

BURGUNDYREPORT



2009RB-04 > February 2009

Extracting Value from Information Technologies

Benoit A. Aubert (CIRANO and HEC)

Blaize Horner Reich (Simon Fraser University)

The Burgundy Reports are synthesis documents written by CIRANO researchers on issues of general interest. Their aim is to encourage discussion and public debate on current issues.

CIRANO is a multidisciplinary interuniversity centre of research. Its mission is to accelerate the transfer of knowledge between researchers and organizations.

CIRANO's PARTNERS

Principal Partner

Ministère du Développement économique, de l'Innovation et de l'Exportation

Corporate Partners

Bank of Canada
Bell Canada
BMO Financial Group
Business Development Bank of Canada
Caisse de dépôt et placement du Québec
DMR
Fédération des caisses Desjardins du Québec
Gaz de France
Gaz Métro
Hydro-Québec
Industry Canada
Laurentian Bank
Ministère des Finances du Québec
Power Corporation of Canada
National Bank of Canada
PSP Investments
Raymond Chabot Grant Thornton
RBC Royal Bank
Rio Tinto Alcan
Scotiabank
State Street Global Advisors
Transat A.T.
Ville de Montréal

University Partners

Concordia University
École Polytechnique de Montréal
HEC Montréal
McGill University
Université de Montréal
Université de Sherbrooke
Université du Québec
Université du Québec à Montréal
Université Laval

Affiliated Institutions

Institut de Finance mathématique de Montréal [IFM2]
Mathematics of Information Technology and Complex Systems [MITACS]
Network for Computing and Mathematical Modeling [RCM2]

The observations and viewpoints expressed in this publication are the sole responsibility of the authors; they do not necessarily represent the positions of CIRANO or its partners.

© 2009 Benoit A. Aubert, Blaize Horner Reich. All rights reserved.

Short sections may be quoted without explicit permission, provided that full credit, including © notice, is given to the source.

ISSN 1701-9990

Financial Partner



Table of Content

	Introduction	3
Searching for the Link Between Information Technology and Productivity		5
	Country Level	5
	Sectorial or Industrial Level	8
	Firm Level	10
	Project Level	13
Understanding the Contribution of IT to Productivity		19
	Measurement Issues	19
	The Lag Between Investing and Reaping the Benefits	20
	The Redistribution of Benefits	21
	The Management of IT	21
	Comparison of the Studies	23
Can IT Projects Deliver Value at the Firm Level? – Conditions for Success		26
	Project Manager	27
	Organizational Managers	28
	Implications for Executives	30
	Implications for Boards	31
	Conclusion	32
	References	34



Benoit A. Aubert

Benoit A. Aubert is President and Chief Executive Officer of CIRANO, and is professor at HEC Montréal.

He focuses his research on the transformation of organizations. His research program includes three major areas: integrated risk management, integration of business processes and fulfillment of contracts. At the focal point of research trends in the fields of information systems, industrial organization and risk, this program is aimed at better understanding the risks and opportunities offered to contemporary organizations. His research work and interventions in various organizations deal more specifically with outsourcing, new forms of organizations, as well as management of activities related to information technologies. He is interested in the various types of contractual relations binding purchasers and suppliers of services (or employees and employers), for the purpose of identifying optimal organization forms. Pr. Aubert has written several scientific articles and has actively taken part in numerous conferences. He is the senior editor of Database magazine. Since 1997, he has also been sharing responsibility for the outsourcing segment of the HICSS conference.

benoit.aubert@cirano.qc.ca



Blaize Horner Reich

Dr. Blaize Horner Reich is professor at Segal Graduate School, Simon Fraser University, Vancouver, and has a Visiting Associate position at Templeton College, Oxford University.

Before obtaining her PhD, Dr. Reich worked for 15 years in Canada and Asia as an information technology practitioner and consultant, focusing on the financial services and utilities sectors. She is currently a board member of several academic journals, non profit organizations and the Industrial Alliance Pacific Insurance and Financial Services Company. Dr. Reich's research has been published in a wide range of journals, including *MIS Quarterly*, *Information Systems Research*, *Journal of Management Information Systems*, *Communications of the ACM*, *California Management Journal*, and the *Project Management Journal*. She has two current research programs: IT governance (including alignment, service and risk management) and IT Project Management. Her research is supported by the Canadian government and she speaks regularly at academic and practitioner conferences. Her team has created a research-oriented website for practitioners,

– www.PMPerspectives.org

breich@sfu.ca

The authors thank Charles-David Sauvageau-Franche and Laurent Da Silva for their precious contribution to this report.

Understanding the relationship between information technology investments and productivity has been a challenge for researchers and a debated topic for managers as well as for policy makers. The term “Information Technology” (IT) itself is an umbrella for a disparate set of elements. For example, it includes the hardware and software which enables companies to instantly exchange production orders, invoices, and payments, thus removing paper interactions, reducing error and delays. This type of technology is likely to streamline business processes and increase productivity. IT also includes investments made in flat screens or upgrades to operating software, which might not change workers’ productivity drastically. Some impacts of IT might be mainly cosmetic.

The diversity of technology is not the sole difficulty when trying to explain the link between IT and productivity. What also makes the study of this link difficult is the constant challenge associated with the implementation of IT in organizations. Companies are too often reporting massive cost increases or large delays for their IT ventures. Sometimes they cancel projects after having spent millions of dollars. Some of these project disasters make the headlines. Anyone familiar with the conduct of IT projects knows a few examples of projects that did not unfold as expected. Yet, companies keep investing in IT, suggesting that there are major expected benefits. Although the implementation of IT is generally associated with important changes in organizations, it is not an asset that is very easy to exploit.

This means that, in order to understand the role of IT in our economy, we have to look at several facets of IT investments. First, it is important to assess the global picture, looking at IT in the overall economy, over a long period. It is also important to assess how IT might have contributed to changes in specific industries. At a more detailed level, we must understand how IT is used in organizations, how it is transforming them, and how it is managed at the project level. Combining these different perspectives enables a proper assessment of the contribution of information technology to our productivity.

The paper is organized as follows. The first part reviews the relevant research on IT and productivity. Results are organized by levels (country, industry, firm, and project). Results show that IT has the potential to lead to productivity increases. The second part tries to identify the conditions under which IT does have a positive contribution. Among these conditions, we note the required changes that must be implemented along with the new technology. We also pay particular attention to project level actions that members of the governance team can take to increase their chances of a successful project.

Searching for the Link Between Information Technology and Productivity

Country Level

The contribution of IT to productivity was first measured at the level of national economies. Countries produce aggregate statistics that allow the magnitude of this contribution to be assessed globally. Put simply, data from national accounts can be used to obtain total investments in information technology, gross domestic product (GDP), and the number of hours worked in a year. If information technologies increase productivity, then investments in IT should lead to an increase in the ratio of GDP to hours worked¹. Consequently, if information technologies contribute to productivity, they should allow us to produce more output per hour of work.

Encouraging Results

The results of studies on this subject have been mixed—some find that IT increases productivity while others see no correlation. We observe, however, that most of the studies reviewed identify a positive relationship linking information technology with productivity. In fact, some authors maintain that the systematic adoption of new technologies by developed countries in recent decades has yielded major productivity gains. This has resulted in a global increase in societies' wealth (Santos and Sussman, 2000; King, 2007). Thus, in the United States, studies such as those by Saito (2000) and Oliner and Sichel (2005) suggest that almost all the increased productivity of the workforce was attributable to IT investments.

¹ The vast majority of country-level studies use Solow's neoclassical growth model (1957), which estimates total factor productivity (TFP) from a Cobb-Douglas production function. These studies all use aggregate national accounts on investment and productivity (total factor productivity or labour productivity) to generate their estimates.

Similarly, in Canada, investments in IT have been the main source of productivity growth since 1996 (Sharpe, 2006). Khan and Santos (2002), and Armstrong, Harchaoui *et al.* (2002), point out that this contribution to productivity, though modest, is positive (see Table 1).

However, significant regional differences characterize the impact of IT on productivity, suggesting that the socio-economic context has a pronounced influence on IT's effectiveness in increasing productivity.

The IT sector is itself a primary beneficiary of the use of these technologies. It has experienced a significant increase in productivity (Oliner and Sichel, 2005). This increase has helped democratize access to IT with investments that constantly reduce the cost of these technologies while boosting their performance (Soete 2001).

An examination of Table 1 reveals that the contribution of IT to productivity was particularly strong during the period 1995–2000. Most studies² consider IT to be the main source of productivity growth in the second half of the 90s. The accumulation of positive results during the period 1995–2000 eventually gave rise to some assumptions regarding the historical impact of IT. Thus, some authors maintain the existence of two distinct periods, one characterized by a significant and positive impact of IT on productivity (1995–2000); the other being called the period of the paradox (all years prior to 1995).³ Some attribute this discrepancy to a lag in the impact of IT implementation on businesses or to the influence of the Internet, which started up in the early 1990s but truly came into its own in the mid-1990s.

² The only exceptions are those of Khan and Santos (2002) and Armstrong, Harchaoui *et al.* (2002).

³ The article by Van Ark and McGuckin Inklaar (2003) is particularly revealing in this regard.

Table 1
Summary of Empirical Studies at the Country Level

Article	Impact	Data	Conclusions
United States			
Dan Sichel (1997)	+	1970-1993	Contribution of IT to labour productivity: 1987-1993 : 0,25%
Stephen Oliner and Dan Sichel (2000)	+	1991-1999	The acceleration in the growth of the productivity of capital between 1996 and 1999 is almost exclusively attributable to IT.
Jorgenson and Stiroh (1995)	Ø	1947-1992	The acceleration of investment in IT was not accompanied by increased productivity in the U.S. in the period 1973–1992.
Canada			
Khan and Santos (2002)	+	1991-2000	Productivity gains attributable to investments in IT amount to 26% between 1996–2000.
Armstrong, Harchaoui <i>et al.</i> (2002)	+	1981-2000	Contribution of IT to labour productivity: 1981-1988 : 29% 1988-1995 : 33% 1995-2000 : 25%
Sharpe (2006)	+	1980-1995	Investments in IT were the main engine driving the acceleration of productivity growth since 1996 in Canada and the U.S.
Other countries			
Van Ark, Inklaar and McGuckin (2003)	+	1990-2000	Contribution of IT to labour productivity: Canada: 1990-1995 = 45% → 1995-2000 = 71% EU: 1990-1995 = 40% → 1995-2000 = 69% U.S. 1990-1995 = 80% → 1995-2000 = 86%
Cette, Mairesse and Kocoglu (2002)	+	1980-2000	Contribution of IT to labour productivity: France: 1995-2000 = 65%
Oulton and Srinivasan (2005)	Ø	1995-2000	No correlation between investments in IT and productivity growth.

Points of Discord

Despite these many positive results, some authors, such as Oulton and Srinivasan (2005) and Jorgensen and Stiroh (1995), dispute the relationship between IT and productivity at the global level. Indeed, this effect is not always observed, even for post-1995 data. For example, in the UK the disconnect between investments in IT and the productivity growth in the workforce remains an enigma (Oulton and Srinivasan, 2005). In fact, unlike the United States,

There has been productivity growth, but it was much stronger in the period following the Second World War than during the phase of rapid computerization.

despite substantial investment in IT the UK did not experience the anticipated productivity growth in the years 1995–2000.

Even when U.S. data are considered, a more long-term analysis raises concerns. In the United States, the annual growth of total factor productivity (TFP) fell from an average of 1.7% in 1947–1973 to approximately 0.5% between 1973 and 1992, at the same time as investment in IT was expanding rapidly (Jorgenson and Stiroh, 1995). These results show that there has been productivity growth, but that it was much stronger in the period following the Second World War than during the phase of rapid computerization. By way of explanation, Soete (2001) suggests that investment in IT alone is no guarantee of productivity growth and that economic, political and social supports must be favourable and adapted to the implementation of IT.

Others have sought to clear up these contradictions by focussing more specifically on developments within each sector of the economy, thus examining whether contrasting results in different sectors might be obscuring the big picture of the true relationship between IT investment and productivity. It is not unreasonable to suspect that the impact of technology may vary across sectors. The following section presents these results.

Sectorial or Industrial Level

As mentioned previously, it is possible that IT's impact on productivity does not affect all sectors and industries in the same way. Has the construction industry been revolutionized by the advent of the Internet or the Blackberry to the same extent as the information sector (journalism)? Some sectors have been transformed. For example, banking underwent a radical transformation of its business processes leading to marked productivity gains (Huang, 2005). Other industries may have been left behind.

Sectors in Which the Influence Is Positive

To Stiroh (2002), the revolution in information technology has enabled IT-producing industries to experience huge productivity gains, particularly owing to the exponential technological growth in IT capital production. These gains have been disseminated throughout the entire economy, creating incentives and investment opportunities for firms in all sectors and driving the prices of IT and computerized business solutions down sharply. After 1995, this increased access to IT resulted in higher annual productivity growth among industries using IT

intensively than among others (3.16% vs. 2.30%).

In Hu and Quan's (2005) empirical research on eight different industries in the United States, they found a significant positive relationship between IT investment and productivity in six of them. These sectors are characterized by high information intensity (e.g. transportation and manufacturing). The results in Hu and Quan (2005) contain more startling conclusions. They observe a feedback effect from productivity to investments in IT, so that firms investing in IT become more productive, and more productive firms invest more in IT. Finally, these authors conclude that the data suggest diminishing marginal returns to IT capital, which is reminiscent of King's (2007) theory of "low-hanging fruit," according to which the IT that is easiest to implement is already in place and potential future gains from IT will require additional effort put into more advanced IT. This may also explain the recent decline in the contribution of IT to productivity in industrialized countries.

Table 2
Summary of Empirical Studies at the Sectorial Level

Impact	Article	Data	Conclusions
+	Stiroh (2001)	3 sectors between 1987–1999 IT producing industries IT using industries Other	IT-intensive industries experienced a greater acceleration in productivity than others (3.26% vs. 2.30%)
	Hu et Quan (2005)	All non-agricultural industries (8) based on single-digit SIC codes, from 1970 to 1999	Positive contribution of IT to productivity in 6 of the 8 industries studied. Feedback effect of productivity on IT. Decreasing marginal return to IT
	Huang (2005)	Taiwanese banking industry 1996–2003	Substitution IT capital for non-IT capital increases the sector's productivity
±	McKinsey et co. (2002)	59 sectors of the economy	Positive contribution of IT to productivity in 6 of the 59 industries
∅	Berndt and Morrison (1995)	All industries at the second level of aggregation according to SIC codes, 1968–1986	There is no productivity differential between investments in IT and other investment types.

Caveats at the Level of the Industry

Results from other studies at the industry level are much less conclusive. To Berndt and Morrison (1995), investment in IT contributes no more to productivity than any other capital investment. McKinsey et al. (quoted by

Martinson and Martinson, 2002) find that IT investments had a positive and significant effect on only 6 of the 59 sectors of the economy. Close observation shows that these results are not necessarily different from those in Hu and Quan (2005), as some sectors overlap between the two studies, suggesting that the nature of the business appears to be correlated with the impact of IT implementation, particularly for industries with high information intensity. These results suggest that specific factors (other than IT investments) are required for productivity growth. This explanation of conditional growth evokes the suggestions made by Soete (2001).

How to ensure that these conditions are met when investing in IT? The answer to this question lies in the firm's micro level decisions regarding the implementation. The following section presents results from studies at the firm level.

Firm Level

An analysis of investments in IT at the firm level yields a better understanding of how they affect businesses. Though our results do not resolve the paradox of productivity, they are informative with regard to firms' incentives and how they implement these technologies. These studies also raise many questions concerning the measures of productivity used.

Issues in Productivity Measurement and the Impact of IT

Bernacconi, Mention and Rousseau (2007) sound a cautionary note with respect to the standard analysis based on financial indicators, which are often used as a proxy for productivity. The authors assert that, ultimately, the success of an IT project is not merely a financial matter. In fact, too great an emphasis on financial performance often obscures whether or not the original targets associated with IT investments were met. In proposing a new framework for assessing IT investments, the authors fundamentally dispute the validity of many studies that focussed on the creation of value and concluded that IT made no significant contribution to the productivity of the firm.

This conclusion is shared by Arogyaswamy and Sugumaran (2003), and Brynjolfsson and Hitt (2000), who emphasize the importance of measuring intangible (as well as tangible) costs and benefits that are contributed by the implementation of IT. These authors suggest account be taken of complementary effects from the implementation of IT in firms, going beyond mere financial success.

These observations have important implications for research conducted at the more aggregate level (country and industry) that fails to find a direct link between productivity and investment in IT. In particular, goals established to ensure a standard of quality or to restructure communications will not necessarily affect the company's productivity in purely financial terms. Therefore, global studies will not necessarily link IT to aggregate measures of productivity such as domestic TFP⁴ or worker productivity, for example. Although it is true that we must measure the success or failure of an IT project in relation to all its impacts on the company, our first focus should be its impact on the business process it was designed to improve.

Positive Impacts – Paths Toward an Explanation

Studies at the firm level yield a better understanding of the relationship between IT investments and productivity gains. The level of detail made possible by this unit of analysis allows researchers to identify the conditions for profitability of these investments.

Work by Statopoulos Dehning (2000) captures this desire for global analysis and a broader understanding of the relationship between IT and productivity. The authors find that companies that invest in IT and are adept with it tend to perform better financially. Success is contingent on the quality of management of IT projects: "It appears from our results, taken in the light of previous studies, that how you manage your IT assets is more important than how much you spend on IT." This conditionality is the focus of Ko and Osei-Bryson (2006) in their study of the conditions under which IT creates value for the company. They find that investments in IT must be accompanied by investments in physical and human capital if the return is to be maximized. In the same vein, Atzeni and Carboni (2006), mention the firm's commitment to complementary investments in physical capital, ongoing training of the workforce, and in business processes as necessary conditions for the realization of potential benefits associated with IT.

How you manage your IT assets is more important than how much you spend on IT.

⁴ TFP or workforce productivity can be deemed financial measures of productivity, since are computed by dividing output (GDP) by an input.

Table 3
Summary of Several Empirical Studies at the Firm Level

Impact	Article	Data	Conclusions
+	Atzeni and Carboni (2006)	Italian manufacturing firms in 1997	The contribution of IT to growth is much greater than their share in investments.
±	Hempell (2005)	German service companies 1994–1999	Well-managed firms are of intensive IT users
	Mashal (2006)	The biggest bank in Jordan between 1985 and 2004	No significant effect for the base model Significant effect for the model with lagged impact
	Ko and Ossei-Bryson (2006)	Large U.S. firms between 1988 and 1992	Investments in IT have a positive impact on productivity conditional on complementary investments in labour and capital
∅	Ataay (2006)	31 major industrial concerns listed by the Istanbul Chamber of Industry in 2002	No significant correlation between adopting technology and productivity

Warnings Against Simple Associations Between IT and Firm Productivity

Hempell (2005) contributes an important methodological qualification to studies having found a positive link between IT and productivity. It appears, in fact, that well managed companies are intensive users of IT and that, consequently, companies investing in IT are more productive than others. The direction of causality is crucial to the estimation. If productive firms tend to invest more in IT, there is no guarantee that these investments are making them more productive. Consequently, we must review our methodological framework in order to control for this possible bias.

Ataay (2006) finds no link between firms' productivity and investments in IT for industries in Turkey.

A next logical step would be to refocus the level of analysis from the firm to the specific project. Project level studies have sought to shed light on the dynamics between IT investment and productivity by examining specific technologies. Well-designed studies are able to capture the impact of IT on productivity with regard to the specific process targeted. In theory, this lets them control for all other factors that may affect the overall performance of the company. The next section describes these elements.

Project Level

Studies at the project level have sketched an informative portrait of the impact IT has on organizational performance. In particular, the pioneering work of Delone and McLean (1992) provides insight into the dimensions of successful implementation of IT projects and over which paths this can ultimately lead to greater productivity for the company as a whole. Their work also reveals that the implementation of IT projects can result in significant boondoggles that raise doubts concerning the advisability of investing heavily in information technology. It is vital to look more closely at the characteristics of these white elephants.

Risks Associated With an IT Project

Computerization is always a risky activity, and along the way a variety of unforeseen events may crop up leading to undesirable results. An undesirable outcome could be defined as "falling short of a target, where this shortfall has more or less significant consequences for the organization" (Bernard, Rivard, et al.). In the literature we find four principal adverse outcomes associated with technology projects: poor quality of the implemented system, cost overruns, time overruns, and dissatisfied users. It is easy to see that these potential failures can be addressed independently since the occurrence of any of them is not necessarily linked to that of any other. For example, a project that comes in on time and within its budget may very well not meet the specified quality objectives.

These adverse outcomes may impede proposed projects, with effects ranging from delayed project launches to outright cancellation if the managers fail to address these various dangers.

Several rankings have been developed to determine success or failure rates of technological projects. The most quoted is the CHAOS ranking, issued by the consulting firm The Standish Group for over a decade. This ranking is generated from their data bank of approximately 50,000 completed IT projects. The data on completed projects are divided into three categories: success, challenged, and failure. To be categorized as a "success," a project must be completed on time and within budget and meet expectations and targets. If a project exceeds its budget by as little as 1%, it is classified as "challenged" and the same goes for deviations in the other two areas. We observe that a project that is performing quite well can easily fall into the middle category of "challenged."

The methods and data used in the CHAOS study have been challenged, at least in part because their indicators focus only on easily quantifiable aspects such as the budget, timing and scope of the project. CHAOS study rankings may not represent the overall success rate of project implementations all that accurately (Sauer, Gemino, et al., 2007; Gemino, Reich, et al., 2008).

Other performance measures have been developed to more credibly reflect the success rate of project implementations. In their study, Gemino et al. compare the method used by the Standish Group with an alternative approach, developed by Sauer et al., based on classifying projects into groups. Gemino et al. use data from a survey of 412 project managers who subscribe to Computer Weekly, a British magazine for IT Professionals. An algorithm was used to classify data into five groups: stars, strong performers, missed deadlines, budget overruns, and abandoned projects. For purposes of comparison with the Standish Group method, in the following table the categories stars and strong performers are grouped under "success" and the two problematic ones as "challenged."

Table 4
Success Rates According to Different Definitions of Success

Assessment method	Standish 2004	Standish method UK data	Group analysis (Sauer et al.) UK data
Success	29%	17%	68%
Challenged	53%	74%	23%
Failure	18%	9%	9%

Source: (Gemino, Reich, et al. 2008)

Thus, we see that the choice of method and criteria profoundly influence the reported success rate of technology project implementation. Using the same data, differences of 51% are observed in the success rate when we vary the method used to qualify as a "success." This suggests that the method for assessing projects may be as important an issue as their actual success rate. Delone and Mclean (2003) also lean in this direction:

“Despite the multidimensional and contingent nature of IS success, an attempt should be made to reduce significantly the number of measures used to measure IS success so that research results can be compared and findings validated.”

One category that is of particular interest for understanding the role of technology in organizations is that of "failure." Whatever method is used, between 10% and 20% of projects that are launched are never completed. Several factors can cause the failure of a project. Among others, there are: unrealistic goals, incorrect estimates of the required resources, a skills shortage, inadequate control measures, and poor risk management (Bernard, Rivard, et al. 2004; Charette, 2005).

Projects having failed are of interest since they are characterized by a significant investment of resources that do not generate a return. These investments are totally wasteful from the company's perspective. When considering overall investments in IT (in terms of an industry or a country), these uncompleted projects thus offset (at least in part) the benefits generated by the completed projects. It then follows that if many projects are not completed, a study of aggregate results based on the total amount companies spend on IT may be significantly biased. This adds an additional layer of difficulty when seeking to establish a relationship between investment in IT and financial performance or between investments in IT and productivity.

In addition, the Standish Group studies (The Standish Group, 2004) observe a marked decline in the failure rate, from 31% (1994) to 18% (2004). According to Jim Johnson, the Chairman of Standish Group, this decrease could be due to a better understanding of the environment by project managers, substantial advances in the field of project management, and a decline in the size of projects. This reduction in the failure rate might explain why it has been easier to draw conclusions about the link between IT and productivity from more recent data (since 1995) than from data collected before the mid-1990s. If a project is not completed, the expenses associated with this project can never be linked to increased productivity. The more projects are completed, the higher the chances IT investments can lead to productivity increases.

Between 10% and 20% of projects that are launched are never completed.

The Impact of IT Projects on Productivity in Traditional Sectors

Following the recommendations of Delone and McLean (1992), several studies have attempted to standardize the productivity measures used to characterize projects as successes or failures. One course has been to focus on the productivity of individual workers or the productivity of a process taken in isolation. That is what Mukopadhyay, Rajiv and Srinivasan (1997) did when they examined the implementation of a barcode system for the U.S. Postal System (USPS). In this case, the results are very positive and highly significant. The new technology has increased both the quality and quantity of units processed.

These positive results are not found for all processes. For instance, Bartel, Ichniowski and Shaw (2007) find a negative correlation between the degree of computerization and the time required to complete various stages of a production chain (inspection time, setup time, and manufacturing time). They studied companies that manufacture valves. Therefore, the effect of IT on a process can vary.

Investment in IT and Processes Associated With the Knowledge Industry

Previous studies have directly measured the relationship between investments in IT and productivity. These studies focussed on processes of the "assembly line" type. Their results are not necessarily transferable to processes typical of knowledge-based industries, which do, however, occupy an increasingly important role in our economy.

Work by Brynjolfsson, Aral and Van Alstyne (2007) is more reflective of the reality of knowledge-based industries. By studying how the employees of a recruiting firm perform their tasks and projects, the authors seek to shed some light on the process by which IT affects the productivity of white collar workers. Drawing on a longitudinal study, they show that workers who use IT are able to handle more projects at once, thus reducing the time required to complete a project. The increase in productivity involves enriching the social structure of work and provides access to more information more quickly. Since the income workers generate is directly correlated with the number of cases completed, productivity gains in the use of IT by the workers are tantamount to money in the bank. In this situation, the company would do well to invest in training human capital concurrently with its investments in IT (Brynjolfsson, Aral, et al., 2007). This leads us back to Soete's (2001) explanation of the complementary nature of investments in IT and in training human capital, which we discussed earlier.

Workers who use
IT are able to
handle more
projects at once.

In a study of Canadian firms between 1999 and 2004, Dostie and Reyaraman (2008) found that workers who use a computer at their workplace are 38% more productive than those who do not. By focussing on utilization rather than on the investment per se, these results provide a clearer picture of the direct impact of IT in the organizational environment, in both manufacturing and knowledge-based industries. This approach does not yield a cost for productivity-boosting investments.

Connections linking the conduct of IT projects to productivity are not all positive. Some studies have shown that the success of a project is conditional on several factors intrinsic to the firm, including its commitment to change or simply attitudes toward the project (Peslak, 2007; Ashurst, Doherty, et al. 2008).

Table 5
Summary of Several Empirical Studies at the Project Level

Impact	Article	Data	Conclusions
+	Brynjolfsson, Aral and Van Alstyn (2007)	Recruitment firm over 10 months	Significant boost to worker productivity (number of projects completed, income per worker, number of hours per project).
	Mukopadhyay, Rajiv and Srinivasan (1997)	United State Postal Service (USPS) over 3 years in 46 sorting centres	Significant increase in the number of packages sorted
	Bartel, Ichniowski and Shaw (2007)	Valve manufacturing industries between 1997 and 2002	Decrease in the time required to perform certain tasks (manufacturing, inspection, commercialization).
	Dostie and Jayaraman (2008)	Canadian firms, 1999–2004	On average, workers who use computers on their jobs are 38% more productive than those who don't.
±	Ashurt, Dohery and Peppard (2008)	25 IT projects in different sectors	There is no unambiguous evidence that IT projects in and of themselves create value added or increase productivity. These productivity gains are conditional on a commitment by the firm to a benefits-oriented approach rather than to the technology itself.
	Peslak (2007)	Survey of finance company officers	The success of IT projects is highly dependent on the attitude of management during the implementation.

The Limitations of Studies of the Relationship Between Productivity and IT Projects

Enormous difficulties emerge, however, when studying a phenomenon as disaggregated as individual projects. In particular, accounting for the full range of impacts on all the firms' business processes poses a significant challenge. These impacts may take the shape of many different types of negative externalities, such transfers of staff from one division of the firm into another to support the new technologies introduced, or the benefits from implementing the new technology may accrue to certain divisions at the expense of others. Therefore, it is necessary to be able to control for these "spillover effects," or else a project must be chosen that does not impact other corporate functions.

Understanding the contribution of IT to productivity

Information technologies (IT) have had a profound impact throughout the economy. They are now integrated into a majority of production activities. However, as we have seen, it is difficult to establish a clear relationship between investments in IT and companies' financial performance or productivity gains.

Several reasons have been proposed to explain difficulties observing this relationship. One of the first authors to explore this paradox was Brynjolfsson (1993). He classified potential sources of the paradox of investments in information technology into four distinct groups. These four groups are: (1) measurement error, (2) a lag in the return to investments, (3) the existence of a phenomenon of redistribution, and (4) the presence of systematic error in the management of IT. The first three are closely related to the methodological choices made in empirical research. However, methodological problems are not the only explanation for the difficulties understanding the impact of IT on productivity.

Measurement Issues

The first group can be described simply. If a large number of benefits are expected from investments in information technologies but there is no way to quantify them, then their impact cannot be measured. Traditional measures are not suitable for capturing non-traditional sources of value creation like IT. One line of reasoning having been put forward in favour of this argument is that the benefits most commonly associated with IT are precisely those aspects of outputs that are most difficult to quantify, such as increased product variety, quality, speed, and customer services. These difficulties in finding good measures are principally concentrated in the services sector and in evaluating the productivity of white-collar workers. One of the main problems in quantifying the outputs of these sectors is the difficulty in assigning accurate costs to them in

order to obtain reliable coefficients to control for inflation and variations in output quality (Brynjolfsson, 1993). Without these reliable coefficients comparisons between output levels are impossible.

Another problem is that the theory of wages suggests that, if the introduction of information technology increases the quality of working life, workers will find that their wages are cut in proportion. Brynjolfsson (1993) suggests that the modest salary increases received by the clerks might be explained by the increased in their quality of working life. This trade-off cannot be measured by government statistics. This corresponds to our expectations, though it does not allow a robust relationship to be established.

The argument for the presence of measurement error is difficult to prove, especially in the output of white-collar workers. Measurement is much easier in a physical process. For example, Mukhopadhyay et al. (1997) demonstrate a positive link between the use of information technology and quality of work. They examine the impact of using optical character recognition and barcode sorting technologies on mail sorting in the United States Postal Service (USPS). This allows them to measure both output and the amount invested in IT with precision; thus addressing a main criticism of other research in this field. This type of analysis at the project level allows potential measurement errors to be contained. Mukhopadhyay et al. are very cautious regarding the possibility of generalizing their results. They point out that the relationship observed in their study could be biased by the presence of characteristics inherent in their project which may be unobservable in other projects.

The Lag Between Investing and Reaping the Benefits

Some authors talk about the existence of a lag in the return to investments made in information technology. If there is a lag between the time of the IT investments and the appearance of profits, it is quite possible that results observed in the short term will show no positive link between IT investments and financial performance. Conversely, a long-term study might reveal a positive correlation and strong performance. This situation might arise when the new technology imposes a learning curve on the workers or the implementation requires restructuring the company in order to fully benefit from this new technology.

This perception is consistent with the study by Brynjolfsson et al. (1991), who find that a period of two to three years is required before the full impact of IT

Technology
imposes a
learning curve
on the workers.

on the organization is observed. In addition, McAfee (2002) finds that implementing an Enterprise Resource Planning (ERP) system without changing the firm's processes results in a decline in performance in the short term. However, after several months performance rises significantly above the initial level. Therefore, managers who are aware of this lag phenomenon may very well continue to invest as much in information technology, even though non-longitudinal studies show no financial gains from these investments.

The Redistribution of Benefits

A third explanation for the inconclusive results is redistribution. This explanation suggests that IT investments can be profitable for some companies in a sector, but from the perspective of the industry as a whole they are unproductive. This somewhat more pessimistic explanation of the paradox says that information technology "redistributes the pieces of the pie" to the benefit of some firms," without actually increasing its total size." This explanation springs from the observation made by certain economists that, compared to other goods, information is particularly vulnerable to the obtained rents being dissipated among firms (Brynjolfsson, 1993). Thus, rather than arising from the creation of new value, gains from investments in IT come at the expense of other firms on the market.

The Management of IT

The aforementioned explanations mainly address problems encountered by some studies at the methodological level. These last explanations are based on theory that encompasses all aspects of the firm and IT investments.

The first of these explanations is from the theory of required technology stock accumulation developed by Oliner and Sichel (2005). This explanation suggests that even if there has been some spending on information technology in recent years, IT capital stocks are still modest. This could be explained by the fact that companies have only recently decided to invest heavily in IT and that technology stocks tend to become obsolete quickly compared to certain other asset groups. Consequently, it is difficult for these stocks to make a mark on the performance of the firm.

The second, more theoretical explanation, that would explain some part of the productivity paradox of information technology might be the presence of systematic error in the management of IT. This hypothesis can be summarized

as follows: Investments in IT are not productive because the managers who invest in these assets are not pursuing the best interest of their firm. Moreover, a further aspect of this explanation is that IT investments are unproductive if companies do not undertake an organizational transformation in tandem with the investment in IT (Porter and Millar, 1985; Santos and Sussman, 2000; Stratopoulou and Dehning, 2000).

Several authors have evoked this hypothesis to explain the paradox. Dos Santos and Sussman (2000) argue that "The reason for delays in obtaining the benefits is due to management's failure to strategically leverage the full potential of IT and their failure to overcome resistance to change." According to them, the reason why the benefits of IT investments are not transmitted to companies' financial results is that they fail to reorganize their organizational structure and that management is unable to overcome resistance to change. Dos Santos et al. advocate, among other things, that the role of IT be reframed to integrate it into the culture of the organization and that multidisciplinary teams be created to fully capitalize on the benefits of IT and to facilitate the transfer of pertinent knowledge amongst employees.

Superior financial performance will only be achieved by companies who have managed to integrate IT into their processes.

According to Porter and Millar (1985), information technology is the pipeline that links the processes within the organization. In consequence, superior financial performance will only be achieved by companies that have not only completed implementation of IT projects, but who have also managed to integrate IT into their processes. These companies then build a competitive advantage through better control of this technology.

Stratopoulos and Dehning (2000) speculate that the paradox is rooted in the fact that many businesses are ineffectual in their implementation of IT projects. Of the numerous companies that invest in the same technology, only those who manage to integrate IT into business processes will be able to add value to it. Their empirical results therefore support the argument that solid investments in IT lead to superior financial performance. However, this performance boost yields a benefit in the medium term, as it tends to be eroded over time as competitors copy the IT investment and the method of implementation used.

Others highlight the link that may exist between IT and organizational change. This is the backdrop for the study by Gregor et al. (2006) investigating potential relationships between IT and associated organizational changes. Working with a survey of 1050 firms they came to the following conclusions:

"Factor analyses showed organizational transformational benefits were recognized as a separate category of benefit, distinct from informational, strategic and transactional benefits. A single factor solution was also readily interpretable, showing that the four categories of benefit were all components of one overarching factor, IT business value."

Their results also reveal that organizations believe that benefits will increase if they improve the flow of information by using IT. These gains are achieved through quicker and more convenient access to information. According to their analysis, the benefits obtained from these organizational changes are highly correlated with the total value of companies' IT assets. This reinforces the notion that IT investments made in conjunction with organizational changes have a much greater impact on companies' financial performance and productivity than they would on their own.

Finally, the last theoretical explanation is summarized by Ataay (2006) as follows: "From a theoretical viewpoint, researchers have argued that, while IT investments have served to increase firms' productivity and consumer value, they have also lowered entry barriers, eliminated market inefficiencies that enable a firm to maintain monopoly power and intensified market competition, thereby failing to create any lasting return to the investing firm (Bakos, 1991; Hitt and Brynjolfsson, 1996)."

In addition, certain studies, such as Pinsonneault and Rivard (1998), seek to empirically verify these assertions. Their study of 59 managers in 3 companies (a bank, a telecommunications company, and a manufacturing company) suggests that when the firm level is undergoing strategic changes, IT is used to strengthen and support specific roles perceived as critical by management. Moreover, their results show the importance of focussing on work processes (not only on outputs). These concepts lead us to reflect on the foundations underpinning models of organizations on markets.

Comparison of the Studies

As we see in Table 6, although some studies still raise doubts about the contribution of IT to productivity, the empirical literature in recent years has tended to draw a positive conclusion. The paradox of the 1980s appears to have made way for a positive impact of IT on productivity, at all levels of analysis. That is why Kohli and Grover (2008) can assert that we have now gathered sufficient empirical evidence to refute Solow's productivity paradox.

IT investments made in conjunction with organizational changes have a much greater impact on companies' financial performance and productivity than they would on their own.

However, when accumulating empirical evidence to support a general conclusion, one must proceed with caution, since there are significant variations in methodology, data used, and the levels analyzed between the different studies. Some authors even maintain that these methodological differences have such a pervasive impact on the results that they explain the divergent estimates and are even at the root of the famous paradox of productivity (Alpar and Kim, 1991).

These problems of comparison are especially relevant in studies using micro data, which often define productivity and IT investments very differently. Moreover, the success of individual IT projects depends on several factors that are specific to the firm and to the context in which they are implemented, making it even more risky to compare results or to generalize to a general economic theory. Any interpretation of studies at the project or firm level should preferably be treated as a specific instance of the economic intuition underlying the IT-productivity relationship that contributes to an increased understanding of the phenomenon, while studies at the macro level should be seen as attempts to reconcile theory with empirical reality on an aggregate level.

Thus, if we observe that IT allows an employee to perform better, the aggregate data should clearly reveal an increase in productivity attributable to IT investments at the project level. However, if this relationship is ambiguous at the level of the worker, for example because the technology is used poorly, it is reasonable that macro data is also fuzzy. The absence of a definitive consensus at the macro level could thus be primarily due to a misunderstanding at the micro level of the relationship between IT and productivity. We also note that project-level studies can more precisely identify the forces in play.

These conclusions with respect to the contribution of IT to productivity do not solve all problems. At the firm level, we must understand the circumstances that allow the organization to generate productivity gains. IT thus has the potential to contribute—it is up to the firm to make it happen.

Table 6
Summary of Empirical Studies on the Impact IT Has on Productivity

Level	(+)	(Ø)	Conclusions
Project	Brynjolfsson, Aral and Van Alstyne (2007) Mukopadhyay, Rajiv and Srinivasan (1997) Bartel, Ichniowski and Shaw (2007)	Ashurt, Dohery and Peppard Peslak (2007)	Several studies find a significant positive effect. However, others find that the impact is conditional on the attitude of management to the implementation.
Firm	Atzeni and Carboni (2006) Hempell (2005)* Mashal (2006)* Ko and Ossei-Bryson (2006)	Ataay (2006) Carr (2003)	An impact that is significant and positive, but conditional on the nature of the firm and its involvement in the implementation process for the IT.
Industry	Stiroh (2001) Hu and Quan (2005) Huang (2005)	Berndt and Morrison (1995) McKinsey and co.(2002)	At this level we observe a significant impact, especially for sectors in which the industries are intensive in communications, such as transportation.
Country	Sichel (1997) Oliner and Sichel (2000) Khan and Santos (2002) Armstrong, Harchaoui <i>et al.</i> (2002) Sharpe (2006) Van Ark, Inklaar and McGuckin Cette, Mairesse and Kocoglu Lee, Gholami and Tong (2005)	Baily (1986) Roach (1987; 1988) Oulton and Srinivasan (2005) Jorgensen and Stiroh (1995)	As of the 90s empirical research at the country level has mostly found a positive correlation between investment in IT and productivity. However, this effect is not present in all countries examined, and it is strongest in the United States, Canada, and several European countries.

* These studies show a significant link between investment in information technology and productivity, but only provided the organizational structure is conducive to the implementation of IT.

THIRD PART

Can IT Projects Deliver Value at the Firm Level? Conditions for Success

As seen in the first section, measuring the contribution of IT to the productivity of the firm offers challenges. However, most studies now tend to agree that there is a contribution. Over time, the focus of the studies has changed. Where before researchers searched for IT's contribution, now the main goal of studies is to understand how IT can generate the highest value.

Most studies on the contribution of IT projects to a firm's productivity present similar findings regarding the conditionality of the relationship. It is therefore important to highlight the necessary conditions in order to maximize the contribution of new IT investments to productivity or financial performance. These conditions are summarized in the table below.

Table 7
Conditions Such That IT Can Contribute to the Productivity of the Firm

Author(s)	Terms	Implications
Gregor (2006), Peslak (2007)	Returns to IT projects depend on the quality of the planning and the extent to which the project ties in with the firm's mission.	- The project must be accompanied by organizational changes in order to fully take advantage of the investments in IT.
Ko and Ossei-Bryson (2006)	The yield to IT projects is contingent on complementary investments in areas related to IT.	- The investment in IT must account for the firm's other capital projects. - E.g. In training the staff for the new technology.
Stratopoulos (2000)	The yield to IT projects depends on the organizational expertise in using IT and previously acquired IT assets.	- The implementation of new technologies must be coordinated with the technologies that are already present in the firm and pre-existing expertise.
Thomas (2008)	The yield to IT projects requires the elaboration of formally defined and quantifiable criteria of success. These criteria make a better use of resources possible throughout the project.	- The need to define clear and tangible criteria for success. - Ensure rigorous follow-up to rapidly correct for unforeseeable events. - Prior to beginning develop measures to quantify the benefits generated by the project.
Ashurst <i>et al.</i> (2008)	The benefits depend on the commitment and on emphasizing the gains that will follow rather than the technology itself during the development, implementation, and use.	- Establish yield targets before starting the project. - Closely monitor the impacts throughout the implementation of the project.
Markus (2004)	IT projects can deliver high value if project deliverables are combined with organizational change in iterative chunks. Benefits have to be realized, not just planned.	- The 3 key elements of an IT project – the IT team, the change target, and the executive sponsors need to collaborate closely to achieve value through IT projects.

These conditions have vital implications for the organization and must guide the process of implementing IT projects. Aligning technological change with the firm's fundamental mission is a basic premise for successful projects. A global vision for development of the project that accounts for past and complementary investments will promote a balance between new technologies and value creation processes within the firm. However, it is important that various criteria for success be known early in the implementation process and that measures are developed to quantify the benefits and focus the efforts on the objectives of the project.

The conditions under which IT can generate the highest impact can be grouped into four categories. The first one is the conditions that are under the control of the project manager and team, responsible for implementing the technology. The second category encompasses the elements that fall under the responsibility of the managers of the organization. The third group contains the actions that the executives should consider. Finally, the last group encompasses the items that should be addressed by the Board.

Project Manager

The literature on project management is abundant and many of its contribution are now well understood and applied in organizations. The rise in the implementation of project management practices in organizations explains in part the increased success rates, in terms of meeting schedule and budgets, that IT projects are experiencing. Project managers are better trained, better supported and have a recognized career path in many organizations. They have evolved clear processes to identify and manage risk, thereby increasing the probability that value will be delivered.

In recent years, there has also been a change in the understanding of the skills that project managers need to be successful in highly complex, multi-organizational projects (Sauer and Reich, 2009). In addition to technical and organizational skills, there needs to be leadership, negotiation, and general business skills. This change has increased the likelihood that project managers will deliver projects of value to the organization.

A recent international study on the business value of project management (Thomas and Mullaly, 2008) found moderate support for a tangible ROI from project management. However, their surveys and case studies found strong support for the finding that a consistent application of project management

techniques and processes results in improved communication, decision making, and effectiveness within organizations. So, although many organizations do not measure ROI from their project management activities, none would abandon them.

Apart from the rise in awareness and implementation of project management principles, many organizations are taking a further step in order to derive value from IT projects. Many are creating a unit called the IT Project Office. These units offer methodologies, quality control, education, and intervention when required. Project management offices also advocate the elaboration of clear goals and performance reporting. They attempt to balance the tensions between change, as embodied in IT projects, and the steady-state operations of the organization.

Organizational Managers

When implementing information technology, users have to be fully involved, especially if the project is expected to change the processes, skills, or structures of business units. Activities and assignments performed by users reflect overall leadership or accountability for the project. Hands-on specific design and implementation tasks will increase the likelihood that users will ensure that the system design fits their reality and that they will be committed to a successful implementation. This is an especially challenging aspect when implementing very large systems. The large number of users forces the project teams to be more creative in finding ways to generate user participation.

When dealing with the user community, change management is an important item of project management. A sense of urgency has to be created in the organization. A rationale for change is provided and project teams ensure that people are involved early on in the project. The messages, measures, management behaviour, and rewards are organized to match the change initiative. Ideally, change leaders help people make sense of change in relation to their day-to-day lives.

One thing that emerges from the literature is that technology can be seen as a necessary but not a sufficient condition for increased productivity. Studies have shown that when technology was implemented without corresponding organizational changes, only limited benefits were achieved. The full range of benefits was obtained when complementary investments (and change) were conducted in parallel with the development of the technology. In these cases

companies can align technology with their strategy and realize benefits (Aubert and Bourdeau, 2007).

In order to achieve expected benefits, managers have their responsibilities, just like project managers have theirs. Managers have to design and actively manage the required organizational changes in order to capture the benefits of the technology. They also need to make the complementary investments in human capital to be able to take advantage of the IT assets. Finally, managers should focus on the links between investment, use and impact, not simply between investment and impact. These elements will be detailed in the next paragraphs.

Ko and Osei-Bryson (2006) insist that the IT investment has to take into account other investments of the firm. This is also mentioned by Stratopoulos (2000). For managers, looking at IT as an asset requiring complementary investments is very important. For too long IT was seen as a tool that had to be deployed and used by the employees. In order to use it, the employees simply needed training on how to use the technology.

Managers should:

- o Conduct process transformation projects in parallel with the IT project, not waiting until the IT artefact is implemented (Markus 2004).
- o Map externalities (positive and negative) on their business – understand spill-over effects. IT often generates unplanned consequences, outside the project boundaries. These effects can distort the incentives to invest in IT (for example when a technology shifts costs from one department to another. The department reducing its costs will have an incentive to pursue the project, even if it is not desirable for the organization).
- o Assess the business risks (not the IT project risks) associated with the business transformation
- o Adjust their incentives and reporting tools with the new business rules and processes
- o Be the person responsible for the productivity gains (because they are associated with business change). IT cannot be responsible. IT is providing assets. Management uses the assets.

This is a tall order, but it is not enough. Very often, there are “unintended consequences” of IT projects. These are outcomes that have not been envisaged

Managers should focus on the links between investment, use and impact, not simply between investment and impact.

or planned for. If they are positive, managers should be ready to enhance, extend, or alter the project to capture new benefits. If they are negative, managers need to provide the leadership to work through the issues, while keeping an eye on the end game. For example, knowing that implementation usually leads to initial productivity declines allows a manager to be calm during the frantic implementation period. The more experience a manager has with IT projects, the better he or she is at providing this critical leadership. Training in project management is a good investment.

Implications for Executives

Executives approve the large projects. They ensure that these projects fit into the overall strategic initiatives and they act in the role of sponsor for individual projects. Sponsors are thought to be the most important element in project success; it is generally recognized that a high level of business-line participation and cooperation is important for project success.

More and more organizations are building comprehensive business cases when thinking about IT projects. These business cases should lay out clearly the benefits envisioned. Moreover, a causal chain linking the IT artifact with the expected business outcome should be developed and monitored throughout the project. As changes occur in the technology, organizational or strategic domains, the link between project and business value can be checked and re-checked. This visualization and monitoring of benefits realization has to be systematic.

During the project, executives as sponsors will provide resources and “cover” from political interference and persuade their peers to support the project. When the project is implemented, executives must be responsible for obtaining the business value from projects. Often the project can be successful from a time and budget perspective and the organization may redesign processes and structures to implement the technology, but there still are no measurable benefits. A classic case is the ‘saving time’ objective – is the time reinvested or wasted? Another example is an increase in quality without a commensurate increase in sales or revenue. Executives need to establish a clear “line of sight” between investment and value, taking into account the costs of implementation. They should make this causal chain visible and help the organization monitor it as the project proceeds.

Executives, in their role as sponsors or steering committee members, have another key role and that is one of boundary spanner. Because they interact with

Executives need
to establish a clear
“line of sight”
between
investment and
value.

the Board, and with key suppliers, customers, competitors and regulators, they are in a unique position to provide early warning to the project of impending changes. Often we see projects derailed by a merger, a new product implementation, or a restructuring within the company. Sometimes, cancelling the project is the prudent decision; in other cases a change in direction or in scope is called for. In any event, early warning of these changes can stop the waste of resources, both monetary and human.

Implications for Boards

Board members approve the large projects and track key activities in the company. When significant IT investments are made, boards have a responsibility that goes beyond approving the business case.

They should assess:

- o If ongoing IT investments are critical to organizational success, does the Board have the knowledge to provide oversight? Is there a lead director for IT (as there is for legal, audit, investment, supplier or customer issues)?
- o Is the company positioned to be successful with this investment? If the company has a poor track record with organizational change and IT projects, what new mechanisms will be in place to ensure success? One example might be a Project Office or consulting support.
- o What are the key indicators that the Board can track to ensure that the project is progressing satisfactorily? These indicators should not be limited to budget and schedule; they should include the complementary changes that will be made within the organization.
 - Ask for a regular report (a form of score card) to monitor these indicators
- o How does the investment fit with current and past investments; how does it open up new ventures, new possibilities
- o The major risks of the project – destabilization of operations, escalation.
 - Ensure that appropriate risk management practices are in place for both the IT project and the business transformation project.

Boards have a responsibility that goes beyond approving the business case.

CONCLUSION

This paper examined the contribution of IT to productivity. Results show that this relationship is neither linear nor simple.

At the national level, many studies found a link between IT investments and productivity. However, several puzzles remain. First, it is not clear that IT represents a more productive investment than other assets. Second, the irregular relationship between IT investments and productivity gains, for example the apparent disconnect between IT investments and productivity in the UK, while similar investments in the USA were fruitful, remains to be explained. The contribution of IT to productivity seemed stronger in specific sectors. The sectors benefiting from gains were mostly high information intensity sectors, such as financial services and retail.

When assessing the impact of IT at the firm level, some explanations emerged. First, the variety of goals behind IT implementation might explain the variety of results. Second, it appears that some firms are clearly better than others at extracting benefits from their IT investments. IT is not a silver bullet. It entails risks and requires specific skill sets in order to generate benefits. The gap between failed projects, which result in losses of investment, opportunity and confidence, and successful projects, which contribute significantly to organizational success and build momentum, is very great.

The investigation of research at the project level shows some of the obstacles between IT investments and increased productivity. First, projects have to be brought to completion in order to generate gains. This is a first hurdle. Second, results suggest that complementary investments made in parallel with the IT investments are required for IT to generate substantial benefits. These investments in training, business reorganization, and new knowledge are necessary to enable the firm to take advantage of the technology.

These elements suggest several lessons for managers. IT managers need to continually improve their management skills; beyond the management of technology towards the management of the business. Various organizational innovations introduced in the last decade, such as project offices or project control methodologies offer support for these managers and increase the chances that IT projects reach completion. Business managers have significant responsibilities. They have to undertake change projects to allow the profitable insertion of IT within their organizations. They also have to assess the ramifications that the changes might have in the organization. The business managers are the ones responsible for the complementary investments that can enable productivity gains from information technology. IT managers can only provide the assets, business managers have to use these assets to generate the gains.

At the executive level, the analysis underlines several responsibilities that are essential for IT investments to succeed. Executives have to assess the overall situation and ensure that resources freed by the introduction of technology are reallocated profitably for the organization. They are the ultimate architect for the business changes introduced in the organization. They have to ensure that the configuration of assets (IT being only one type) will be appropriate to ensure the future of the organization.

Boards also have a responsibility with the strategic investments in IT. They review the business case for large investments. However, they also have to monitor the complementary investments. Boards have to ask for the appropriate indicators and scorecards to track how effectively IT investments are used. They also have to ensure that appropriate risk management practices are in place in the organization.

In conclusion, IT can have a substantial contribution to productivity. However, for IT to generate significant benefits, it has to be well understood and well managed. IT can generate benefits when it is implemented along with additional investments, mostly in the form of knowledge and business reorganization. The absence of these investments in many instances might explain the unsteady contribution of IT to productivity observed in different studies. In order to extract these benefits, IT and business managers, as well as the executives of the organization, have to coordinate their actions.

References

- Alpar, P. and M. Kim (1991). "A microeconomic approach to the measurement of information technology value." Journal of Management Information Systems 7(2): 55-69.
- Ark, B. V., R. Inklaar, et al. (2003). "The Contribution of ICT-Producing and ICT-Using Industries to Productivity Growth: A Comparison of Canada, Europe and the United States." International Productivity Monitor 6: 56-63.
- Armstrong, P., T. Harchaoui, et al. (2002). "A Comparison of Canada-U.S. Economic Growth in the Information Age, 1981-2000: The Importance of Investment in Information and communication Technologies." Statistics Canada, Analytical Studies Branch Research Paper Series 11F0027MIE(No. 001).
- Ashurst, C., N. F. Doherty, et al. (2008). "Improving the impact of IT development projects: the benefits realization capability model." European Journal of Information Systems 2008(17): 352-370.
- Ataay, A. (2006). "Information Technology Business Value : Effects of IT usage on labor Productivity." Journal of American Academy of Business 9(2).
- Atzeni, G. E. and O. A. Carboni (2006). "ICT productivity and firm propensity to innovate investment : Evidence from Italian microdata." Information Economics and Policy 18.
- Aubert, B. and S. Bourdeau (2007). Alignment and IT Project Value Maximization, PACIS, Auckland NZ, 4-7 July, 8 pages.
- Baily, M. N. (1986). "What Has Happened to Productivity Growth?" Science 234: 443-451.
- Bartel, A., C. Ichniowski, et al. (2007). "How does Information technology affect productivity? Plant-level comparisons of product innovation, process improvement, and worker skills." The quarterly journal of Economics 122(4).
- Bernard, J.-G., S. Rivard, et al. (2004). "L'exposition au risque d'implantation d'ERP: Éléments de mesure et atténuation." Systèmes d'Information et Management 9(2).
- Berndt, R. E. and C. J. Morrison (1995). "High-tech capital formation and economic performance in U.S. manufacturing industries : An exploratory analysis." Journal of Econometrics 65.
- Brynjolfsson, E. (1993). "The Productivity Paradox of Information Technology." Communication of the ACM 36(12).
- Brynjolfsson, E., S. Aral, et al. (2007). "Information, Technology and Information Worker Productivity : Task level Evidence." NBER Working paper No. w13172.
- Brynjolfsson, E. and L. M. Hitt (2000). "Beyond Computation : Information technology, organizational transformation and Business performance." The journal of Economics Perspectives 14(4).
- Brynjolfsson, E., T. Malone, et al. (1991). "Does Information Technology Lead to Smaller Firms?" MIT Center for Coordination Science: Working Paper Series 123.
- Carr, N. G. (2003). "IT doesn't Matter." HBR at large.
- Cette, G., J. Mairesse, et al. (2002). "Diffusion of ICT's and Growth of the French Economy over the Long-term, 1980-2000." International Productivity Monitor 4.
- Charette, R. N. (2005). "Why Software fails." IEEE Spectrum.
- DeLone, W. H. and E. R. McLean (1992). "Information Systems Success: The Questfor theDependent Variable." Information Systems research 3(1): 60-95.
- DeLone, W. H. and E. R. McLean (2003). "The DeLone and McLean Model of Information Systems Success: A Ten-Year Update." Journal of Management Information Systems 19(4): 9-30.

- Dostie, B. and R. Jayaraman (2008). "Organizational Redesign, Information Technologies and Workplace Productivity." IZA - Discussion paper series **3612**.
- Gemino, A., B. H. Reich, et al. (2008). "**Examining IT Project Performance.**" ASAC Proceedings IS Division, Halifax 29(1) May 24-27.
- Gregor, S., M. Martin, et al. (2006). "The transformational dimension in the realization of business value from information technology." Journal of Strategic Information Systems **15**(2006): 249-270.
- Hempell, T. (2005). "What's spurious, what's real? Measuring the productivity impacts of ICT at the firm-level." Empirical economics **30**.
- Hu, Q. and J. Quan (2005). "Evaluating the impact of IT investments on productivity: a causal analysis at industry level." International Journal of Information Management **25**.
- Huang, T.-H. (2005). "A Study on the Productivities of IT Capital and Computer Labor: Firm-level Evidence from Taiwan's Banking Industry." Journal of Productivity analysis **24**.
- Jorgenson, D. W. and K. Stiroh (1995). "Computers and Growth." Economics of Innovation and New Technology **3**: 295-316.
- Khan, H. and M. Santos (2002). "Contribution of ICT use to output and labour productivity growth in Canada." Bank of Canada Working Paper No 2002-7.
- King, W. R. (2007). "IT Strategy and Innovation : Productivity and IS." Information Systems Management **24**(3).
- Ko, M. and K.-M. Osei-Bryson (2006). "Analyzing the impact of information technology investments using regression and data mining techniques." Journal of Enterprise Information Management **19**(4).
- Lee, S.-Y. T., R. Gholami, et al. (2005). "Time series analysis in the assessment of ICT impact at the aggregate level – lessons and implications for the new economy." Information & Management(2005): 1009.
- Markus, M.L., "Technochange management: using IT to drive organizational change", Journal of Information Technology (2004) 19, 4–20.
- Martinsons, M. and V. Martinsons (2002). "Rethinking the value of IT, Again." Communication of the ACM **45**.
- Mashal, A. (2006). "Impact of Information Technology Investment on productivity and profitability : The case of a leading Jordanian Bank." Journal of information technology Case and Application Research **8**(4).
- McAfee, A. (2002). "The impact of enterprise technology adoption on operational performance: An empirical investigation." Production and Operations Management Journal **11**(1): 33-53.
- McKinsey and Co. (2002). U.S. Productivity Report. 1995-2000.
- Mention, A.-L., A. Rousseau, et al. (2007). "Performance et technologies de l'information : proposition d'un cadre d'analyse multidimensionnel." Centre de Recherche Public Henri Tudor.
- Mukhopadhyay, T., S. Rajiv, et al. (1997). "Information Technology Impact on Process output and quality." Management Science **43**(12).
- Oliner, S. and D. Sichel (2000). "The resurgence of growth in the late 1990s: is information technology the story?" Journal of Economic Perspectives **14**(4).
- Oliner, S. D. and D. E. Sichel (2005). "Les technologies de l'information et la productivité : Situation Actuelle." L'Actualité économique **81**(1-2).
- Oulton, N. and S. Srinivasan (2005). "Productivity growth in UK industries, 1970–2000 : Structural change and the role of ICT." Bank of England, Quarterly Bulletin **45**(2).
- Peslak, A. R. (2007). "Organizational information systems : Rate of return and influencing variables as viewed by top financial executives." Industrial Management & Data Systems **108**(1): 43-59.

- Porter, M. E. and V. E. Millar (1985). "How information gives you competitive advantage." Harvard Business Review.
- Roach, S. S. (1987). America's Technology Dilemma: A Profile of the Information Economy. Morgan Stanley Special Economic Study.
- Roach, S. S. (1988). White-Collar Productivity: A Glimmer of Hope? New York Special Economic Study (unpublished memorandum). M. Stanley.
- Saito, Y. (2000). "Increased Labor productivity and IT Investment in the United States." International Department Working Paper Series 00-E-1.
- Santos, B. D. and L. Sussman (2000). "Improving the return on IT investment : the productivity paradox." International journal of information management 20.
- Sauer, C., A. Gemino, et al. (2007). "IT Project Performance: The Impact of Size and Volatility." Communications of the ACM 50(10): 79-84.
- Sharpe, A. (2006). "The Relationship between ICT Investment and Productivity in the Canadian Economy: A Review of the Evidence." CSLS Research Report 2006(5).
- Sichel, D. (1997). The Computer Revolution: an Economic Perspective. Washington, DC.
- Soete, L. (2001). "ICT, Knowledge work and employment : The challenges to Europe." International Labour Review 140(2).
- Stiroh, K. J. (2001). "Investing in information technology : Productivity payoffs for U.S. Industries." Current Issues in Economics and Finance 7(6).
- Stiroh, K. J. (2002). "Information technology and the U.S. Productivity revival : A review of the evidence " Business Economics 37(1).
- Stratopoulou, T. and B. Dehning (2000). "Does Successful investment in information technology solve the productivity paradox?" Information and Management 38.
- Sugumaran, V. and B. Arogyaswamy (2003). "Measuring IT performance : "Contingency" Variables and Value Modes." The Journal of Computer Information Systems 44(2).
- The Standish Group. (2004). "Standish: Project Success Rates Improved Over 10 Years." from <http://www.softwaremag.com/L.cfm?doc=newsletter/2004-01-15/Standish>.
- Thomas, J., Mullaly, M. (2008). Researching the Value of Project Management. Newtown, Pennsylvania: PMI Publishing
- Sauer, C. and B.H. Reich (2009). "Rethinking IT Project Management: Evidence of a New Mindset and Its Implications", International Journal of Project Management, 27, 182-193.

Some of the most recent

Burgundy Reports published by CIRANO

A Banker's Perspective on the Financial Crisis

Robert Amzallag, Michel Magnan, Bryan Campbell, January 2009

Are We Making a Dragon Out of a Dragonfly? Understanding China's Role in Global Production Networks

Ari Van Assche, January 2009

Experimental Economics: A Revolution in Understanding Behaviour

Jim Engle-Warnick, Sonia Laszlo, April 2008

When and Why Does it Pay to be Green?

Paul Lanoie, Stefan Ambec, Iain Scott, November 2007

Des billets verts pour des entreprises vertes?

Paul Lanoie, Stefan Ambec, Iain Scott, November 2007

Le Québec et les droits de scolarité universitaire

Robert Lacroix, Michel Trahan, February 2007

Les nanotechnologies: bénéfiques et risques potentiels

Bernard Sinclair-Desgagné, Dina Feigenbaum, Albert Nsamirizi, May 2006

Les terrains contaminés au Québec : quels sont les risques pour les prêteurs?

Sophie Lavallée, May 2006

Pour un financement durable de la santé au Québec

Claude Montmarquette, Joanne Castonguay, Virginie Giroux, December 2005

L'utilisation des nouvelles technologies par les consommateurs et les détaillants canadiens

Jacques Nantel, December 2005

La problématique de la dette publique au Québec : causes, conséquences, solutions

Marcelin Joanis et Claude Montmarquette, September 2005

The site www.cirano.qc.ca provides online access to all of these publications



2020, University street, suite 2500, Montréal (Québec) H3A 2A5

Tel.: 514-985-4000 • Fax : 514-985-4039

www.cirano.qc.ca • info@cirano.qc.ca