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The Effect of Organizational Innovation and Information Technology on Firm Performance

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Preface

This paper examines the issue of whether investment in information and communication technologies (ICT), combined with organizational changes and worker skills contribute to better performance in Canadian firms. We find that Canadian firms have actively engaged in organizational changes in the areas of production and efficiency practices, human resource management (HRM) practices, and product/service quality-related practices. These practices along with ICT use are found to be related to better firm performance. We find that while ICT is productive on its own, it is more productive in firms that combine high levels of ICT with high levels of organizational change. The firms that combine ICT with organizational changes have a high incidence of productivity improvement as well as high rates of innovation. These findings suggest that to be successful, firms typically need to adopt ICT as part of a "system" or "cluster" of mutually-reinforcing organizational approaches. We also find that ICT and human capital are complements in the services sector. The firms that combine high levels of ICT and high levels of worker skills have better firm performance.

Keywords: Information technology, innovation, organizational change, productivity.

JEL Code: J24, L20, O30

Executive summary

Canadian businesses have invested heavily in information and communication technologies (ICT). Growth in ICT capital services was much faster than non-ICT capital services in the Canadian business sector after the mid-1990s. During the same period, Canadian businesses have undergone substantial organizational change in the areas of production, human resource management (HRM), and product/service quality-related practices. This paper examines the contribution of ICT and organizational change to firm performance in Canada.

Previous studies, at the sectoral level, show that ICT investment has contributed to strong labour productivity growth in Canada after the mid-1990s. Moreover, industries that have invested heavily in ICT, for example retail trade, finance, and communication services, have experienced more rapid productivity growth. Rapid technological progress in ICT-producing industries has also contributed to strong productivity growth in Canada after the mid-1990s.

Studies at the firm and plant level find strong evidence that the use of ICT is linked to the performance of Canadian manufacturing plants. Plants that use advanced technologies have faster productivity growth and superior productivity growth performance is then reflected in market-share gains. Amongst the advanced technologies examined, communication technologies are associated with the best performance. More important, these studies conclude that firm performance depends on how these technologies are implemented. Successful implementation of these technologies requires a human resource strategy to develop the necessary worker skills. It requires that firms overcome financing problems associated with acquiring new and untried technologies. And, it requires innovation accompanied by the development of best practices in quality control and engineering.

The objective of this paper is to examine whether ICT and organizational innovation is associated with better firm performance in Canada. The paper extends previous studies to include firms in both the manufacturing and services sectors. While most ICT investment is made in the services sector, there is little previous evidence on the contribution of ICT to the performance of firms in the services sector.

The paper asks a number of questions.

Has ICT contributed to better firm performance in the manufacturing sector?

The results in the paper show that ICT is linked to better business performance in the manufacturing sector. The manufacturing firms with higher ICT share of total investment in machinery and equipment are more likely to report improved productivity performance. They are also more innovative and are more likely to introduce product and process innovations.

Do firms in the services sector benefit from ICT?

The analysis in the paper shows that firms in the services sector have also gained from ICT. The share of workers using computers is found to be linked to better productivity performance among the firms in the services sector. ICT is also found to be linked to higher innovation in the services sector.

Do organizational changes enhance the benefits of ICT in Canadian business?

The paper finds that while ICT is productive on its own, it is more productive in firms that combine high levels of ICT with high levels of organizational change. The firms that combine ICT with organizational change have better productivity performance and have higher rates of innovation. These findings suggest that to be successful, firms typically need to adopt ICT as part of a "system" or "cluster" of mutually-reinforcing organizational approaches. The evidence also shows that ICT and human capital are complements in the services sector. The firms that combine high levels of ICT and high levels of worker skills have better firm performance.

The interaction between ICT and organizational innovation is found to be different between industrial sectors. While production and efficiency practices and human resource management practices are linked to better firm performance for both manufacturing and services sectors, the role of product/service quality-related strategies differs between the two sectors. The evidence in the paper shows that product/service quality-related strategies are related to better performance only among firms in the dynamic services sector (including communication services; finance, insurance and real estate; business services; education and health; and information and cultural industries). These findings suggest that the dynamic services firms in Canada are enjoying the benefits of ICT. ICT has contributed to better performance of those firms as ICT has enabled them to improve product quality, especially customer service, timeliness and convenience.

Chapter 1. Introduction

"Information technology is best described not as a traditional capital investment, but as a "general purpose technology" (Bresnahan and Trajtenberg, 1995). In most cases, the economic contributions of general purpose technologies are substantially larger than would be predicted by simply multiplying the quantity of capital investment devoted to them by a normal rate of return. Instead, such technologies are economically beneficial mostly because they facilitate complementary innovations".

(Brynjolfsson and Hitt, 2000, p. 24)

Do computers contribute to productivity growth? Most of the *aggregate-leve*l evidence shows that investment in information and communication technologies (ICT) is making an important contribution to economic growth and labour productivity growth across OECD countries (OECD, 2000; Oliner and Sichel, 2000; Council of Economic Advisors, 2000; Jorgenson and Stiroh, 2000). These studies found that technological progress, particularly the rapid advances in semiconductor technology, and capital deepening are the primary factors behind the acceleration in the U.S. growth in recent years (Jorgenson and Stiroh, 2000).[1]

Harchaoui et al. (2002) describe the similarities between Canada and the United States in the late 1990s. Like the United States, Canada experienced dramatic increases in both GDP growth and multifactor productivity growth in the period post 1995. As in the United States, ICT growth was the largest contributor to the growth in capital services in Canada. Subsequent studies confirm that Canada shows trends similar to those in the United States, but in somewhat attenuated form. (Harchaoui et al., 2003; Rao et al., 2003; Gu and Wang, 2003).

A recent paper by Jorgenson, Ho and Stiroh (2002) generates new *industry-level* data to examine the sources of the U.S. economic resurgence after 1995. The results show that during the past decade, productivity growth in the U.S. economy revived modestly during the period 1990-1995 and accelerated sharply after 1995. A substantial portion of this increase is due to ICT-producing industries, although some ICT-using industries also made modest contributions. Recent work at the OECD finds that services sectors have made significant contributions to productivity growth in many OECD countries. For example, productivity gains in the distribution sector have been relatively rapid over the past decade (OECD, 2000).

There have been a few Canadian studies that explore the relationship between ICT and productivity growth at industry level. Rao and Tang (2001) find that Canadian ICT-producing industries experienced rapid productivity growth in the 1990s. But the contribution from this source to aggregate productivity was significantly smaller in Canada than in the U.S., as the ICT-producing sector in Canada is much smaller and its productivity grew at a significantly slower pace relative to that in the United States. Similarly, a study by Gu and Ho (2000) attribute much of the Canada–U.S. manufacturing productivity gap to the performance of two sectors, machinery and electronic products, both of which are important producers of ICT products. And, a study by Gera, Gu and Lee (1999) found that ICT investments and international R&D spillovers from the ICT sector are an important source of labour productivity growth across Canadian industries.

Over the last decade, there are many *firm-level* studies in the U.S. examining the relationship between ICT investment and firm performance. The evidence is mixed.[2] Studies using the 1980s data found no evidence that computers contributed positively to output growth (see, for example, Loveman, 1994; and Barua et al., 1995). In contrast, studies such as Brynjolfsson and Hitt (1995, 1996) and Lichtenberg (1995) employing more recent data over the 1988-1992 period have found a positive relationship between ICT investment and labour productivity.

A recent study by Brynjolfsson and Hitt (1998) explores the relationship between computers and *productivity growth*. The study uses data that included more than 600 large U.S. firms over the period 1987 to 1994. The findings show that computers make a positive contribution to output growth. More interestingly, the study concludes that, "as a general purpose technology, the pattern of growth contribution appears to suggest that computers are a part of a larger system of technological and organizational changes that increased productivity over time."

Many studies have focused on the services sector firms and have examined the relationship between ICT and firm performance (for a review of the literature, see Brynjolfsson and Hitt, 2000). While the evidence from these studies seems to be mixed, Brynjolfsson and Hitt (1995) report an important result. They find the contribution of ICT to output growth is as high in the services sector as in the manufacturing sector.

A number of Canadian studies find strong evidence of a link between the use of ICT technologies and performance of plants. Baldwin, Diverty and Sabourin (1995), Baldwin and Sabourin (2002) and Baldwin, Sabourin and Smith (2003) link technology surveys to longitudinal data on the performance of manufacturing plants. They find that plants that use advanced technologies are more likely to experience productivity growth and that the superior productivity growth is then reflected in market share gains. Amongst the advanced technologies examined, communication technologies is associated with the best performance. But they also point out that it is not ICT use alone that matters. Plants that combine ICT use with other advanced technologies tend to do better than those using only one or two isolated technologies.

This study also points out that the various measures of performance are related. Plants that adopt more advanced technologies experience faster productivity growth. Those that experience faster productivity growth gain market share. Thus, advanced technology use is positively related to both measures of performance. Finally, the paper observes that there are various business practices that involve considerable organizational change that have an independent effect on market share growth. Plants that make use of cross-functional design teams, concurrent engineering, total quality management, just-in-time inventory control, process simulation, and quality function deployment all experienced market-share growth. Organizational change matters.

Baldwin and Sabourin (2002) raise an important caveat that must be kept in mind when interpreting the results of these studies. They argue that simply purchasing advanced technologies does not necessarily lead to success. Firm performance critically depends on how these technologies are implemented. Successful implementation of these technologies requires a human resource strategy to develop the necessary worker skills. It requires that firms overcome financing problems associated with acquiring new and untried technologies. And, it requires innovation accompanied by the development of best practices in quality control and engineering. They raise this issue because of the findings that emerge from a number of associated studies that do not just examine the technological stance of a firm. A large number of firm-level studies in Canada have linked surveys on the emphasis given to business strategies to longitudinal data on firm performance (e.g., Baldwin and Johnson, 1995-1998). These studies find that the firms with comprehensive innovation strategies tend to be the most successful, outperforming firms that only have individual strategies in terms of their growth in market share and profitability. But in these surveys, the innovator is always a complete firm. Marketing, financing, management and innovation strategies are all well developed within those most successful firms.

A recent study by Baldwin, Sabourin and Smith (2003), that links technology use to plant performance in the food processing sector, also finds that plants that were using new computer-driven advanced technologies experienced greater growth in labour productivity and market share during the period 1988 to 1997—but, more importantly for this paper, that the use of advanced technologies is associated with the adoption of business practices associated with improving product quality (continuous quality improvement), material management (materials requirement planning, just-in-time inventory control) and various process/product development practices (rapid prototyping, concurrent engineering). Technology use is not conducted in isolation of other best practices in a firm.

Perhaps equally important for our purposes, Baldwin, Sabourin and Smith (2003) find that a plant's performance is not related just to its technological stance, but to other areas of competencies. In particular, plants that gave greater emphasis both to the use of advanced technologies but also to human-resource strategies, such as training, experience superior productivity gains. Organizations that continuously improve quality, train workers and recruit skilled workers do better than others.

In a similar vein, the OECD (2002) argues that ICT improves productivity by enabling "organisational innovation." The greatest benefits from ICT appear to be realised when ICT investment is combined with other organisational assets, such as new strategies, new business processes, new organisational structures and better worker skills. It is this issue that we explore in this paper.

Empirical evidence suggests that organizational changes may improve economic performance of firms through their mutually-reinforcing relationship with ICT. The OECD (2002) argues that ICT is key to facilitating new organisational approaches, from lean production, to teamwork, to customer relations. ICT enable firms to introduce significant organisational changes in the areas of re-engineering, decentralisation, flexible work arrangements and outsourcing. It allows firms to produce with greater flexibility and with shortened product cycles to satisfy shifting consumer preferences. In fact, organisational innovation and ICT may be regarded as complementary factors. To be successful, firms typically need to adopt ICT as part of a "system" or "cluster" of mutually reinforcing organizational approaches (Milgrom and Roberts, 1990).

Some studies argue that an explanation for the so-called "productivity paradox" (i.e., Robert Solow's observation that "you can see the computer age everywhere but in the productivity statistics") can be attributed to an insufficient response of organizational changes to adapt to changing business environment, to make better use of knowledge, technology and human resources, to respond to new demands from suppliers and customers, and to use ICT effectively (OECD, 2002; Sharpe, 1999). Other studies argue that the extent of firm-level organizational change may be the difference between "old" and "new economy" (OECD, 2002).

In this paper, we examine the issue of whether ICT combined with organizational innovations such as the restructuring of production processes, human resource management (HRM) practices, and better worker skills contribute to better firm performance.

1.1 Literature review: The link between ICT, organizational changes and firm performance

At the firm level, many empirical studies find that organizational changes are related to better firm performance. More important, these studies find that ICT has a positive impact on firm performance when combined with new organizational practices (Table 1). Some notable studies include, Bresnahan, Brynjolfsson and Hitt (2002)[3]; and Black and Lynch (2000, 2001).

Black and Lynch (2000) find a positive and significant relationship between the proportion of non-managers using computers and the productivity of establishments. The findings also show that firms that reengineer their workplace to incorporate more high performance practices are more productive. Profit sharing and/or stock options are also associated with improved productivity performance. And, employee voice has a larger positive effect on productivity when it is done in the context of unionized establishments.

Table 1. Selected firm-level studies on the impact of ICT and organizational change on firm performance

Study	Sample	Issues	Main findings
Lichtenberg (1995)	U.S. firms, 1989-1991	Output contribution of capital and labour deployed in information systems	One information systems employee can be substituted for six non-information systems employees without affecting output.
Hitt and Brynjolfsson (1997); Brynjolfsson and Hitt (1997)	More than 600 large U.S. firms, 1987-1994	The impact of ICT adoption and organizational decentralization on productivity	Firms that both adopt ICT and organizational decentralization are, on average, 5 percent more productive than those that adopt only one of these.
Black and Lynch (2000 and 2001)	U.S. firms, 1987-1993, and 1993-1996	The impact of work practices, ICT and human capital on productivity	The adoption of certain newer work practices, higher educational levels, and the use of computers by production workers have a positive impact on plant productivity.
Brynjolfsson and Yang (1997)	Fortune 1000 U.S. firms, 1987-1994	The impact of ICT and intangible assets on firm performance	The market value of $US 1 of ICT capital is the same as that of $US 10 of capital stock. This may reflect the value of intangible investment associated with ICT.
Brynjolfsson, Hitt and Yang (2000)		The impact of ICT adoption and organizational decentralization on productivity	The market value of $US 1 of ICT capital is higher by $US 2-5 in decentralized firms than centralized firms.
Bresnahan, Brynjolfsson and Hitt (2002)	300 large firms, 1987-1994	Complementarities between ICT, human capital and decentralized organizational structures	ICT combined with workplace practices such as higher skills, new products and services, greater use of delegated decision-making lead to higher productivity. Successful firms adopt ICT as part of a system or cluster of mutually reinforcing organizational changes.

In a subsequent study, Black and Lynch (2001) examine how workplace practices, human capital investments, and ICT are related to establishment productivity. The results show that what appears to matter the most for productivity is how human resource management (HRM) systems are implemented. Greater employee voice in decision-making is what seems to matter most for productivity—rather than Total Quality Management (TQM) *per se*. In addition, unionized establishments that have adopted HRM practices that promote joint decision-making coupled with incentive-based compensation have higher productivity than other similar non-union plants, while those businesses that are unionized but maintain more traditional labour-management relations have lower productivity. Finally, productivity is higher in plants with more-educated workers or greater computer usage by non-managerial employees.

Bresnahan, Brynjolfsson and Hitt (2002) surveyed about 300 large firms to obtain information on organizational practices and worker characteristics and combine the survey data with a panel detailing ICT capital levels and mix over the 1987-1994 period. The major findings include: 1) skilled labour is complementary with a cluster of three distinct changes at the firm level: ICT, new work organization, and new products and services; and 2) interactions between ICT, new workplace practices and human capital positively predict firm productivity. Firms that adopt decentralized organizational structures do appear to have a higher contribution of ICT to productivity. The most interesting finding is that new work practices are associated with improved firm performance only when the practices are implemented as a bundle—and not separately. In other words, successful firms adopt ICT as part of a system or cluster of mutually reinforcing organizational changes (Brynjolfsson and Hitt, 2000).

1.2 Objectives of the paper

In this paper, we attempt to address three questions:

- Is firm performance improved through ICT, worker skills and organizational innovations?
- Are organizational changes and worker skills complementary to ICT in improving firm performance?
- How does the relationship between productivity, ICT, worker skills and new organizational practices vary across the manufacturing and services sectors?

Our study has three novel features. First it uses a comprehensive establishment-level micro data set—Statistic Canada's 1999 "Workplace and Employee Survey" (WES). The survey is a cross-sectional survey of 6,351 business establishments across the entire spectrum of the Canadian economy.[4] It enables us to empirically assess the relationship between ICT use, organizational practices and firm performance.

Second, the paper examines the interactions between ICT use, organizational changes in the areas of production practices, HRM practices and product/service related practices and human capital as drivers of better firm performance in the knowledge-based economy (KBE).

Third, the analysis extends beyond manufacturing to include services sectors such as dynamic services and distributive services sectors (wholesale trade, retail trade and transportation). Previous studies suggest that dynamic services are more innovative and require a higher share of knowledge workers. Investment in intangible activities, diffusion of knowledge, new technologies and high-quality human capital are the main factors contributing to the growth of this sector. At the same time, ICT has become a main determinant of productivity growth in transport, wholesale and retail trade (Pilat, 2001).

Endnotes

1. Gordon (2000), among others, has argued that while there has been tremendous productivity growth in ICT-producing industries, there is only limited evidence of any incremental productivity growth in ICT-using industries.
2. For a comprehensive literature review of firm-level studies, see Brynjolfsson and Hitt (2000).
3. Brynjolfsson and Hitt (2000) provide an excellent review of the large sample empirical studies on ICT, organisational practices and productivity. The review paper includes the case study literature as well. The findings show strong links between ICT and investment in complementary organizational practices.
4. More precisely, the WES is a cross-sectional survey of the workplace. For our discussion in the rest of the paper, we will use the terms workplace, establishment, and firm interexchangeably.

Chapter 2. Organizational innovation: A framework

Organizational innovation is a broad concept that includes strategies, structural, and behavioural dimensions. It includes competitive strategy (i.e., role of innovation, costs, people, etc.); structural characteristics of the organization such as hierarchy, functional lines, and organizational boundaries; work processes including the use of different production inputs, the flow of work, job design, work allocation, and use of suppliers and subcontractors; HRM practices including hiring and firing; and industrial relation practices involving the strategies and institutional structures affecting the labour-management relationship.

Following the OECD (2002), we define organizational changes to include three broad streams: 1) the restructuring of production and efficiency processes, which include business re-engineering, downsizing, flexible work arrangements, outsourcing, greater integration among functional lines, and decentralization; 2) human resource management (HRM) practices, which include performance-based pay, flexible job design and employee involvement, improving employees' skills, and institutional structures affecting the labour-management relations; and 3) product/service quality-related practices emphasizing total quality management (TQM) and improving coordination with customers/suppliers. A framework for our discussion of organizational innovation is shown in Table 1 and Table 2.

Production and efficiency practices

Production and efficiency practices allow a firm to design, produce and market its products more efficiently than its competitors. Reducing the cost of doing business, increasing the speed of delivery, enhancing the flexibility of the organization, and achieving economies of scale are the main characteristics of production and efficiency practices. These activities work together to achieve better productivity performance, lower cost of production, higher quality, and better customer service.

In practical terms, production and efficiency practices are often associated with making production processes "lean" and more responsive to market changes. These practices include a return to "core business", "re-engineering" and "outsourcing". All these practices entail a concentration of the activities of the firm on essential parts of the business, where its comparative advantage lies. Additional practices such as "just-in-time" production and "benchmarking" are expected to make the firm more responsive to the market while at the same time encouraging the adoption of successful practices in other organizations. Other practices such as "decentralization" involve the decentralization of management responsibility and empowering of employees in order to achieve enhanced flexibility (OECD, 2002).

Table 2. Types of organizational innovation

Production and efficiency practices	Human resources management practices	Product/service quality-related practices
• Business re-engineering • Downsizing • Flexible work arrangements • Outsourcing • Greater integration among functional areas • Decrease in the degree of centralization	• Performance-based pay • Flexible job design and employee involvement • Developing employee's skills • Labour-management cooperation	• Total quality management (TQM) • Improving coordination with customers/suppliers • Improving customer satisfaction

Firms re-engineer their business process in order to achieve efficiencies in the form of lower cost, higher product quality and better customer service. Business reengineering covers the entire range of business activities—distribution coordination, reduced time to market, improved or just-in-time manufacturing, improved inventory management, lower procurement costs, reduced processing errors, extended business reach and better customer service. More extensive use of ICT can help firms achieve the potential gains of reengineering (OECD, 2002).

Outsourcing can be a key element of production and efficiency practices. This allows firms to leverage talent and resources and gain potential benefits of advance skills and technologies without having to directly invest in them.

Decentralization of management responsibility and more diffused decision-making structures can help firms achieve enhanced flexibility. It is argued that flatter hierarchies and devoted decision-making diffuse information quickly within firms, and help improve the innovative and creative abilities of staff and a firm's responsiveness to clients.

Cost-reduction strategies are generally associated with "downsizing" and flexible work arrangements." Cappelli (2000) argues that the distinctiveness of downsizing, as opposed to more traditional layoffs, is that in the former case, the job cuts do not necessarily appear to be driven by shortfalls in demand but instead appear to be driven by the search for operating inefficiencies.

Firm flexibility may also involve using part-time, temporary, or contract workers. Flexible work arrangements can increase "numerical " flexibility of the firms, referred to as the ability of firms to vary labour inputs. This allows firms to adjust their workforce to business cycles and demand trends. For workers, such practices can facilitate their mobility between different careers, jobs and markets.

Human resources management (HRM) practices

In the knowledge-based economy, there is a greater tendency to forge more explicit links between HRM practices and overall corporate strategy (Newton, 1996). Firms use HRM practices as a strategic tool to achieve business objectives such as cost reduction and product development. HRM practices produce a skilled and motivated work force that can adapt to,

and take advantage of, new technologies and changing markets. HRM practices cover a range of personnel management areas including performance-based pay, job rotation, flexible job designs, employee involvement, skills training, and communication procedures. Baldwin (1999) describes the findings of a number of Canadian studies that find an emphasis on HRM practices is closely related to the innovation stance of the firm.

Performance-based pay links workers' pay in part to either the performance of the firm, or individual performance. It is designed to strengthen employee incentives and increase trust and commitment. There are many ways to relate pay to performance: individual incentive systems, productivity/quality gain sharing and other group incentives, profit sharing and merit pay, and skill-based pay. There is ample evidence to suggest that performance-based pay can help motivate, attract and retain outstanding performers (Lawler et al., 1998). Performance-based pay is being used by a substantial share of firms in OECD countries, particularly companies which are implementing a range of organizational changes (OECD, 2002).

Flexible job design and employee involvement: A key objective of HRM policies is to get employees more involved in their jobs. Freeman, et al. (2000) argue that many American firms use HRM policies such as self-directed teams, quality circles, profit sharing, and other diverse programs, to involve employees in their jobs. HRM practices such as teamwork and job rotation seem to raise skill demands primarily for behavioural and interpersonal skills such as the ability to get along with others and work in teams (Cappeli and Neumark, 1999). In this paper, we consider a number of individual HRM practices including employee suggestion programs, flexible job design and job rotation, job enrichment/enlargement, and job redesign, information sharing with employees, quality circles and problem-solving teams, self-directed work groups, and joint labour-management committees.

Previous studies find that flexible job design and employee involvement (EI) are associated with increased benefits to employers. Cappelli and Neumark (1999) find that work practices that transfer power to employees, may raise productivity, although the statistical case is weak. Similarly, Freeman et al. (2000) find that EI that is more likely to be associated with profit-sharing and other forms of shared compensation, could do more for workers than for firms. EI is found to have an effect on labour productivity.

Developing employee skills: HRM practices focus on "high skill" strategies that make better use of, and continuously renew, human capital (OECD, 1998). In the KBE, work requires creative thinking, self-motivation, and academic basics. Problem-solving, decision-making, business, financial, negotiating, and interpersonal skills, in addition to technical skills are essential for workers (Newton, 1996). A recent OECD (2002) study notes that firms are now developing their own customized training strategies, which are increasingly on-line. Some large firms are involved in setting up corporate universities using ICT technologies and offering a combination of satellite-based learning, web-based training, virtual reality and virtual campuses, sometimes in conjunction with more traditional methods.

Lynch and Black (1995) find that smaller establishments are much less likely to provide formal training programs than larger establishments. Importantly, regardless of size, those employers who have adopted some of the practices associated with what have been called "high performance workplaces" are more likely to have formal training programs. And, there are significant and positive effects on establishment productivity associated with investments in human capital.

In the empirical literature, there is ample evidence on the effects of individual HRM practices on productivity performance. Some notable studies include, profit sharing (Kruse, 1993); training (Bartel, 1989); and information sharing (Kleiner and Bouillon, 1988).

Ichniowski, Shaw and Prennushi (1997) find that interaction effects are important determinants of productivity. Firms realize the largest gains in productivity by adopting clusters of complementary HRM practices, and benefit little from making marginal changes in any one HRM practice. The study investigates the productivity effects of innovative HRM practices using data from a sample of 36 homogeneous steel production lines owned by 17 companies. The findings show that lines using a set of innovative HRM practices, which include incentive pay, teams, flexible job assignments, employment security, and training, achieve substantially higher levels of productivity than do lines with more traditional approaches, which include narrow definitions, strict work rules, and hourly pay with close supervision.

Labour-management cooperation: Many studies find that effective labour-management relationship is key to fostering organizational change and raising productivity. Unions may raise productivity by lowering the costs of introducing new HRM practices and encouraging employee participation. Black and Lynch (2001) find that unionized establishments that promote joint decision-making, coupled with incentive-based compensation, have higher productivity than other similar non-union plants, while those businesses that are unionized but maintain more traditional labour-management relations have lower productivity. In our analysis, we consider enhancing labour-management cooperation to be an important objective of industrial relations strategy in the new economy.

Product/service quality-related practices

Over the past twenty years, the composition of the business sector has shifted from traditional industries (e.g., steel, chemicals) with long product cycles and an emphasis on process R&D to more innovative, faster-changing industries, often with short product cycles (e.g., computer equipment). Shorter product cycles increased the need to constantly renew products and improve the quality of goods (OECD, 2000). To respond to this challenge, businesses increasingly focus on practices such as total quality management (TQM), improving coordination with customers/suppliers, and improving customer satisfaction.

There is widespread recognition of TQM as a critical competitive strategy and thus, a primary concern of all levels of management, including senior management (Easton and Jarrell, 1998). Baldwin and Johnson (1998) report that TQM is closely related to the success of small and medium-sized firms in Canada.

Table 3. Elements of human resources management practices

Human resources management practices	Strategies
Performance-based pay	• Individual incentive systems • Productivity/quality gain sharing and other group incentives • Profit sharing plan • Merit pay and skill-based pay
Flexible job design and employee involvement	• Employee suggestion programs • Flexible job design • Greater reliance on job rotation and multiskilling • Information sharing with employees • Quality circles, problem-solving teams • Self-directed work groups • Joint labour management committees
Developing worker skills	• Formal job-related training • On-the-job training • Participation in training subsidies program • Participation in other training programs
Labour-management cooperation	• Enhancing labour-management cooperation

TQM is based on: 1) customer focus which includes elements such as emphasis on customer requirements, customer satisfaction, and changes in processes; 2) systematic improvement involving a wide-spread systematic organizational focus on quality improvement, cycle-time reduction, waste reduction and the adoption of prevention-based orientation; 3) supplier performance and supplier relationships, which means choosing suppliers on the basis of product quality rather than solely on price; 4) employee involvement and development, meaning teams to identify and solve quality problems; and 5) statistical tools such as control charts for monitoring and continuous control.

Competition in the market places the importance on customer relations and customer satisfaction. To satisfy customers, firms must design, manufacture, and deliver products and services that meet their tangible and intangible needs better than their competitors, and provide superior value. In order to retain and maintain customers and build loyalty, firms provide quality after-sales and other services (Monga, 2000).

ICT are playing a key role in the growth of customer relations management (CRM) practices. For example, to communicate with clients, sales forces in the field are supplemented by interactive web sites and call centres. In addition, advanced database technology, world-wide web integration, sales force automation and multi-media-based front office applications are emerging as key elements of CRM. Evidence from surveys of managers and case study literature show that the most important reasons for investing in ICT are product quality improvements, especially customer service, timeliness, and convenience (Bresnahan et al., 2002).

Individual organizational practices (e.g., TQM, on-the-job training, etc.) have positive effects on firm performance (Easton and Jarrell, 1998). However, studies show that higher productivity gains are realized when firms implement bundles of high performance practices, as opposed to single practices (OECD, 2002). Black and Lynch (2000) find that bundling of production and HRM practices is particularly effective. Mavrinac and Siesfeld, (1998) found that synergies exist between flexible employee management and compensation programs and TQM.

Chapter 3. Data

Data for our analysis were taken from the 1999 "Workplace and Employee Survey" (WES), a survey developed by Statistics Canada and Human Resource Development Canada. The WES is a linked employer-employee survey. The employer survey provides comprehensive information for about 6,351 business establishments across a complete cross-section of the Canadian economy. This study utilizes the employer workplace survey on innovative business strategies, organizational changes, training and other HRM practices, and quality-related strategies. The reference period for the WES is a 12-month period ending in March 1999. The WES is essentially a survey of small firms—over 85 per cent of the establishments employ less than 20 employees. We have removed non-profit operations from the data for the analysis in the paper. The final sample used consists of 5,501 firms in the business sector.

Constructing key variables

The variables for our analysis include ICT use, human capital, organizational innovation, and firm performance. In this section, we discuss how these variables are constructed from the WES employer survey.

ICT use

We have constructed two measures of ICT use from the WES: the share of workers using computers and the share of ICT investment in total machinery and equipment (M&E). The former is calculated as the number of employees using a micro-computer, minicomputer, mid-range computer or mainframe computer (Q43) as a share of the total number of employees (Q4a). The latter is constructed as the share of expenditures on new software and hardware plus computer-controlled or computer-assisted technologies (Q44b and Q45b) in total expenditures on M&E (Q44b, Q45b, Q46b). The share of workers using computers captures the outcomes of all ICT investment activities by establishments, past and present, while the ICT investment share represents current investment activities only. As such, the ICT investment share is a less comprehensive measure than the share of workers using computers.

Human capital

Human capital is measured as the share of knowledge workers in the total number of workers. We define knowledge workers as managers plus professional workers (see, for example, Gera, Gu and Lin, 2001).

Organizational innovations

The WES provides a rich set of measures of organizational innovations, as listed in Tables 1 and 2. The variable for an element of organizational innovations takes the value of one if the workplace adopted the organizational innovation. Otherwise, it is equal to zero.

Firm performance

The objective of the paper is to examine whether ICT and organizational innovations are related to firm performance. In our analysis, we use three binary measures of firm performance: productivity, sales growth, and unit production costs. The measures for productivity and sales growth are equal to one if the establishment reports an increase in productivity or sales growth. The measure for unit production costs is equal to one if the establishment reported a decrease.

All three measures of firm performance are subjective measures that are based on respondents' perception of firm performance. As shown in Appendix Table A1, the three measures are highly correlated. This suggests that the three measures taken together capture overall success of the firms.

To further examine the issue of whether ICT and organizational innovations are related to firm performance, we will also use two objective measures of firm performance: products and process innovation. The variable for product innovation takes the value of one if the workplace introduced new or improved products over the survey reference year (between April 1, 1998 and March 31, 1999). The variable for process innovation is set to one if the workplace introduced new or improved processes.

Summary statistics

Table 4 presents sample means for ICT use, share of knowledge workers, and firm performance in Canadian business sector, by firm size and industrial sectors. A number of interesting findings emerge from this Table.

- The share of workers using computers is higher among dynamic services[5] (66%) than in wholesale and retail trade and transportation (38%), and manufacturing industries (34%). The share of workers using computers is similar between large firms (44%) and small firms (46%).
- The share of ICT in total M&E investment is much higher among large firms (54%) in comparison to small firms (24%).
- The share of knowledge workers is highest in services industries, which along with their higher share of workers using computers suggests that firms that employ more knowledge workers are more likely to have higher levels of computer use.
- A higher proportion of manufacturing firms (51%) and large firms (55%) report increases in productivity than do small firms (39%), dynamic services firms (38%) and wholesale and retail trade firms (38%).

Table 4. Sample means of ICT, human capital and firm performance

Variables	All	Manufac-turing	Dynamic services	Distributive services	Large firms	Small firms
Share of workers using computers	0.46	0.34	0.66	0.38	0.44	0.46
ICT investment share	0.24	0.27	0.32	0.21	0.54	0.24
Share of knowledge workers	0.24	0.18	0.27	0.25	0.16	0.25
Increase in productivity	0.39	0.51	0.38	0.38	0.55	0.39
Increase in profitability	0.36	0.44	0.37	0.35	0.51	0.35
Increase in sales growth	0.46	0.57	0.42	0.48	0.57	0.46
Product innovation	0.45	0.55	0.41	0.50	0.62	0.45
Process innovation	0.32	0.47	0.32	0.30	0.62	0.31

Note: Dynamic services industries include the communication, finance, insurance and real estate, business services, education and health, and information and cultural industries. Distributive services industries include wholesale and retail trade and transportation services.

- About half of the firms report introducing new products or improved products (45%) in Canadian business sector. The fraction of large and manufacturing firms that introduce product and process innovations is greater than that of small and non-manufacturing firms.

Table 5 shows the fraction of workplaces adopting various elements of organizational innovations: the restructuring of production and efficiency practices; HRM practices; and product/service quality-related practices. Our results show the following.

- Among production and efficiency practices, the incidence of firms adopting flexible work arrangements (24%) and business re-engineering (19%) is much higher than other individual practices.
- Within HRM practices, the incidence of practices such as increasing employee involvement/participation (63%) and enhancing labour-management cooperation (55%) is highest. Additionally, a high proportion of firms also report adopting individual incentive systems (31%), formal job-related training (29%) and classroom training (20%).
- Among product/service quality-related practices the incidence is higher for firms adopting the improving product quality (78%) and improving coordination with customers/suppliers (66%) practices than for those adopting TQM (13%).

Table 5. Mean incidence of organizational innovation

Organizational innovations	Mean (%)
Production and efficiency practices	
Business re-engineering	0.19
Downsizing	0.09
Flexible work arrangements	0.24
Outsourcing	0.12
Greater integration among different functional areas	0.13
Decrease in the degree of centralization	0.03
Human resources management (HRM) practices	
Performance-based pay	
Individual incentive systems	0.31
Productivity/quality gain sharing and other group incentives	0.08
Profit sharing plan	0.08
Merit pay and skilled-based pay	0.17
Flexible job design and employee involvement	
Employee suggestion programs	0.07
Flexible job design	0.07
Information sharing with employees	0.11
Quality circles, problem-solving teams	0.06
Joint labour management committees	0.04
Self-directed work groups	0.02
Greater reliance on job rotation and multiskilling	0.15
Increase employee involvement/participation	0.63
Human resources investment policies	
Formal job-related training	0.29
Classroom training	0.20
Participating in training subsidies program	0.05
Participating in other training programs	0.03
Improving industrial relations	
Enhancing labour-management cooperation	0.55
Product/service quality-related practices	
Improving product quality	0.78
Improving coordination with customers/suppliers	0.66
Total quality management	0.13

Endnotes

5. The dynamic services industries include communication and other utilities, FIRE, business services, education and health care, and information and cultural industries.

Chapter 4. Empirical methods and results

Organizational innovation consists of three main types: production and efficiency practices; human resource management practices; and product/service quality-related practices. In turn, each of these organizational innovations consists of various single practices, as listed in Tables 2 and 3.

To examine the relationship between organizational innovation and firm performance, we first construct an overall measure of organizational innovation as the first principal component of the variables that reflect the importance of the various single practices that comprise the organizational innovation. The measure of organizational innovation is calculated as a weighted sum of the variables, indicating the importance of individual practices using the weights as determined from the principal components analysis.

The measures for three organizational innovations (production and efficiency practices; HRM practices, and product/service quality-related practices are constructed as:

(1) **Production and efficiency practices (PEP)** = β_1 (PE1) + β_2 (PE2) + β_3 (PE3) + β_4 (PE4)+ β_5 (PE5) + β_6 (PE6)

(2) **HRM practices (HRM)** = γ_1 (HRM1) + γ_2 (HRM2) + γ_3 (HRM3) + γ_4 (HRM4) + γ_5 (HRM5) + γ_6 (HRM6) + γ_7 (HRM7) + γ_8 (HRM8) + γ_9 (HRM9) + γ_{10} (HRM10) + γ_{11} (HRM11) + γ_{12} (HRM12) + γ_{13} (HRM13) + γ_{14} (HRM14) + γ_{15} (HRM15) + γ_{16} (HRM16) + γ_{17} (HRM17)

(3) **Product/service quality-related practices (PQP)** = η_1 (PQP1) + η_2(PQP2) + η_3(PQP3)

where β, γ, and η's are the weights determined by the principal component analysis. The variables and the weights assigned to them are shown in Appendix Tables A3 and A4. As shown in these tables, all variables receive positive weights. The measures of all three organizational changes are standardized by subtracting means and dividing by standard errors.

ICT, organizational changes and firm performance

In this section, we present regression results for the relationship between ICT, organizational change, human capital and firm performance.

Table 6. Effects of ICT and organizational innovation on productivity performance

Probit model estimates Variables	(1)	(2)	(3)	(4)
Production and efficiency practices	0.207			0.153
	(10.29)			(6.92)
HRM practices		0.211		0.114
		(8.99)		(4.64)
Product/services quality-related practices			0.105	0.046
			(6.45)	(2.68)
Share of workers using computers at work	0.140	0.132	0.139	0.117
	(3.13)	(2.85)	(2.96)	(2.52)
Share of ICT in M&E investment	0.002	0.023	0.036	-0.016
	(0.07)	(0.60)	(1.01)	(-0.45)
Share of knowledge workers	-0.067	-0.011	-0.043	-0.054
	(-1.18)	(-0.17)	(-0.72)	(-0.95)
Number of observations	5,501	5,501	5,501	5,501

Note: t-statistics are in parentheses. All regressions control for industry fixed effects, firm size and foreign ownership. t-statistics are adjusted for heteroscedasticity using the Huber-White method.

Our empirical specification is a Probit model that relates firm performance to the measures of ICT, organizational changes (OC) and human capital (HK):

$$(4) \quad y_i^* = \alpha_o + \beta_1 ICT_i + \beta_3 OC_i + \beta_4 HK_i$$

$$+\gamma_1 SIZE_i + \gamma_2 OWNERSHIP_i + \gamma_3 INDUSTRIES_i + \varepsilon_i ,$$

where y_i^* is the unobserved performance measure for firm i. The observed counterpart y_i to the unobserved firm performance measure is change in productivity, introduction of product innovations or introduction of process innovations during the reference year. The variable y_i takes the value of one if the firm reports an increase in productivity, introducing product innovations or introducing process innovations. Otherwise, it is equal to zero.

$$y_i = 1, \text{ if } y_i^* > 0, \text{ and}$$
$$y_i = 0, \text{ if } y_i^* \leq 0$$

In our regression analysis, we control for firm size, foreign ownership and industry fixed effects, which have been found to be important determinants of productivity changes in previous empirical studies. The error term ε_i follows a normal distribution. In all estimations, we weight observations by sampling weights.

To examine the magnitude of the effects of ICT and organizational changes on firm performance, we will present marginal effects from the Probit model, evaluated at the sample means.

Empirical results for the total business sector

Table 6 presents Probit model regression results for productivity performance. In all specifications, we introduce two measures of ICT use, the share of workers using computers at work and the share of ICT investment in total M&E investment. And, we also include the share of knowledge workers in all specifications.

In the first three specifications, we individually introduce three organizational changes (PEP, HRM and PQP). In the last specification, we introduce three organizational innovations in the same equation.

We find strong and robust evidence that the share of workers using computers is positively related to productivity performance. The coefficient on the variable is positive and statistically significant at the 5 percent level in all specifications. However, the magnitude of the effect is quite small. Our results show that a 10 percentage-point increase in the share of workers using computer is associated with a one percentage-point increase in probability of productivity improvement. However, as we will find in the next section, the contribution of ICT to firm performance becomes quite large when combined with organizational changes.

The share of ICT is found to have little effect on productivity performance in Canadian business sectors. This may reflect the fact that productivity improvements due to ICT investments occur only after a certain time lag or with initial adjustment costs.

Our results show that three organizational changes (the restructuring of production process, HRM practices, and product/service quality related practices) are all positively related to firm performance. The effects are quite large. The estimates in specification (4) show a one standard deviation increase in the measure of production and efficiency practices is associated with a 15 percentage point increase in the incidence of productivity improvement. For HRM practices and product/service quality-related practices, the effects are increases of 11 and 5 percentage points in the incidence of productivity improvement respectively.

The story for knowledge workers is more ambiguous. The coefficient on the share of knowledge workers is small, negative and statistically insignificant. Findings in the previous work suggest that firms which are ICT-intensive are likely to have more managers and professionals relative to their industry competitors (Bresnahan et al., 1999). We interpret our result as suggesting that the share of knowledge workers has little additional effect on firm productivity after the measures of organizational changes and ICT use are taken into consideration.

Table 7 examines the issue of whether ICT and organizational changes are related to other measures of firm performance such as sales growth, profit changes and innovativeness. Overall, our results show that ICT and organizational changes are positively associated with these various measures of firm performance. We find that for product and process innovations, it is the ICT investment that matters, whereas for sales and profit growth, the share of workers using computers appears to matter more.

While organizational changes are found to be related to better firm performance in Canadian industries, the importance of organizational changes for firm performance differs across various practices, as shown in Table 8.

Table 7. Effects of ICT and organizational innovation on firm performance

Probit model estimates	Dependent variables			
Variables	Sales growth	Profit changes	Product innovation	Process innovation
Production and efficiency practices	0.064(2.63)	0.032(1.47)	0.153(5.27)	0.114(5.06)
HRM practices	0.096(3.49)	0.124(5.16)	0.143(4.64)	0.133(5.91)
Product/services quality-related practices	0.082(4.75)	0.047(2.75)	0.140(8.03)	0.098(6.25)
Share of workers using computers at work	0.070(1.44)	0.061(1.27)	-0.012(-0.23)	-0.002(-0.04)
Share of ICT in M&E investment	-0.006(-0.16)	0.020(0.56)	0.148(3.69)	0.214(6.25)
Share of knowledge workers	-0.054(-0.84)	0.038(0.62)	0.062(0.95)	-0.013(-0.21)
Number of observations	5,501	5,501	5,501	5,501

Note: t-statistics are in parentheses. All regressions control for industry fixed effects, firm size and foreign ownership. t-statistics are adjusted for heteroscedasticity using the Huber-White method.

Among various types of productivity and efficiency practices, we find that downsizing is the least important for firm performance. The implementation of downsizing is associated with the smallest increase in the incidence of productivity improvement and the rate of innovation.

For HRM practices, our results show that flexible job design and employee involvement are more important for firm performance than performance-based pay or improving industrial relations. The introduction of flexible job design and employee involvement is associated with the largest increase in the incidence of productivity improvement and the rates of product and process innovation.

For product/service quality-related practices, our results show that total quality management and improving product quality matter more for firm performance. The firms that adopt these practices have higher incidence of productivity improvement and higher rates of innovation.

Empirical results for individual industries

A number of previous studies show that the services sector in Canada has invested heavily in ICT and it accounts for most of ICT investment over the past decade. The services sector has also experienced rapid productivity growth (Rao and Tang, 2001; Gu and Wang, 2003).

A number of studies conclude that the nature and extent of organizational changes differ between manufacturing and services sectors. OECD (2002) finds that the fraction of firms that introduced organizational changes is highest in services sectors across OECD countries. A study by McKinsey Institute suggests that service firms often have difficulty improving performance by using organizational practices devised for manufacturing firms (Barkin et al., 1998). For example, reducing costs and changing management may be less effective in service firms than in manufacturing firms, since critical elements for service firms are customer service, innovation and product quality improvement.

Table 8. Fraction of firms reporting productivity improvement or innovation by ICT and OC (%)

	Productivity improvement			Product innovation			Process innovation		
	Yes	No	Diff.	Yes	No	Diff.	Yes	No	Diff.
ICT									
High share of workers using computers	45.94	33.01	12.93	50.15	41.11	9.04	36.52	27.88	8.64
High-ICT investment	48.32	35.65	12.67	63.28	39.07	24.21	55.84	23.64	32.20
Production and efficiency practices									
Business re-engineering	67.12	32.31	34.81	81.10	36.89	44.21	66.51	23.75	42.76
Downsizing	45.38	38.20	7.18	52.39	44.47	7.92	38.46	31.11	7.35
Flexible work arrangements	62.25	31.41	30.84	73.21	36.28	36.93	53.88	24.75	29.13
Outsourcing	72.93	34.07	38.86	76.76	40.76	36.00	62.48	27.47	35.01
Greater integration among different functional areas	67.84	34.71	33.13	77.94	40.52	37.42	66.17	26.87	39.30
Decrease in the degree of centralization	73.32	37.85	35.47	81.11	44.15	36.96	72.25	30.60	41.65
HRM practices									
Performance-based pay									
Individual incentive systems	52.20	32.76	19.44	59.05	38.87	20.18	43.17	26.59	16.58
Productivity/quality gain sharing and other group incentives	65.89	36.48	29.41	70.01	43.02	26.99	58.11	29.48	28.63
Profit sharing plan	60.01	36.97	23.04	68.37	43.13	25.24	46.53	30.47	16.06
Merit pay and skilled-based pay	57.97	34.90	23.07	65.53	40.99	24.54	50.94	27.82	23.12
Flexible job design and employee involvement									
Employee suggestion programs	59.42	37.27	22.15	75.71	42.84	32.87	65.87	29.15	36.72
Flexible job design	65.85	36.76	29.09	73.25	43.03	30.22	60.28	29.58	30.70
Information sharing with employees	58.17	36.37	21.80	72.54	41.68	30.86	64.87	27.53	37.34
Quality circles, problem solving teams	67.16	37.14	30.02	79.64	43.11	36.53	72.65	29.31	43.34
Joint labour management committees	62.58	37.80	24.78	70.70	44.06	26.64	67.69	30.19	37.50
Self-directed work groups	71.91	38.09	33.82	73.48	44.54	28.94	69.47	30.91	38.56
Greater reliance on job rotation and multiskilling	66.97	33.84	33.13	75.53	39.78	35.75	58.74	26.97	31.77
Increase employee involvement/participation	46.17	38.85	7.32	57.06	25.21	31.85	41.23	15.83	25.40
Human resources investment policies									
Formal job-related training	53.61	32.74	20.87	63.10	37.79	25.31	51.44	23.65	27.79
Classroom training	54.87	34.75	20.12	62.16	40.84	21.32	50.62	26.95	23.67
Participating in training subsidies program	58.78	37.87	20.91	69.73	43.98	25.75	49.89	30.89	19.00
Participating in other training programs	64.49	38.07	26.42	72.79	44.35	28.44	61.66	30.87	30.79
Improving industrial relations									
Enhancing labour-management cooperation	45.12	31.07	14.05	54.79	33.28	21.51	40.00	21.58	18.42
Product/service quality-related practices									
Improving product quality	43.79	21.63	22.16	54.55	12.55	42.00	38.89	8.71	30.18
Improving coordination with customers/suppliers	43.93	29.09	14.84	54.39	27.49	26.90	38.80	18.28	20.52
Total quality management	69.37	34.14	35.23	78.91	39.39	39.52	66.61	26.40	40.21

Manufacturing firms tend to focus on the introduction of new production approaches. The effective use of ICT in the auto industry is closely related to the implementation of just-in-time delivery. In services, organizational changes such as employee participation and teamwork are more important for improving product quality and customer relations. Sundbo and Gallouj (1998) suggest that services may be better suited to deal with modern demands for flexible organisations than manufacturing, as their functions and tasks are often less specialised. Similar evidence is provided by other studies on the management of ICT in service firms (Pilat, 2001).

Consequently, in our subsequent analyses, we examine the relationship between ICT, organizational changes and firm performance separately for manufacturing and services sectors. We further divide the services sector into the dynamic services sector and the wholesale, retail trade and transportation sector. The dynamic services sector includes communication and other utilities, FIRE (finance, insurance and real estate), business services, education and health care, and information and cultural industries. These two services sectors differ in terms of their use of ICT, worker skills and capacity for organizational change.

Table 9. Effects of ICT and organizational innovation on productivity performance by sector

Probit model estimates Variables	Manufac- turing	Dynamic services	Distributive services
Production and efficiency practices	0.104	0.082	0.212
	(3.47)	(2.82)	(5.12)
HRM practices	0.129	0.103	0.104
	(3.57)	(3.00)	(2.38)
Product/service quality-related practices	0.036	0.078	0.035
	(1.46)	(3.87)	(1.06)
Share of workers using computers at work	-0.004	0.188	0.157
	(-0.06)	(3.46)	(1.90)
Share of ICT in M&E investment	0.114	-0.027	-0.028
	(2.19)	(-0.57)	(-0.41)
Share of knowledge workers	-0.101	-0.076	-0.054
	(-0.89)	(-1.07)	(-0.52)
Number of observations	1,368	2,072	1,192

Note: t-statistics are in parentheses. All regressions control for industry fixed effects, firm size and foreign ownership. t-statistics are adjusted for heteroscedasticity using the Huber-White method.

The results in Table 9 show that the relationship between ICT, organizational changes and firm performance is somewhat different across industrial sectors. For the manufacturing sectors, production and efficiency practices, HRM practices, and ICT investment emerge as strong predictors of productivity performance. However, organizational innovations related to product/service quality-related practices are not related to productivity improvement in the manufacturing sector. In contrast, for the dynamic services sector, product/service quality-related practices, along with production and efficiency practices and HRM practices are important for productivity performance. For the dynamic services sector, our results also show that the share of workers using computers matter for productivity performance while ICT investment has little effect. These results are consistent with the previous findings that service firms tend to focus more on organizational changes that are related to product/service quality to reap productivity benefits (Pilat, 2001).

The story for the distributive services sector (wholesale and retail trade, and transportation service) is very much similar to that of the dynamic services sector. For the distributive services sector, production and efficiency practices, HRM practices, the share of workers using computers matters for productivity performance. ICT investment and product/service quality-related strategies have little impact on performance.

We have also examined the issue of whether ICT and organizational changes are related to alternative measures of firm performance such as sales growth, profits changes and innovation among industrial sectors. Overall, our results from these alternative measures of firm performance are similar. First, we find that organizational innovations related to production and efficiency practices and HRM practices are related to better firm performance for both manufacturing and services sectors. Second, we find that product/service quality-related strategies are important for firm performance in the dynamic services sector, while these strategies are less important in manufacturing and distributive services sectors. Third, we find that for product and process innovation, ICT investment matters more than the share of workers using computers in both manufacturing and services sectors.

Complementarities between ICT and organizational changes

In this part of the paper, we test the hypothesis that ICT and organizational changes are complements. Milgrom and Roberts (1990) argue that to be successful, firms typically need to adopt ICT as part of a "system" or "cluster" of mutually reinforcing organizational approaches.

The underlying argument behind the bundling of ICT and organizational innovations is the following. ICT enable firms to introduce organisational changes in the areas of re-engineering, decentralisation, flexible work arrangements, outsourcing, lean production, teamwork and customer relations. It also allows firms to produce with greater flexibility and shortened product cycles to satisfy shifting consumer preferences. In turn, these organizational changes are essential for realizing the full benefits of ICT (Brynjolfsson and Hitt, 2000; OECD, 2002).

To examine this complementarity hypothesis between ICT and organization changes, we first look at correlations between ICT and various measures of organizational changes. If ICT and organizational changes are complements, we should observe a positive correlation between them. The incidence of organizational changes should be higher in those firms that use ICT. Second, we use regression analysis to compare performance of firms with various combinations of ICT and organizational changes. If these practices are complements, then firms that adopt these practices as a system should outperform the firms that fail to combine ICT and organizational changes.

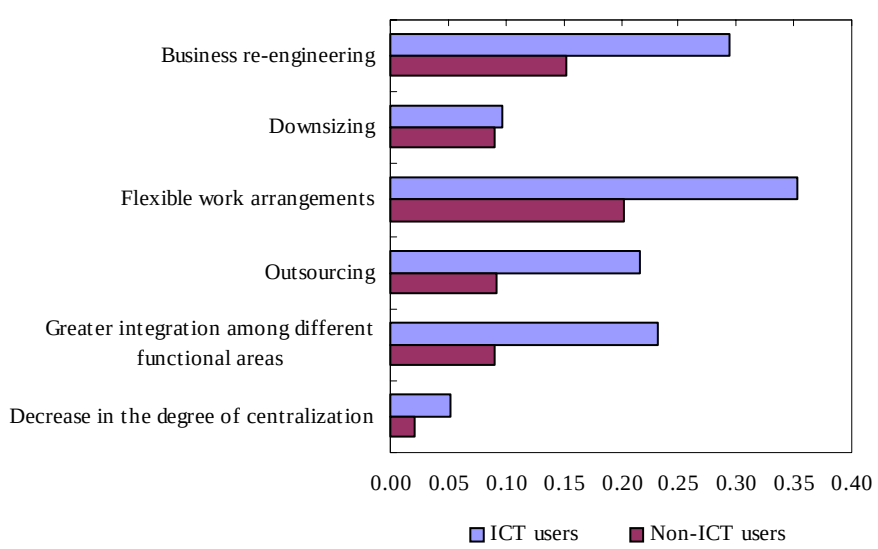
Correlation

Previous studies for OECD economies show that changes in organization and workplace practices are introduced hand-in-hand with investment in ICT (OECD, 2002). Our results from the WES confirm these findings for Canada. We find that the incidence of organizational changes is much higher in the firms that invest in ICT or have a high share of workers using computers than is the case in the firms that do not invest in ICT or have a low share of workers using computers.

Figures 1, 2 and 3 show the fractions of firms that introduce organizational changes for ICT-investing firms and non-ICT investing firms.

- The incidence of production and efficiency practices is much higher in firms that invest in ICT than is the case for non-ICT investing firms. For example, 35 percent of the firms that invest in ICT report introducing flexible work arrangements, compared with 20 percent of non-ICT investing firms. It appears that ICT allowed significant organizational changes in the areas of business re-engineering, flexible work arrangements, outsourcing and greater integration among different functional areas (Figure 1).

Figure 1. Incidence of production and efficiency practices



- Incidence of HRM practices is much higher among ICT-investing firms than in non-ICT investing firms. Firms investing in ICT are more prone to use a profit sharing plan, individual incentive systems and merit pay. Information sharing with employees, job rotation and multiskilling and increased employee involvement/participation schemes are found to complement investment in ICT. The link between formal job-related training and classroom training and investment in ICT are particularly strong (Figure 2).
- The implementation of product/service quality-related practices does not appear to be much different between the firms that invest in ICT and those that do not (Figure 3).

Figure 2. Incidence of HRM practices

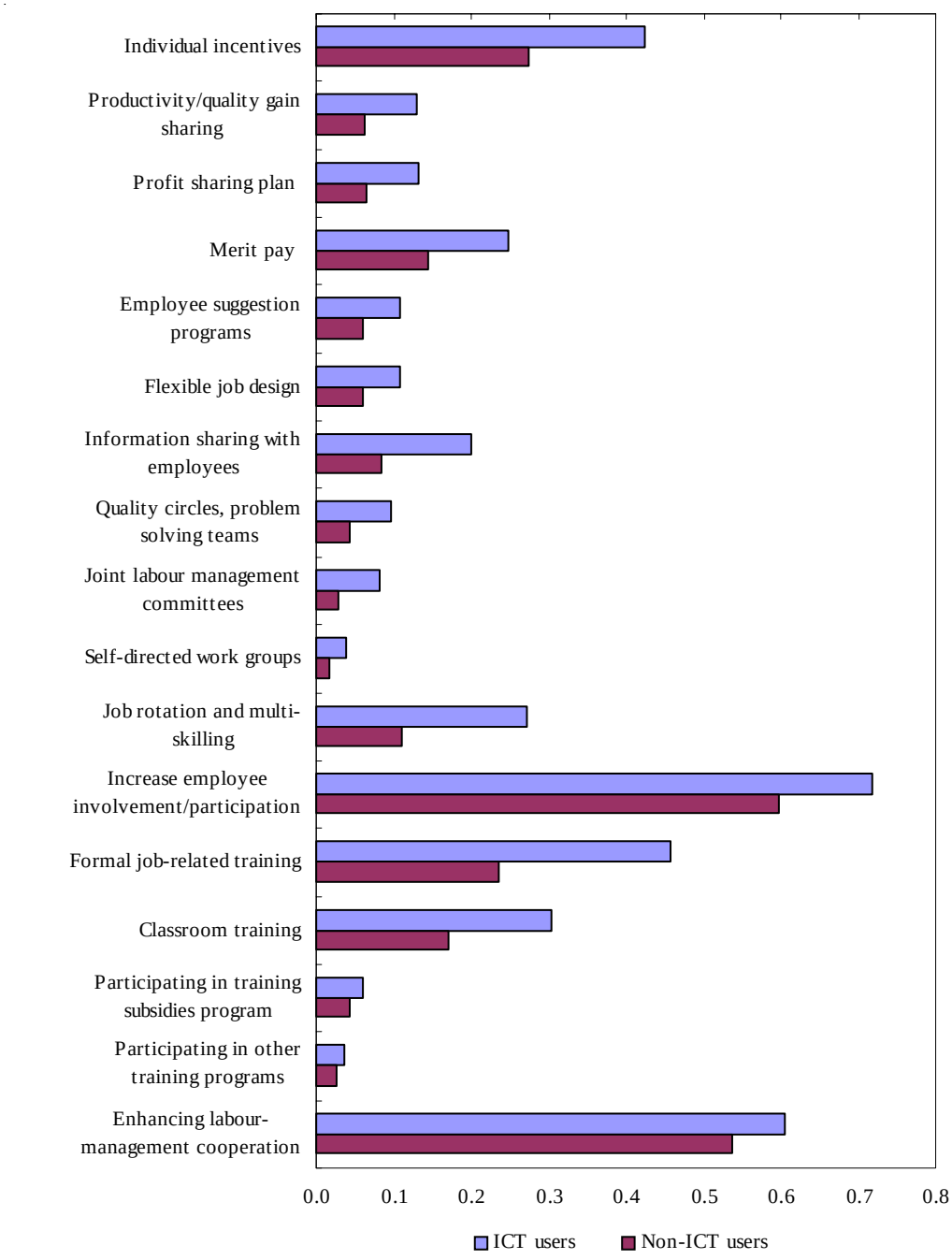


Table 10. Correlation coefficients between ICT, organizational innovation and human capital

	Production and efficiency practices (PEP)	HRM practices (HRM)	Product/ service quality-related practices (PQP)	Share of knowledge workers	ICT investment share	Share of workers using computers
Production and efficiency practices (PEP)	1					
HRM practices (HRM)	0.4516*	1				
Product/service quality-related practices (PQP)	0.4010*	0.3748*	1			
Share of knowledge workers	0.0810*	-0.0155*	0.0420*	1		
ICT investment share	0.2119*	0.2155*	0.1429*	0.0759*	1	
Share of workers using computers	0.1522*	0.1681*	0.1081*	0.2012*	0.3239*	1

Note: One asterisk denotes statistical significance at the 5 percent level.

Table 10 presents correlation coefficients between ICT, organizational changes, and the share of knowledge workers across firms in the Canadian business sector.[6] We find that ICT investment share and the fraction of workers using computers are positively correlated with the share of knowledge workers. This suggests that firms that invest in ICT or have large share of workers using computers tend to have large share of knowledge workers. We also find that ICT use is correlated with the measures of organizational changes in the areas of production and efficiency practices, HRM practices and product/service quality-related practices, supporting the view that ICT and organizational changes are complements.

Table 11 presents the correlation coefficients between the share of workers using computers and various elements of organizational changes. With the exception of two HRM practices (participating in training subsidies program and enhancing labour–management cooperation), we find that ICT use is positively correlated with all types of organizational changes. While the overall conclusion from the table is consistent with the finding from Table 10 and Figures 1 to 3 that ICT, organizational changes and human capital are complements, a number of findings for individual organizational practices are worth noting.

We find that ICT use is higher in firms that implement business re-engineering, flexible work arrangement and greater integration among different functional areas than in other firms. ICT use is also greater in organizations that are decentralized.

Our results also show that while the correlation with ICT use is positive for all individual HRM practices, it is stronger for practices such as individual incentive systems and job rotation and multiskilling. In addition, firms with a larger share of workers using computers tend to invest more in human resources such as formal job-related training and classroom training.

Regression results

Our finding on positive correlation between ICT, organizational changes and human capital is consistent with the view that all three are complements. In this section, we bring firm performance measures into our analysis. If ICT and organizational changes are complements, the firms that combine these changes should have better performance that those that do not.

Table 11. Correlation between computer use and ICT investment, human capital and new organizational practices

Correlation between computer use and:	Correlation coefficients	Correlation between computer use and:	Correlation coefficients
ICT use		**HRM practices**	
Share of ICT in M&E investment	0.3239*	*Performance-based pay*	
Human capital		Individual incentives system	*0.2199**
Share of knowledge workers	0.2012*	Productivity/quality gain sharing and other group incentives	0.1068*
		Profit sharing plan	0.0985*
Production and efficiency practices		Merit pay and skilled-based pay	0.1144*
Business re-engineering	0.1115*	*Flexible job design and employee involvement*	
Downsizing	0.0107*	Employee suggestion programs	0.0505*
Flexible work arrangements	0.1011*	Flexible job design	0.0714*
Outsourcing	0.0876*	Information sharing with employees	0.0850*
Greater integration among different functional areas	0.1388*	Quality circles, problem solving teams	0.0367*
Decrease in the degree of centralization	0.0925*	Joint labour management committees	0.0191*
		Self-directed work groups	0.0450*
Product/service quality-related practices		Greater reliance on job rotation and multiskilling	0.1482*
Improving product quality	0.1049*	Increase employee involvement/participation	0.0878*
Improving coordination with customers/suppliers	0.0509*	*Human resources investment policies*	
Total quality management	0.0874*	Formal job-related training	*0.1881**
		Classroom training	0.1766*
		Participating in training subsidies program	-0.0332*
		Participating in other training program	0.0184*
		Improving industrial relations	
		Enhancing labour-management cooperation	-0.0290*

Note: One asterisk denotes statistical significance at the 5 percent level.

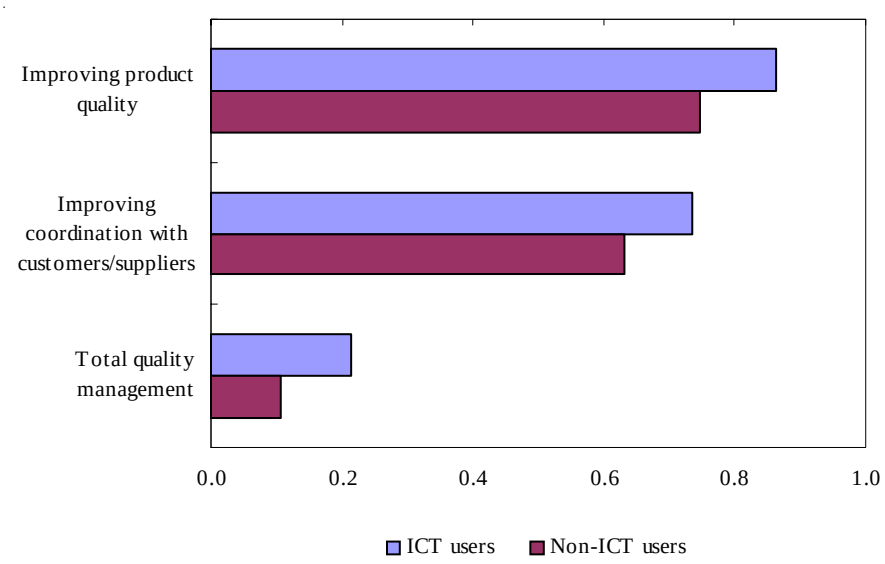
Specifically, we re-estimate Probit equation (4) and examine how various combinations of ICT, organizational changes (OC) and human capital are related to firm performance. For instance, to examine the complementarities between ICT and organizational practices (OC), we divide our sample of firms into four quadrants: High-ICT and High-organizational changes (OC); High-ICT and Low-OC; Low-ICT and High-OC; and Low-ICT and Low-OC. We introduce dummies (D) denoting the four quadrants and run a regression as shown in (5).

$$(5) \quad y_i^* = \alpha_o + \beta_1 ICT_i + \beta_2 HK_i + \delta_1 D_{i,high-ICT,high-OC} + \delta_2 D_{i,low-ICT,high-OC} + \delta_3 D_{i,high-ICT,low-OC} + \gamma_1 SIZE_i + \gamma_2 OWNERSHIP_i + \gamma_3 INDUSTRIES_i + \varepsilon_i$$

Our results suggest that ICT investment matters more for productivity performance in the manufacturing sector whereas for the services sector, the fraction of workers using computers is important for productivity performance. We define High- and Low-ICT firms accordingly. For the services sector, we define High-ICT as those firms that have an above-medium share of workers using computers. Low-ICT firms are defined as those firms that have a below-medium share of workers using computers. For the manufacturing sector, High-ICT include those firms with positive ICT investment whereas Low-ICT firms include those with no ICT investment. For firm innovation performance, our results indicate that it is ICT investment that matters. Therefore, for our regression analysis on innovation performance, we use ICT investment to divide the firms into High- and Low-ICT groups.

High-OC firms in Equation (5) are defined as those firms that have an above-median measure of organizational changes. Low-OC firms are defined those firms that have a below-medium measure of organizational changes.

Figure 3. Incidence of product/service quality-related strategies



We have run regression (5) using all five measures of firm performance: productivity improvement, sales growth, profit growth, product innovation and process innovation. However, we will present the results for productivity and innovation performance only. The results for sales and profit growth are similar to those for productivity performance.

Complementarity between ICT and production and efficiency practices

The results in Table 12 show that the firms that have a high level of ICT and make intensive use of production and efficiency practices (business re-engineering, outsourcing and flexible work arrangements) have the best performance among Canadian firms. The firms that have a high level of ICT and do not adopt production and efficiency practices have poor performance. And the differences are quite large. The incidence of productivity improvement for firms that have a high level of ICT and adopt production and efficiency practices is 34 percentage point higher that that for firms that have low level of ICT and do not adopt the organizational change. The rates of product innovation are 40 percentage points higher, and the rates of process innovation are 47-percentage points higher.[7]

Table 12. Complementarities between ICT and production and efficiency practices and their impact on firm performance

Marginal effect estimates from Probit models	All industries	Manufac-turing	Dynamic services	Distributive services
Dependent variable: Productivity improvement				
High ICT, high PE	0.336	0.262	0.290	0.488
	(6.67)	(3.74)	(3.98)	(5.25)
Low ICT, high PE	0.196	0.204	0.154	0.274
	(3.64)	(3.29)	(2.52)	(2.71)
High ICT, low PE	0.069	0.135	0.154	0.110
	(1.62)	(2.12)	(2.70)	(1.38)
Dependent variable: Product innovation				
High ICT, high PE	0.395	0.304	0.379	0.403
	(7.69)	(4.57)	(5.08)	(4.35)
Low ICT, high PE	0.254	0.213	0.187	0.322
	(5.23)	(3.39)	(2.95)	(3.75)
High ICT, low PE	0.152	0.159	0.165	0.127
	(3.15)	(2.56)	(2.48)	(1.45)
Dependent variable: Process innovation				
High ICT, high PE	0.472	0.365	0.378	0.578
	(8.79)	(5.36)	(5.28)	(5.94)
Low ICT, high PE	0.221	0.201	0.084	0.321
	(4.65)	(3.14)	(1.54)	(3.88)
High ICT, low PE	0.251	0.192	0.236	0.260
	(5.46)	(2.93)	(3.93)	(2.91)

Note: t-statistics are in parentheses. All regressions control for industry fixed effects, firm size and foreign ownership. t-statistics are adjusted for heteroscedasticity using the Huber-White method.

We find that this inter-relationship between ICT and production practices exists for both manufacturing and services sectors. The firms that combine a high level of ICT and production practices have the highest incidence of productivity improvement and have the highest rates of product and process innovations for both manufacturing and services sectors. We find that the use of ICT does not lead to better productivity and innovation performance if firms do not combine ICT with production and efficiency practices. This suggests that the adoption of production and efficiency practices is essential to realize the full potential of ICT.

Complementarity between ICT and HRM practices

Much the same story is evident when we examine the complementarity between ICT and HRM practices such as performance-based pay, flexible job design, employee involvement and human resource investment policies. The incidence of productivity improvement was higher in firms that use ICT and adopt HRM practices (Table 13). The rates of product and process innovations are also higher. Shifting from low levels of ICT to high levels is associated with greater improvement in firm performance for high-HRM firms than for low-HRM firms.

For the distributive services sector, the adoption of HRM practices is not associated with better firm performance for firms with low levels of ICT. Lack of attention to ICT can undermine HRM investment.

Table 13. Complementarities between ICT and HRM practices and their impact on firm performance

Marginal effect estimates from Probit models	All industries	Manufac-turing	Dynamic services	Distributive services
Dependent variable: Productivity improvement				
High ICT, high HRM	0.248	0.262	0.344	0.276
	(4.47)	(3.85)	(4.66)	(2.72)
Low ICT, high HRM	0.113	0.227	0.154	0.070
	(2.22)	(3.32)	(2.49)	(0.57)
High ICT, low HRM	0.086	0.147	0.136	0.164
	(2.09)	(2.40)	(2.44)	(2.22)
Dependent variable: Product innovation				
High ICT, high HRM	0.317	0.304	0.365	0.305
	(6.42)	(4.39)	(4.91)	(3.27)
Low ICT, high HRM	0.122	0.175	0.238	0.021
	(2.29)	(2.50)	(3.68)	(0.21)
High ICT, low HRM	0.142	0.146	0.179	0.090
	(2.94)	(2.37)	(2.76)	(1.01)
Dependent variable: Process innovation				
High ICT, high HRM	0.455	0.381	0.467	0.481
	(9.16)	(5.41)	(6.46)	(5.18)
Low ICT, high HRM	0.201	0.281	0.257	0.109
	(4.29)	(3.97)	(4.07)	(1.31)
High ICT, low HRM	0.241	0.220	0.255	0.224
	(5.21)	(3.62)	(4.43)	(2.57)

Note: t-statistics are in parentheses. All regressions control for industry fixed effects, firm size and foreign ownership. t-statistics are adjusted for heteroscedasticity using the Huber-White method.

Complementarity between ICT and product/service quality-related practices

Examining the inter-relationship between ICT and organizational changes in product/service quality-related practices leads to a similar story. Firms that combine high levels of ICT and product/service quality-related practices have the best performance among Canadian firms (Table 14). Shifting from low levels of ICT to higher levels of ICT is associated with greater improvement in productivity for high-PQP firms.

Surprisingly, our results do not detect evidence of complementarity between ICT and PQP in the manufacturing sector. The results, however, are consistent with our previous findings that PQP work practices do not emerge as significant factor for firm performance in this sector.

In the services sector, however, PQP is among the main drivers of firm performance. Our results show that firms that adopt PQP practices have better firm performance if they also have a high level of ICT. These firms have a higher incidence of productivity improvement and higher rates of innovation. This is true for both dynamic services and distributive services sectors.

Table 14. Complementarities between ICT and product and service quality-related practices and their impact on firm performance

Marginal effect estimates from Probit models	All industries	Manufac-turing	Dynamic services	Distributive services
Dependent variable: Productivity improvement				
High ICT, high PQP	0.274	0.134	0.289	0.386
	(4.14)	(1.43)	(3.27)	(3.10)
Low ICT, high PQP	0.007	0.031	0.097	-0.123
	(0.11)	(0.36)	(1.27)	(-0.97)
High ICT, low PQP	0.076	0.106	0.139	0.127
	(1.99)	(1.95)	(2.65)	(1.82)
Dependent variable: Product innovation				
High ICT, high PQP	0.290	0.075	0.337	0.277
	(4.19)	(0.71)	(3.14)	(2.18)
Low ICT, high PQP	0.145	0.021	0.214	0.161
	(2.14)	(0.25)	(2.69)	(1.16)
High ICT, low PQP	0.160	0.154	0.193	0.124
	(3.83)	(2.86)	(3.51)	(1.61)
Dependent variable: Process innovation				
High ICT, high PQP	0.352	0.289	0.398	0.339
	(5.23)	(3.20)	(4.26)	(2.66)
Low ICT, high PQP	0.149	0.239	0.230	0.101
	(2.12)	(2.73)	(3.17)	(0.74)
High ICT, low PQP	0.263	0.217	0.285	0.263
	(6.49)	(3.93)	(5.50)	(3.37)

Note: t-statistics are in parentheses. All regressions control for industry fixed effects, firm size and foreign ownership. t-statistics are adjusted for heteroscedasticity using the Huber-White method.

Complementarity between ICT and human capital

Finally, we examine the complementarity of ICT and knowledge workers. Our results show that the share of knowledge workers is not related to firm performance. However, the story is different when we examine the complementarity hypothesis. Our results in Table 15 show that firms that have a high level of ICT and a high share of knowledge workers have the best performance among firms in the dynamic services and distributive services sectors. These firms have a high incidence of productivity improvement and high rates of product and process innovations. Shifting from low levels to high levels of human capital is associated with an improvement in firm performance for firms with high levels of ICT. This is consistent with previous findings at the industry level that ICT and human capital are complements (Gu and Wang, 2003). For the manufacturing sector, we do not find any evidence of complementarity between ICT and human capital.

Table 15. Complementarities between ICT and human capital and their impact on firm performance

Marginal effect estimates from Probit models	All industries	Manufac-turing	Dynamic services	Distributive services
Dependent variable: Productivity improvement				
High ICT, high HK	0.102	0.097	0.086	0.205
	(2.26)	(1.39)	(1.42)	(2.52)
Low ICT, high HK	0.029	0.006	-0.011	0.070
	(0.67)	(0.12)	(-0.20)	(0.84)
High ICT, low HK	0.114	0.129	0.199	0.145
	(2.32)	(1.75)	(3.13)	(1.30)
Dependent variable: Product innovation				
High ICT, high HK	0.210	0.127	0.262	0.158
	(4.10)	(1.79)	(3.56)	(1.69)
Low ICT, high HK	0.028	0.030	0.010	0.003
	(0.68)	(0.56)	(0.20)	(0.03)
High ICT, low HK	0.116	0.180	0.109	0.068
	(2.00)	(2.57)	(1.53)	(0.49)
Dependent variable: Process innovation				
High ICT, high HK	0.286	0.205	0.331	0.256
	(5.89)	(2.87)	(5.00)	(2.87)
Low ICT, high HK	0.019	0.056	0.053	-0.032
	(0.50)	(0.98)	(1.10)	(-0.47)
High ICT, low HK	0.223	0.227	0.239	0.182
	(4.23)	(3.10)	(3.65)	(1.53)

Note: t-statistics are in parentheses. All regressions control for industry fixed effects, firm size and foreign ownership. t-statistics are adjusted for heteroscedasticity using the Huber-White method.

Endnotes

6. We find a small but negative correlation coefficient between the measure of HRM practices and the share of knowledge workers.
7. A study for Denmark also finds that firms that combined ICT and organizational changes had higher rates of innovation (Danish Ministry of Business and Industry, 1996).

Chapter 5. Conclusion

Concerns about the ICT "productivity paradox" were raised in the late 1980s. Since then, a large number of studies have emerged both at the industry and firm level that have substantially improved our understanding of the relationship between ICT and firm performance. In particular, the firm-level studies have argued than an explanation for the so-called "productivity paradox" can be attributed to an insufficient response of organizational changes that adapt to a changing business environment, that make better use of knowledge, technology and human resources, that respond to new demands from suppliers and customers, and that use ICT effectively (OECD, 2002; Sharpe, 1999).

Firm-level studies in both the U.S. and Canada show that ICT investment, when accompanied by organizational change and investment in human capital, has a significant impact on productivity and economic performance (Brynjolfsson and Hitt, 2000; Bresnahan, Brynjolfsson and Hitt, 2002; Black and Lynch, 2000, 2001; Baldwin and Sabourin, 2002; Baldwin, Sabourin and Smith, 2003). The most interesting finding is that new work practices are associated with improved firm performance only when the practices are implemented as a bundle—and not separately. In other words, successful firms adopt ICT as part of a system or cluster of mutually reinforcing organizational changes.

In this paper, we examine the issue of whether investments in ICT combined with organizational changes such as the restructuring of the production process, human resource management (HRM) practices and product/service quality-related practices and worker skills contribute to better firm performance among Canadian firms. In particular, we examine the role of complementarities between ICT use, organizational changes and human capital as drivers of firm performance. And, more importantly, we extend the analyses beyond manufacturing to include dynamic services and distribution services sectors. Previous studies suggest that the dynamic services sector is playing a key role in spurring productivity throughout industrial economies.

Our findings are broadly consistent with the previous empirical work on ICT and new organizational practices. In particular, our analysis suggests that Canadian firms have actively engaged in organizational changes in the areas of production and efficiency practices, HRM practices and product and quality-related practices. These practices combined with ICT are strongly associated with better firm performance. We find that the firms that adopt organizational changes and introduce ICT have a higher incidence of productivity improvement and higher rates of innovation.

We find that the role of ICT and new organizational practices are different between industrial sectors. In the manufacturing sector, production and efficiency practices and HRM practices, and ICT investment emerge as strong predictors of firm performance. Product/service quality-related practices and the share of workers using computers, however, do not emerge as strong predictors of firm performance in this sector.

In contrast, for the dynamic services sector, product/service quality-related practices and the share of workers using computers along with production and efficiency practices and HRM practices emerge as strong predictors of better firm performance. These findings suggest that the dynamic services firms in Canada are enjoying the benefits of ICT and technological and organizational innovations. These firms focus more on organizational changes that are related to product/service quality-related practices. The story for the distribution services sector is very much similar to that of the dynamic services sector except the lack of significance of product/service quality-related practices in this sector.

Our analysis shows that ICT use is correlated with workers skills suggesting that firms that use high levels of ICT also employ more knowledge workers. ICT use is also found to be correlated with organizational innovations in production and efficiency practices, HRM practices and product/service quality-related practices, supporting the view that ICT and organizational changes are complements.

More important, our findings show that successful firms typically adopt ICT as part of a "system" or "cluster" of mutually-reinforcing organizational approaches. We find that while ICT is productive on its own, it is more productive in firms that combine high levels of ICT with high levels of organizational changes in the areas of production and efficiency practices, HRM practices, product/service quality-related practices. The firms that combine ICT with organizational changes have a high incidence of productivity improvement and have high rates of innovation. Our results also suggest that ICT and human capital are complements in dynamic services and distribution services sectors. The firms that combine high levels of ICT and high levels of human capital have a higher incidence of productivity improvement and higher rates of innovation in this sector.

Appendix A

Table A1. Correlation between productivity performance and other measures of firm performance

Performance measures	Correlation coefficients
Unit production costs	0.26
Sales growth	0.57
Product quality	0.44
Profitability	0.47
Productivity relative to your main competitors	0.21
Sales growth relative to your main competitors	0.28
Profitability relative to your main competitors	0.21

Table A2. Weights assigned to individual practices for constructing a measure of production and efficiency practices

	Weights
Business re-engineering (PE1)	0.48848
Downsizing (PE2)	0.24599
Flexible work arrangements (PE3)	0.45577
Outsourcing (PE4)	0.44609
Greater integration among different functional areas (PE5)	0.46626
Decrease in the degree of centralization (PE6)	0.27705

Table A3. Weights assigned to individual practices for constructing a measure of HRM practices

	Weights
Performance-based pay	
Individual incentive systems (HRM1)	0.17924
Productivity/quality gain sharing and other group incentives (HRM2)	0.18501
Profit sharing plan (HRM3)	0.18163
Merit pay and skilled-based pay (HRM4)	0.20926
Flexible job design and employee involvement	
Employee suggestion programs (HRM5)	0.33009
Flexible job design (HRM6)	0.32941
Information sharing with employees (HRM7)	0.37370
Quality circles, problem solving teams (HRM8)	0.32306
Joint labour management committees (HRM9)	0.26918
Self-directed work groups (HRM10)	0.24865
Greater reliance on job rotation and multiskilling (HRM11)	0.19786
Increase employee involvement/participation (HRM12)	0.17418
Human resources investment policies	
Formal job-related training (HRM13)	0.27585
Classroom training (HRM14)	0.27096
Participating in training subsidies program (HRM15)	0.08772
Participating in other training programs (HRM16)	0.10006
Improving industrial relations	
Enhancing labour-management cooperation (HRM17)	0.15613

Table A4. Weights assigned to individual practices for constructing a measure of product/service quality-related practices

	Weights
Improving product quality (PQP1)	0.64600
Improving coordination with customers/suppliers (PQP2)	0.65301
Total quality management (PQP3)	0.39530

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