investigate the intervening roles of BPR in the ICT - business performance and the non-ICT - business performance relationships (Figure 1).

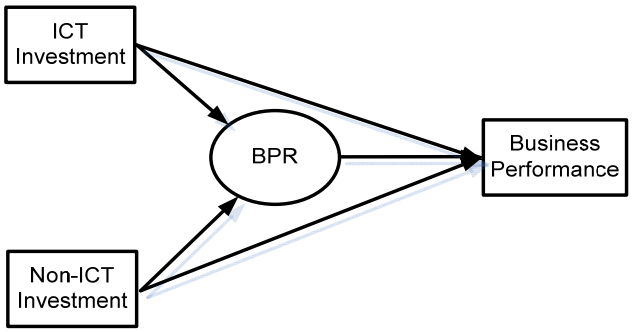

Fig 1. The research model

The extent of BPR is a highly abstract and multi-dimensional concept, so in order to measure it with a high level of reliability we used a multi-item scale, which has been developed based on a detailed review of the relevant literature and consists of 9 items-variables that 'reflect' BPR (reflective items) shown in the Appendix. In particular, the items regarding the development of cross-functional processes, employee empowerment, job enrichment and creation of multi-skilled interdepartmental teams were taken from Gunasekaran and Nath (1997). Process improvement, simplification and abolition and also decrease of the intention of supervision were among the first process change activities proposed by Hammer and Champy (1993). The items

regarding the creation of cross functional roles of process coordinators as well as the customer-centric approach of the processes were conceptualized from the work of Champy (2002).

The model shown in Figure 1 was estimated using structural equation modeling techniques (SEM) (Kline 2005), based on data collected through a survey among Greek companies, titled 'Usage of information and communication technologies, modern organization forms and innovation in the Greek companies', which was conducted in cooperation with ICAP SA, one of the largest business information and consulting companies of Greece. This survey was based on a structured questionnaire; in the Appendix are shown the questions of it that have been used in this study. The sample of the survey was randomly selected from the database of ICAP and included 304 Greek firms (103 small, 103 medium and 98 large ones) from the 27 most important sectors of Greek economy. From the same database of ICAP two 'similar' samples were also randomly created, which had the same percentages of small, medium and large firms, and also the same percentages of firms from the above 27 sectors, with the initial sample. Initially the questionnaire was sent by mail to the 304 firms of the first sample; the ones which refused to participate were replaced by 'similar' companies (i.e. from the same size and industry group) from the second sample and then after its exhaustion from the third, so that the percentages of the initial sample of company sizes and industries can be maintained. In this way finally were received complete questionnaires from 271 companies (88 small, 105 medium and 78 large ones).

IV. DATA ANALYSIS AND RESULTS

The hypothesized research model of Figure 1 was estimated using SEM implemented through the AMOS 6 software. Initially BPR construct validity and reliability was examined. Construct validity means that the items selected for measuring a construct "fit" together in such a way so as to capture the essence of the construct (Straub et al 2004). We have examined the most important dimension of it, the convergent validity. Convergent validity is evidenced when items thought to reflect a construct converge showing high correlations with one another. We assessed it by examining the estimated loadings of the nine items of the BPR construct, which are shown in Table 1; all these loadings are statistically significant and exceed the 0.6 cut-off level suggested by the relevant literature (e.g. Chin 1998), so it can be concluded that the BPR construct is characterized by convergent validity.

TABLE 1. ITEM LOADINGS OF THE BPR CONSTRUCT AND OVERALL MODEL FIT INDICES.

BPR Construct	
Indicator	**Loading**
BPR_1	0.724
BPR_2	0.700
BPR_3	0.784
BPR_4	0.699
BPR_5	0.706
BPR_6	0.781
BPR_7	0.748
BPR_8	0.724
BPR_9	0.676

Model Fit	
Chi-Square	**113.79**
RMSEA	**.071**
Incremental Fit	
NFI	**.927**
RFI	**.900**
CFI	**.957**
TCI	**.940**
CFI	**.956**

Construct reliability means that the items selected for measuring a construct constitute an error-prone operationalization of it (Straub et al 2004). It was tested by calculating Cronbach's α for the BPR construct using the SPSS 15.0 Software; the calculated value was 0.914 exceeding the threshold level of 0.7 proposed by the relevant literature (e.g. Straub et al 2004), confirming therefore reliability of the BPR construct.

In Table 1 we can see the values of the goodness-of-fit indices for the estimated model, which provide an indication of how well it fits to and explains the observed data. We remark that the model has a satisfactory fit to the data, since all the incremental fit indexes are above the threshold level of 0.9, according to the suggestions of the relevant literature (e.g. Straub et al 2004), and the RMSEA is less than the maximum acceptable value of 0.08, as suggested by Browne and Cudeck (1993).

In Figure 2 we can see the path coefficients of the estimated model and their statistical significance levels (with *,**, and *** denoting 1%, 5% and 10% significance levels respectively). We remark that the path from ICT investment to BPR is significant (0.137) and also the path from BPR to business performance is significant as well (0.159). Those two significant paths reveal an intervening role of BPR in the relationship between ICT investment and business performance. We also remark that the direct path from ICT investment to business performance is significant as well (0.328). So it is concluded that the extent of BPR is not a complete but a partial mediator in the relationship between ICT investment and business performance. In particular, we can see that the total effect of ICT investment on business performance is: 0.328 (direct effect) + 0.137*0.159 (indirect effect through BPR) = 0.350. We remark that the direct effect is much stronger than the indirect one through BPR, which accounts for 0.137*0.159/0.350 = 6.2% of the total effect of ICT investment.

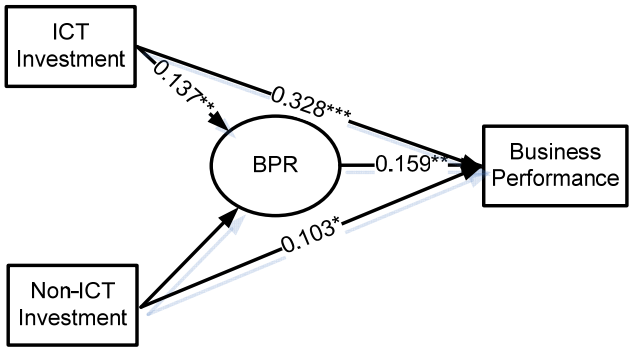

Fig 2. Results

With regard to the non-ICT capital we remark that the path from the non-ICT investment to BPR is not statistically significant, so we can conclude the BPR does not mediate the relationship between non-ICT investment and business performance. Also we can see that the direct path from the non-ICT investment to business performance is significant (0.103) indicating a direct effect of the non-ICT investment on business performance.

V. Conclusions

This study has investigated empirically whether and to what BPR has an intervening role in the relationship between ICT investment and business performance, based on firm-level data from 271 Greek firms. The main conclusion is that the BPR is a partial mediator in the relationship between ICT investment and business performance. This finding is consistent with the ones of the two previous studies on this topic (Grover et al 1998, Albadvi et al 2006). By examining the magnitude of this partial mediation it has been found that it is small: in the Greek national context only a small part (6.2%) of the total effect of ICT on business performance is through enabling and facilitating process redesign and improvement, which has a positive impact on business performance. This is due to the small effect of ICT investment on BPR (0.137), which means that ICT only to a small extent leads to BPR, and also due to the small effect of BPR on business performance (0.159), which means that BPR results only to small improvements of business performance.

Also, a comparison between the ICT capital and the non-ICT capital was made from the above viewpoint. It has been concluded that the non-ICT capital does not have a statistically significant effect on the extent of BPR and that the relationship between non-ICT investment and business performance is not mediated by BPR.

As basic limitation of this study could be mentioned the unique - through fundamental – measure of business performance that has been used (value added per employee). Therefore further research is required concerning the intervening role of BPR in the ICT-business performance relation using various financial and non-financial measures of business performance. Also another limitation is that this study has been based on data from Greek companies, so the conclusions might – at least to some extent – reflect characteristics of the Greek national context. Therefore further research is require on this topic in various national contexts.

Appendix

Survey Questions (used in this study)

- Yearly total sales revenue (without VAT) : _____ Euro
- Yearly total expenses for buying materials and services (without VAT): _____Euro
- Number of employees: _____
- Value of assets at the end of the year (without VAT) : _____Euro
- Value of computer equipment (hardware, software and networks) at the end of the year (without VAT) : _____Euro

Answer the following questions in a scale 1 – 5, where 1 = Not at all, 2 = To a small extent, 3 = To a moderate extent, 4 = To a large extent, 5 = To a very large extent, by clicking the appropriate box in the right of each question

- To what extent have you performed the following business process reengineering (BPR) activities in the last 5 years?

BPR ACTIVITIES					
Creation of new horizontal (inter-departmental) processes (crossing several departments)					
Creation of new inter-departmental units/workgroups (e.g. customer or product-focused)					
Creation of new horizontal process coordination roles for monitoring coordinating the execution of process crossing several departments.					
Simplification of processes					
Improvement of processes					
Abolition of processes					
Redesign of processes so that they become customer-focused					
Job enrichment and increase of decision making competences for employees involved in some processes					
Decrease of the intension of supervision and of the number of supervisors in some processes					

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