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The Diffusion and Adoption of Advanced Technologies in Canada: An Overview of the Issues

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Table of Contents

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Executive Summary

The adoption of advanced technologies is a means of fostering productivity improvement. The growth of the real per capita income of Canadians depends in the long run almost exclusively on productivity growth. If we want to consume more as a country, we must produce more. For this reason, it is very important to identify and address the issues surrounding the diffusion and adoption of advanced technologies and business practices in Canada.

Many theories seek to explain the process of advanced technology diffusion and adoption. One key insight is that the diffusion of technologies is intrinsic to the innovation process, since learning, imitation and feedback effects help to further develop the initial innovation. Some theories focus on networks of communication, institutions, and organizations, and social systems as determinants of adoption and diffusion. Other theories address the costs and benefits that firms must weigh when deciding whether to adopt a new technology, and the uncertainty that is often present in that decision. These theories take into account barriers to adoption as part of an explanation for the rate of diffusion.

Canadian firms generally trail their U.S. counterparts in the adoption of advanced technology. This result occurs in part because Canada has a higher proportion of small and medium enterprises than the United States. Smaller firms tend to be slower adopters. Large Canadian firms do not tend to lag much behind their U.S. counterparts. Canadian firms compare well with their international counterparts outside of the United States. Within Canada, regional differences in technology use are relatively minor, but variations across industries are considerable. Evidence suggests that advanced technology use will be more prevalent in industries relying on science-based research. Differences in plant size, financial capabilities, and the applicability of certain technologies all additionally contribute to differences in advanced technology use across industries.

According to one study, Canadian enterprises identified increased efficiency and reduced cost as the two most important drivers behind the adoption of ICT. These perceptions are consistent with the international average. In contrast, costs were identified as the single most significant barrier to the adoption of ICTs for Canadian businesses. Relative to the other 10 countries analyzed in the study, Canada ranked very high in terms of business perceptions of cost as a barrier.

What do stakeholders perceive to be important issues in the adoption and diffusion of advanced technology? Common to all of the documents reviewed in this paper is an emphasis on the need for governments to take certain actions to ensure technological competitiveness, especially in the areas of measuring progress toward

objectives, promoting investment, research and development, and education and training. A report by the Economist Intelligence Unit argued that to compete successfully businesses will have to use technology to instill an adaptability to change and achieve the requisite speed of innovation, get to know and interact with their customers more regularly and intensively, and focus on specialization.

The academic literature is extensive on R&D policies but limited on diffusion policies. Nonetheless, across countries, a gradual reorientation of policy towards diffusion appears to be taking place. Diffusion policies stress the importance of creating an infrastructure conducive to the rapid spread of awareness and knowledge of innovations. Many different policies affect technology diffusion, including industrial policy and policies in the areas of R&D, education, infrastructure and transport, employment and industrial relations, trade and investment, accounting, and environmental protection.

There are many critical gaps in our knowledge and understanding of technological diffusion in Canada. Key gaps include the identification of

- leading and lagging industries in terms of adoption;
- key barriers to technological diffusion in Canada including economic-policy-related barriers;
- appropriate direct policy interventions to overcome specific barriers;
- the impact of increasing globalization and the economic ascendancy of the large developing countries on diffusion in Canada; and
- specific challenges small and medium enterprises face in adopting technology.

Another issue requiring more research is whether strong R&D performance is a prerequisite for the broad diffusion of technologies. Possible tradeoffs between supporting R&D and supporting diffusion in the presence of limited public funds to promote innovation merit discussion.

The Diffusion and Adoption of Advanced Technologies in Canada: An Overview of the Issues

Introduction[1]

A key driver of productivity and economic growth in Canada is the use of more advanced technologies and business practices, whether embodied in machinery and equipment or introduced through organizational change. Innovations in the form of new technologies and practices may be either developed by the firms themselves through their research and development (R&D) efforts or adopted by firms through other channels, the most obvious being the direct purchase of capital from sources in Canada and other countries.

Much of the debate about innovation and productivity in Canada has focused on our R&D performance. There is no doubt that the development of new technologies through our domestic R&D effort contributes to productivity growth and that R&D should be encouraged widely through public policy. However, for two reasons domestic R&D is by no means the complete story when it comes to the innovation and productivity agenda. First, Canada accounts for a very small part of the world supply of innovation – to the degree that R&D is a proxy for innovation, less than 3 per cent of total OECD R&D expenditures in 2003 (OECD, 2003). Second, the number of firms that actually perform R&D in Canada is small. In 2004, only around 10,000 enterprises, representing far less than one per cent of all business units in Canada, performed R&D. The incidence of R&D performance varies greatly across sectors, with around 5 per cent of manufacturing firms performing R&D compared to 0.5 per cent of firms in the service sector.

The reality is that while R&D is not undertaken by the vast majority of Canadian firms, these firms do adopt new technologies. From this perspective, the innovation and productivity performance of the vast majority of firms in Canada depends on the diffusion of new technologies and their adoption by firms. Without diffusion, invention and innovation/commercialization would have little economic and social impact.

This paper is intended as an issues or scoping document on the diffusion and adoption of advanced technologies and business practices in Canada. The first section provides context for the emphasis placed on the adoption of advanced technologies for productivity improvement by briefly discussing why productivity growth is important. The second section briefly reviews the academic literature on issues related to

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[1] This paper was written by Elad Gafni under the supervision of Dr. Andrew Sharpe. An earlier version of this paper was prepared for the Discovery Roundtable on the Diffusion and Adoption of Advanced Technologies and Business Practices held by the Prime Minister's Advisory Council on Science and Technology (PMACST), June 19-20, 2005. We would like to thank the staff of the PMACST, especially Gilles Jasmin, for their comments.

technological diffusion. The third section summarizes the evidence on technological diffusion in Canada. The fourth section reviews a number of recent documents produced by governments and stakeholders that address current technological issues in Canada. The final section identifies a number of key issues related to the critical gaps in our knowledge and understanding of technological diffusion in Canada.

I. The Importance of Productivity

This section provides context for the emphasis placed on the adoption of advanced technologies as a means of fostering productivity improvement by discussing why productivity growth is important. The growth of the real per capita income of Canadians depends in the long run almost exclusively on productivity growth. If we want to consume more as a country, we must produce more. Increases in the proportion of Canadians who have jobs, longer working time, and improved terms of trade of course can contribute to real income growth in the short-to-medium run, but these sources of real income growth are not sustainable in the long run.

Historically, real income growth has closely (but not perfectly due to fluctuations in profit margins) tracked labour productivity growth in Canada. The strong income growth in the 1945-73 period, known as the golden age of capitalism, reflected a productivity surge; weaker income growth appeared after 1973 when productivity growth decelerated; and income growth rebounded in the 1996-2000 period when productivity growth accelerated.

The benefits of productivity are not just a higher material standard of living. Real income gains generate greater tax revenues that can be used to provide better social programs, and improved health and educational systems. Equally, productivity gains can be taken in the form of fewer hours of work and more leisure. Productivity growth, which makes a larger economic pie, provides society with more options and choices to meet needs and wants.

Despite its importance, the term productivity is not a particularly popular with the general public. This unfortunate situation largely stems from misconceptions, such as the association of productivity with wage cuts, job losses, and the intensification of work. First, cutting wages has nothing to do with productivity. At the lower wage level the same amount of labour is needed to produce a given output level, so productivity is unaffected by the wage cut. Indeed, over time such a development would have a negative effect on labour productivity growth as cheaper labour would lead firms to substitute labour for capital. In contrast, a policy that increased wages would have the opposite effect, leading to the substitution of capital for labour and increasing labour productivity.

Second, at the economy-wide level, there is little to fear in terms of overall job loss from productivity growth. Productivity growth produces real income gains, which in turn are spent to ensure that aggregate demand remains adequate to maintain high employment. While the economy can diverge from high employment levels because of

inappropriate macro-economic policies, it does have a long-term tendency to return to these levels. At the industry level, however, productivity gains can result in significant job losses. The best example is agriculture, which has enjoyed phenomenal productivity gains and at the same time has seen its workforce shrink dramatically in both absolute and relative terms. Since technological change cannot be stopped, workers made redundant because of rapid productivity growth must move to expanding sectors and public policy must support this adjustment.

It is true that work speed-up initiated by a firm can increase productivity, at least in the short run. But this source of productivity gains has little importance in the overall scheme of things and is certainly not sustainable. There are many other more effective ways to increase productivity than work intensification, so there is no need for public policy to focus on this manner of increasing productivity. Productivity is more about working smarter, not harder.

Productivity growth is driven largely by the pace of technical change, capital investment, which embodies new technologies, and the skills of the labour force. In turn, many policies can affect these three fundamental productivity drivers. The role of the government in the productivity area is, through framework policies, to create an environment conducive to innovation, investment and human capital formation.

Given the myriad influences on the drivers of productivity, a productivity agenda can be all encompassing and come from either side of the political spectrum. The debate on productivity is really about the way we want society to increase its wealth. Policy-makers must separate the special interests from the general interest when evaluating proposals to improve productivity put forward by interest groups.

II. Theories of Technological Diffusion

A. Innovation and Diffusion

- ***The diffusion of advanced technologies is intrinsic to the innovation process, as learning, imitation and feedback effects arise to further develop the initial innovation – diffusion is innovation!***

Diffusion is not only the means by which innovations bestow welfare gains upon society. It is also an endogenous characteristic of the innovation process itself, as learning, imitation, and feedback effects which arise during the spread of a new technology further develop the initial innovation. Rosenberg (1982) emphasizes the fact that the diffusion of innovations is often accompanied by learning about their use in different environments, and that this in turn feeds back into improvements in the original innovation.

Alternately, the "chain-linked model" proposed by Kline and Rosenberg (1986) serves as a far better representation than the linear model of the complex, disorderly, and highly interactive process of innovation, and is more useful in understanding the interactions between innovation and diffusion. In the same manner that Thomas Kuhn refutes the notion of "scientific development as a process of accretion," (1996:3), the relationship between innovation and diffusion must not be viewed as linear or incremental progression but rather as a more complex, organic, interaction.

B. Conceptual Frameworks and Modeling of Technological Diffusion

- ***Students of sociology, organizational behaviour, and evolutionary economics focus on human-to-human contact in explaining technological diffusion – networks of communication, institutions and organizations, and social systems shape the determinants of change and mechanisms of information flow.***
- ***Economists concentrate on the decision-making choices of the micro-economic unit – individual heterogeneity determines diffusion patterns.***

The diffusion of innovations has been explored from a number of different perspectives: historical, sociological, economic (including business strategy and marketing) and network and systems theoretical. Since the innovation and diffusion process is extremely complex and widely heterogeneous cross-sectionally by firm size, industry, and other specific firm-related characteristics, much insight can be gained from interdisciplinary investigation.

The sociological and organizational literature focuses on systems of interactions, the role of economic factors, the strategies of firms and development agencies, and the important role of organizations and institutions. This work is exemplified by Rogers (1995), who provides a useful set of five analytic categories that classify the attributes that influence the potential adopters of an innovation:

(1) the relative advantage of the innovation;
(2) its compatibility, with the potential adopter's current way of doing things and with social norms;
(3) the complexity of the innovation;
(4) trialability, that is the ease with which the innovation can be tested by a potential adopter; and
(5) observability, that is the ease with which the innovation can be evaluated after trial.

In addition to these attributes, Rogers also points to a variety of external or social conditions that may accelerate or slow the diffusion process:

(1) whether the decision is made collectively, by individuals, or by a central authority;

(2) the communication channels used to acquire information about an innovation, whether mass media or interpersonal;
(3) the nature of the social system in which the potential adopters are embedded, its norms, and the degree of interconnectedness; and
(4) the extent of change agents' (advertisers, development agencies, etc.) promotion efforts.

In contrast to the focus on the external environment touted by sociologists, economists have grounded their approach in the decision-making of the micro-economic unit. They have tended to view the process as the cumulative result of a series of rational individual calculations that weigh the marginal benefits of adopting a new technology or business practice against the costs of change. This "probit" or "rank" approach, as it is termed in the literature (e.g. Stoneman, 2002), highlights the heterogeneity of individual agents, so that different members of the population obtain different benefits out of any new innovation. In general, analyses of the rank models suggest that factors that affect the diffusion path are:

(1) firm characteristics widely defined to include size, location, history, among others;
(2) discount rates and attitudes to risk;
(3) price, technology and market expectations; and
(4) the number of product variants on the market.

The marketing literature on diffusion is primarily focused on two questions: how to encourage consumers and customers to purchase new products or technologies; and how to detect or forecast the adoption of new products in the marketplace. The Bass (1969) model has found perennial acceptance, and argues that mass media are important early on in the diffusion process but that as time passes, interpersonal communication becomes far more important. The Bass model is a specific example of a larger set of models, known as "epidemic models", in which technology may be considered to spread as might an infection in a population.

C. Patterns of Diffusion and Adoption

- ***Technology adoption is an absorbing state – firms are willing to take on new technologies when they feel that the benefits will outweigh the costs.***
- ***Barriers to the adoption of new technologies impede the diffusion of innovations and often modulate the process to resemble an S-shape when plotted versus time.***

The decision to adopt a new innovation is unlike most economic decisions in that at any point in time the choice being made is not between adopting or not adopting a new innovation, but between adopting now or deferring the decision until later. The distinction is important not merely stylistically, but because of the way in which it affects the perceptions of the benefits and costs. By and large, the benefits from adopting a new

technology are flow benefits that are received throughout the life of the acquired innovation. The costs, however, are typically borne at the time of adoption and cannot be recovered. This is especially true of non-pecuniary real costs associated with learning.

Adoption is characterized by sunk costs. Consequently, adoption is an absorbing state, in the sense that we rarely observe a new technology being abandoned in favour of an old one. This is because once the new technology is adopted, the decision to abandon requires giving up the benefits without regaining the costs, they are said to be sunk. In addition, under uncertainty about the benefits of the new technology, there is an option value to waiting before sinking the costs of adoption. This value arises from the fact that waiting may reduce the chance that the wrong decision is made. Thus, while diffusion may be delayed, it is not necessarily inefficient per se, because it reduces the likelihood of less productive technology being adopted.

No matter the source or nature of a technology, its adoption takes time. The classic observation regarding diffusion is that when the number of users of a new product (market penetration) is plotted versus time, the resulting curve is S-shaped. This finding suggests that the rate at which new innovations are adopted starts at a low level and increases slowly. The rate of adoption then accelerates until a point of inflection is reached, after which the penetration rate continues to increase, but at a decreasing rate.

D. Determinants of the Rate of Diffusion

- ***Any determinant, be it economic, social, cultural or otherwise, that influences the evaluation of the costs and benefits to adopting a new technology can either positively or negatively affect the rate of diffusion.***
- ***The evaluation of the costs and benefits to adopting a new technology is usually riddled with uncertainties and lack of perfect information.***

When the diffusion of past innovations of widely different characteristics is plotted as a function of time, the classic S-shaped pattern emerges. However, what is typically striking is the wide variation in the elapsed time for diffusion. This variation has inspired researchers to derive a list of factors that might be expected to influence the diffusion of innovations. Hall (2004) classifies these determinants into four main groups:

(1) those that affect benefits received;
(2) those that affect the costs of adoption;
(3) those related to the industry or social environment; and
(4) those related to uncertainty and information problems.

The extent to which the older technology remains a substitute for the new innovation is an extremely influential determinant in the diffusion rate of the product or practice. When researchers compared, for example, the historical diffusion pattern for the automatic clothes washer to that of the radio in the United States, they found that the adoption of the latter was approximately 10 times more rapid than the former. The

rationale offered is that the manual clothes washing machine provided an acceptable substitute to the automatic version, whereas there was no good substitute for the radio.

The cost of technology includes not only the price of acquisition, but more importantly the cost of the complementary investment and the real costs of learning (time and effort) required to make use of the technology. The significance of complementary investment, such as the training of workers, is increasing as modern technologies become more complex. In addition, the adoption of a new innovation may require the re-organization of the workplace that will use it. Brynjolfsson (2000) finds that the full cost of adopting new computer information systems based on networked personal computers is about ten times the cost of the hardware.

In general, larger firms adopt new innovations first. However, while large and dominant firms can spread the costs of adoption over more units, they also may not feel pressure to reduce costs that leads to investment in new technologies.

III. Technological Diffusion in Canada

A. Technology Use in Canada versus the United States and the International Community

A report by Baldwin and Sabourin (1998) makes use of the 1989 and 1993 Statistics Canada technology use surveys to study the incidence and competitiveness of Canadian technology users relative to the international community, and in particular the United States. Table 1 compares the incidence of advanced technology use in manufacturing by firm employment size in 1989 and 1993 between Canada and the United States. In every industry for which comparable data exist, Canadian firms generally trail their U.S. counterparts in the adoption of advanced technology. It is important to note, however, that the gap is inversely related to firm size, with very little disadvantage existing for large Canadian firms. Since technology use increases with size, part of the technology gap can be attributed to the fact that a larger percentage of establishments in Canada are small. However, of particular note is that the overall "technology gap" had been halved from 16 percentage points in 1989 to 8 percentage points in 1993.

Table 1 Use of at Least One Technology by Employment Size, 1989 and 1993

Employment Size (Number of Employees)	Use of at Least One Technology			
	1989		1993	
	Canada	United States	Canada	United States
	(% of establishments)			
20 to 99	50	67	70	75
100 to 499	81	89	85	94
500 or more	98	98	94	97
All sizes	58	74	73	81

When compared to the international competitors, Canadian plants fare relatively well, with the larger plants tending to be more competitive than their smaller counterparts. The growing strength of non-traditional economic powers in the developing world is likely to increase competitive pressure on Canadian firms both directly, from establishments in countries such as India and China, but also indirectly through providing similar productivity-enhancing pressure on traditional competitor firms in the United States and Europe.

B. Technology Use in Canada across Regions

Within Canada, regional differences in technology use are relatively minor. The evidence suggests that:

- Ontario establishments rank above the national average in all cases;
- Quebec lags Ontario in each technology group, especially in inspection and communications technologies;
- There is no discernible pattern in Atlantic Canada – this region lags other regions with regards to design and engineering but leads other regions in fabrication and assembly as well as inspection and communications. However, while the adoption rate of technologies may be lower in Atlantic Canada than the rest of the country, firms in this region that adopt are generally as competitive as those in the rest of Canada;
- The Prairies and British Columbia are approximately as competitive as the rest of Canada in design and engineering but they lag substantially in fabrication and assembly.

C. Industry Differences in Technology Use in Canada

Technology use in Canadian firms varies considerably across industries. Some, like electronics, are founded upon intensive use of advanced technologies, while others, like textiles and clothing, are much less likely to use advanced technologies. Since the high technology sector played a substantial role in stimulating growth in the late 1990s, it is important to know whether Canadian plants have a particular advantage or disadvantage in high- as opposed to low-technology industries. On the basis of the use of at least one technology, Canadian manufacturing industries have been classified into three groups based on high, moderate and low technology adoption rates:

- Electronic products, paper, machinery, primary metals, and transportation equipment had high adoption rates;
- Other manufacturing industries, petroleum and chemicals, non-metallic minerals, rubber and plastic, and fabricated metal products had moderate rates; and
- Food processing, printing and publishing, wood, textiles and clothing, and furniture and fixtures had low rates.

Establishments with high technology adoption rates were found to be generally at least as competitive as establishments in medium and low adoption industries. Interestingly, Baldwin et al. (1995) find that firms who employed advanced technologies in 1989 enjoyed higher productivity, profitability, and growth levels in the 1980s than those firms not using advanced technologies. Thus, superior performance leads to the adoption of advanced technologies, which in turn leads to increased productivity – a virtuous cycle of growth.

D. Technology Use in the Canadian Manufacturing Sector

Differences in the incidence of advanced technology use in 1989, 1993 and 1998 by functional technology group are given in Table 2, from Baldwin et al. (1999). The data demonstrate that increases in the rate of adoption were relatively small during the first part of the 1990s, a period during which the manufacturing sector was suffering from a major recession. However, the 1993-98 period was characterized by rapid growth, which led to a substantial rise in advanced technology use. The results indicate that increases in adoption rates in the late 1990s corresponded closely to the relative performance or success of the different technologies in the 1980s.

Table 2 Functional Advanced Technology Use – 1989 to 1998

Technologies	**Use** (% of establishments)		
	1989	**1993**	**1998**
Design and Engineering	17	34	51
Processing, Fabrication, Assembly	21	25	44
Network Communications	17	18	47
Integration and Control	17	24	49
Automated Materials Handling	5	4	5
Inspection	10	10	13

1) Firm Size Differentials in Technology Adoption

Differences in the incidence of advanced technology use by firm size and functional technology group in 1989, 1993 and 1998 are given in Table 3. While the evidence is mixed as to whether innovation increases proportionately with size (Scherer, 1992), the evidence that larger firms make greater use of advanced technologies is much stronger (Baldwin and Sabourin, 1995). Evidence also suggests that large and small plants differ markedly in their economic performance (Baldwin, 1998), and that one major reason behind this may be technology-use differentials. The data showed that:

- In 1989, advanced technology use was found to increase with plant size;
- Adoption rates of large plants were more than double, and sometimes more than triple, those of small plants;
- Large plants had substantially higher adoption rates than medium-sized plants;

- Considerable growth in technology use occurred from 1989 to 1998 in each functional group and for all size classes;
- Differences in the adoption rates between small and large plants have not changed during the nineties, except for network communication technologies where large plants increased their adoption rate advantage relative to small plants. This suggests that smaller plants have fallen behind in one of the most important functional groups in the last decade;
- By contrast however, the medium size classes have reduced the gap between themselves and the largest plants in all of the functional groups over the same period.

Table 3 Functional Technology Use by Firm Size – 1989 to 1998

Technologies	Small			Medium			Large		
	(% of establishments)								
	1989	**1993**	**1998**	**1989**	**1993**	**1998**	**1989**	**1993**	**1998**
Design and Engineering	11	28	44	23	37	63	54	72	87
Processing, Fabrication, Assembly	12	15	34	30	34	62	71	70	90
Network Communication	11	10	35	23	24	69	57	60	92
Integration and Control	9	16	38	23	31	66	63	65	90
Automated Materials Handling	3	3	4	6	5	6	16	13	17
Inspection	7	6	8	13	13	18	39	41	45

2) Canadian-owned versus U.S.-owned Firms

A marked difference between technology adoption rates of Canadian- and foreign-owned plants exists for the entire 1989 to 1998 period. During the recession from 1989 to 1993, foreign-owned plants increased their use of technologies at a faster rate than domestically-owned firms. This supports the view that foreign-owned plants generally react less to local or domestic macro-economic conditions. When establishment size is taken into account, differentials between foreign- and domestically-owned plants continue to exist, although they are somewhat reduced. The poor overall performance of domestically-owned firms on average must be attributed primarily to the medium and small size classes.

3) Technology Adoption Differences by Manufacturing Industry

Evidence suggests that firms in industries relying on science-based research are more likely to be innovative, and since the introduction of advanced technology is often associated with an innovation, advanced technology use will be more prevalent in these industries. Differences in plant size, financial capabilities, and the applicability of certain

technologies all additionally contribute to differences in advanced technology use across industries. The adoption rates of advanced technologies increased substantially from 1989 to 1998 across all industries. Industries that were among the leaders in advanced technology use in 1989 continued to be so in 1998, and in fact the gap between the most and least intensive users widened over this period.

E. Technology Adoption: Benefits and Barriers

Research by Statistics Canada on technology use in Canada found that the benefits arising from technology adoption cited by manufacturing establishments were (in order of importance):

(1) Improvements in product quality;
(2) Productivity gains due to labour reductions;
(3) Increased skill requirements;
(4) Increased capital requirements;
(5) Greater product flexibility (relatively more important in Canada than the U.S. due to short production runs in the Canadian economy);
(6) Reduced setup time;
(7) Increased equipment utilization rate; and
(8) Lower inventory.

Barriers to technology adoption cited by manufacturing establishments were (in order of importance):

(1) Overall cost;
(2) Lack of financial justification;
(3) Cost of technology acquisition;
(4) Need for market expansion;
(5) Cost of education and training;
(6) Time to develop software;
(7) Cost to develop software;
(8) Lack of technical support; and
(9) Worker resistance.

Another general barrier to technology adoption not captured by the Statistics Canada surveys may be a lack of leadership across firms on average. Worker resistance is generally at the bottom of the list of problems in Canada as well as in the United States. The most significant difference in the two countries is the greater emphasis that is placed by Canadian plant managers on the need for market expansion.

F. International Comparisons of Reasons for and Barriers to Advanced Technology Adoption

A recent study conducted by the U.K. Department of Trade and Industry titled *Business in the Information Age: The International Benchmarking Study 2004* provides insight into the reasons for the adoption of advanced technologies and the barriers to this adoption for 11 countries (Australia, Canada, France, Germany, Ireland, Italy, Japan, South Korea, Sweden, the United Kingdom, and the United States). A total of 2,716 businesses in the United Kingdom and 500 in each of the 10 other countries were surveyed on ICT usage, plans, and sentiment within their businesses.[2] The survey offers a unique opportunity to benchmark Canadian experience in the area of technology adoption against that of other countries.

The study investigated the main drivers of ICT adoption among businesses, and identified to what extent these drivers were realized in instances where technology was implemented. Canadian enterprises identified increased efficiency and reduced cost as the two most important drivers behind the adoption of ICT, with 22 per cent and 15 per cent of all businesses pointing to these two factors respectively (Table 4). These perceptions are consistent with the international average of 21 per cent for increased efficiency and 16 per cent for reduced cost. Indeed, improving efficiency was the most commonly cited driver of adoption for all but two of the 11 countries surveyed.

The next three most important reasons for businesses in Canada to adopt ICTs were customer communication (13 per cent), speed of access to information (13 per cent), and keeping up with progress (12 per cent). These reasons appear to be somewhat less of a concern for Canadian businesses than for businesses in other countries. For example, all other counties gave greater weight to keeping up with progress as a reason to adopt ICT, while the international average was double that of Canada. The final three reasons identified by Canadian businesses for adopting ICT (improving quality of service (8 per cent), staff communication (8 per cent), and enabling more information to be shared (6 per cent)) appear to be equally important for Canadian businesses and their international counterparts.

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[2] The survey included micro businesses (0-9 employees), small businesses (10-49 employees), medium businesses (50-249 employees), and large businesses (250+ employees). The survey results were weighted to reflect employee distribution; therefore, data referencing, for example, "30 per cent of businesses" should be understood to mean "businesses accounting for 30 per cent of all employment in that country". Weighting by employment takes into account the economic importance of the businesses involved and allows for more meaningful comparisons to be made between countries, avoiding distortions due to differing industrial structures in each country.

Table 4: Reasons for Adopting ICT as Identified by Businesses, per cent of all businesses in each country, 2004

	Canada	United Kingdom	France	Germany	Italy	Sweden	Ireland	United States	Australia	Japan	South Korea	Average (excluding Canada)
Increased efficiency	22	22	13	14	8	21	22	14	25	49	23	21
Reduced cost	15	13	n.a.	29	8	35	11	13	16	11	10	16
Customer communication	13	18	18	24	16	27	19	13	17	8	5	17
Speed of access to information	13	10	23	32	23	n.a.	14	17	11	4	11	16
Keep up with progress	12	15	27	20	31	24	17	20	21	48	18	24
Improve quality of service	8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6	n.a.	n.a.	n.a.	6
Staff communication	8	8	10	14	n.a.	13	n.a.	7	9	4	n.a.	9
Enable more information to be shared	6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	7	n.a.	7
Customer demands	n.a.	9	9	n.a.	n.a.	10	7	n.a.	n.a.	n.a.	4	8
Integral to my type of business	n.a.	8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	8
Simplify process	n.a.	n.a.	9	14	11	13	8	n.a.	11	n.a.	34	14
Supplier communication	n.a.	n.a.	9	17	12	15	n.a.	n.a.	11	3	n.a.	11
Keep up with competitiors	n.a.	n.a.	n.a.	n.a.	14	n.a.	8	7	n.a.	n.a.	5	9

Source: "Business in the Information Age: The International Benchmarking Study 2004", Department of Trade and Industry, United Kingdom, Figure 8.3e.

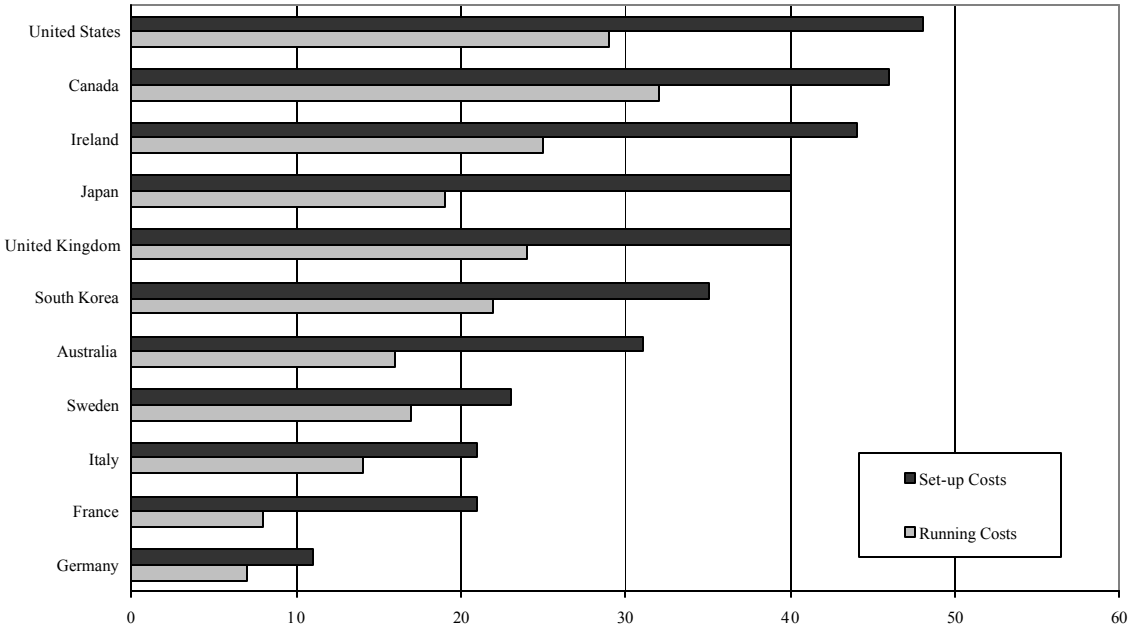
Question posed to 2,716 businesses in the United Kingdom and 500 businesses in each other country: "What were the main reasons for adopting the online technologies you currently have?" and "which of these reasons have been realised?"

Note: (i) Data are available only for the top eight overall drivers of ICT adoption in each country as identified by businesses in each respective country; therefore, a value of "n.a." indicates that the particular driver of ICT adoption did not rank in the top eight most important drivers of ICT adoption for the respective country.

(ii) Data are also available for the percentage of businesses in each country that were able to realize their stated goal for ICT adoption. In Canada, the per cent of businesses that achieved their goal is essentially identical to the per cent of businesses that listed each respective goal as a driver in ICT adoption. Only businesses in Australia, France, Germany, Italy, and Sweden diverged significantly (more than 10 per cent overall) from the above figures, in that a lower percentage of businesses were successful in achieving each goal than the percentage of businesses that listed the respective goal as a driver in adopting ICT.

According to the study, costs remain the single most significant barrier to the adoption of ICTs for Canadian businesses. Furthermore, by breaking down costs into set-up costs and running costs, the study finds that set-up costs are perceived as a far greater impediment to technological adoption than are running costs. Relative to the other 10 countries analyzed in this study, Canada ranks very high in terms of business perceptions of cost as a barrier. In fact, Canada had the highest percentage of businesses that perceived running costs as a barrier, at 32 per cent in 2004, and ranked second highest in terms of business perceptions toward set-up costs, with 46 per cent of Canadian businesses identifying them as a barrier to ICT implementation (Chart A). English-speaking countries were most likely to cite costs, both fixed and variable, as a barrier to ICT implementation. France, Germany and Italy were found to be the least concerned with costs as a barrier to adoption among the countries studied.

Chart A: Business Perceptions of Cost as a Barrier to Technology Implementation, per cent of all businesses in each country, 2004



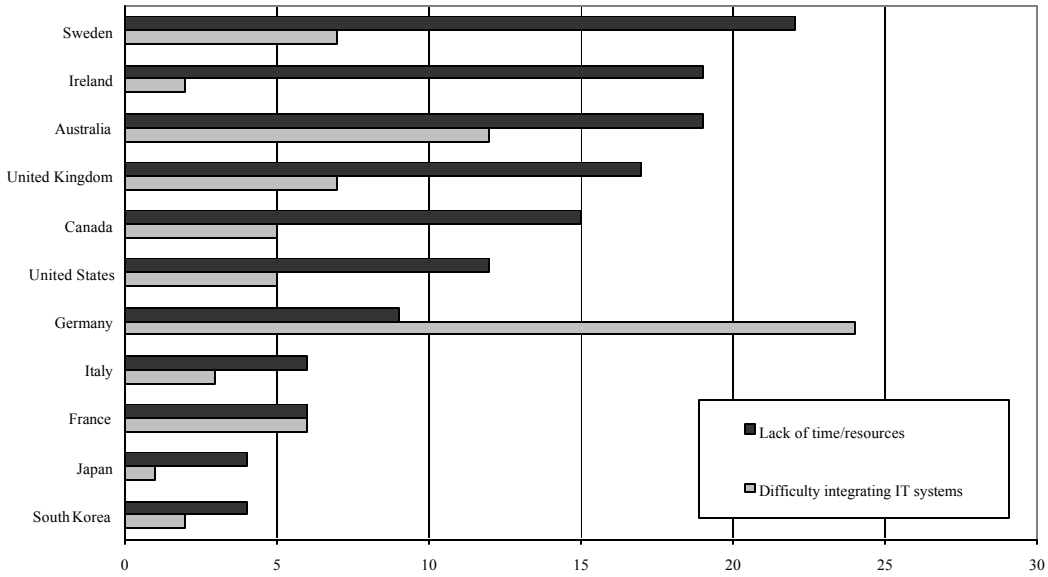
Source: "Business in the Information Age: The International Benchmarking Study 2004", Department of Trade and Industry, United Kingdom, Figure 5.2g. Question posed to 2,716 businesses in the United Kingdom and 500 businesses in each other country: "Can you tell me what has made it difficult for you to implement technology?"

"Functional aspects" (lack of time and resources and difficulty integrating IT systems) and "people factors" (lack of skills, reluctance of staff, and lack of knowledge) were also analyzed across countries as potential barriers to ICT implementation. In terms of "functional aspects", Canada was found to be in the middle of the pack in terms of business perceptions toward both barriers, with 15 per cent of Canadian businesses citing lack of time and resources and only 5 per cent of Canadian businesses mentioning difficulties integrating IT systems as serious impediments (Chart B).

"People factors" were discovered to be relatively insignificant obstacles for Canadian businesses in terms of ICT adoption. Of the 11 countries studied, Canada ranked second

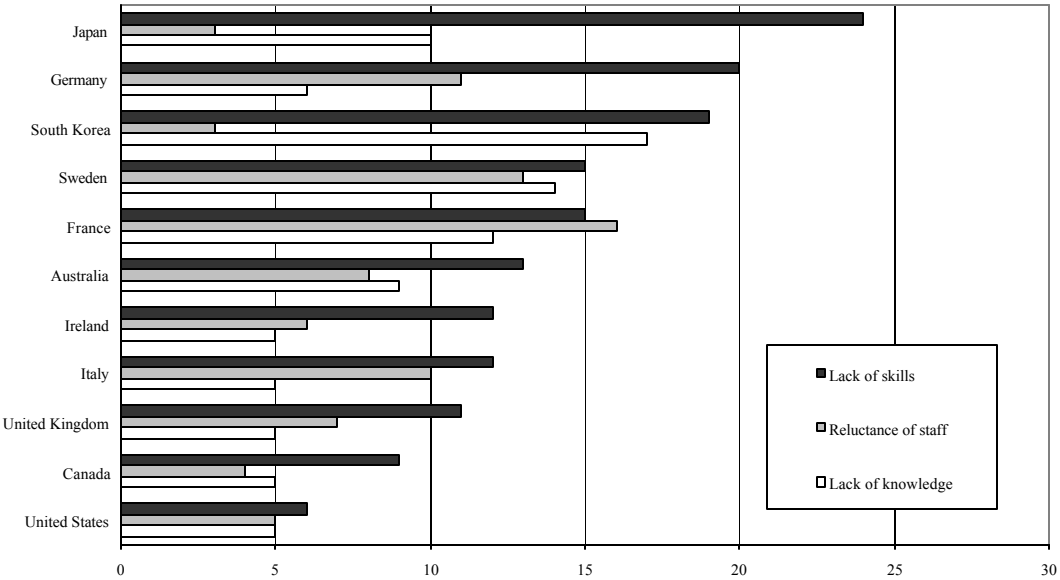
last, with only 9 per cent of businesses citing lack of skills as troublesome, 4 per cent identifying reluctance of staff, and 5 per cent attributing lack of knowledge as a serious barrier (Chart C). According to this evidence, it is clear that costs, both set-up and running costs, are perceived to pose far greater challenges to Canadian businesses in implementing ICT than do "functional aspects" or "people factors".

Chart B: Business Perceptions of "Functional Aspects" as a Barrier to Technology Implementation, per cent of all businesses in each country, 2004



Source: "Business in the Information Age: The International Benchmarking Study 2004", Department of Trade and Industry, United Kingdom, Figure 5.2i. Question posed to 2,716 businesses in the United Kingdom and 500 businesses in each other country: "Can you tell me what has made it difficult for you to implement technology?"

Chart C: Business Perceptions of "People Factors" as a Barrier to Technology Implementation, per cent of all businesses in each country, 2004



Source: "Business in the Information Age: The International Benchmarking Study 2004", Department of Trade and Industry, United Kingdom, Figure 5.2j. Question posed to 2,716 businesses in the United Kingdom and 500 businesses in each other country: "Can you tell me what has made it difficult for you to implement technology?"

G. Canada's Relative Productivity Levels

An indirect approach to the identification of gaps in the use of technologies across countries is the use of relative labour productivity levels. Differences in the use of best practice technologies are a key factor behind differences in industry labour productivity levels across countries. Therefore, the existence of a labour productivity gap is prima facie evidence of a gap in the use of advanced technologies.

Chart 1 provides estimates of Canada's level of output per hour relative to that in the United States for 29 industries in 1999 based on productivity benchmarks developed by Industry Canada. In nine industries (mining, construction, wood, paper, printing and publishing, primary metals, non-metallic mineral products, motor vehicles, other transportation equipment) output per hour in Canada in 1999 exceeded that in the United States. However, in the other 20 industries, output per hour was lower in Canada. It is likely in these industries that Canadian firms employ less advanced technologies than their U.S. counterparts.

IV. Stakeholder Perceptions of Technological Diffusion and Adoption

A number of documents that address the issue of technological diffusion and adoption have recently been released in Canada, the United States and other OECD countries by major stakeholders and by governments. This section provides a synthesis of the key themes of these studies.

A. The Role for Governments

Common to all of the documents is an emphasis on the need for governments to take certain actions to ensure technological competitiveness. A focus on research and development is highlighted by all stakeholders, with recognition that R&D leads to an innovative environment, greater absorptive capacity, and higher adoption rates of advanced technologies. Education and training are also emphasized as the need for a skilled workforce becomes ever more important. Lack of attention to these areas can start a downward innovation cycle – less national focus on R&D leads to fewer students going into science and technology related fields, which in turn results in less domestic corporate R&D, which leads to fewer science and engineering job opportunities and, therefore, an even smaller national focus on R&D.

In *Manufacturing in America*, a publication of the U.S. Department of Commerce, several recommendations are made to help governments foster technology adoption:

- Lead a benchmark analysis to measure progress in technological adoption – a key component of any business strategy is a means of measuring progress toward a defined goal;

- Foster coordination and cooperation among federal, provincial, and municipal governments – strengthen partnerships to promote technology transfer;
- Create the conditions necessary for economic growth and manufacturing investment; for example, promote research and experimentation tax credits, eliminate regulations that stifle innovation, and review patent legislation;
- Modernize the legal system to eliminate disincentives to investments;
- Support R&D;
- Invest in education, skills training and retraining, as well as higher education;
- Promote cooperative technical assistance programs on standards.

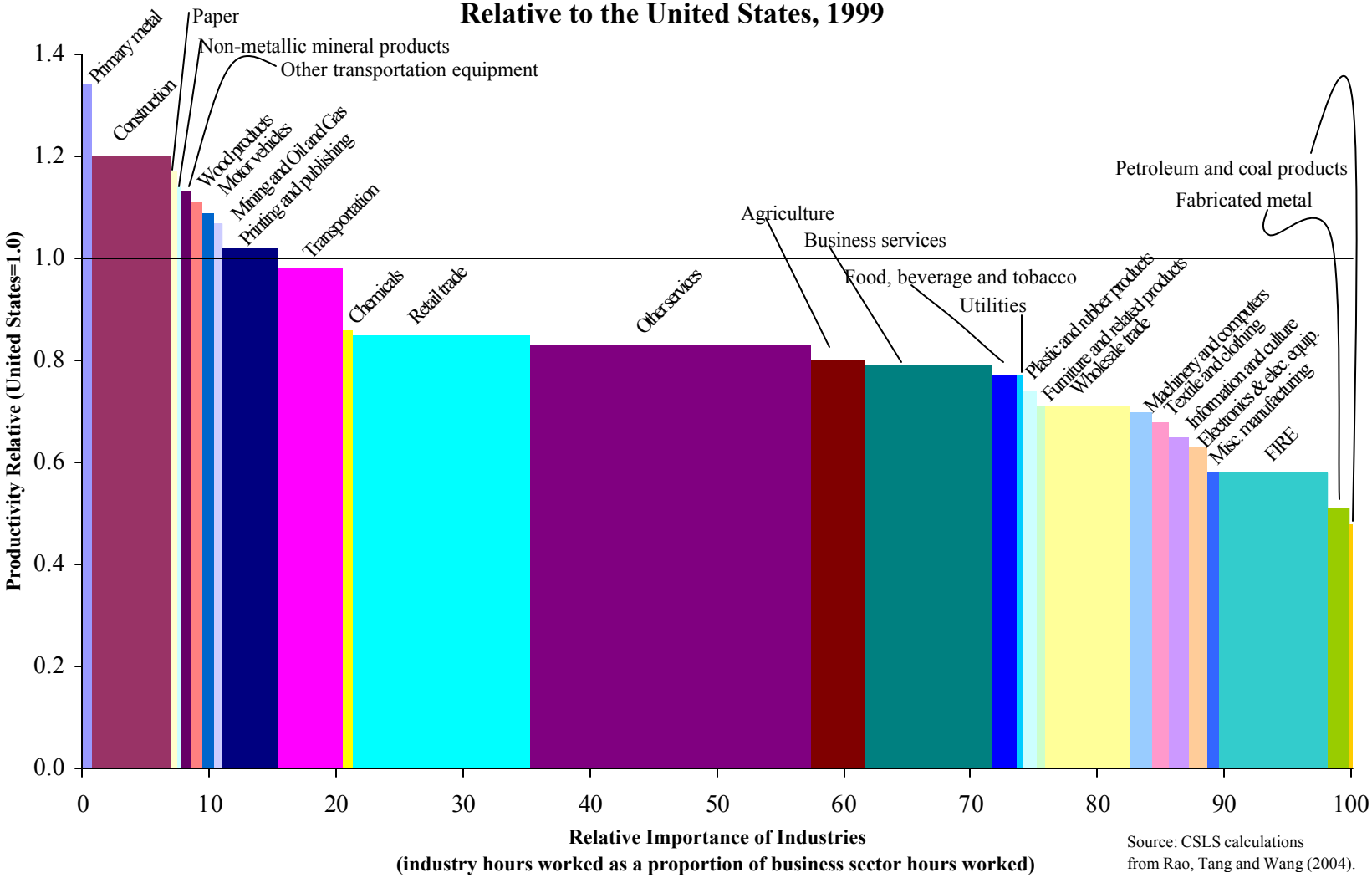
B. A New Way of Doing Business

A recent report from the Economist Intelligence Unit (EIU), entitled *Business 2010: Embracing the Challenge of Change*, suggests that the pace of change in the next few years will be relentless, and will pose the greatest of challenges for firms. Based on interviews with executives and decision-makers worldwide, EIU research found that *how* companies do business will often be more important than *what* they do. To compete successfully, they argue, businesses will have to instill an adaptability to change and achieve the requisite speed of innovation, get to know and interact with their customers more regularly and intensively, and focus on specialization. There exists widespread agreement that technology will be critical to a firm's ability to achieve these goals and remain productive, especially in an increasingly globalized competitive environment.

C. A Canadian Investment Deficit

Both the C. D. Howe Institute and Ontario's Institute for Competitiveness and Prosperity have recently released documents warning of investment shortages in Canada. In the late 1980s, a booming economy and the prospect of freer trade helped investment per worker in Canada keep pace with that in other developed nations, and enabled the country to close a long-standing gap with the United States. Since then, however, Canada's investment per worker has slipped. In 2005, the average investment per Canadian worker was $1,150 less than the typical worker in OECD countries, and $2,690 (23 per cent) less than a counterpart in the United States. This trend threatens the future competitive viability of Canadian firms on the international stage.

Chart 1: Industry Levels of Output per Hour in Canada Relative to the United States, 1999



Source: CSLS calculations from Rao, Tang and Wang (2004).

V. Public Policy Issues Related to Technological Diffusion and Adoption and Remaining Gaps in our Understanding of Diffusion

Stoneman (2002: 178) has noted that while it is recognized that the process of diffusion or use of technology creates productive potential, policy initiatives have largely bypassed opportunities to improve the diffusion process. This situation broadly reflects the state of the academic literature, which is extensive on R&D policies but limited on diffusion policies. But Stoneman points out that a gradual reorientation of policy towards diffusion appears to be taking place, as evidenced by major technological policy initiatives by the U.S. and U.K. governments that stress the importance of creating an infrastructure conducive to the rapid spread of awareness and knowledge of innovations.

Stoneman demonstrates that there is a serious theoretical case for diffusion policy based on market failures in the areas of imperfect information, market structures, and externalities. Despite this justification, he notes that there have been very few policy initiatives to promote technological diffusion, and that the few schemes that have been implemented to counter problems of imperfect information have been directed at small and medium-sized enterprises (SMEs). These schemes include regional innovation centres to provide consultancy services to SMEs, programs to facilitate the adoption of specific technologies, attempts to cluster firms in particular locations to encourage the interchange of knowledge and ideas, and programs to stimulate the formation of networks.

Despite the limited number of policies designed to promote diffusion directly, Stoneman points out that the diffusion of many innovations is strongly affected by public policy and that there is a wide range of "diffusion policies in disguise." He gives as an example the U.K. policy on foreign direct investment, which led to the establishment of Japanese automakers in the United Kingdom and gave an enormous impetus to technology diffusion among domestic auto companies. Many different policies affect technology diffusion, including industrial policy and policies in the areas of R&D, education, infrastructure and transport, employment and industrial relations, trade and investment, accounting, and environmental protection.

There are many critical gaps in our knowledge and understanding of technological diffusion in Canada. The following points briefly highlight a number of issues that require further investigation to ensure Canada's technological success in the coming years.

- Identification of sectors where Canadian firms are world class and where they are lagging their counterparts in the United States and other countries in technological adoption and use.
    - Very little international data exists for advanced technology use outside the manufacturing sector for all years, for manufacturing since 1998, and for business practices in general.
- Identification of key barriers to technological diffusion in Canada.

    - Do the barriers that were identified for the manufacturing sector in the 1998 Statistics Canada survey continue to apply, in the same order of importance, and are they relevant to other industries?
- Identification of general economic policies that may currently be inhibiting technology diffusion in Canada or that could be used to foster diffusion.
    - Examples may include specific policies in the general policy areas of competition, investment, tax, trade, and others.
- Identification of appropriate direct policy interventions that can overcome the specific barriers to the adoption of advanced technologies and business practices and generally promote the diffusion process in Canada based on past experience of what works and what does not work.
- Identification of the specific impacts of current trends in globalization and the increasing economic importance of the developing world on technological diffusion in Canada.
    - Much literature shows that technologies, and even more so business practices, are more easily adapted by a firm if the adopting country is "similar" to the country originating the technology. As the relative importance of Asian countries as a source of the world supply of innovations increases, and that of the United States falls, will it become more difficult for Canadian firms to adopt new technologies from other countries given the greater dissimilarity and weaker linkages between Canada and Asia than between Canada and the United States?
- Identification of the specific challenges that SMEs in Canada confront with regard to technological adoption.
    - SMEs often lack the requisite absorptive capacity needed for advanced technology adoption – avenues for leveraging the unique capabilities of national laboratories and universities could include access to sophisticated research tools and assistance in business planning that SMEs would otherwise not be privy to.
    - Investment in many technologies becomes cost-efficient for the firm only at a certain level of output – opportunities for technology collaboration should be explored.
- Improved communication, networking, and coordination among all stakeholders.
    - Both innovation and diffusion are characterized by complicated human-to-human interactions that often provide outcomes unimaginable ex-ante. Intensive collaboration, across disciplines and with all stakeholders, allows for the free flow of knowledge and information, new and old, and creates an optimal condition for innovation to flourish.
- The issue of whether strong R&D performance is a prerequisite for the broad diffusion of technologies.
    - Some economists argue that a free rider policy of de-emphasizing national R&D effort and emphasizing the adoption of technologies developed in other countries will not be effective without R&D, because countries need an absorptive capacity created through R&D to assimilate new technologies. Others argue that since the vast majority of firms will never undertake R&D, yet do adopt new technologies, free riding can be a

viable strategy. The relative virtues of these two positions and possible tradeoffs between supporting R&D and supporting diffusion in the presence of limited public funds to promote innovation merit discussion.

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