THE EFFECT OF ORGANIZATIONAL INNOVATION AND INFORMATION TECHNOLOGY ON FIRM PERFORMANCE*

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Abstract

This paper examines the issue of whether investment in information and communication technology (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 and have high rates of innovation. These findings seem to 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 service sectors. The firms that combine high levels of ICT and high levels of worker skills have better firm performance.

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" 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)

1 Introduction

Do computers contribute to productivity growth? Most of the *aggregate-leve*l evidence shows that investment in information and communications technology (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).

Over the last decade, there are many *firm-level* studies in the US 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 positive relationship between ICT investment and labour productivity.

A recent study by Brynjolfsson and Hitt (1997) explores the relationship between computers and *productivity growth*. The study uses data that included more than 600 large US 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

[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).

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 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 service 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 and Sabourin (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, communications technology 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.

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.

A recent study by Baldwin and Sabourin (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 such 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 and Sabourin (2003) find that a plant's performance is related not just to its technological stance, but to other areas of competencies. In particular, plants that gave greater stress 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, 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. 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 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 whether ICT and organizational innovation are associated with better performance in Canada. The paper extends the previous studies in Canada to include firms in both manufacturing and service sectors. While most ICT investment is made in the service sector, there is little evidence on the contribution of ICT to the performance of the firms in the service sector in Canada. We have three objectives in this paper:

- 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 manufacturing and services?

This paper 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 in 1999.[7] It provides a rich set of measures on organizational changes and firm performance that allow us to examine the relationship between ICT use, organizational practices and firm performance.

Second, the paper examines the role of complementarities 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 service sectors such as dynamic service and distributive service sectors (wholesale trade, retail trade and transportation). Previous studies at the aggregate level 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).

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 OECD (2002), we define organizational changes to include three broad streams: 1) the restructuring of production 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

[7] More precisely, The WES is a cross-sectional survey of workplace. For our discussion in the rest of the paper, we will use the terms workplace, establishment, and firm interexchangeably.

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).

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 including manufacturing – 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 Resource Management (HRM) Practices

In the KBE, 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 increased 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 diverse other 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[5]. 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.

[5] See for example, Minister of Industry, 2001

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 some combinations 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 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, 1995); 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 includes 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 analyses, 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 is a closely related to the success of small and medium-sized firms in Canada.

TQM is based on: 1) customer focus which includes elements such as emphasis on customer requirements and customer satisfaction and changes in processes; 2) systematic improvement meaning a wide-spread systematic organizational focus on quality improvement, cycle-time reduction, and 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 shows 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.

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 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 12 - month period ending in March 1999. We have removed non-profit operations from the data for the analysis in the paper. The final sample used consists of 5501 firms in the business sector.

3.1 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 ICT investment per worker. 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 expenditures on new software and hardware plus computer-controlled or computer-assisted technologies (Q44b, Q45b) per worker. The share of workers using computers captures the outcomes of all ICT investment activities by establishments, past and present, while the ICT investment per worker represents current investment activities only. As such, the ICT investment per worker 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; Lavoie *et al*., 2003).

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 WES provides a rich set of measures on firm performance. We use five such measures: productivity changes, sales growth, profit changes, product innovation and process innovation. In our empirical analyses, the measures for productivity, sales growth and increase in profit are equal to one if the establishment reports an increase in productivity or sales growth or profit increase during the period between April 1, 1998 and March 31, 1999. The variable for product innovation takes the value of one if the workplace introduced new or improved products. The variable for process innovation is set to one if the workplace introduced new or improved processes.[8]

The five measures of firm performance are highly correlated and capture different aspects of the overall success of the firms. While none of the above measures is perfect, the five measures taken together should capture the overall success of the firms.

3.2 Summary Statistics

Table 3 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[6] (66%) than in wholesale & 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%);

- ICT investment per worker is similar between large firms (1663 dollars per worker) in comparison to small firms (1629 dollars per worker);

- 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; and

[8] Process innovation is often introduced in conjunction with new technologies (ICT and non-ICT) such as robots, advanced manufacturing cells, automated process control and many similar state- of-the-art technologies, all of which are integral to new processes. ICT as a general purpose technology should facilitate the introduction of process innovations.

[6] The dynamic service industries include communication & other utilities, FIRE, business services, education and health care, and information & cultural industries.

- 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%).

- 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 4 shows the fraction of workplaces adopting various elements of organizational innovations: the restructuring of production process; 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%).

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 1 and 2.

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 standardized variables, using the weights as determined from the principal components analysis.[9]

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

[9] The principal component analysis extracts a component that reflects most of the variance among individual practices, thus producing a comprehensible summary of all individual practices.

(1) **Production and Efficiency Practice (PEP)** = β_1 (PE1) $+\beta_2$ (PE 2) $+\beta_3$ (PE 3) $+\beta_4$ (PE4) + β_5 (PE 5) $+\beta_6$ (PE 6)

(2) **HRM Practice (HRM)** = γ_1 (HRM1) $+\gamma_2$ (HRM 2) $+\gamma_3$ (HRM 3) $+\gamma_4$ (HRM 4) $+\gamma_5$ (HRM 5) $+\gamma_6$ (HRM 6) $+\gamma_7$ (HRM 7) $+\gamma_8$ (HRM 8) $+\gamma_9$ (HRM 9) $+\gamma_{10}$ (HRM 10) $+$ γ_{11} (HRM 11) $+\gamma_{12}$ (HRM 12) $+\gamma_{13}$ (HRM 13) $+\gamma_{14}$ (HRM 14) $+\gamma_{15}$ (HRM 15) $+$ γ_{16} (HRM 16) $+\gamma_{17}$ (HRM 17)

(3) **Product/Service Quality Practice (PQP)** = η_1 (PSQ1) + η_2(PSQ2) + η_3(PSQ3)

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 A1 – A3. 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.

4.1 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.

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

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

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

where y_i^* is 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.

$y_i = 1$, if $y_i^* > 0$, and
$y_i = 0$, 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 Total Business Sector

Table 5 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 ICT investment per worker. 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 1 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.[10]

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 15 percentage point increase in the incidence of productivity improvement. For HRM practices and product/service quality practices, the effects are 11 and 5 percentage points increase 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 and negative and statistically insignificant. However, we find that the share of knowledge workers is positively related to the two measures of ICT use and the measures of organization changes. This is consistent with evidence in the

[10] The two measures of ICT use are correlated and have a correlation coefficient of 0.20. When we introduce the two measures separately in our regression, the coefficients on ICT are similar. The coeeficient on the share of workers using computers are positive and significant, and the coefficient on ICT investment per worker is not significant.

previous work 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. The share of knowledge workers is linked to better productivity performance through its effect on ICT and organizational innovation.

Table 6 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 7.

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 practice, 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 Manufacturing and Service Sectors

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 service 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 service sectors. OECD (2002) finds that the fraction of firms that introduced organizational changes is highest in service 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 services firms are customer service, innovation and product quality improvement.

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 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 service sectors. We further divide the service sector into the dynamic services sector and the wholesale, retail trade and transportation sector. The dynamic service sector includes communication & other utilities, FIRE (finance, insurance and real estate), business services, education and health care, and information & cultural industries. These two service sectors differ in terms of their use of ICT, worker skills and capacity for organizational change.

The results in Table 8 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 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 service sector, our results also show that the share of workers using computers matter for productivity performance while ICT investment has little effect. Theses 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 service sector (wholesale & retail trade, and transportation service) is very much similar to that of the dynamic service sector. For the distributive service 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 service sectors. Second, we find that product/service quality-related strategies are important for firm performance in dynamic service sectors, while these strategies are less important in manufacturing and distributive service 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 service sectors.

4.2 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 is 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 (Arnal *et.al*., 2001). 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 high share of workers using computers than is the case in the firms that do not invest in ICT or have 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 arrangement, 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 arrangement, outsourcing and greater integration among different functional areas (Figure 1).

- 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 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).

Table 9 presents correlation coefficients between ICT, organizational changes, and the share of knowledge workers across firms in Canadian business sector.[11] We find that ICT investment per worker 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 10 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 9 and Figures 1 to 3 that ICT, organizational changes and human capital are complement, a number of findings for individual organizational practices are worth noting.

We find that 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

[11] We find small but negative correlation coefficient between the measure of HRM practices and the share of knowledge workers.

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.

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

Our results suggest that ICT investment matters more for productivity performance in the manufacturing sector whereas for the service sector and the fraction of workers using computers is important for productivity performance. We define High- and Low-ICT firms accordingly. For the service sector, we define High-ICT as those firms that have above-medium share of workers using computers. Low-ICT firms are defined as those firms that have below-medium share of workers using computers. For the manufacturing, 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 below-medium measure of organizational changes.

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 11 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 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 point higher.[12]

We find that this inter-relationship between ICT and production practices exists for both manufacturing and service 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 service 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 full potentials from 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 12). 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 service 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.

Complementarity between ICT and Product/Service Quality-Related Practices

[12] A study for Denmark also find that firms that combined ICT and organizational changes had higher rates of innovation (Danish Ministry of Business and Industry, 1996)

Examining the interrelationship 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 13). 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 an 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 service sectors.

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 14 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 service and distributive service 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 (Autor, Katz and Krueger, 1998; Gu and Wang, 2003). For the manufacturing sector, we do not find any evidence of complementarity between ICT and human capital.

5 Conclusion

Concerns about 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 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).

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, 2003, 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 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 service 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 suggest 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 service 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 service sector is very much similar to that of the dynamic service 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 seem to suggest that to be successful, firms typically need to 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 service and distribution service 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.

REFERENCES

Armstrong, P., T. Harchaoui, C. Jackson, and F. Tarkhani (2002) A Comparison of Canada-U.S. Economic Growth in the Information Age, 1981-2000: The Importance of Investment in Information and Communications Technologies. Economic Analysis Research Paper Series. No. 1. 11F0027MIE2002001 Ottawa: Statistics Canada.

Baldwin, J. R., (1999) *Innovation, Training and Success*. Analytical Studies Research Paper Series No 137. 11F0019MIE1999137. Analytical Studies Branch. Ottawa: Statistics Canada

Baldwin, J. R., B. Diverty, D. Sabourin (1995) "Technology Use and Industrial Transformation," in T. Courchene (ed.) *Technology Information and Public Policy.* The Bell Canada Papers on Economic and Public Policy, Volume 3. John Deutsch Institute for the Study of Economic Policy. Queen's University.

Baldwin, J.R. and J. Johnson (1995) "Business Strategies in Innovative and Non-Innovative Firms in Canada," Analytical Studies Research Paper Series 11F0019MIE1995073. Analytical Studies Branch. Ottawa: Statistics Canada, published in *Research Policy,* 25, 785-804.

Baldwin, J.R. and J. Johnson (1996) "Human Capital Development and Innovation: A Sectoral Analysis," In *The Implications of Knowledge-Based Growth for Micro-Economic Policies*, Peter Howitt (ed.). Calgary: University of Calgary Press.

Baldwin, J.R. and J. Johnson (1997) "Differences in Strategies and Performances of Different Types of Innovators," Analytical Studies Research Paper Series 11F0019MIE1997102. Analytical Studies Branch. Ottawa: Statistics Canada.

Baldwin, J.R. and J. Johnson (1998) "Innovator Typologies, Related Competencies and Performance," In *Microfoundations of Economic Growth*, edited by G. Eliasson and C. Green. Ann Arbor: University of Michigan. 227-53.

Baldwin, J. R. and D. Sabourin (2002), "Advanced Technology Use and Firm Performance in Canadian Manufacturing in the 1990s," *Industrial and Corporate Change* 11 (4): 761-89.

Baldwin, J. R., D. Sabourin and David Smith (2003), "Impact of Advanced Technology Use on Firm Performance in the Canadian Food Processing Sector," Economic Analysis Research Paper Series. No. 12. 11F0027MIE20030012. Analytical Studies Branch, Ottawa: Statistics Canada.

Barkin, T.I., J. J. Nahirny and E.S. Van Metre (1998), "Why are Service Turnarounds So Tough," *McKinsey Quarterly*, No. 1, pp. 46-54.

Bartel, A. (1989), "Formal Employee Training Programs and Their Impact on Labour Productivity," NBER Working paper No. 3026.

Barua, A., K., C. H. Kriebel, and T. Mukhopadhyay (1995), "Information Technologies and Business Value: An Analytic and Empirical Investigation," *Information Systems Research*, 6(1), pp. 3-23.

Black, S.E. and L.M.Lynch (2000), "What's Driving the New Economy: The Benefits of Workplace Innovation," NBER Working Paper No. 7479.

Black, S.E. and L.M.Lynch (2001), "How to Compete: The Impact of Workplace Practices and Information Technology on Productivity," *The Review of Economics and Statistics*, Vol. LXXXIII, 3: 434-445.

Bresnahan, F. B., E. Brynjolfsson, and L. Hitt (2002), "Information Technology, Workplace Organization and The Demand for Skilled Labour: Firm-Level Evidence," *The Quarterly Journal of Economics*, February, pp. 339-377.

Bresnahan, F. B., E. Brynjolfsson, and L. Hitt (1999), "Information Technology, Workplace Organization and the Demand for Skilled Labour: Firm-Level Evidence," NBER Working Paper No. 7136, May.

Bresnahan, F.B., and M. Trajtenberg (1995), "General Purpose Technologies, 'Engine of Growth'?" *Journal of Econometrics*, 65:83-108.

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

Brynjolfsson, E. and L. Hitt (1997), "Information Technology and Organizational Design," MIT Sloan School Working Paper.

Brynjolfsson, E. and L. Hitt (1996), "Paradox Lost? Firm-Level Evidence on the Returns to Information Systems Spending," *Management Science*, 42(4), pp. 541-558.

Brynjolfsson, E. and L. Hitt (1995), "Information Technology as a Factor of Production: The Role of Differences among Firms," *Economics of New Innovation and New Technology*, 3(4), pp. 183-200.

Brynjolfsson, E., L. Hitt and S. Yang (2000), "Intangible Assets: How the Interactions of Information Systems and Organizational Structure Affects Stock Market Valuations," mimeo, MIT and Wharton.

Brynjolfsson, E. and S. Yang (1997), "The Intangible Benefits and Costs of Computer Investments: Evidence from Financial Markets," in Proceedings of International Conference on Information Systems, Atlanta, GA.

Cappelli, P. (2000), "Examining the Incidence of Downsizing and its Effect on Establishment Performance," NBER Working Paper No. 7742.

Cappelli, P. and D. Neumark (1999), "Do High-Performance Work Practices Improve Establishment-level Outcomes?" NBER Working Paper No. 7374.

Council of Economic Advisors (2000), *Economic Report of the President*, United States, Government Printing Office.

Danish Ministry of Business and Industry (1996), *Technological and Oraganizational Change: Implications for Labour Enterprise Performance and Industrial Policy, Country Report Denmark.*

Diewert, W. E. and A. M. Smith (1994), "Productivity Measurement for a Distribution Firm," NBER Working Paper No. 4812.

Easton, G.S. and S.L.Jarrell (1998), "The Effects of Total Quality Management on Corporate Performance: An Empirical Investigation," *Journal of Business*, Vol. 71, No. 2, pp. 253-307.

Freeman, R.B., M.M. Kleiner and C. Ostroff (2000), "The Anatomy of Employee Involvement and its Effects on firms and Workers," NBER Working Paper No. 8050, December.

Gera, S., W. Gu, and F. Lee (1999), "Information Technology and Productivity Growth: An Empirical Analysis for Canada and the United States," *Canadian Journal of Economics*, Vol. 32 No. 2, April.

Gordon, R (2000), "Does the 'New Economy' measures up to the Great Inventions of the Past?" *Journal of Economic Perspectives,* 14(4), pp. 49-74.

Gu, W. and M. Ho (2000), "A Comparison of Industrial Productivity Growth in Canada and the United States," Jorgenson and Lee (ed.), *Industry-Level productivity and International Competitiveness Between Canada and the United States*, Industry Canada Research Monograph, pp. 121-154.

Gu, W., W. Wang (2003), "ICTs and Productivity Growth in Canadian Industries," paper presented at the annual Canadian Economic Association Meeting, 2003.

Harchaoui, T., F. Tarkhani, C. Jackson, and P. Armstrong (2002) "Information Technology and Economic Growth: Canada and the U.S."" *Monthly Labour Review* 125 (10) 3-12.

Hitt, L. and E. Brynjolfsson (1997), "Information Technology and Internal Firm Organization: An Exploratory Analysis," *Journal of Management Information Systems*, 14: 77-99.

Ichniowski, C., K. Shaw, and G. Prennushi (1997), "The Effects of human Resource Management Practices on Productivity: A Study of Steel Finishing Lines," *American Economic Review*, Vol. 87, No. 3, pp. 291-313.

Jorgenson, D.W., M.S. Ho, and K.J.Stiroh (2002), "Information Technology, Education and the Sources of Growth across U.S. Industries," *mimeo*, Harvard University.

Jorgenson, D.W. and K.J.Stiroh (2000), "Raising the Speed Limit: U.S. Economic Growth in the Information Age," *Brookings Papers on Economic Activity*, pp. 125-211.

Kleiner, M. and M. Bouillon (1988), "Providing Business Information to Production Workers: Correlates of Compensation and Profitability," *Industrial and Labor Relations Review*, July, 41(4), pp. 605-17.

Kruse, D. L. (1993), *Profit sharing: Does it make a difference?* Kalamazoo, MI: Upjohn Institute.

Lavoie, M., R. Roy, and P. Therrien, "A Growing Trend Toward Knowledge Work in Canada", *Research Policy,*Volume 32, Issue 5, pp. 827-844.

Lawler, E., S.A.Mohrman, and G.E. Ledford (1998), *Strategies for High Performance Organizations – the CEO Report: Employee Involvement, TQM and Reengineering Programs in fortune 1000 Corporations*, Jossey-Bass, San Francisco.

Lichtenberg, F. R. (1995), "The Output Contributions of Computer Equipment and Personal: A Firm-level Analysis," *Economics of Information and New Technology*, 3: 212-223.

Loveman, G. W. (1994), "An Assessment of the productivity Impact of Information Technologies," in Allen, Thomas J. and Scott Morton, Michael S. (ed.), *Information Technology and the Corporation of the 1990s: Research Studies,* Oxford University Press, pp. 84-110.

Lynch, L. and S. Black (1995), "Beyond the Incidence of Training: Evidence from a National Employers Survey," NBER Working Paper No. 5231, August.

Mavrinac, S. and T. Siesfeld (1998), "Measures that Matter: an Exploratory Investigation of Investors' Information Needs and Value Priorities," in *Enterprise Value in the Knowledge Economy: Measuring Performance in the Age of Intangibles*, OECD and Ernst and Young Centre for Business Innovation.

Milgrom, P. and J. Roberts (1990), "The Economics of Modern Manufacturing: Technology, Strategy, and Organization," *American Economic Review*, 80(3), pp. 511-528.

Monga, R.C. (2000), "Managing Enterprise Productivity and Competitiveness," ILO Working Paper PMD-3.

Newton, K. (1996), "The Human Factor in Firms' Performance: Management Strategies for Productivity and Competitiveness in the Knowledge-Based Economy," Industry Canada, Occasional Paper No. 14, Nov.

OECD (1998), *High-Performance Workplaces and Intangible Investment*, Paris.

OECD (2000), *A New Economy?: The Changing Role of Innovation and Information Technology in Growth*, DSTI/IND/STP/ICCP(2000)/Final, Paris.

OECD (2002), *Organisational Change and Firm Performance*, DSTI/DOC(2002)14, Paris.

Oliner, S. and D. Sichel (2000), "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?" *Journal of Economic* Perspectives, 14(4), pp. 3-22.

Pilat, D. (2001), "Innovation and Productivity in Services: State of the Art," in OECD, *Innovation and Productivity in Services*, Paris [Proceedings of a joint OECD-Australia workshop, Sydney, November 2000], 2001.

Rao, S. and Jianmin Tang (2001), "The Contribution of ICTs to Productivity Growth in Canada and the United States in the 1990s," *International Productivity Monitor*, No. 3, Fall, pp. 3-18.

Rao, S. M. Ho, and J. Tang (2003), "The Impact of ICTs on Economic and Productivity Growth at the Industry Level: A Canada –U.S. Comparison," paper presented at the annual Canadian Economic Association Meeting, 2003.

Sharpe, A. (1999), "Organizational Structure, Information Technology and Productivity: Can Organizational Change Resolve the Productivity Paradox?" Report prepared for the Applied Research Branch, Human Resources Development Canada, January.

Sundbo, J. and F. Gallouj (1998), *Innovation in Services – SI4S Project Synthesis*, STEP Group.

Table 1. Types of Organizational Innovation

Production and Efficiency Practices	Human Resources Management Practices	Product/service Quality-related Practices
• Business re-engineering • Downsizing • Flexible work arrangement • 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

Table 2. Elements of Human Resources Management Practices

Human Resources Management Practices	Strategies
Performance-based Pay	• Individual incentive systems • Productivity/quality gain sharing & other group incentives • Profit sharing plan • Merit pay and skill-based pay
Flexible Job Design & Employee Involvement	• Employee suggestions programs • Flexible job design • Greater reliance on job rotation and multi-skilling • 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 program
Labour-management Cooperation	• Enhancing labour-management cooperation

Table 3. Sample Means of ICT, Human Capital and Firm Performance

Variables	All	Manuf.	Dyn. Services	Distrib. Services	Large Establish-ments	Small Establish-ements
Share of Workers using Computers	0.46	0.34	0.66	0.38	0.44	0.46
ICT Investment ($) per Worker	1629	1252	3388	616	1663	1629
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
Increases in Profitability	0.36	0.44	0.37	0.35	0.51	0.35
Increases in Sales	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 & real estate, business services, education & health, and information & cultural industries. Distributive services industries include wholesale, retail and transportation services. Large establishments are defined as those with more than 100 workers. Small establishments are defined as those with less than or equal to 100 workers.

Table 4. Mean Incidence of Organizational Innovation

Organizational Innovations	Mean (%)
Production and Efficiency Practices	
Business re-engineering	0.19
Downsizing	0.09
Flexible work arrangement	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 resource investment policies	
Formal job-related training	0.29
Classroom training	0.20
Participating in training subsidies program	0.05
Participating in other training program	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

Table 5. Effects of ICT and Organizational Innovation on Productivity Performance

Probit model estimates

Variables	(1)	(2)	(3)	(4)
Production and efficiency practices	0.207 (10.29)			0.153 (6.92)
HRM practices		0.211 (8.99)		0.114 (4.64)
Product/services quality practices			0.105 (6.45)	0.046 (2.68)
Share of workers using computers at work	0.140 (3.13)	0.132 (2.85)	0.139 (2.96)	0.117 (2.52)
ICT Investment per Worker	0.002 (0.07)	0.023 (0.60)	0.036 (1.01)	-0.016 (-0.45)
Share of knowledge workers	-0.067 (-1.18)	-0.011 (-0.17)	-0.043 (-0.72)	-0.054 (-0.95)
No. of observations	5501	5501	5501	5501

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.

Table 6. Effects of ICT and Organizational Innovation on Firm Performance

Probit model estimates

	Dependent Variables			
Variables	Sales Growth	Profit Changes	Product Innov.	Process Innov.
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 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)
ICT Investment per Worker	-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)
No. of observations	5501	5501	5501	5501

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.

Table 7. 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	32.2
Production and Efficiency Practices									
Business re-engineering	67.12	32.31	34.81	81.1	36.89	44.21	66.51	23.75	42.76
Downsizing	45.38	38.2	7.18	52.39	44.47	7.92	38.46	31.11	7.35
Flexible work arrangement	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	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	39.3
Decrease in the degree of centralization	73.32	37.85	35.47	81.11	44.15	36.96	72.25	30.6	41.65
HRM Practices									
Performance-based pay									
Individual incentive systems	52.2	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	34.9	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	30.7
Information sharing with employees	58.17	36.37	21.8	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	37.8	24.78	70.7	44.06	26.64	67.69	30.19	37.5
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	25.4
Human resource investment policies									
Formal job-related training	53.61	32.74	20.87	63.1	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
Participating in other training program	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	21.58	18.42
Product/Service Quality – related Practices									
Improving product quality	43.79	21.63	22.16	54.55	12.55	42	38.89	8.71	30.18
Improving coordination with customers/suppliers	43.93	29.09	14.84	54.39	27.49	26.9	38.8	18.28	20.52
Total quality management	69.37	34.14	35.23	78.91	39.39	39.52	66.61	26.4	40.21

Table 8. Effects of ICT and Organizational Innovation on Productivity Performance by Sector

Probit model estimates

Variables	Manuf.	Dynamic Services	Distributive Services
Production and efficiency practices	0.104 (3.47)	0.082 (2.82)	0.212 (5.12)
HRM practices	0.129 (3.57)	0.103 (3.00)	0.104 (2.38)
Product/services quality practices	0.036 (1.46)	0.078 (3.87)	0.035 (1.06)
Share of workers using computers at work	-0.004 (-0.06)	0.188 (3.46)	0.157 (1.90)
ICT Investment per Worker	0.114 (2.19)	-0.027 (-0.57)	-0.028 (-0.41)
Share of knowledge workers	-0.101 (-0.89)	-0.076 (-1.07)	-0.054 (-0.52)
No. of observations	1368	2072	1192

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.

Table 9. Correlation Coefficients between ICT, Organizational Innovation and Human Capital

	Production and efficiency practices (PEP)	HRM Practices (HRP)	Product/ service quality-related practices (PQP)	Share of knowledge workers	ICT Investment per Worker	Share of workers using computers
Production and efficiency practices (PEP)	1					
HRM practices (HRP)	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 per Worker	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. 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**	
ICT Investment per Worker	0.3239*		
		Performance-based pay	
		Individual incentive systems	0.2199*
Human Capital			
Share of knowledge workers	0.2012*	Productivity/quality gain sharing and other group incentives	0.1068*
Production and Efficiency Practices		Profit sharing plan	0.0985*
Business re-engineering	0.1115*	Merit pay and skilled-based pay	0.1144*
Downsizing	0.0107*		
		Flexible job design and employee involvement	
Flexible work arrangement	0.1011*		0.0505*
		Employee suggestion programs	
Outsourcing	0.0876*	Flexible job design	0.0714*
Greater integration among different functional areas	0.1388*	Information sharing with employees	0.0850*
Decrease in the degree of centralization	0.0925*	Quality circles, problem solving teams	0.0367*
		Joint labour management committees	0.0191*
		Self-directed work groups	0.0450*
Product/Service Quality – related Practices			
Improving product quality	0.1049*	Greater reliance on job rotation and multiskilling	0.1482*
Improving coordination with customers/suppliers	0.0509*	Increase employee involvement/participation	0.0878*
Total quality management	0.0874*		
		Human resource investment policies	
		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 the 5 percent level

Table 11. Complementarities between ICT and Production and Efficiency Practices and their Impact on Firm Performance

Marginal effect estimates from Probit models

	All industries	Manuf.	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.

Table 12. Complementarities between ICT and HRM Practices and their Impact on Firm Performance

Marginal effect estimates from Probit models

	All Industries	Manuf.	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.

Table 13. Complementarities between ICT and Product and Service Quality-related Practices and their Impact on Firm Performance

Marginal effect estimates from Probit models

	All Industries	Manuf.	Dynamic Services	Distributive Services
Dependent Variable: Productivity Improvement				
High ICT, high PSQ	0.274	0.134	0.289	0.386
	(4.14)	(1.43)	(3.27)	(3.10)
Low ICT, high PSQ	0.007	0.031	0.097	-0.123
	(0.11)	(0.36)	(1.27)	(-0.97)
High ICT, low PSQ	0.076	0.106	0.139	0.127
	(1.99)	(1.95)	(2.65)	(1.82)
Dependent Variable: Product Innovation				
High ICT, high PSQ	0.290	0.075	0.337	0.277
	(4.19)	(0.71)	(3.14)	(2.18)
Low ICT, high PSQ	0.145	0.021	0.214	0.161
	(2.14)	(0.25)	(2.69)	(1.16)
High ICT, low PSQ	0.160	0.154	0.193	0.124
	(3.83)	(2.86)	(3.51)	(1.61)
Dependent Variable: Process Innovation				
High ICT, high PSQ	0.352	0.289	0.398	0.339
	(5.23)	(3.20)	(4.26)	(2.66)
Low ICT, high PSQ	0.149	0.239	0.230	0.101
	(2.12)	(2.73)	(3.17)	(0.74)
High ICT, low PSQ	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.

Table 14. Complementarities between ICT and Human Capital and their Impact on Firm Performance

Marginal effect estimates from Probit models

	All Industries	Manuf.	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.

Figure 1: Incidence of Production and Efficiency Practices

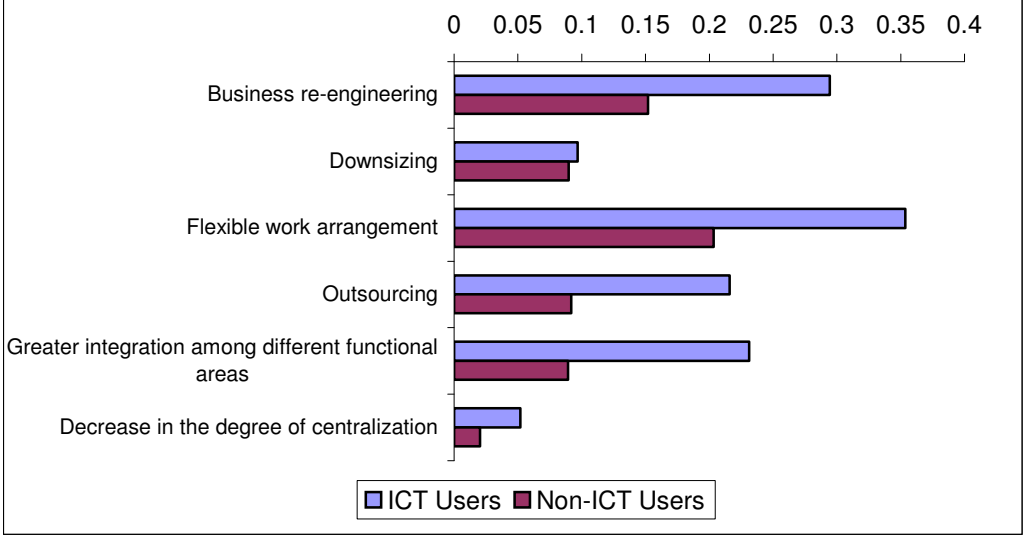
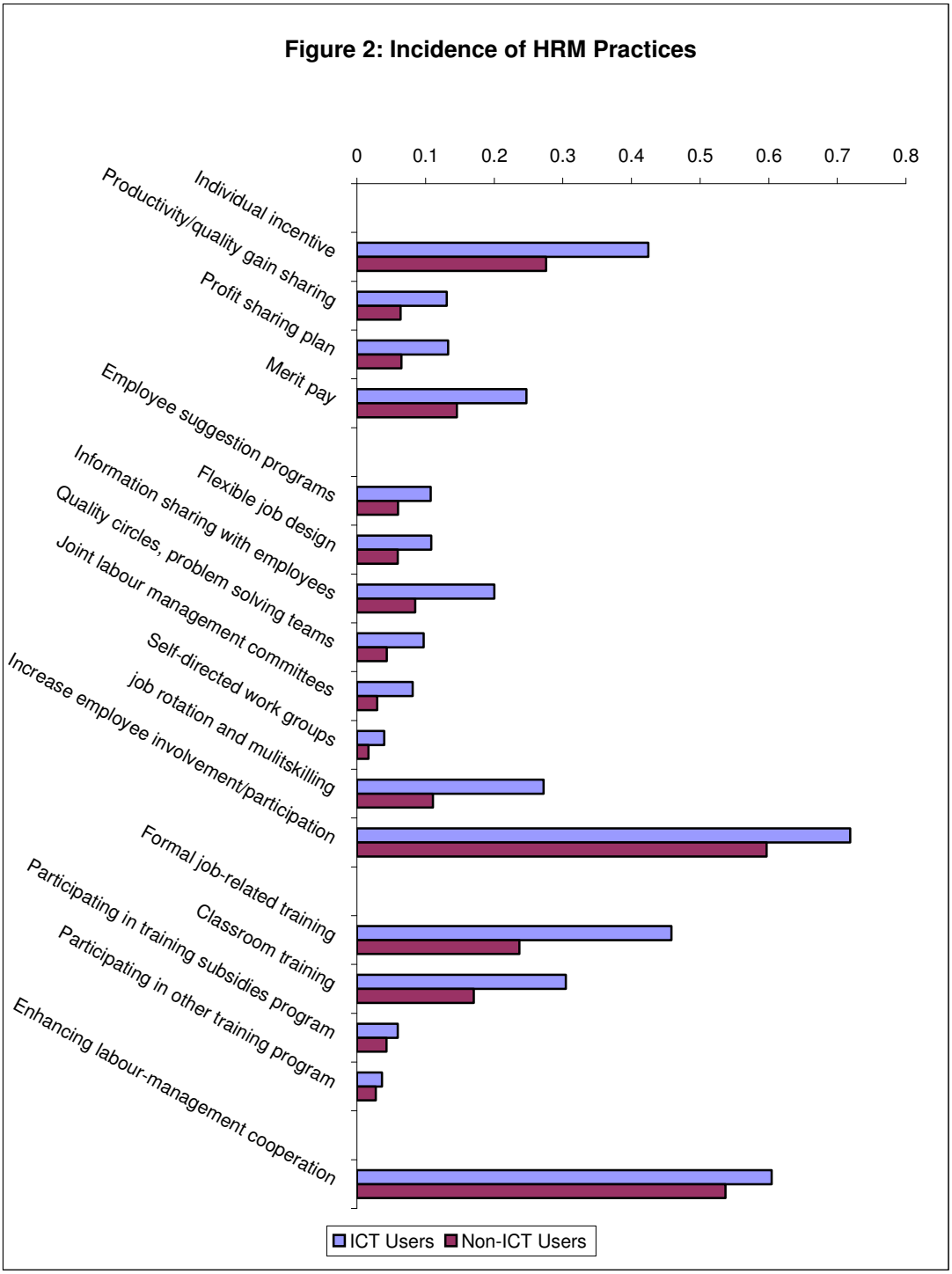


Figure 2: Incidence of HRM Practices



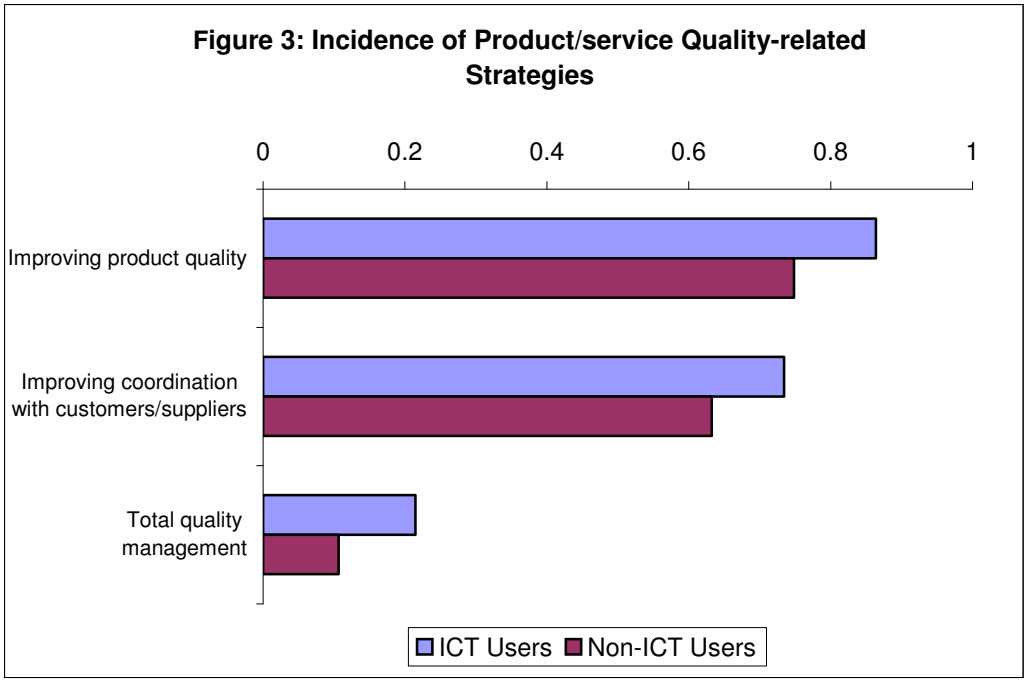


Figure 3: Incidence of Product/service Quality-related Strategies
0
0.2
0.4
0.6
0.8
1
Improving product quality
Improving coordination with customers/suppliers
Total quality management
ICT Users
Non-ICT Users

Appendix Table A1. 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 A2. 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)	0.3737
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 resource 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 program (HRM16)	0.10006
Improving industrial relations	
Enhancing labour-management cooperation (HRM17)	0.15613

Table A3. Weights assigned to Individual Practices for Constructing a Measure of Product/Service Quality-related Practices

	Weights
Improving product quality (PSQ1)	0.6460
Improving coordination with customers/suppliers (PSQ2)	0.65301
Total quality management (PSQ3)	0.3953