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A Proposal for a Framework of Research Approaches on Information Technology Impacts on Corporate Level Productivity

[1]Abbas Keramati and [2]Amir Albadvi
[1]Department of Industrial Engineering, Faculty of Engineering, University of Tehran, Tehran, Iran
[2]Department of Industrial Engineering, Faculty of Engineering, Tarbiat-Modares University, Tehran, Iran

Abstract: During the last three decades, much study has been conducted on the impact of Information Technology (IT) on productivity at various levels. With a careful scan of the published work at corporate level productivity, we shows that, researchers have developed 3 different approaches in assessing the correlation between IT implementation and productivity measures. Broadly speaking, the first two approaches focus on the effects of IT investment on direct and intermediary, financial and non-financial, measures of productivity. None of these two approaches could positively prove either a direct correlation or lack of such a relation. The third approach, "complementary" approach, considers the IT implementation but emphasizes the role of complementary investments that enhance and complement the IT implementation. In this article, an effort has been made to provide satisfactory evidences to show that IT implementation, when rationally backed up by suitable complementary investment, will lead to a considerable increase in productivity at corporate level.

Key words: Information technology, productivity, complementary investment, intermediary measures

INTRODUCTION

The effects of IT on productivity have been extensively researched over recent years. While some studies show a positive significant correlation between IT and productivity many others could not show that. This fact has called IT productivity paradox in the literature. A review of literature and categorization of the past studies could help researchers to conducting new research paradigms and explaining productivity paradox. The key purpose of this study is to investigate a possible trend in IT evaluation process at corporate level. Therefore we have tried to categorize studies of IT impacts on productivity at firm level regarding productivity measures and to propose a study approach for evaluation of IT impacts on productivity at firm level with considering complementary investments.

There are some papers that proceed to organize the published researches of IT implementation impacts on productivity for classifying the researches in order to facilitate identifying what we know, how well we know it and what we do not know (Dedrick *et al*., 2003). These studies have categorized the published researches of IT impacts on productivity based on productivity levels (Brynjolfsson *et al*., 1996; Chan, 2000; Dedrick *et al*., 2003). However a categorization of studies based on the productivity measures is still not well published. We focused on firm level productivity and categorized researches based on productivity measures into three groups: direct measures approach, intermediary measures approach and complementary approach. This categorization helps us to organize and assess the researches and propose a conceptual model for future study.

IT productivity paradox: Many researchers analyzed empirical data of 1960s-1980s period and found little evidence that IT significantly increased productivity (Brynjolfsson and Yang, 1996). As Robert Solow claimed, "You can see the computer age everywhere but in the productivity statistics" (Brynjolfsson and Yang, 1996). He used term "productivity paradox" to show this fact. Sourly, while one study shows a negative correlation between productivity, another study suggests that computer capital contributes to growth more than ordinary capital.

Brynjolfsson (1996) proposes four explanations for the productivity paradox:

- Mis-measurement of inputs and outputs
- Lags due to learning and adjustment
- Mismanagement of information and technology and
- Redistribution and dissipation of profits

Brynjolfsson (1996) attributes the measurement error to the difficulty of developing accurate, quality-adjusted price deflators; He argues that improvements in product quality and the introduction of new products need to be

properly accounted for in the value of output. Lags as an explanation of the paradox suggest that the benefits associated with investments in IT may take several years before they show in the bottom line. This is due to a period of learning associated with adjustment and possibly restructuring of the organization caused by new IT. The third proposition, mismanagement of information and technology, suggests that IT is not productive and managers who choose to invest in IT are not acting in the best interests of the company. Finally, redistribution as an explanation of the productivity paradox argues that IT rearranges the shares of the pie, in favor of some companies without making it any bigger.

There are some researches that tried to capture the explanations of IT and Productivity Paradox. Brynjolfsson and Hitt (1996) considered and empirically tested the possibility of the productivity paradox as an artifact of mis-measurement. They used the neoclassical production theory in order to determine the contribution of such inputs as computer capital and information systems staff labor to output. They measured output in inflation-adjusted dollar terms because, this partially accounts for changes in product quality and introduction of new products. They conclude that their results indicate that IT had made a substantial and statistically significant contribution to firm output and that the productivity paradox disappeared by 1991, at least in their sample of firms. By focusing on one of the four possible explanations (mis-measurement) for the productivity paradox, Brynjolfsson and Hitt (1996) were able to show a significant relation between investment in information systems and firm output.

Stratopoulos and Dehning (2000) research considers the possibility that a portion of the productivity paradox is attributable to mismanagement.

Schrage (1997) describes a rather colorful variation of the productivity paradox. He says that companies have wasted billions of dollars "believing the big lie of the Information Age." According to Schrage, the spending spree on IT was justified by a "beautiful hypothesis" that companies that had more and better information could improve their financial performance and competitive position. The hypothesis was slew, according to Schrage, by an "ugly fact" that managers had acted irresponsibly in relying on technology to solve fundamental problems.

Empirical findings of Strassmann (1990) indicate that the lack of any significant correlation between the investment in IT and performance points to possible irrational behavior of the management. Shafer and Byard (2000) developed a framework for exploring each of the four explanations of productivity paradox by Data Envelopment Analysis (DEA) on two-digit code industries data set.

Productivity paradox is still a research area on IT and productivity. One of the most important explanations of productivity paradox is the role of organizational complementary investments, which organizations have to invest on them for realizing more productivity (Boyer *et al*., 1997).

METHODS

We conducted a review of more than 50 IT and productivity journal articles from 1999 to 2003. The journal searched included Journal of management information systems, Communications of the ACM, Information systems research, MIS Quarterly, ACM computing survey, Information systems frontier, Information and management. These journals were selected because they are regarded to management aspect of information technology and are highly ranked every time. We could not review another journal because of the time and resource limitations. Articles were selected if they involved research in firm level and their title, abstract, or keywords emphasized information technology, computer, technology and productivity, productivity paradox, efficiency, effectiveness, evaluation, payoffs, performance or value. Because the scope of this review is corporate or firm level productivity, the following key words were also eventually added: complementary investment, organizational change and IT enabled changes.

Classification of the articles in this research was a two-stage process. At the first stage the articles selected based on the level of measurement. The articles selected if their title, abstracts and key words emphasized on empirical study of the effects of information technology, systems or computers on firm performance or changing, improving or enabling the organizations business processes. As the second stage the firm level articles were reviewed totally in order to determine the productivity measures. The articles were classified regarding the financial or non-financial measures of performance or productivity; and also, the articles which empirically tested the effects of IT on performance considering the role of complementary investments (e.g., total quality management, work force empowerment, change management) were recognized. This article survey has being done at October until December, 2003. Also, we have considered the papers addressed by three comprehensive literature reviews done by Brynjolfsson *et al.* (1996), Chan (2000),and Dedrick *et al.* (2003). The first stage of classification process of the articles addressed by these three papers was skipped because firm level studies were separated by the authors of those three papers.

DEFINITIONS

IT in organizations: In the technological aspect, IT is one of the many tools available to managers for coping with changes. Different tools and techniques, which can be put into information aspect, are: data processing; database management system; information and knowledge management systems; artificial intelligence and soft computing; data structure and algorithm; data mining and data warehousing (Vandenbosch and Huff, 1997)

In the application aspect, information technologies are used by organizations to facilitate the business processes for instance administration and accounting, production and operation, human resource management and management control. Communication technologies such as fax, email, Electronic Data Interchange (EDI); advanced manufacturing technologies (ATMs) such as Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), Flexible Manufacturing System (FMS), Just In Time (JIT), Robotic, Manufacturing Requirement Planning (MRPII), Enterprise Resource Planning (ERP) and computer application software such as word processor and spreadsheet are most common information technologies which can be employed by organizations.

Productivity in organizations: Productivity is the quotient obtained by dividing output by one of the factors of production. In this way it is possible to speak of the productivity of capital, investment, or raw materials according to whether output is being considered in relation to capital, investment or raw materials, etc.

Basic definitions of productivity: Depending upon who is defining it-whether it is an economist, accountant, manager, politician, union leader, or industrial engineer-we will get a slightly different definition of the term productivity. However, if we closely examine the various definitions and interpretation of this term, three basic types of productivity appear to be emerging: Partial Productivity is the ratio of output to one class of input. Total-factor Productivity is the ratio of net output to the sum of associated labor and capital (factor) inputs. Total productivity is the ratio of total output to the sum of all input factors.

Productivity levels: Several levels of productivity are identified: Individual, Firm (or organizational), Industry and National (or Economy or Country) level are most popular categorizes. Individual level Productivity shows how a person uses his/her qualifications to improve his/her performance. Firm level productivity shows how a firm applies its people, financial, information and other resources to achieve its goals. Industry level productivity is similar to firm level except it shows the productivity of an economical sector such as banking, service sector and industrial firms and so on. Finally, Country productivity level shows how a country exploits of its geographical, historical, political and natural and other assets in order to development.

Productivity measures: In order to productivity measurement it is necessary to develop the relevant productivity measure(s). There are many measures presented in productivity literature that can be selected and used by the measurers. Also measurers can develop appropriate measures according to two critical factors: measured goals and applications and goals of measurement. Productivity measures must show the current situation and its differences with desirable goals of measured region (country, economy sector and/or firm). In addition the measures be selected or developed in accordance with applications and goals of measurement. Economists, accountants, managers, politicians, union leaders, or industrial engineers use productivity in different purposes and develop different measures.

FINDINGS: RESEARCH APPROACHES

Direct measures approach: The 'Direct Measures' approach mainly focused on various direct measures of productivity such as a number of partial productivity measures (including workforce and capital productivity (Mahmood and Mann, 1993; Rai *et al*., 1997) and total factor productivity (Alpar and Kim, 1990) as well as profitability and cost reduction [Desmaris *et al*., 1997; Strassmann, 1990). For instance sales per employee and total factors, Rate Of Return (ROR), return on sales, market value and production function factors (Hitt and Brynjolfsson, 1996; Loveman, 1994; Mahmood and Mann, 1993) are used in this approach. These measures are financial and in accordance with a ratio of output per input, that is the more popular and traditional definition of productivity. Judging on these measures, many studies show a significant positive correlation between IT investment and productivity. Table 1 shows the findings of a selected number of pioneering or significant works supporting this idea. In spite of the large number of studies supporting this positive correlation (Alpar and Kim, 1990; Desmaris *et al*., 1997; Rai *et al*., 1997), a noticeable number of studies show that investment in IT does not necessarily lead to an increase in these direct measures (Loveman, 1994; Mahmood and Mann, 1993). These contradictory findings lead to the so-called 'Productivity Paradox'.

Table 1: Selected works on direct measures approach

Researcher(s)	Measures	Findings
Strassmoun (1985)	Profitability ratios and return on management	Some of the firm that invested on IT had very good operation but the others didn't have
Alpar and Kim (1990)	Multifactor (loans and demand deposits)	IT results in decrease in costs and increase in time deposits.
Harris and Katz (1991)	Operating expense as a percentage of premium income	Firms that are profitable have higher growth on IT expense ratios and lower growth on operating expense ratios.
Mahmood and Maun (1993)	Return on investment, return on sales, growth in revenue, sales by total assets, sales by employee, market value to book value	Individual IT investment variables were found to be weakly related to organizational strategies and economic performance.
Loveman (1994)	Performance ratios (ROI)	Contribution of investment on IT was about 0 during a period of 5 years study
Hitt and Brynjolfsson (1996)	Production function Business profitability Consumer surplus	IT increased productivity and consumer value, but did not result in supranormal business profitability. There is no inherent contradiction between increased productivity, increased consumer value and unchanged business profitability.
Mitra and Chaya (1996)	Level of IT investments made by the firm IT budget as a percentage of sales	Higher IT investments are associated with lower average production costs, lower average total costs and higher average overhead costs. There was no evidence that IT reduces labor costs in organizations.
Desmaris *et al.* (1997)	Cost-benefit analysis Operating costs Reduction in training time Annual monetary benefits	Introduction of an electronic performance support system is expected to reduce employee training time, resulting in a financial break-even point between 1 and 3 years.
Rai *et al.* (1997)	Labor and related expenses Total property, plant and equipment Total number of employees Company sector Sales Return on assets Return on equity Labor productivity Administrative productivity	All measures of IT investment are positively associated with firm output. IT capital and client/server expenditures are positively associated with return on assets. Most expenditure except software and telecom are associated with increased labor productivity. IS staff, hardware, software and telecom expenditures are negatively related with administrative productivity.
Tam (1998)	Total shareholder return Return on equity, assets, sales Book value of assets Market value	IT investment is not correlated with shareholder return. Level of computerization is not valued by the stock market in developed and newly developed countries. There is no consistent measurement of IT investment.

We can see the productivity paradox at firm level as well as at industry and country levels. Also the productivity paradox is appeared when different researchers used different measures of productivity. Therefore the productivity paradox is not just related to a specific level or measure of productivity (Table 1).

In addition, productivity paradox is not a particular specification of the past decades. More recent researches show that although IT managers have great expectations when selecting an IT solution, but 4% are happy with the implementation outcome (Han, 2003). Accenture Ltd.'s "Future of Enterprise Solutions Study" found while organizations have invested "millions of dollars and attention" to automate and streamline their information flow and business processes, few can claim they've achieved the kind of payback they expected (Han, 2003).

Researches categorized under direct measures approach show that productivity measures in this approach are strongly in correspondence with expenses and incomes that expressed on corporate balance sheet. But the IT investments and incomes are noticeably different. For example, the purposes of an investment in a financial auditing information system are less similar to the purposes of investment on developing an automated customer service. Investment on providing a chargeable customer service is likely to demonstrate instant output, which can be directly traced in financial measures.

Researchers consider the Intermediary measures, e.g., IT impacts on quality of product and processes, to improve their measurement process.

Intermediary measures approach: In an effort to explain the cause of productivity paradox, selection of data set and measurement methods have been highlighted (Brynjolfsson and Yang, 1996). This effort leads to a new generic type of IT productivity measures, called Intermediary Measures. These measures are generally related to intangible costs and benefits, managerial behavior and utilization of capacities (Brynjolfsson, 1996; Brynjolfsson and Hitt, 2000; Brynjolfsson *et al.*, 1996; Brynjolfsson and Yang, 1996).

Although, direct measures are often calculated by means of corporate balance-sheet data, intermediary measures are often investigated by non-financial data. It is also proposed that due to the problem of inconsistent results that may arise in assessing the direct measures of productivity; one can focus on the intermediary measures of productivity such as inventory levels (Barua *et al.*, 1995), timelines, the innovation of new products and procedures (Becchetti *et al.*, 2003) the rate of capacity utilization (Barua *et al.*, 1995), quality of products, customization, convenience and variety (Mukhopadhyay *et al.*, 1995). Table 2 shows selected works carried out in supporting this approach.

Table 2: Selected works on intermediary measures approach

Researcher(s)	Productivity measures	Findings
Brynjolfsson (1993)	Mis-management, mis-measurement, time lag	Apparent lack of productivity is due to mis-measurement of outputs and inputs, lags due to learning and adjustment, redistribution and dissipation of profits and mismanagement of information and technology.
Dos Santos *et al.* (1993)	Stock price reactions around announcements of IT investments	On average, IT investments are zero net present value investments; they are worth as much as they cost. Innovative IT investments increase the value of the firm.
Belcher and Watson (1993)	Decision making improvements Cost savings on: information distribution, services and software replacement Other intangible benefits	Benefits included improved productivity, improved decision making, information distribution cost savings, services replacement cost savings, and software replacement cost savings. Benefits were found to exceed the system's costs.
Newman and Kozar (1994)	Positive identification of jewelry Availability of decision support for gemologist throughout evaluation process	System resulted in: Better asset management and financial control Increased productivity Reduced costs and increased revenue Better quality Merchandise
Barua *et al.* (1995)	Five intermediate variables: Capacity utilization, inventory turnover, relative price, relative inferior quality and new products Final performance variables: market shares, return on assets	The five intermediate variables had significant positive impacts on the final performance variables of the strategic business units.
Mukhopadhyay *et al.* (1995)	Inventory turnover Obsolete inventory Premium freight Annual production volume Parts variety New parts introduction	EDI resulted in cost reductions ($100 savings per vehicle, annual savings of $220 million)
Clark and Stoddard (1996)	Inter-organizational redesign, use of electronic data interchange (EDI) and continuous replenishment (CRP)	It is important to merge technological and process innovations. Inter-organizational business process design, in the form of CRP using EDI, represented a dramatic performance improvement for the channel overall, benefiting both retailers and manufacturers.
Tam (1996)	Organizational adoption of IT Mainframe purchases Price elasticity of mainframe computing	Organizations' reactions to price changes (i.e., price elasticity) are not constant.
Vandenbosch and Huff (1997)	Perceived improvements in organizational performance:	EISs contributed to gains in efficiency more frequently than to gains in effectiveness. However EISs could also be used to help formulate problems and foster creativity.
Anderson *et al.* (2003)	1. Market value 2. Intangible assets value (Innovation 3. Effects of investment in complementary assets such as greater use of teams, broader decision-making authority and worker training	1. IT productivity paradox remains in their data and it presents a new IT productivity paradox. 2. Two parallel explanations for the paradox: Complementary investment in organizational assets accompanying implementation of ERP and related systems increased intangible asset value. And the interweaving of IT links throughout the supply chain created value by enabling each member of the supply chain to identify and respond to dynamic customer needs.
Becchetti *et al.* (2003)	Impact of investment in IT on intermediate variables.	Telecommunications investment positively affects the creation of new products and processes, while software investment increases the demand for skilled workers, average labor productivity and proximity to the optimal production frontier.

For example Barua *et al.* (1995) considered five intermediary measures of productivity including: capacity utilization, inventory turnover, relative price, relative inferior quality and new products as well as market shares and return on assets as direct measures of final performance variables. They concluded that partial support was received for the positive impacts of the economic input variables on five intermediate variables. The five intermediate variables had significant positive impacts on the final performance variables of the strategic business units.

In the other research, Brynjolfsson (1996) considered consumer surplus and economic growth as intermediary measures of productivity and labor productivity as direct measure of productivity. He found that IT has no effect not only on labor productivity but also on intermediary measures (consumer surplus and economic growth).

Becchetti (2003) analyzed the impact of IT investments on intermediate measures of productivity and efficiency at firm level. Among intermediate measures he considered the demand for skilled workers, the introduction of new product and processes and the rate of capacity utilization as well as productivity measures including total factor productivity, the productivity of labor and the distance from the ''best practice''. He found that telecommunications investment positively affects the creation of new products and processes, while software investment increases the demand for skilled workers, average labor productivity and proximity to the optimal production frontier.

Table 3: Selected works on complementary measures approach

Researcher(s)	Productivity measures	Findings
Brynjolfsson and Yang (1996)	Measures of the organizational structures	Firms that combine higher computer investments with these organizational characteristics have disproportionate increases in their market valuations
Lucas *et al.* (1996)	Changes in organizational structure, workflows and functions, interface operations, technology	Introduction of financial imaging system resulted in improvements to customer service, control of certificates, higher quality images, improved search speed, cost reduction, research time reduction, staff reduction.
Brown *et al.* (1995)	Aunouncements that firms are using information systems (investment)	The stock market reacted favorably to announcements that firms were using successful Strategic Information Systems (SIS). In subsequent years these firms tended to be more productive and more profitable than other firms in their respective industries.
Henderson *et al.* (1995-96)	Organizational learning New products and services	The benefits anticipated from IT investments (e.g., iunovation) are marginal unless integrated, dynamic processes exist to actively manage and adapt these investments.
Brynjolfsson and Hitt (1998)	Productivity Decentralization IT spending	Investment in computers does not automatically increase productivity, but is part of a broader system of organizational changes that does increase productivity.
Francalanci and Galal (1998)		Productivity gains result from worker composition (more information workers) and IT investments.
Grover *et al.* (1998)	Ranking of importance among investments in strategic systems, traditional development, decision support systems, infrastructure, business process redesign and maintenance, need to be used in prioritizing investments.	An IS planning culture among top management is associated with strategic systems investments. Diversity of types of IT is associated with BPR and infrastructure investment and does not favor traditional systems investment. Managing IT requires change management skills. Both IS and business inputs
Bresnahan *et al.* (2000)	Decentralization and investment on human capital	1. Greater levels of IT are associated with increased delegation of authority, greater levels of skill and education in the workforce and the greater emphasizes on pre-employee screening for education and training. 2. These work practices are correlated with each other
Bresnahan (2002)	Labor productivity Organizational changes	The effects of IT on labor demand are greater when IT is combined with particular organizational investments.
Devaraj *et al.* (2002)	Organizational change	IT investment combined with business process reengineering positively and significantly influences performance.
Brynjolfsson (2003)	Human and organizational capital Work practices Decision making process	The greatest IT benefits are realized when an IT investment is coupled with a specific set of complementary business investments.
Sherer *et al.* (2003)	Investment in change management	Planned communications and change management strategies led to the smooth implementation of the upgrade process and contributed to the payoff from the IT investment.
Dewan *et al.* (1998)	Demand for IT investment (total stock of IT capital, net of depreciation)	The level of IT investment is positively related to the degree of firm diversification. Furthermore, diversification demands greater IT than unrelated diversification. Firms that are less vertically integrated have a higher level of IT investment. Finally, firms with fewer growth options in their investment opportunity set tend to have a higher IT investment.

IT investment impacts on decision making procedures, consumer welfare, innovative business process was considered by researchers as intermediary measures (Table 2).

Although the intermediary measures approach reveals many important facts about IT impacts on performance of organizations via non-financial data, but there are three problems related to this approach. The most important problem is the productivity paradox that remained on some of the research results of this approach, as we can see in Table 2. Also impact of IT investment on intermediary measures is not isolated from other organizational investments effects (Lee, 2001). Finally intermediary and intangible measures aren't simple to compute (Brynjolfsson *et al*., 1996).

Direct and intermediary measures are used simultaneously by a number of researchers and interaction between these measures and IT implementation are investigated. Although the productivity paradox isn't disappeared completely but this hybrid measures (combination of direct and intermediary measures) shows a very important fact: If IT investment will be integrated with complementary organizational investments, it leads to higher productivity. These findings direct to a new approach in IT impacts on productivity, called complementary approach.

Complementary approach: While there are still a number of researchers adhering to the first two approaches, which may of course be well suited in some situations, third 'complementary' approach have evolved. In this approach researchers believe that "IT investment will positively affect the productivity if complementary investments are made". Instead of measuring the traditional measures of productivity that are related to industrial age, they focus on IT ability to create the new shape of values (Berndt and Morrison, 1995).

Organizations can achieve more production from their IT investment if IT investments are coordinated with organizational redesign and other managerial decisions (Hunter and Lafkas, 2003), business strategy and nature of managerial work (Pinsonneault and Kreamer, 1997; Pinsonneault and Rivard, 1998; Belleflamme, 2001). Also investment on management skills, user training, application of standards and the way people work and how their performance is measured and controlled are critical to realizing more productivity from IT investment (Davern and Kauffman, 2000).

Recent researches focuses on the impact of IT on organizational structure and culture (Lau *et al*., 2001). For example Lau *et al*. (2001) investigated on the effect of complexity, formalization, decentralization; span of control, outsourcing and lateral communication as the factors of structure and team working and learning as organization culture. They find that IT investment has significant impacts on organizational structure and culture.

Decentralization and investment on human capital are considered by Lau *et al*. (2001) as IT complementary investments. They conclude that greater levels of IT are associated with increased delegation authority, greater levels of skill and education in the work force. Table 3 is dedicated to some of the works published in this area.

The direct and intermediary measure approaches is based on this believe that IT investment intern lead to cost reduction and improves quality, variety, innovation and etc. But paradoxical results and a huge variation across organization (some have spent vast sums on IT with little benefit, while others have spent similar amounts with tremendous success) change the critical question facing IT managers and researchers from 'Does IT increase productivity?' to 'How can we invest on IT to increase productivity?' the results of this approach shows that investment on IT does not automatically increase productivity, but is part of a broader system of organizational investment for changes that does increase productivity (Brynjolfsson and Hitt, 1998).

Most importantly, the highest productivity of IT will be realized when IT investment is integrated with complementary investments; new strategies, new business processes, new working practices and new organizations all appear to be important in realizing the maximum benefit of IT. These changes will require a time consuming period of reengineering and redesign of organization in order to best utilize their IT investment.

DISCUSSION AND CONCEPTUAL MODEL

We considered the productivity measures as the bases of our categorization of research approaches in IT effects on organizational level productivity. This classification is consistent with work of Renkema and Berghout (1997) on classification of IT evaluation approaches at the proposal stage. They discerned four basic categories of information systems evaluation at proposal stage including financial, multi-criteria, ratio and portfolio approaches. The financial and ratio approaches are very similar to the direct measures approach and findings shows resembling related problems. The advantage of multi-criteria method is in that those consider the financial and non-financial measures. This method is consistent with the intermediary measures approach described in this study. Within both portfolio and intermediary approaches, measures of performance are used not so much to measure but to illustrate complementary needs for companies to realize IT values. Similarity between these two categorizations shows comparable difficulties and solutions on IT evaluation at both proposal and operation stages.

We concluded that the corporate level measurements have failed to identify a strong relationship between IT investment and firm productivity. Direct measures are strongly related to bottom line measures of productivity and performance. Hitt and Brynjolfsson (1996) showed that while IT investment affects productivity and contributes to consumer welfare (through lower prices or better service, for example), it does not necessarily improve profitability. They proposed that the productivity benefits associated with IT use may be passed on to consumers through lower prices and not lead to greater profitability. They also proposed that it is important to measure the impacts of IT on intermediate outputs such as inventory levels, planning cycles, asset utilization and other measures of operations performance, which are known to have a direct link with productivity.

In the second approach, called intermediary, productivity measures are defined to determine the impacts of IT on the organizational performance measures which can't be seen in the bottom line data. But we show that the paradoxical results and strong variety across the firms are remained as the most important problems of this approach. We must not expect either measures of financial performance or measures of organizational functions performance, necessarily indicate the impacts of IT on productivity.

In this article we addressed a wide range of productivity measures and measurement methods, abstracted in Table 1 and 2. Researchers and managers those interested to evaluate the productivity of IT through the direct or intermediary approaches can select proper productivity measures and method of measurement which show the prosperity of firm to achieve organizational goals and excellence.

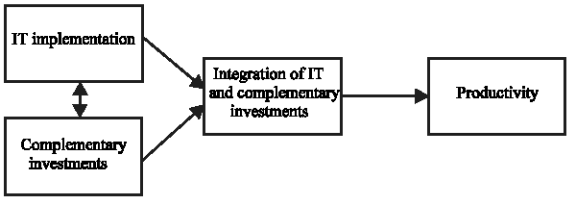

Fig. 1: Conceptual model

Complementary approach shows that the strategic emphasis is changed from "IT to improve and support ongoing operations "to "IT as a capability builder". IT is not simply a tool for automating existing processes, but is more importantly an enabler of organizational changes that can lead to productivity gains. We should test the IT effect on organizational transformation and to build capability on best practices, instead of its effect on traditional productivity measures. The potential of IT to arise productivity will been unlocked when the investments in complementary assets such as software, training, and organizational transformations have been realized (Dedrick *et al*., 2003). More researches are required to develop an understanding of the mechanisms by which these returns accrue to firms.

As more research is conducted, we are gradually developing a clearer picture of the relationship between IT and productivity. Figure 1 shows the proposed conceptual model of how IT can affects the organizational productivity by enabling the complementary investment.

Above Fig. 1 proposes a research paradigm in relationship between IT investment and its effects on productivity improvement via enabling the complementary investments.

In spite of the potential of information technologies such as flexibility, location independence, empowerment, low transaction costs and work collaboration to improve business performance, managers in many companies that have implemented IT are chastened by the failure of these technologies to live up to their promise (Han, 2003). Researchers have often diagnosed this problem as a failure to integrate investments in information technologies with complementary investments to support these technologies (Brynjolfsson, 2003; Brynjolfsson and Hitt, 1998; Brynjolfsson and Hitt, 2000; Davern and Kauffman, 2000). Complementary investment is described by Brynjolfsson (2003) as including human capital, business process design, organizational strategies and work practices such as manufacturing planning and control and quality assurance. Numerous empirical studies have suggested that integration of IT and complementary investments such as workforce empowerment and quality management programs are critical to the successful implementation of IT (Brynjolfsson and Hitt, 1998).

The mutual relation between IT investment and complementary investments is showed in the Fig. 1. In one hand, IT implementation (e.g., communication IT, production and operation IT) can be considered as the enablers of complementary investments (e.g., changes on strategies, process and products). On the other hand, new strategies and new business process reengineering and redesign have a critical role on the IT planning and architecture.

Integration of IT and complementary investment lead to improvement in customer and supplier relationship and company performance. Since IT and complementary investments apply for firm excellence, organizational productivity will increase. Although a set of complementary investments are addressed by this research but our understandings about complementary investments which can realize the potential of IT for firms, are poor. Future researches in IT and productivity could be pay attention to determine the complementary investments and the mechanisms which affect the IT productivity growth. Recognition of complementary investments, via IT productivity study, helps managers to design and implement suitable and productive infrastructure and architecture of IT in their organizations.

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