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Innovation in Canadian Manufacturing Enterprises

Survey of Innovation and Advanced Technology 1993

John Baldwin Moreno Da Pont

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Moreno Da Pont

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Innovation in Canadian Manufacturing Enterprises

Survey of Innovation and Advanced Technology (1993)

John Baldwin and Moreno Da Pont
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Introduction

Most empirical work on economic growth has focused on measuring one outcome of the innovation process (productivity gain), or one result (patents), or one input into the process (research and development expenditures). Each of these gives only a partial view of innovation. There are other inputs into innovation besides research and development. Patents are not used for all innovations. Productivity gains, which are associated with producing more output using fewer inputs, are most prevalent for improvements made to the production process and are difficult to measure for product innovations.

Innovation surveys have begun to provide a more comprehensive look at the innovation system. On the one hand, these surveys provide a richer picture of the innovations that are produced and the inputs that go directly into the commercialization of ideas. As such, they describe the nature of the innovative output and the nature of inputs that facilitate innovation across a wide range of firms and industries. On the other hand, they delve into complementary strategies that contribute to success. Innovation depends upon more than just technological facilities. It also requires skills in marketing, management and finance.

This survey focuses first on the nature of innovative outputs. Innovations differ in a large number of dimensions. They may involve major pathbreaking discoveries or more routine applications of findings that others have already applied elsewhere. They may be oriented towards products or processes or both. Even within specific innovation categories, differences exist. For example, some product innovations will result in the production of entirely new goods while others will result in quality improvements for existing goods. This report examines both the characteristics of innovative firms in the Canadian manufacturing sector and the general effects of introducing various types of innovation, as reported by these firms.

On the input side, this survey asks where the major ideas for innovation originate. The research and development unit has long received the lion's share of attention from both statisticians and economists. But other sources of technological capability exist, especially in production engineering. And on the product development side, both marketing and sales personnel potentially play important roles in developing new products.

Inputs for innovations come not only from inside but also from outside the firm. Both suppliers and customers interact to improve product lines and production processes. Consultants, suppliers, research agencies, universities, related firms and competitors all contribute to innovation. Since innovation is a collaborative affair, this survey documents the network of contacts that is used to support innovation in Canada.

Several additional topics that touch on the input side to the innovation process are also pursued. First, the intensity of research and development activity is investigated in some depth. Second, the impact of innovation on the demand for labour and on the skill levels of the labour force are examined. Finally, the role of new advanced technology as part of the innovation process is explored.

The effectiveness of a country's innovation system depends upon the incentives provided for innovation. Public policy here plays many roles. Sometimes it is interventionist, for example, with regards to offering technical support services. Sometimes, it focuses more on establishing broad framework policies like intellectual property laws. The survey investigates the extent to which intellectual property laws are used by innovators to protect their innovations from imitators. It also investigates whether firms experience impediments in other areas where public policies affect innovation—in skill development, in technological support, and in market information.

Throughout this study, the characteristics of innovations are classified by their importance. Some innovations are path-breaking—like lasers and transistors. Others involve only incremental improvements, but may have a significant impact when cumulated over a long period. It is important not to restrict our interest to just the former, since much of economic well-being stems from the smaller incremental types of innovations. Therefore, firms who reported that they had at least one major innovation are divided into three groups—depending upon whether their most important innovation was a world-first, the first of its kind in Canada, or neither of these two. The characteristics of the innovative regime pursued by each are documented separately.

The Survey

The data on innovation presented in this paper were collected through the Innovation and Advanced Technology Survey. Although the focus here is on characteristics of the subset of surveyed firms that were found to be innovative, the survey itself has a much broader scope and includes sections dealing with the nature of research and development, intellectual property usage, advanced technology adoption and the general characteristics of the surveyed firms.

The Innovation and Advanced Technology Survey was conducted in late 1992 and early 1993, using a sample of manufacturing firms of all sizes. The questionnaire is made up of eight sections: section 1 contains general questions, section 2 - R&D questions, sections 3 and 4 - innovation questions, section 5 - intellectual property questions and sections 6, 7 and 8 - technology questions. This publication focuses on sections 2, 3, 4 and 5.[1]

Three types of units were sampled: large plants whose head offices are located elsewhere in Canada; the corresponding head offices of these plants; and small firms that have both their management and plant at the same location. The first five sections were sent to head-office management, while the last three were addressed to plant managers (see Table 1).

Table 1

The types of sampling units and the sections to which they were required to respond

Firm Size	Sections				
	1 General	2 R&D	3,4 Innovation	5 Intellectual property	6,7,8 Technology
	Questions asked of				
Head offices	all	all	all	all	
Small firms (Group 1)	all		some	all	
Small firms (Group 2)	all	all			some
Large plants					all

Note: 'all' means respondents were asked to answer all questions in the section while 'some' means that they were only asked to answer some of the questions.

Within large firms,[2] plant managers were sent the technology sections and management in the corresponding head office was sent the first five sections. Together, the head office responses of large firms to questions on general characteristics, R&D, innovation and intellectual property, along with responses to technology questions as provided by their plants, offer a comprehensive overview of these firms' innovative and technological capabilities.

[1] Technology sections of the survey are reported in John Baldwin and David Sabourin. *Technology Adoption in Canadian Manufacturing.* Statistics Canada: Catalogue #88-512, 1995 and in John Baldwin, David Sabourin, and Mohammed Rafiquzzaman. *Benefits and Problems Associated with Technology Adoption in Canadian Manufacturing.* Statistics Canada: Catalogue #88-514, 1995.

[2] Large firms are defined as the more complex firms that account for the majority of economic activity in the Canadian manufacturing sector. These "large firms" range in employment size from about 20 employees to over 500 employees. Small firms generally have less than 20 employees.

The small firms were handled somewhat differently. In order to reduce response burden, they were separated into two groups. Sections 1, 3, 4 and 5 were sent to the first group, while the second group received sections 1, 2, 6, 7 and 8. For certain sections, small firms were only asked selected questions to further reduce their response burden.

There were 1,595 head offices (answering the first five sections) sampled, 1,954 large plants (answering the last three sections) sampled, 1,088 of the first group of small firms (answering the first, third, fourth and fifth sections) sampled, and 1,092 of the second group of small firms (answering the first, second, sixth, seventh and eighth sections) sampled, for a total of 5,729 units sampled.

The survey was conducted in several steps. Initially, the firm was contacted to determine who within it (both in the head office and in the plant) should be sent each section. These individuals were then contacted by phone to confirm their ability to answer the survey. Then the questionnaire was mailed out to these designated individuals. Finally, extensive telephone follow-ups were performed. Over half of the responses were received via telephone interviews. The response rate for the survey as a whole, across all sections, was 85.5% and ranged from 92.9% for the second group of small firms to 77.7% for the large plants.

The data presented in this report are based on the 1,366 large firms that indicated that they either had or had not introduced an innovation. Much of the detail reported is based on the subset of 573 firms that indicated they were innovative and that provided details about their most important innovation. Reported data are employment-weighted.[3] Thus, the proportion of firms that are shown to have a given characteristic (for example, those who have process innovations) represents the proportion of total employment accounted for by large manufacturing firms with that characteristic (i.e., a process innovation). The target population consists of large Canadian firms that have at least one manufacturing plant in Canada.

[3] The employment used for this purpose is the manufacturing employment of the business entity that controls the firm answering the survey.

Survey Results

How Prevalent is Innovation?

Innovation involves the successful commercialization of an invention that enables firms to produce new goods or services, to improve on existing ones, or to improve the way existing or new products are produced or distributed.

Canadian manufacturing firms are intensively involved in the innovation process (Figure 1). Some 36% (company-weighted)[4] of all large Canadian firms either introduced an innovation over the period of 1989-91, or were in the process of introducing an innovation in 1992-93. These innovative firms accounted for 42% of employment (employment-weighted).[5]

Innovations cover a wide range of new products and processes. Some will be considered more significant than others. On the one hand, the innovation may be so path breaking that it is the first of its kind to be adopted in the world (a world-first). In other cases, the innovation may be a Canadian-first. Finally, if an innovation is new to the firm in question but has already been adopted by at least one other Canadian firm, it is neither a world- nor a Canadian first (other innovations).

In order to assess how innovations are distributed across categories, firms were asked to classify their most important innovation into one of the three categories. Of all large firms, 8.5% (weighted by employment) described their most important innovation as a world-first. These firms were able to introduce innovations that involved either the use of new advanced technologies, or the development of distinct products, or some combination of the two that was highly unique. Some 15% of firms described their most important innovation as a first within Canada. The remainder (18%) produced innovations that were imitative.

Although the data presented are for the larger more complex firms accounting for the majority of economic production in the Canadian manufacturing sector, these firms vary considerably in terms of size. In order to examine whether or not the intensity of innovation differs across size classes, the large firms were divided into three employment-size categories: firms with fewer than 100 employees; firms with between 100 and 500 employees; and firms with more than 500 employees.

Approximately 43% of firms in the two largest size classes are innovative as compared to 35% of firms in the smallest class (Figure 2). Firms in the largest employment size class are most likely to introduce world- or Canadian-first innovations, while those in the smallest size class are least likely to introduce

[4] A company-weighted result reveals the percentage of firms in the population that possess a given characteristic.

[5] An employment-weighted result reveals the percentage of total employees accounted for by firms in the population that possess a given characteristic.

Figure 1

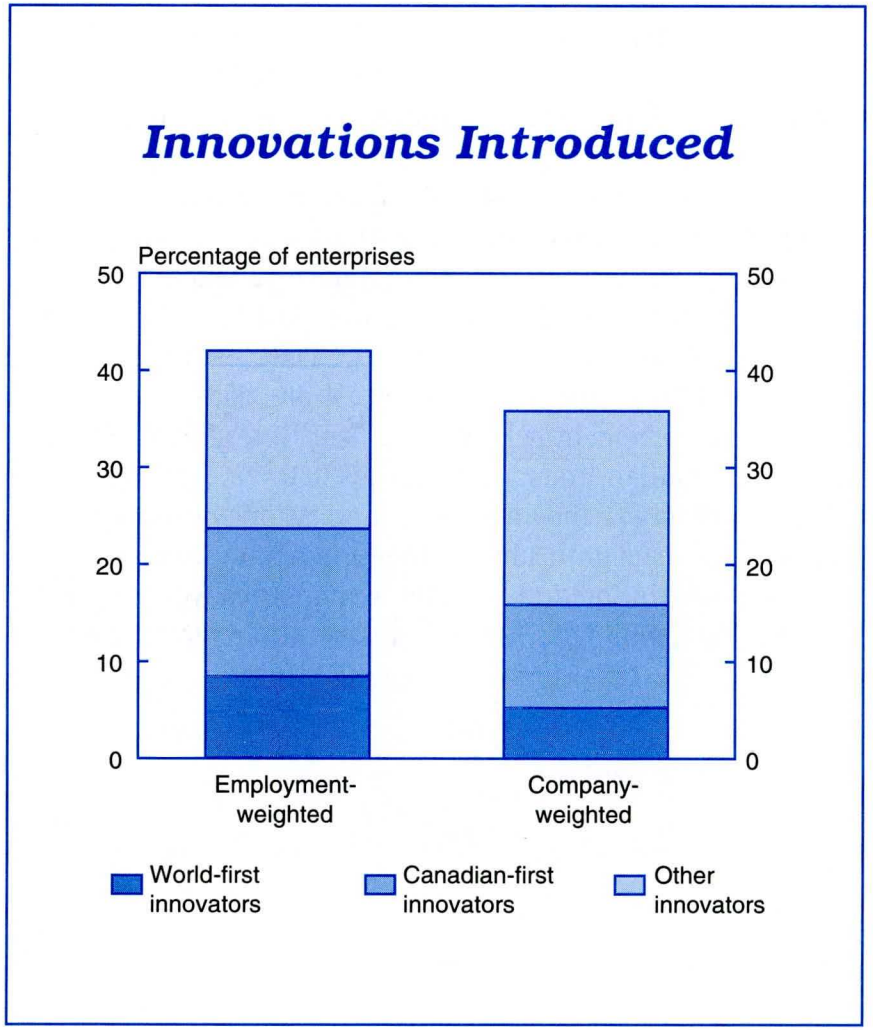
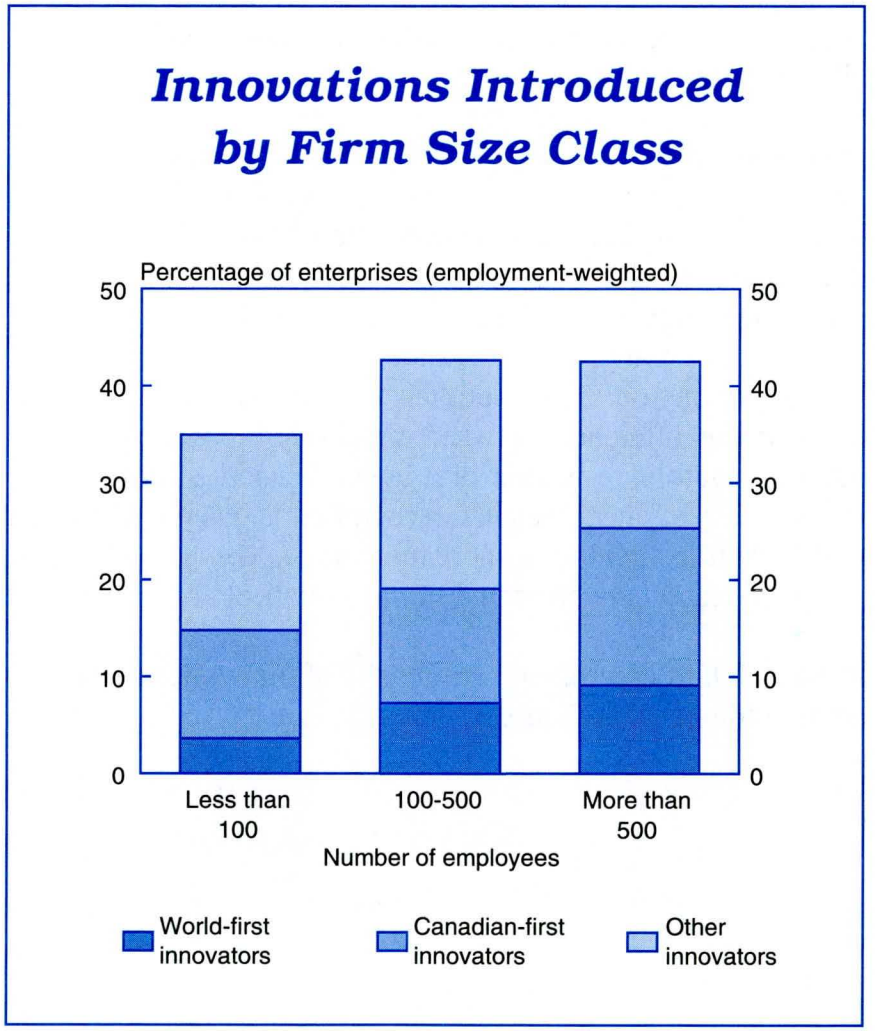


Figure 2



innovations of this nature. Imitative innovations are introduced at approximately the same rate by firms in the two smaller groups and are less likely to be introduced by firms in the largest group. This being said, imitative innovations are still the most frequently used method of innovation by firms in all three size classes.

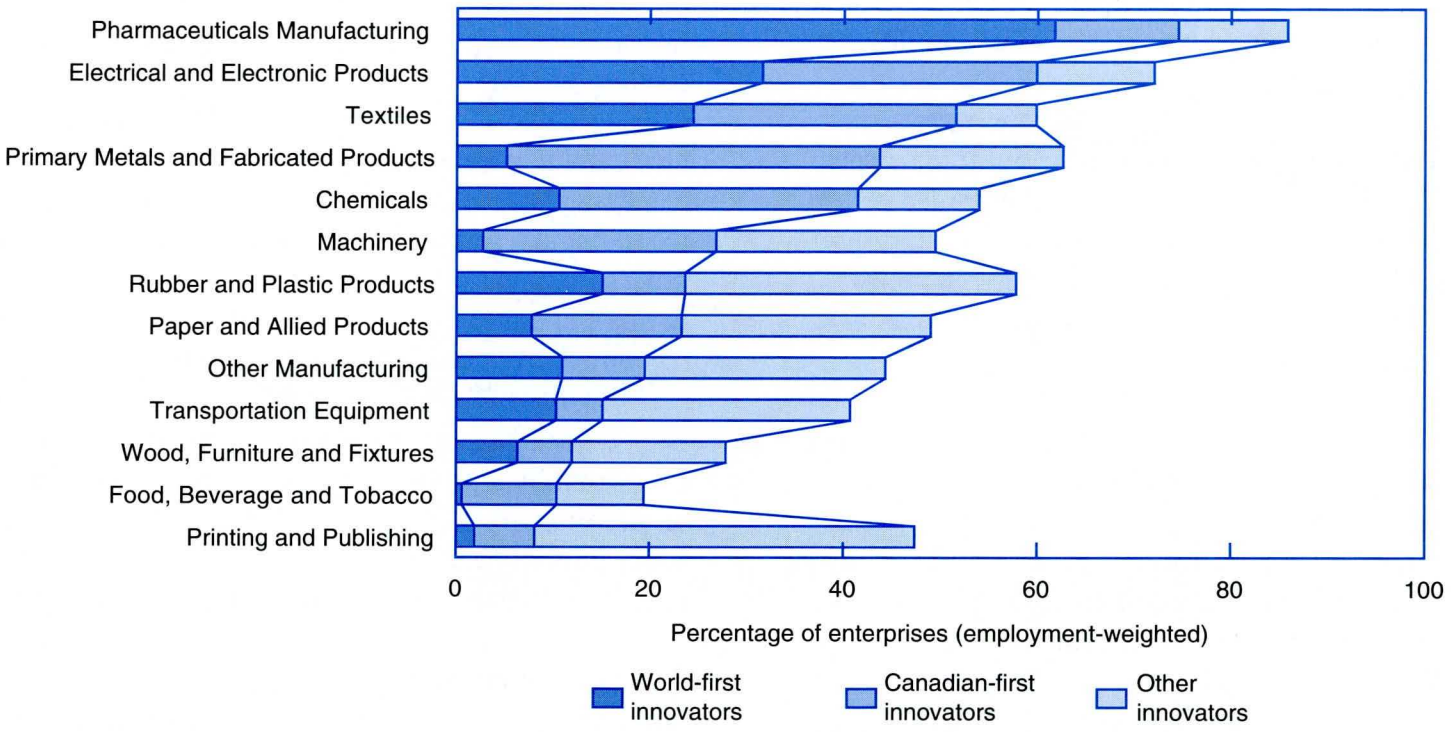
In subsequent sections of this study, firms will generally be divided into one of two categories—those that produce world-first innovations and all other innovators. Differences between these categories will be used to show how characteristics of innovative firms vary by the significance of the innovation produced. Although the innovative behaviour of firms will vary depending on the size of their workforces, this study will focus on the differences between world-first innovators and all other innovators, regardless of firm employment-size. However, by using employment weights, recognition is given to the fact that large firms tend to be more innovative. Company-weighted results are presented in the statistical appendices.

Substantial differences in the intensity of innovation exist across industries. In Figure 3, industries are ranked in descending order according to the percentage of firms classified to the industry who introduced either world- or Canadian-first innovations.

The leading industry is Pharmaceuticals with over 74% of total industry employment belonging to firms introducing either world- or Canadian-first innovations, and over 85% of employment in firms producing any one of the three types of innovations. Electrical and Electronic Products are second with 60% of employment in firms introducing firsts and 72% of employment in innovative firms. Textiles, Primary Metals and Chemicals follow with intensities ranging from 51% to 41% for firms introducing firsts. Wood, Furniture and Fixtures; Food; and Printing and Publishing have the lowest intensities, with 8%-12% of employment belonging to firms introducing either world- or Canadian-firsts. If industries had instead been ranked according to the amount of innovations introduced, regardless of the significance of the innovation, Rubber and Plastics; and Printing and Publishing industries would move up in ranking, while the Textile industry would move down.

Figure 3

Innovation Intensity by Industry



Types of Innovation

The innovation systems of countries differ in their tendency to concentrate on product innovations as opposed to process innovations. Countries that specialize in product innovations are seen to have innovation systems characterized by firms with imaginative new ideas. These are countries that benefit from leading the product life-cycle. Countries that produce predominantly process innovations are seen to have technological systems that permit advances in production processes and associated products.

A product innovation is the commercial adoption of a new product.[6] Product innovations may be accompanied by technological change when the underlying manufacturing processes are modified in order to produce the innovative product. In such cases the innovation is referred to as a combined product-process innovation.

A process innovation is the adoption of new or significantly improved production methods. These methods may involve changes in equipment or production organization or both. They may be intended to produce new or improved products, which cannot be produced using conventional plants or production methods, or to increase the production efficiency of existing methods.

The surveyed firms are classified according to whether they described their innovations as either process, product, or combined product-process innovations (Figure 4). Some firms introduced several different innovations and, therefore, chose two or in some cases all three of the innovation types as being descriptive of their innovative behaviour.

Overall, Canadian innovative firms favour process over product innovations. Some 59% of innovators introduce purely process innovations compared to only 42% with purely product innovations. However, a large percentage (62%) introduce combined product-process innovations. The innovation process does not split neatly into two groups since innovation on both the product and process side go hand in hand in such a large percentage of the population. Equally, the importance of technological competence is emphasized by the fact that process innovations are at work in at least 80% of the innovating population (i.e., 80% of firms introduced process or combined product-process innovations).

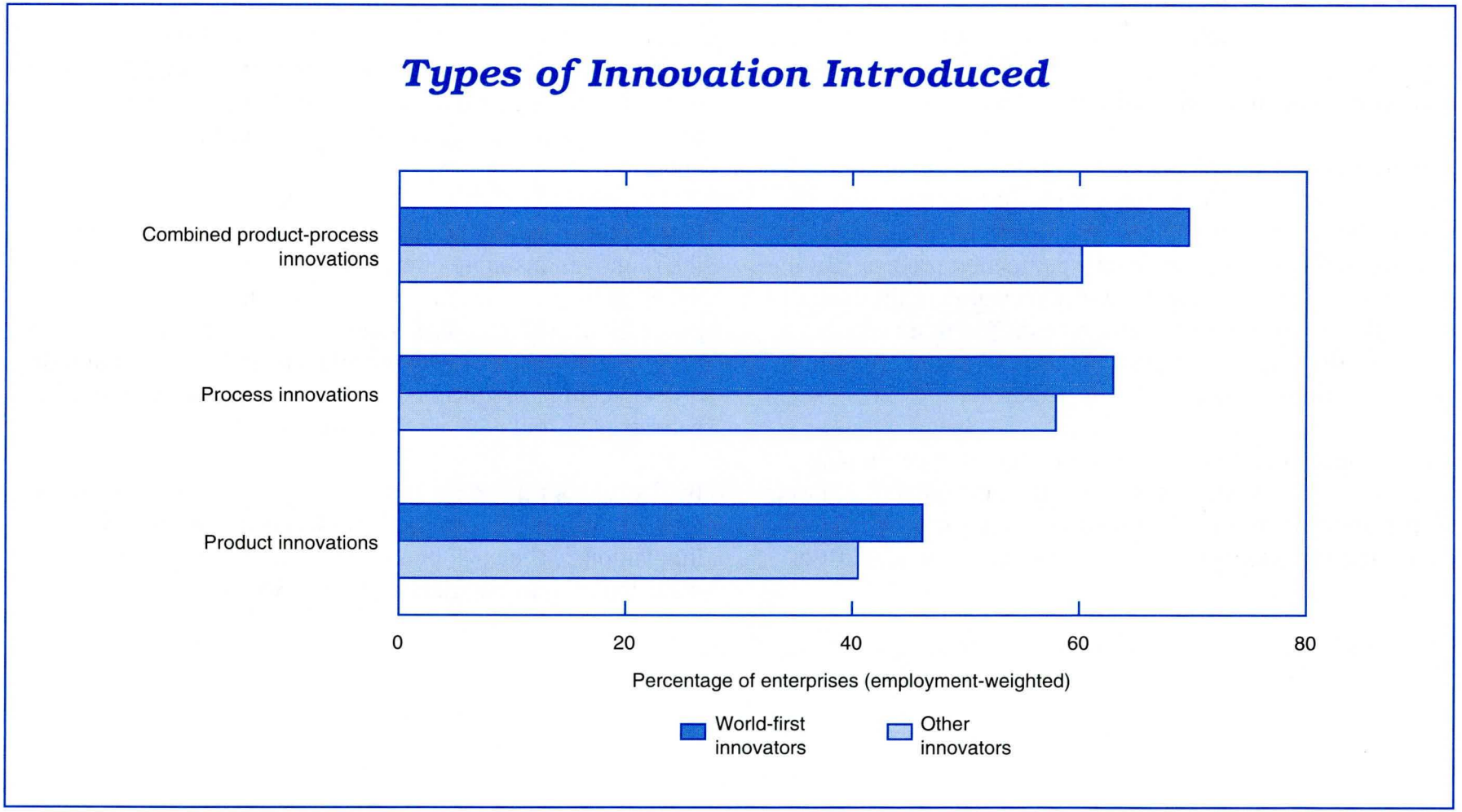
Both world-first and other innovators are most likely to introduce combined product-process innovations with process-only innovations following closely behind. The concentration on some form of process innovation, either by itself or as part of a product innovation is evident in both firm segments.

World-first innovators are more likely than others to introduce multiple types of innovation. A higher percentage of world-first innovators pursue each of the three innovation types, although the differences are not statistically significant. The largest difference between the two segments occurs for the combined product-process category. Some 70% of world-first innovators introduce combined innovations, while only 60% of other innovators do so. World-first innovators are different in

[6] Changes in products that are purely aesthetic (such as changes in color or decorations), or which simply involve minor design or presentation alterations to a product while leaving it technically unchanged in construction or performance are not considered to be product innovations.

that they emphasize changes both to manufacturing technologies and to end-products produced. It is not so much the emphasis on products or processes that distinguishes the world leaders from the followers, as it is the ability of the leaders to master both product conception and the production process.

Figure 4



Features of Innovation

Product innovations differ in a number of dimensions. On the one hand, they may be completely new products in that they satisfy fundamentally new functions. On the other hand, they may satisfy the same basic functions as existing products, but they may allow improved performance at an equivalent or lower cost. Quality improvements may come about through the use of higher performance components or materials, or the development of a more complex product which consists of a number of integrated technical subsystems.

Process innovations also take different forms. On the one hand, they may involve completely new production processes that are based on radically new production technologies or on changes in the organization of the production process. On the other hand, they may simply involve increases in the extent to which the production line is automated. The latter occurs when existing capital equipment is used in greater quantities but in traditional ways.

Both world-first and other innovators note that developing new production techniques is one of the most important facets of their innovative behaviour (Figure 5). It is cited by 63% of world-first innovators and 54% of other innovators. Most of the innovative effort by firms is geared towards developing new manufacturing techniques.

Some 35% of non world-first innovators also indicate that increased automation is important, while only 26% of world-first innovators list this feature. Non world-first innovators are slightly more likely to focus on the type of incremental improvements in process innovations that are associated with increasing the amount of automation. The two groups implement changes to the organization of technical facilities with about the same frequency.

World-first innovators incorporate new product features into their innovations more often than other innovators. They also list all of the other characteristics associated with product innovations with greater frequency (Figure 6). The use of new parts, the inclusion of new materials in end products, and the development of products with new functions are all named by between 41% and 48% of world-first innovators.

By way of contrast, only 21% to 27% of non world-first innovators list these as characteristics associated with their product innovations. The most important category for this group is the inclusion of new materials in innovative products.

Figure 5

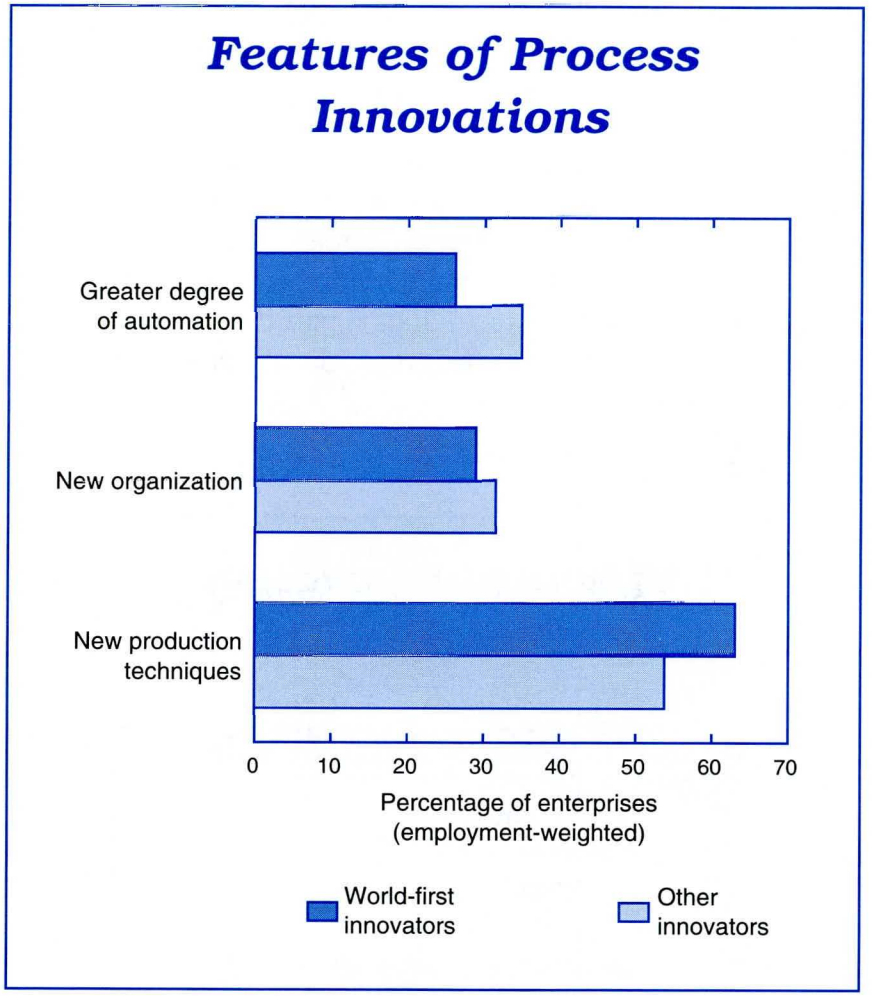
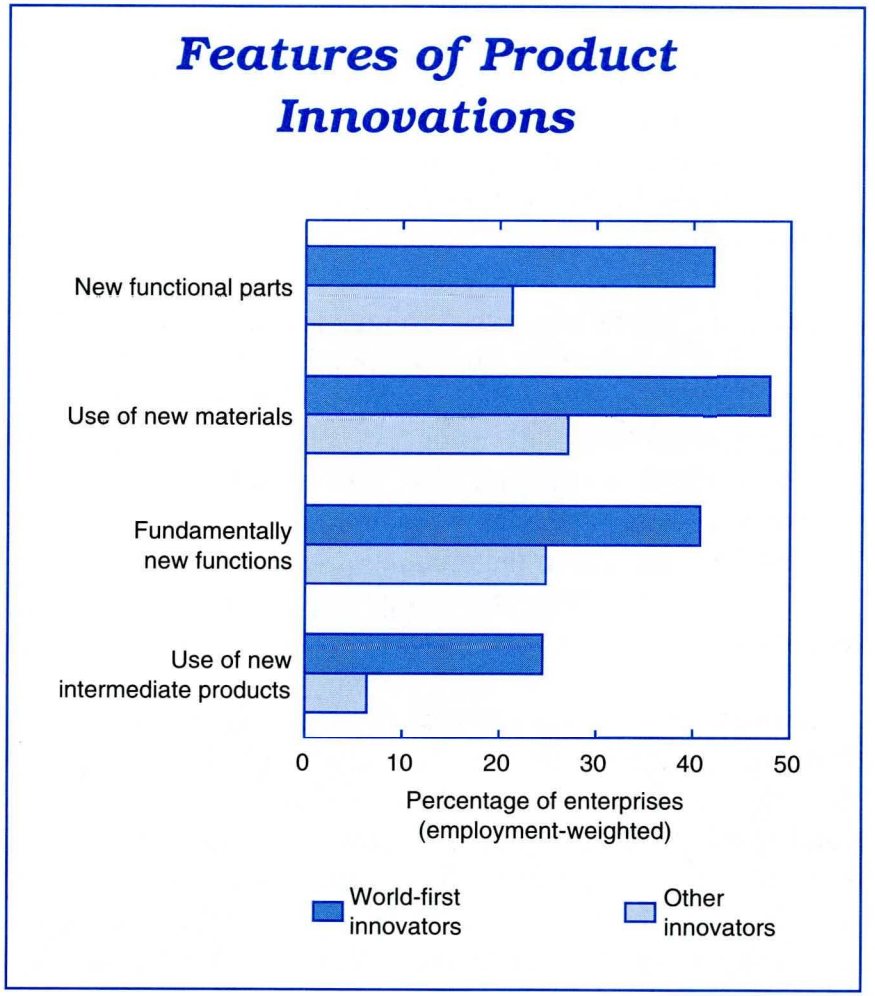


Figure 6



The Benefits of Innovation

Innovations are often seen to be the key to a firm's success. However, not all innovations are the same. World-first innovators are more likely to focus on new product characteristics and their innovations are more likely to involve new production techniques that coincide with the introduction of new products. Innovations, then, might be expected to have quite different effects on each group. This does not occur as often as might be expected.

Product innovations may either change the nature of existing products by improving their quality or by extending the product line that a firm offers. Process innovations may reduce lead times when they allow design, development and production to be compacted into a shorter time period. They may increase the technological prowess of a firm when the innovation involves changes in the production process. Finally, they may influence the quality of work by improving working conditions.

Both world-first and other innovators experience these changes frequently (Figure 7). Indeed, other innovators are slightly more likely to have experienced many of these effects than are world-first innovators. Some 56% of world-first innovators report an improvement in product quality. Some 52% of Canadian-firsts do the same. However, even more of the other group of innovators (57%) improve product quality through their innovations.

Some 9% of world-firsts report reductions in lead time, while 24% of Canadian-firsts and 33% of all other innovators do the same.

Similarly, other innovators are slightly more likely than either world-firsts or Canadian-firsts to report that they have improved working conditions and that they have extended their product line.

Changes in both the quality of products and the diversity of products will affect relations with customers. All three classes of innovators indicate that improved interactions with their customers were attributable to the innovations they introduced (Figure 8). Some 63% of world-firsts report this benefit, while 83% of Canadian-first innovators and 75% of other innovators experience the same benefits.

Figure 7

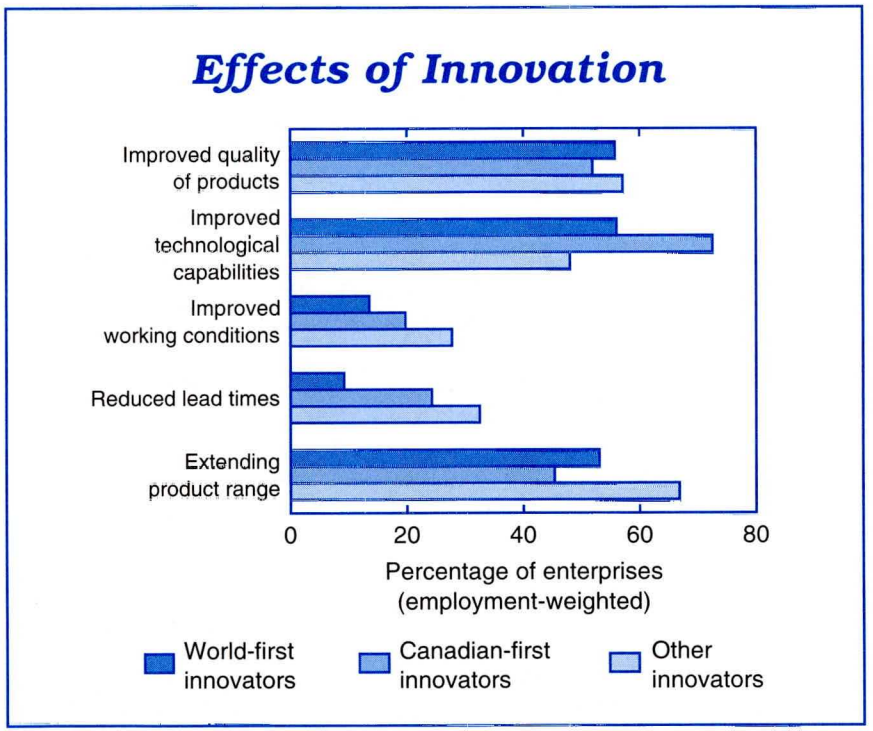
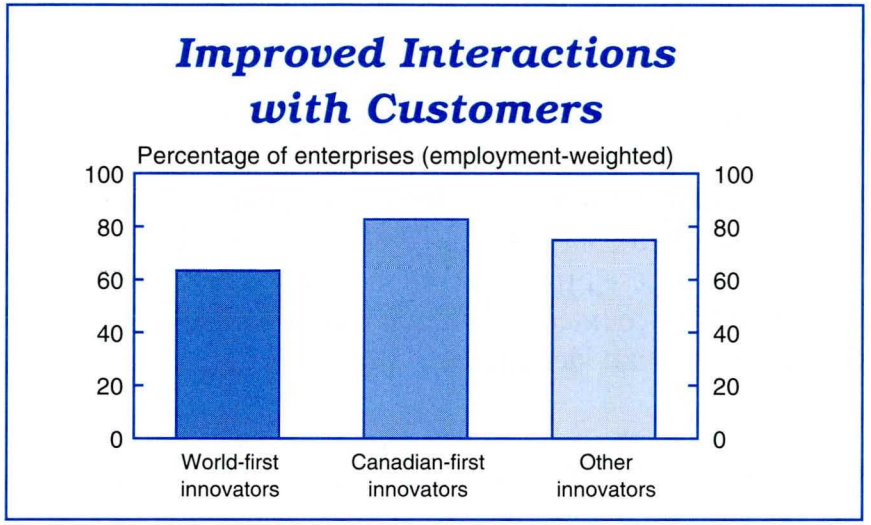


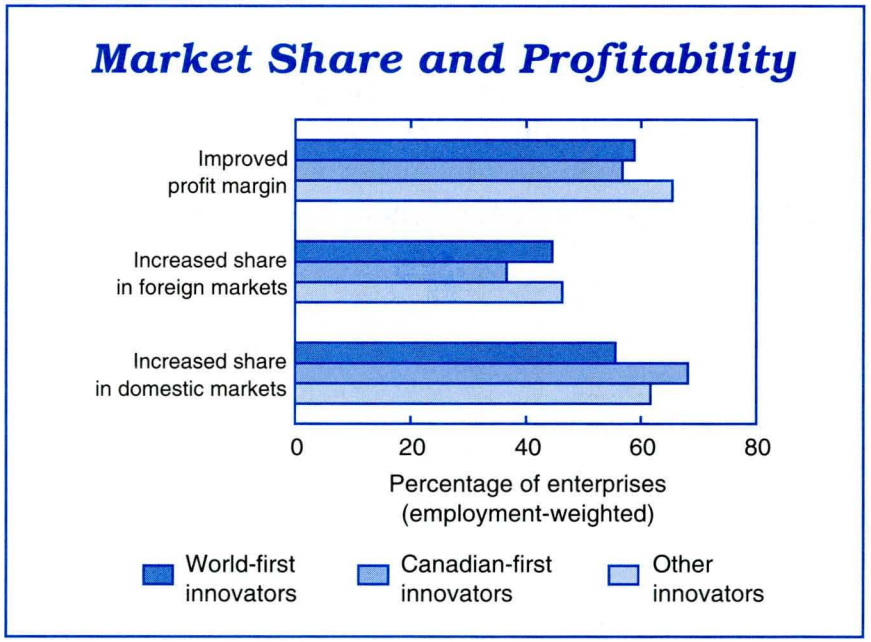
Figure 8



Finally, the benefits of innovation extend to both gains in output and in profitability. In a separate study that linked administrative data on firms' performance (market share and profitability) to their response to questions that were designed to gauge their innovativeness, firms that adopted a more-innovative strategy by developing new products and processes were found to be more successful than the less-innovative firms.[7] The more-innovative firms increased their market share and their profitability relative to the less-innovative firms.

The results of this survey confirm the earlier findings. Innovation leads to increases both in market share and profitability (Figure 9). Some 56% of world-first innovators indicate that their innovation served to increase their share of the domestic market, 45% increase their share of foreign markets and 59% increase their profit margins as a result of their major innovation. All innovators, whether they be Canadian-firsts, world-firsts or others, have very similar experiences. The other group is slightly more successful than world-firsts at increasing domestic market share and improving profit margins, and is also able to increase foreign market share just as frequently. Canadian-firsts do slightly better than both other groups when it comes to increasing their share of domestic markets.

Figure 9



In summary, while innovations may differ in terms of their originality, each group of innovators report benefits with about the same frequency. It is, of course, possible that the intensity of these benefits differ, but that was not investigated here.

[7] John Baldwin, William Chandler, Can Le, and Tom Papailiadis. *Strategies for Success*. Statistics Canada: Catalogue #61-5230RPE, 1994.

Internal Sources of Innovative Ideas

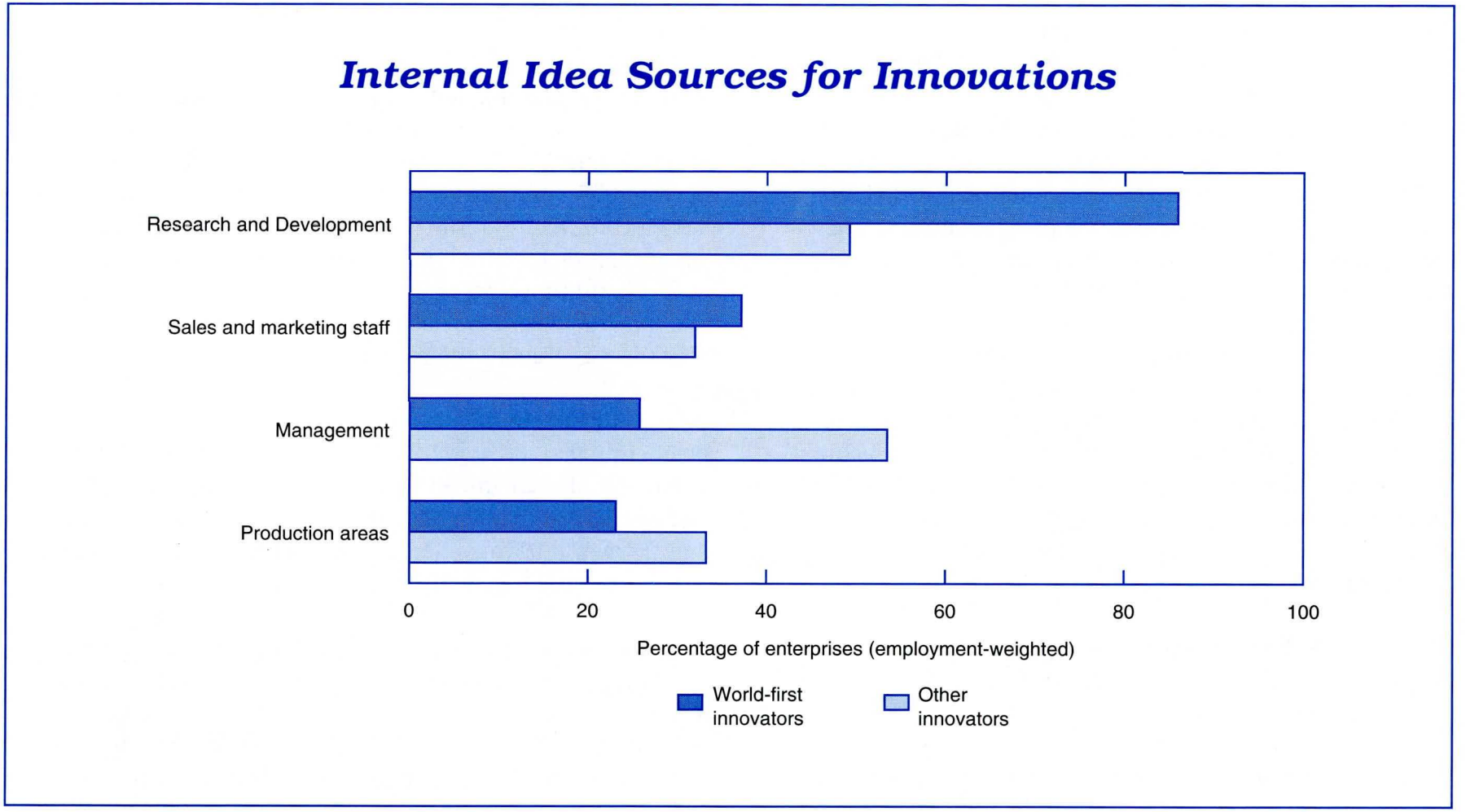
Innovative ideas originate from sources both within and outside the firm. The main sources within firms include research and development units, sales and marketing staffs, management, and ideas generated by workers in production areas. Research and development units (R&D) have traditionally received the greatest emphasis as a source of innovative ideas, though increasingly the importance of other sources, when used in conjunction with research and development, has been recognized.

Research and development efforts are, by far, the most important source of information used by world-first innovators, with 86% of firms relying on this source to facilitate innovation (Figure 10). In fact, no other internal source of ideas is used by more than 37% of world-first innovators. Clearly, research and development efforts are paramount to the successful introduction of world-first innovations.

Non world-first innovators also rely heavily on research and development efforts (49%); but they rely even more heavily on ideas from management (54%). Ideas from production areas and from sales and marketing staffs are also used by approximately 32% of these firms. Overall, non world-first innovators differ from their counterparts in that they are more apt to rely on multiple internal idea sources.

The largest differences between the two groups lie in their relative uses of ideas from management and from research and development departments. Non world-first innovators are much more likely to use ideas from management; world-first innovators are more reliant on ideas from research and development groups.

Figure 10


Internal Idea Sources for Innovations
Research and Development
Sales and marketing staff
Management
Production areas
0
20
40
60
80
100
Percentage of enterprises (employment-weighted)
World-first innovators
Other innovators

External Sources of Innovative Ideas

While considerable emphasis has traditionally been given to such internal sources of innovative ideas as the research and development department, it is recognized that external networks are also essential to the innovative process.

A variety of external sources for innovative ideas are available to firms. Some of these are complements to the internal research and development units—consultants, private R&D institutions, and government development agencies. Each of these provide outside sources of R&D. Other external sources include suppliers, customers, and related firms. Customers and suppliers aid one another because they have a symbiotic relationship. Related firms, especially within multinational families, provide an efficient conduit for the transfer of proprietary knowledge from one to another. Trade fairs and conferences allow suppliers of technologies to provide information about these technologies to potential customers. Finally, competitors are monitored for new ideas and new products, which are then copied using techniques such as reverse-engineering.

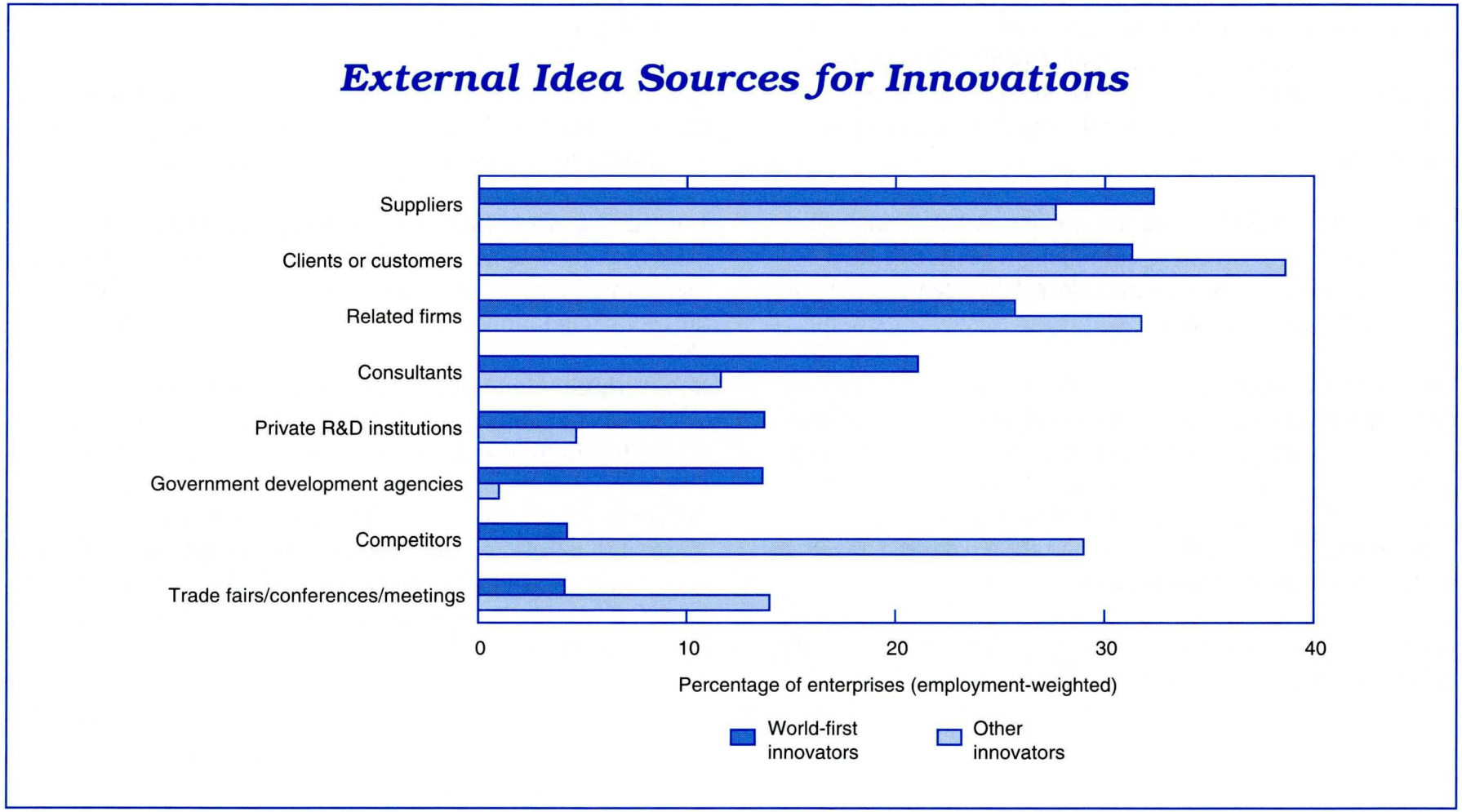
Overall, world-first innovators are relatively less likely to integrate external idea sources into their innovation activities. Of those listing a source of ideas, 99% of world-firsts indicate an internal source was helpful, but only 83% list external sources. For non-world firsts, the relative percentages are 96% and 90%, respectively. One reason for this difference may be that innovations of the magnitude necessary to be called world-firsts are so unique that the number of outside sources of useful information are often limited. This being said, the vast majority of both segments of innovators do use external ideas extensively.

External sources that are used frequently by both world-first and other innovators include suppliers, customers and related firms (Figure 11). These three sources are used by between 36% and 39% of innovative firms. It might be expected that the non world-first innovators would rely on outside parties more often than their counterparts. But the fact that even the world-first innovators frequently use these sources indicates the importance of the relationship that develops between firms and their customers and suppliers.

Non world-first innovators do use certain sources more frequently than do world-firsts. The largest such difference occurs for ideas obtained from competitors. Almost 29% of non-world-first innovators use some form of reverse-engineering for their innovative ideas. Trade fairs and conferences are also used more frequently by this group.

External idea sources that are tapped into more frequently by world-first innovators include those which provide external R&D: consultants, private research institutions and government development agencies. World-first innovators rely somewhat more heavily on internal R&D and on R&D provided by external sources; they rely less on customers. However, like non world-first innovators, they combine ideas from a variety of sources to generate innovations.

Figure 11


External Idea Sources for Innovations
Suppliers
Clients or customers
Related firms
Consultants
Private R&D institutions
Government development agencies
Competitors
Trade fairs/conferences/meetings
0
10
20
30
40
Percentage of enterprises (employment-weighted)
World-first innovators
Other innovators

Internal Sources of Ideas for New Technologies

An ingredient that is essential to most process innovations is the development of new technologies. New technologies involve the use of new production equipment, new production techniques, and new organizational structures. As was the case for sources of innovative ideas, firms make use of both internal and external sources for the development or application of these technologies.

There are three main internal technology sources available: the research portion of R&D; the development portion of R&D (experimental development); and ideas developed through the production engineering process.

World-first innovators tend to use all three sources frequently, with anywhere from 55 to 68 percent of firms obtaining ideas from each (Figure 12). While both research *and* development are important for world-firsts, production engineering—the division of the firm that is devoted to operations—receives the same emphasis. World-firsts tend to take a balanced approach to the production of internal ideas.

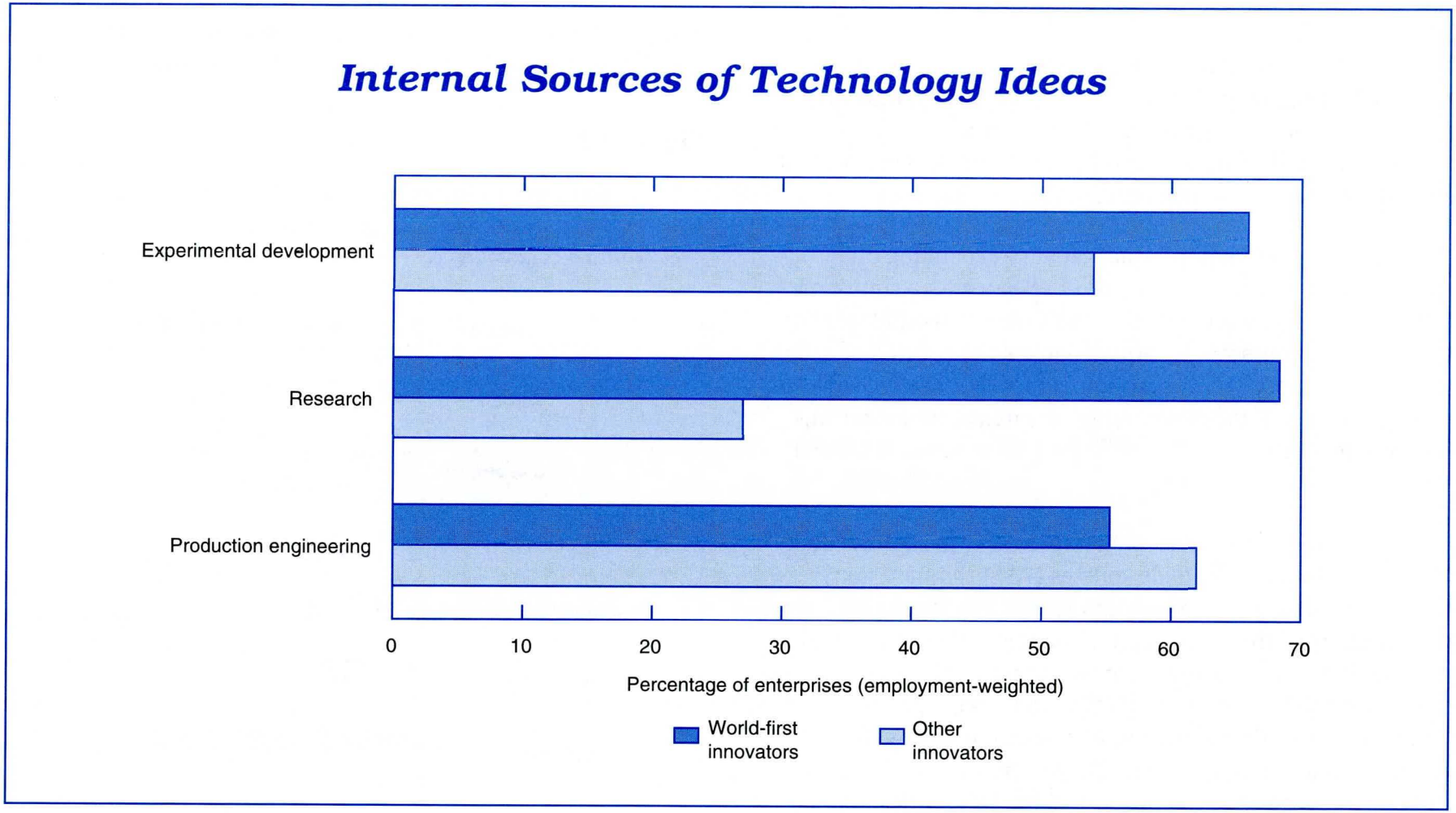
Non world-first innovators tend to use production engineering and experimental development frequently (62% and 54% of firms, respectively). They do not, however, make much use of research. Only 27% of the firms perform it to develop new technologies.

Non world-first innovators then tend to use research much less frequently than world-firsts and use experimental development and production engineering at about the same rate.

The fact that world-first innovators rely on research much more than their counterparts lends credence to earlier findings that showed research and development to be the most important source of innovative ideas for world-first innovators.

Non world-first innovators concentrate on finding more efficient means of implementing previously developed innovations. Toward that end, their focus is not so much on the research required to conceive of new technologies but rather the development of better ways to use existing techniques. Much of this work can be accomplished through experimental development and production engineering. This group of firms is less oriented to basic research and more to solving assembly line problems.

Figure 12


Internal Sources of Technology Ideas
Experimental development
Research
Production engineering
0
10
20
30
40
50
60
70
Percentage of enterprises (employment-weighted)
World-first innovators
Other innovators

External Sources of Ideas for New Technologies

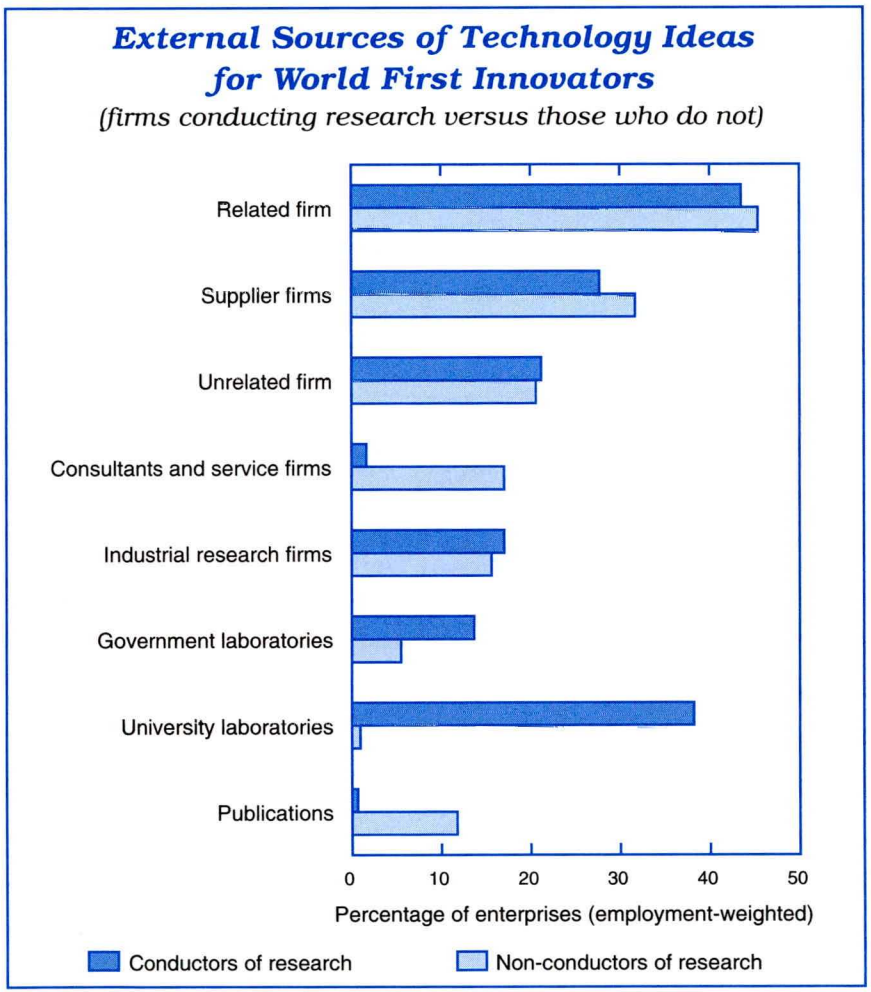
In general, all innovators use both external and internal sources to generate ideas for new technologies. However, while world-first innovators rely less on outside sources for ideas about innovations, they are more likely to rely on both sources for technology ideas. Of those world-first innovators listing ideas for new technology, 97% use internal sources and 81% use external sources. For other innovators, these percentages are 91% and 67%, respectively.

The sources of external information vary depending on whether the innovator makes use of research as a source of internal technology and whether the firm is a world leader or essentially an imitator. Figure 13 depicts the sources of external ideas for those world-first innovators that use research for internal ideas and those not using research facilities for this purpose; Figure 14 does the same for non world-first innovators.

World-first innovators that rely on research are slightly more likely to make use of outside sources (73%) than are non world-firsts that use research labs (68%). But these two groups rely on many of the same outside sources. World-firsts with a research lab focus most frequently on related firms (44%), universities (38%), suppliers (28%), and unrelated firms (21%). Non world-firsts that make use of research also rely on both suppliers and unrelated firms. They differ in that they place less emphasis on the services offered by universities and more emphasis on the findings of outside consultants.

World-first innovators that do not rely on research labs for internal technology ideas differ from those world-firsts that conduct research in that they are much less likely to use universities, and are more likely to use the services of consultants. They are also much more likely to use external sources than are non-world first innovators who do not conduct research. Non world-firsts without research lab support differ

Figure 13



from their counterparts with research facilities in that they are slightly more likely to use ideas from related firms and from industrial research firms, and slightly less likely to use ideas from suppliers, unrelated firms and consultants.

As a result, the pattern of outside sources used is different for the two segments of innovators (Figure 15). World-firsts are much more likely to stress related firms, universities, industrial research firms, government laboratories and unrelated firms. Non world-firsts are generally much less likely to use external sources.

Figure 14

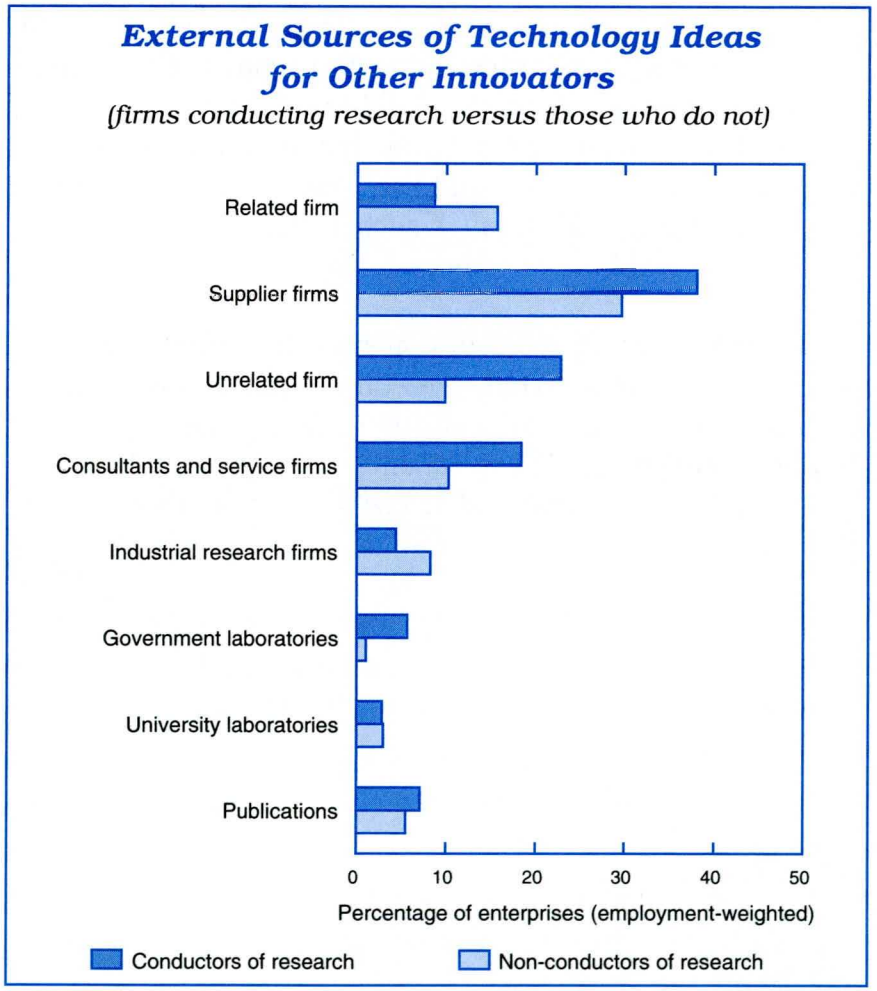
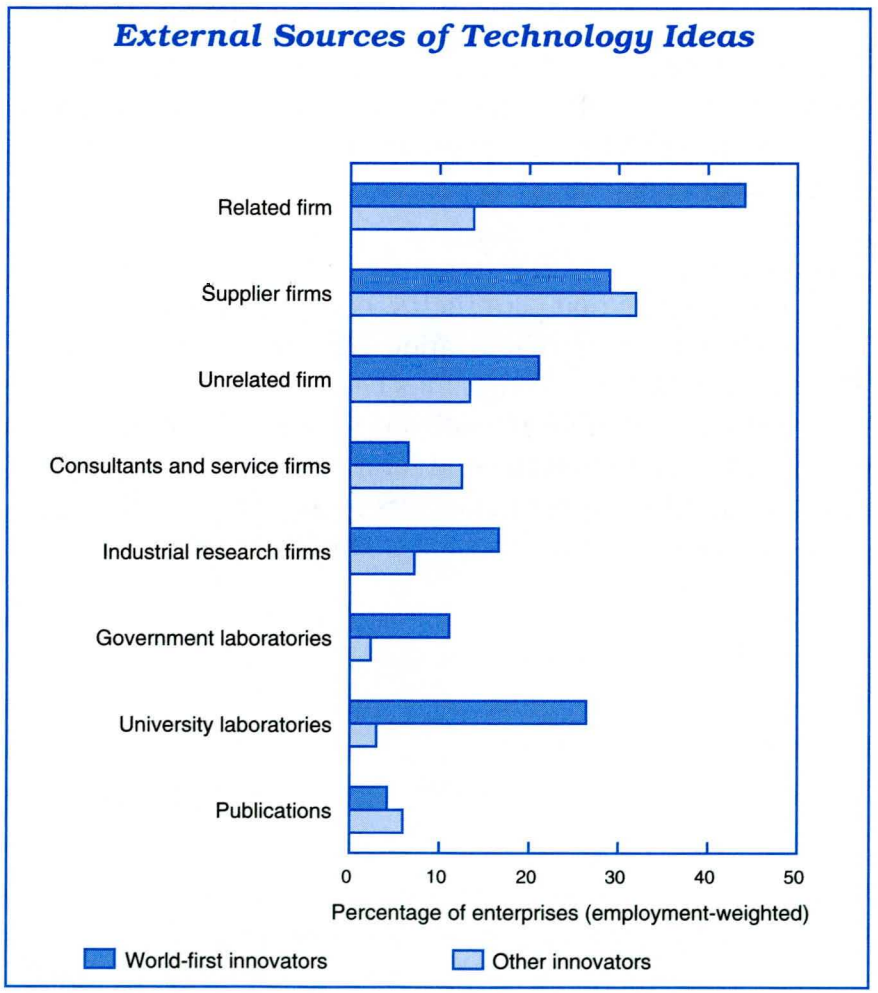


Figure 15



The Importance of R&D Activity

Research and development activity is an important source of ideas for innovation in the case of both world-first and other innovators. Both sets of firms use experimental development as a critical internal source of information for new technologies that are used in the production of the innovation. World-firsts place a heavy emphasis on the research component in addition to experimental development for this purpose.

This emphasis on R&D is confirmed by the intensity of R&D activity in both sets of firms. Some 93% of the world-first innovators perform R&D on either an ongoing or an occasional basis. Some 85% of the other group of innovators perform some R&D.

R&D may be performed continuously or only occasionally (Figure 16). Firms that perform R&D continuously have a stronger commitment to innovation. Of world-first innovators, 82% perform R&D on a continuous basis, while less (53%) of the other group of innovators do so. By way of contrast, only 11% of world-first innovators perform R&D on an occasional basis, while 32% of other innovators do so. Thus, world-firsts have a much greater commitment to the R&D process.

Research and development activity may be pursued in a variety of different ways. It can be done through separate R&D facilities, or in other departments of the firm, or via contracts with other firms. Some firms will use a combination of these methods.

All three methods are important for those world-first innovators that perform R&D (Figure 17). Some 74% have a separate R&D department, 52% perform R&D in other departments, and 36% contract R&D out to other firms (firms may use more than one source at any given time). World-first innovators use separate R&D units more frequently than non world-first innovators. While 74% of world-first innovators conduct at least some of their R&D through such dedicated units, only 54% of non world-first innovators do so.

In summary, research and development is important to both groups of innovators. While these groups differ substantially in many respects, they both perform R&D continuously, and they both pursue R&D in several different ways, both in specific R&D departments and across the firm in other departments.

Figure 16

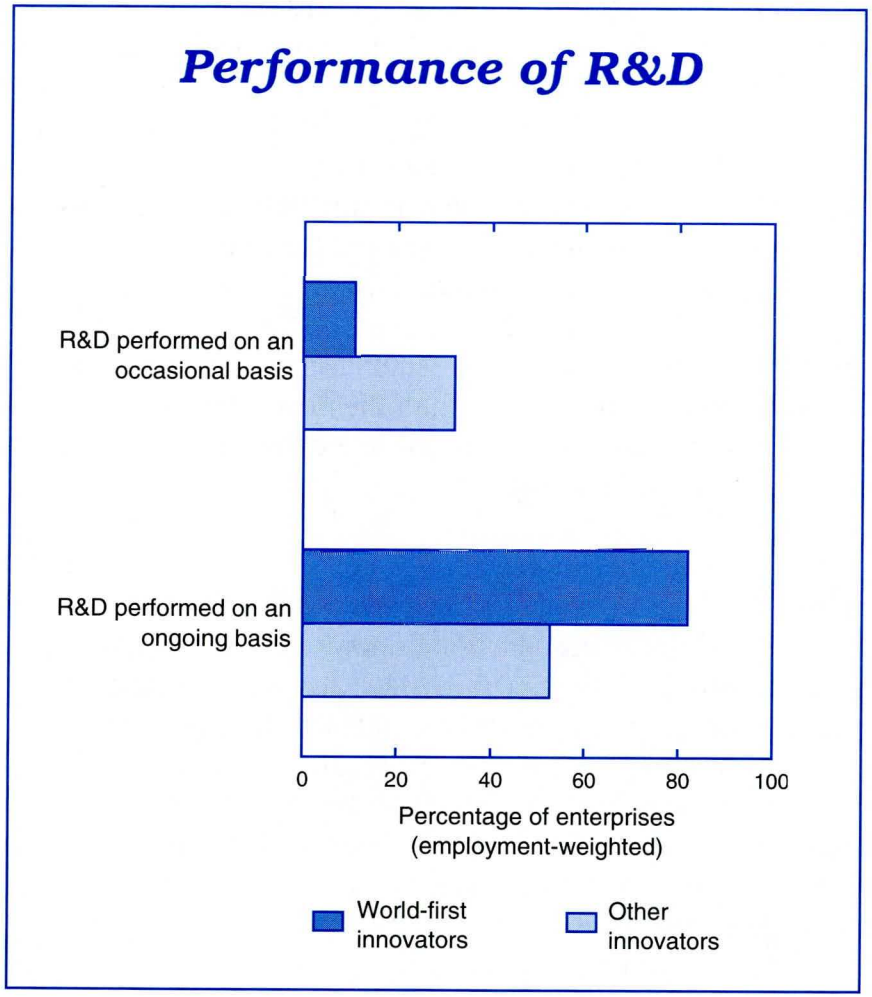
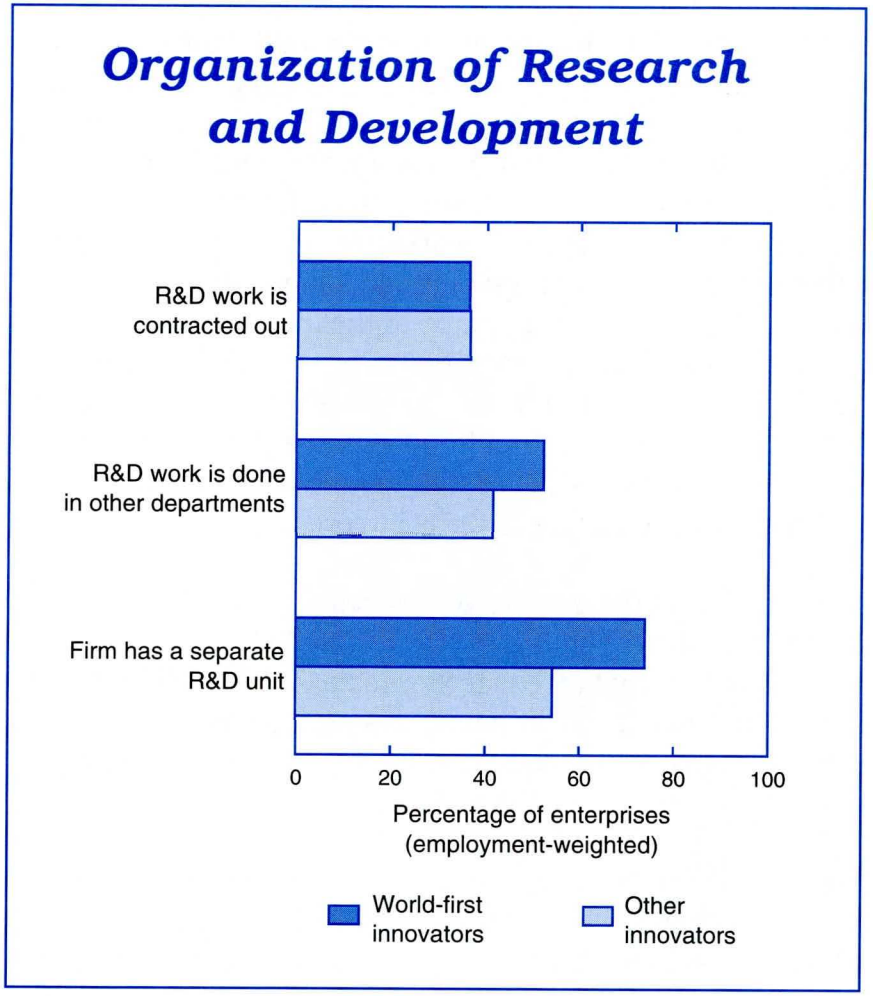


Figure 17



What Happens to Workers in Innovative Firms?

Process innovations often reduce costs by decreasing the quantity of factors of production required per unit of output. This would reduce the demand for labour if output of the innovative firm remains constant after the innovation. However, innovative firms also indicate that their share of domestic and foreign markets often increase as a result of their introducing an innovation. This increase in market share may be the result of either the commercialization of product innovations that allow firms to change their output mix, or the introduction of process innovations leading to more efficient production methods which, thereby, allow firms to aggressively compete for market share. Whether the demand for labour in a particular firm increases or decreases as a result of innovation will depend on which of these offsetting forces is largest.

The net effect of these forces on the demand for labour is generally positive (Figure 18). Over 40% of all world-first innovative firms indicate that they increased demand; only 7% decreased demand. Other innovators are also more likely to increase than decrease their demand for workers, though the differences here are smaller and less significant.

Not all workers are affected in the same way by innovation. Non-production workers consist mainly of white collar workers who are seen as having the skills necessary to benefit from the computer-based technological revolution. Production workers, on the other hand, are usually blue collar workers and their relative numbers have decreased recently compared to non-production workers.[8]

[8] Eli Berman, John Bound and Zvi Griliches. *Changes in the Demand for Skilled Labour within US Manufacturing Industries.* National Bureau of Economic Research: Working paper #4255, 1993.

The demand for labour in these two groups has been affected quite differently by innovations. Innovators increase demand for non-production workers substantially more frequently than they decrease demand—both in the case of world-first innovators and other innovators. However, there is less of a difference in the frequency with which an innovation has increased the demand for production workers and the frequency with which it has decreased the demand for production workers, especially in the case of other innovators. Non world-first innovators tend to place greater emphasis on automation and introduce fewer new products than their counterparts. These tendencies are more likely to result in a decrease in the amount of production workers required.

The changes that technology-driven process innovations have on the skill levels of workers has been a subject of controversy. In some circles, the introduction of new technologies has been equated with de-skilling. Others have claimed that innovation and technological change are associated with increases in skill levels. New more flexible forms of production, it is argued, can only be achieved through a highly skilled workforce with greater conceptual skills than were previously required.

The differences in the demand for blue and white collar workers suggests that greater skill levels are associated with innovation. Indeed, this is reflected in the effect of innovation on skill levels (Figure 19). Less than 2% of innovators, whether they be world-first or not, indicate that skill levels decreased as a result of innovation. Between 34% and 43% indicate no change in skill levels. Some 64% of non world-first innovators indicate that skill levels increase; some 57% of world-first

innovators require higher skill levels after innovation. Non world-first firms may be more likely than world-firsts to decrease demand for production workers but their overall skill levels are increasing, not decreasing. This suggests that the adoption of new and flexible production methods will, in the majority of cases, result in a requirement of increased employee skills.

Figure 18

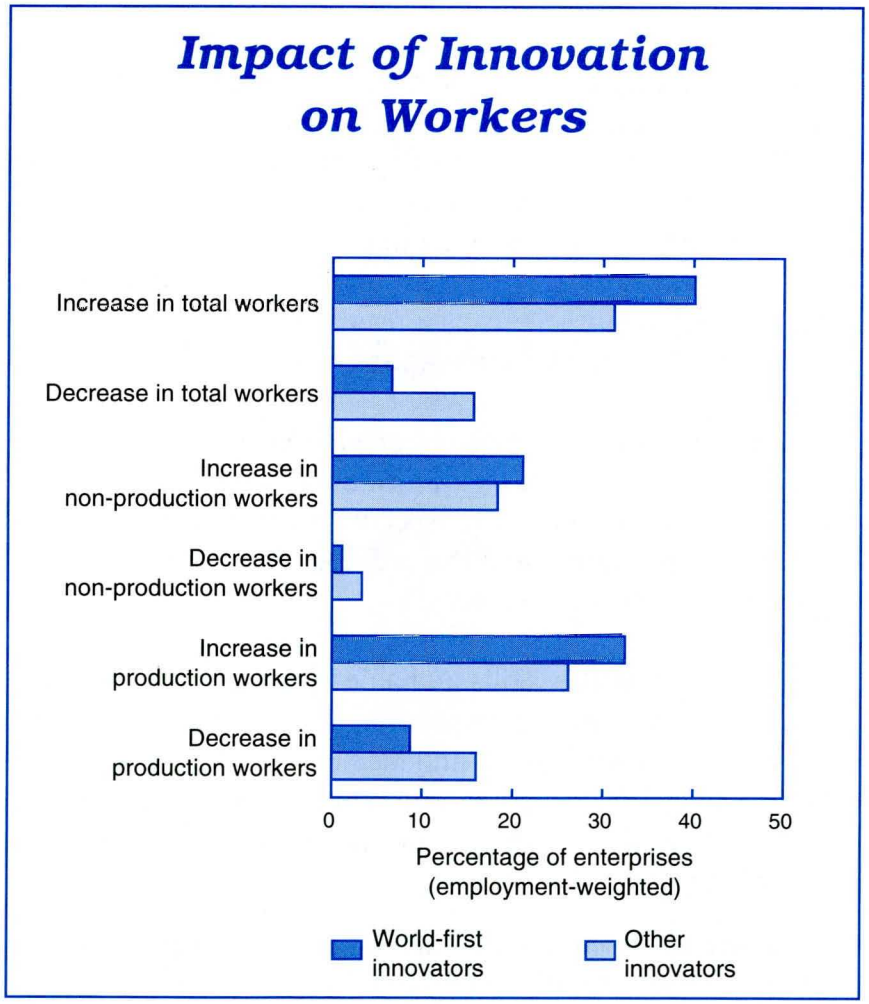
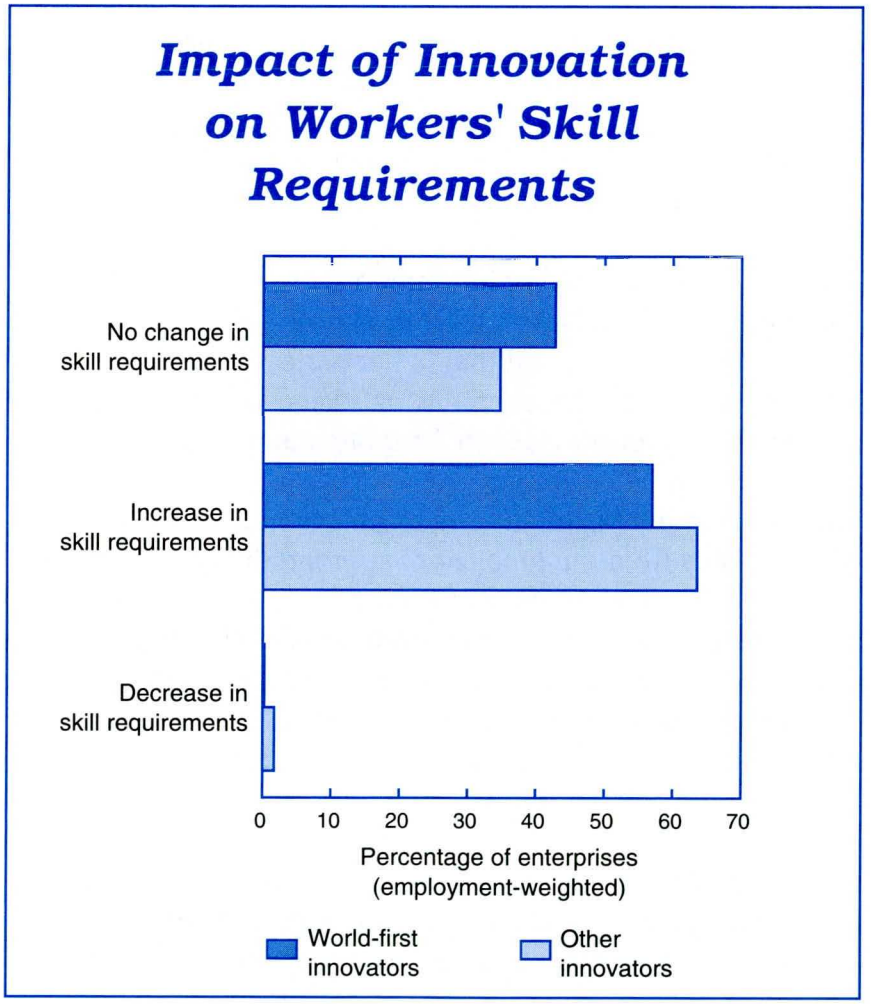


Figure 19



Why is Innovation Difficult?

Innovation is hindered by many factors. These range from inadequate benefits to excessive costs. For example, benefits from innovation may be inadequately exploited if firms are unable to capitalize on new products because they cannot adequately market them. Or, firms may choose not to innovate because they perceive the costs of capital that are required for the commercialization of an invention are too high.

Most of the returns and costs associated with innovation are determined by the actions of individuals and firms operating in market systems. However, some areas receive special emphasis from public policies. These are areas where the market is sometimes said to have particular problems.

Markets for labour and for information are often seen to be imperfect since both skills and information have characteristics of a 'public good'—a good that is not perfectly appropriable. When goods are not appropriable, markets do not function well and goods are not provided in adequate quantities.

The labour market is often used as an example of a market which suffers from the problem of appropriability. It may not provide the optimal amount of training if firms perceive that the benefits they receive from investments in skill training are likely to be lost because of labour turnover. Similarly, markets for information are imperfect if the information, once produced, becomes freely available for all to use, without due compensation being paid for that information.

Public policy intervention in these areas is aimed at overcoming market imperfections. Public education programs are aimed at improving labour skills. Government trade missions provide market information for export markets. Standards and regulations provide information that consumers can use to evaluate the safety of products. Public monies are used to fund basic research, both at research institutes and at universities. Technical service programs are subsidized to help provide information on technology and technical advice on how to improve operations. Networks of firms are encouraged to facilitate the spread of information on technology.

Innovators find that each of the areas addressed by public policies present them with impediments (Figure 20). The impediment most frequently cited by both world-first and other innovators is the lack of skilled labour. Some 60% of world-first innovators and 40% of other innovators report this to be a problem. Innovators, therefore, report both substantial increases in skill requirements as a result of innovation and that the lack of skills impedes innovation.

The second most frequently mentioned problem by world-first innovators is a lack of market information (39%). A lack of good information about the prospective market for new products creates uncertainty and this reduces the tendency to invest in the innovation process.

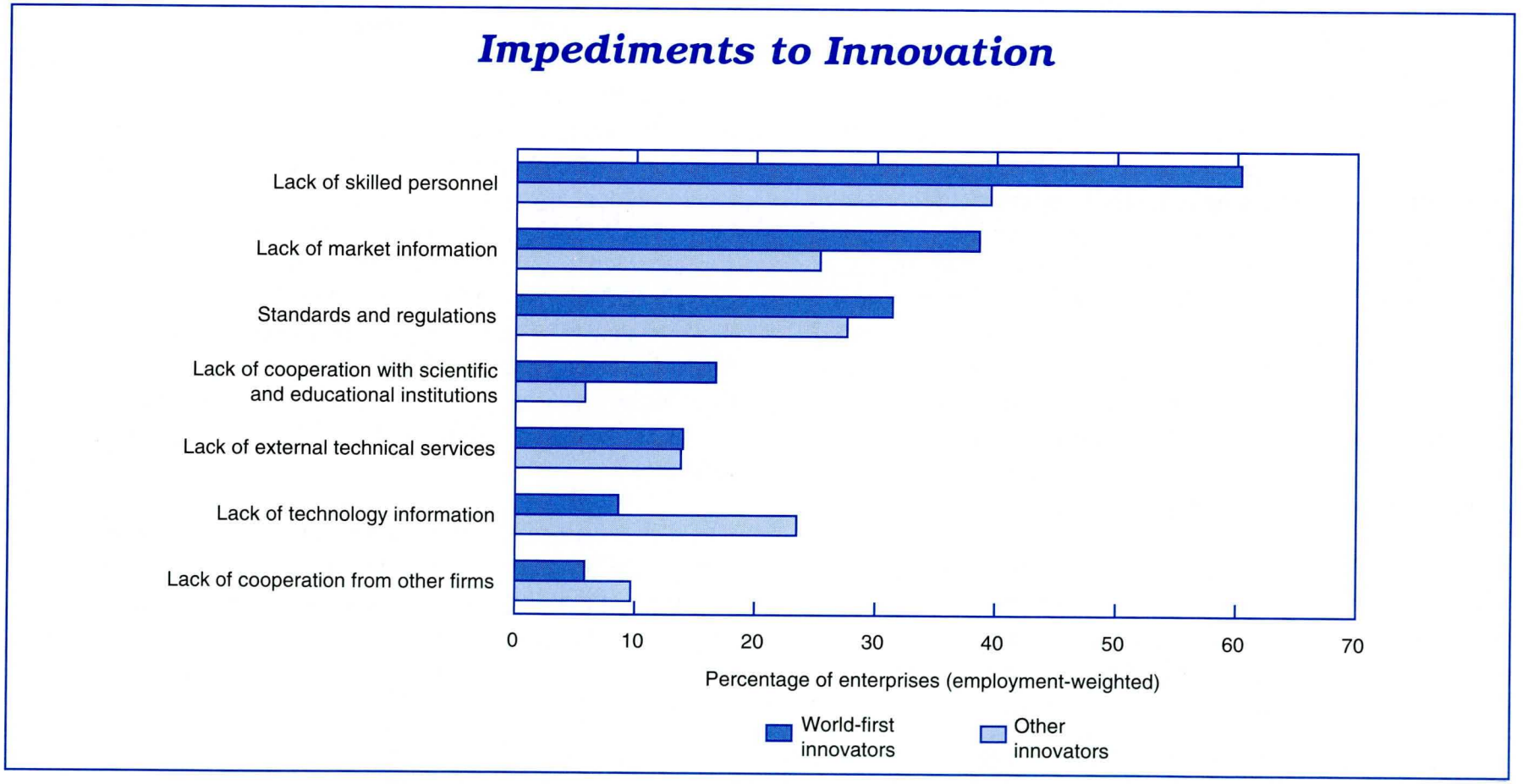
That the lack of worker skills and a dearth of market information rank first and second respectively is consistent with the results of the Growing Small and Medium-Sized Enterprise (GSME) Survey.[9] This study found that the two government programs given the greatest importance were labour training and market information programs.

[9] John Baldwin, William Chandler, Can Le, and Tom Papailiadis. *Strategies for Success*. Statistics Canada: Catalogue #61-5230RPE, 1994.

Both world-first and other innovators also find that standards and regulations are an important impediment, with 31% of the former and 28% of the latter indicating this was a difficulty. The pattern of problems experienced by other innovators is somewhat similar to world-first innovators, though they occur less frequently. This suggests that these problems are not so much barriers to innovative activity as they are problems that accompany it.

There is one exception—where other innovators report impediments with greater frequency than do world-first innovators. Some 23% of other innovators report impediments due to a lack of technology information. These firms, then, benefit more from outside technology support, probably because they rely less on internal research facilities for their innovative ideas.

Figure 20



How do Firms Protect their Innovations?

Innovation requires substantial investments for the commercialization of new ideas and inventions. This investment will not be made if the innovation is easily copied by others.

Intellectual property rights offer innovators one way to protect their innovations. Intellectual property rights are legally enforceable rights over an innovative product or process. They can take the form of patents, trade marks, trade secrets, industrial designs, copyrights or integrated circuit designs.

A patent gives the inventor the exclusive right to produce an original invention for a limited period in return for the public disclosure of information about the innovation. Trademarks are devices or words legally registered as distinguishing a manufacturers' goods. The industrial designs act protects the ornamental aspects of goods. Copyrights give the author of a text the right to print, publish, and sell copies of an original work. Integrated circuit design protection safeguards the original three-dimensional pattern of layout design embodied in an electronic circuit. Finally, innovations can be protected through secrecy. Trade secrets can be licensed to others with the requirement that the recipient not divulge information about the secret. These agreements are enforced by the courts as unfair trade practices under common law.

Firms may choose other methods as substitutes or complements for these intellectual property rights that depend upon regulatory or judicial oversight. Careful design of products may make it difficult for others to copy the innovation. Being first in the market may give a firm a sufficient lead; because of the importance of cumulative learning imitators cannot hope to produce a similar product at the same cost. Firms can bundle complementary characteristics such as services to reduce the chance that their customers will switch to the products of imitators.

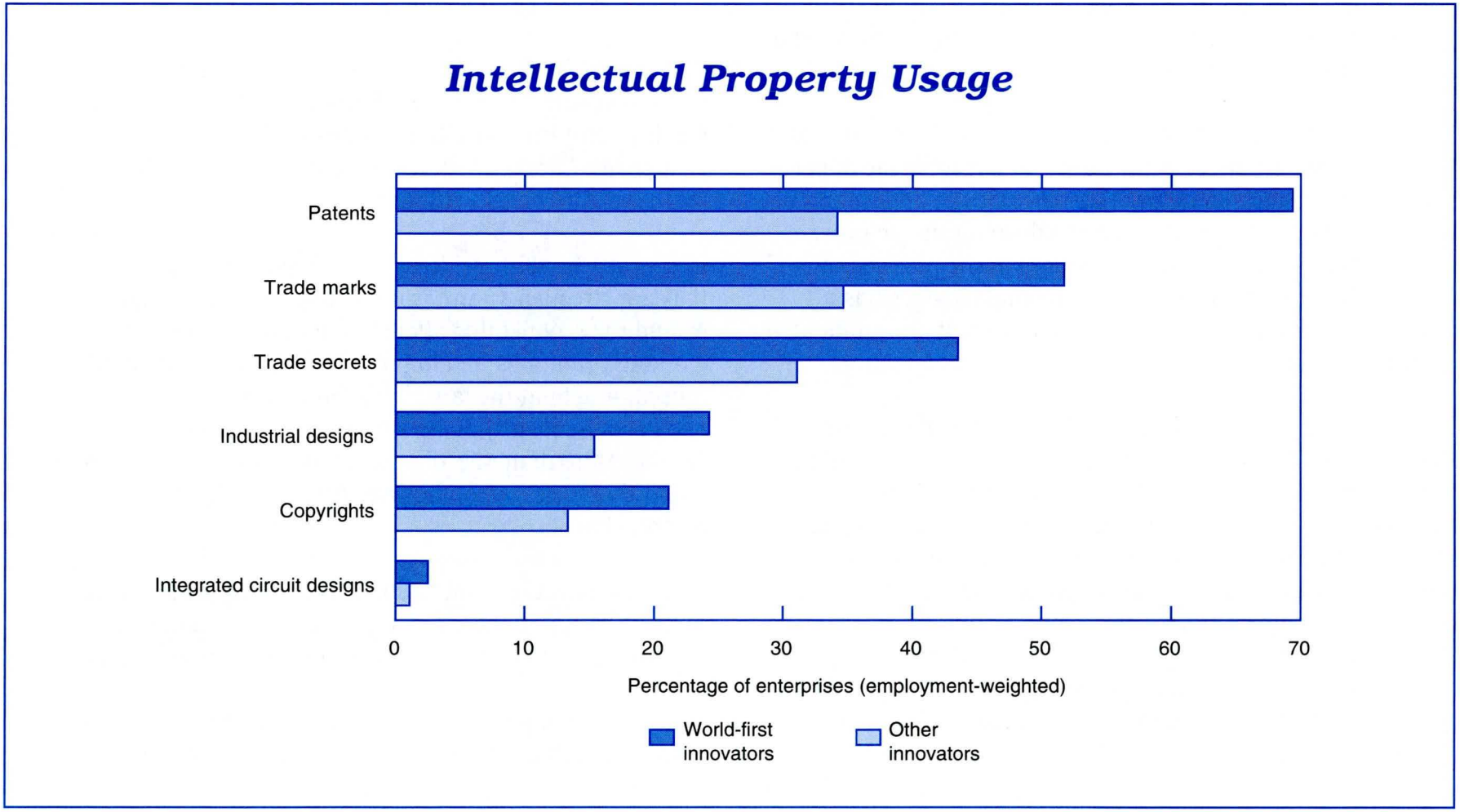
Both world-firsts and other innovators use intellectual property rights extensively (Figure 21). Patents are used most frequently, followed by trade marks, trade secrets, industrial designs, copyrights, and integrated circuit designs.

World-first innovators use intellectual property rights more frequently then do other innovators. Over 80% of world-firsts use at least one of patents, trade marks, trade secrets, industrial designs, copyrights, or integrated circuit designs, while only 63% of other innovators use any of these intellectual property rights. Some 69% of world-first innovators use patents; only 34% of other innovators use them. Trade marks are used by some 52% of world-firsts and by 35% of other innovators. Trade secrets are used by 44% of world-firsts and by 31% of other innovators. Protection is offered by industrial designs for 24% of world-first innovators and by 15% of other innovators.

World-first innovators, then, are more likely to make use of intellectual property rights. Their innovations are sufficiently unique that making use of intellectual property rights is an important strategy for this group of firms. Other innovators are much less likely to make use of intellectual property rights, thereby confirming that these firms produce innovations that

are quite different from the first set. Their innovations tend to be more concentrated on incremental process improvements, which do not lend themselves as frequently to protection via intellectual property rights. They also do not tend to have the unique characteristics required for such instruments as patents.

Figure 21



Conclusion

Innovation policies encourage both the development of new ideas and their widespread diffusion. The development of major inventions, from the stage of brand new ideas to commercial production, captures the imagination of most scientific writers. These inventions often have dramatic visible effects on the economic system. Transistors and other electronic components have created a computer-based revolution over the last forty years. Lasers have dramatically altered both communications and production systems.

Other types of innovations are more incremental in nature and receive less attention. In some cases, they involve the application of new products in new ways—such as the application of the laser to bar coding and point-of-sale analysis. In other cases, they involve incremental changes in the production process. While each of several incremental changes has a relatively small effect when considered by itself, the cumulative effect of a sequence of incremental changes is often large.

This study focuses on both types of changes using the taxonomy of world-first innovations, Canadian-first innovations and all other innovations. All three types potentially make significant contributions to economic growth. While world-firsts are important, the two other categories cannot be ignored. Canadian-firsts, for example, would include the production and development of products introduced into Canada for the first time by multinationals. Even if the resulting products only serve the domestic market, Canadian consumers benefit either from new products, an improvement in product quality, or lower costs. Innovations that are neither world-firsts nor Canadian-firsts can also have a substantial effect on economic performance. A firm that buys new machinery and equipment from a foreign supplier to duplicate the equipment that has already been purchased by its domestic competitors will fall into the third category. The benefits associated with a reduction in production costs that result from this action can be substantial.

Quantitatively, these other innovations are introduced the most frequently. Some 18% of innovative firms (weighted by employment) introduce innovations of this nature over a three-year span. Another 15% are responsible for Canadian-firsts, and 8% are involved with world-firsts.

Innovators in all three groups report similar effects with about the same frequency. Innovations improve product quality, extend the product line offered, reduce lead times, improve working conditions and improve technological capabilities. Indeed, in all but the latter case, other innovators report these results as frequently as do world- and Canadian-first innovators. More than 55% of innovators in each of these groups report that innovation improves profit margins or increases market share.

While the effects of innovation are relatively similar across innovation types, there are differences in the nature of the innovations and in the inputs used to support innovation.

The innovation process is often described in terms of new products, such as steam engines, gasoline, aeroplanes,

computer chips, and lasers. However, innovation in production processes underpins the evolution of new industries that produce innovative products. The Canadian evidence substantiates the importance of technological competence in process engineering. Process innovations are important in at least 81% (weighted by employment) of innovators—either because the innovation involves purely process changes or because it simultaneously involves products and processes.

The main difference between world-first and all other innovators lies in the extent to which world-firsts stress both product and process innovations. World leaders show a special ability to manage both the product conception stage and changes in technology associated with the production process.

In keeping with the emphasis that all types of innovators place on process innovation, a large proportion of innovators in each of the three groups indicate that their innovations involve changes in the production process.

On the product side, innovations are more or less equally split between radically new products (those with fundamentally new functions) and improvements in quality due to new functional parts or new materials. World-first innovators tend to introduce radically new products with greater frequency than other innovators.

On the input side of the innovation process, many sources of ideas are used. Internally, research and development, sales or marketing, management, and production all make a contribution. However, the emphasis given to each of these sources differs by innovation type. World-first innovators tend to rely more frequently on research and development divisions than any of the other internal sources—sales, marketing, management, or production. In contrast, non world-first innovators rely more evenly on all of these sources, with management being cited the most often.

Research and development is given relatively more emphasis by world-first than by non world-first innovators. Some 86% of world-firsts indicate that they find research and development divisions to be a useful source of ideas for innovations as compared to 49% of non world-firsts. Some 82% of world-firsts perform R&D on a continuous basis; some 53% of other innovators do so. The main difference then is that non world-first innovators do less R&D and rely on a number of other sources for ideas.

External sources of innovative ideas are also used extensively by all types of innovators, but they are used more frequently by non world-first innovators. The most important outside source for non world-first innovators is customers, followed by related firms and suppliers. The most important external sources for world-firsts are suppliers, followed by customers and related firms. Innovation clearly depends upon forward links from suppliers to their customers and backwards linkages from customers to their suppliers. In this respect, both groups of innovators are quite alike. They do, however, differ in terms of the other sources from which innovative ideas are obtained. In particular, non world-firsts rely heavily on competitors as an external source of ideas.

Process innovations make up an important part of the innovation process. They frequently involve the use of new technologies. New technologies consist of new production equipment, new production techniques, and new organizational structures. Internal sources of ideas for new technologies originate in the pure research group, the experimental development division, and in production engineering. All three are used frequently by world-firsts. Non world-firsts tend to rely primarily upon experimental development and production engineering. Indeed, the two innovative groups rely upon both of these applied engineering groups with about the same intensity. Non-world firsts differ primarily because they concentrate much less on pure research. Research *and* development may be important for non world-firsts but it is the development component that receives the most emphasis in this group.

Both groups make heavy use of suppliers for information on technologies. But with the exception of suppliers, external sources of technology differ for the two groups of innovators. World-firsts are more likely to use outside groups that complement their research and development facilities—related firms, industrial research firms, universities—than are non world-first firms. Non world-firsts are more likely to use the services of consultants along with information garnered from publications.

It is important to understand not only what inputs are used by the innovation process but also how innovation affects the nature of the inputs used. Nowhere is this more important than understanding the effect of innovation on the demand for labour. Innovative firms more frequently indicate that innovation had the effect of increasing demand for labour as opposed to decreasing it. However, innovation affects white collar workers more positively than it does blue collar workers. Innovators increase demand more frequently for non-production workers than they decrease it. The differences are less marked for production workers.

Innovators also stress that skill levels of workers increase as a result of the innovation. Some 64% of non-world firsts indicate that skill levels increase; some 57% of world-first innovators require higher skill levels as a result of innovation.

Public policy is directed at supporting the innovative process in a number of different ways. Policies are aimed at reducing impediments in several areas where markets are seen to have imperfections. These encompass such areas as labour training, market information, regulations and standards, and technical services. Innovators confirm that they indeed experience impediments in each of these areas. The areas that give them the greatest difficulty are lack of skilled personnel, lack of market information, and government standards and regulations. In each of these cases, world-first innovators generally experience these problems more frequently than non world-first innovators. This suggests these problems do not block innovation as much as they accompany more innovative efforts.

Public policy also facilitates innovation by setting the framework in which innovators can protect the intellectual property that accompanies innovations. Both world-first and non

world-first innovators use intellectual property rights extensively. Over 80% of world-first innovators use at least one of patents, trade marks, trade secrets, industrial designs, copyrights, or integrated circuit designs. The percentage of non world-firsts that do so was lower (63%), but nonetheless significant.

In summary, the Canadian innovation system produces a variety of innovations, from world-leaders to the incremental changes that result from the general diffusion of knowledge about new production techniques. These different innovations have similar beneficial effects in terms of improving a firm's market share or profit margin. They are, however, the product of quite different innovation systems.

Statistical Tables

Table 1

Percentage of Firms Introducing Innovations

	employment-weighted	company-weighted
All innovators	42.0 (5.3)*	35.8 (1.5)*
World-first innovators	8.5 (1.7)*	5.2 (0.6)*
Canadian-first innovators	15.2 (3.3)*	10.7 (0.9)*
Other innovators	18.3 (2.8)*	19.9 (1.2)*

* standard error estimates

Table 2

Percentage of Firms Introducing Innovations by Firm Employment Size Class

	Firms with fewer than 100 employees		Firms with 100 - 500 employees		Firms with more than 500 employees	
	employment-weighted	company-weighted	employment-weighted	company-weighted	employment-weighted	company-weighted
All innovators	34.9 (2.3)*	30.4 (1.9)*	42.6 (3.1)*	42.0 (3.0)*	42.5 (6.3)*	50.1 (3.4)*
World-first innovators	3.6 (0.8)*	3.1 (0.6)*	7.2 (1.4)*	7.0 (1.4)*	9.1 (2.0)*	12.1 (2.0)*
Canadian-first innovators	11.2 (1.5)*	9.7 (1.2)*	11.9 (2.0)*	11.8 (1.9)*	16.2 (3.9)*	13.1 (1.7)*
Other innovators	20.2 (2.0)*	17.6 (1.6)*	23.6 (2.7)*	23.3 (2.5)*	17.2 (3.2)*	24.9 (3.0)*

* standard error estimates

Table 3

Innovation Intensity Across Industries

Industry Class	World-first innovators		Canadian-first innovators		Other innovators	
	employment-weighted	company-weighted	employment-weighted	company-weighted	employment-weighted	company-weighted
	(percentage)					
Pharmaceuticals Manufacturing	61.8 (12.4)*	36.6(11.3)*	12.8 (7.3)*	6.2 (3.4)*	11.3 (5.9)*	23.9(10.2)*
Electrical and Electronic Products	31.6 (12.1)*	22.6 (5.6)*	28.3 (9.9)*	17.9 (5.0)*	12.2 (4.2)*	22.7 (5.4)*
Textiles	24.5 (10.6)*	10.8 (4.7)*	27.1 (9.3)*	13.7 (4.3)*	8.3 (3.3)*	14.9 (4.3)*
Primary Metals and Fabricated Products	5.2 (2.8)*	2.7 (1.1)*	38.6(15.2)*	8.9 (2.7)*	18.9 (8.5)*	16.3 (3.5)*
Chemicals	10.6 (4.4)*	11.8 (3.9)*	30.9 (9.4)*	13.1 (3.4)*	12.5 (3.9)*	24.7 (5.2)*
Machinery	2.7 (1.7)*	5.0 (2.3)*	24.1 (7.8)*	23.2 (4.9)*	22.7 (7.6)*	21.2 (4.5)*
Rubber and Plastic Products	15.1 (5.5)*	8.3 (2.9)*	8.5 (3.0)*	17.4 (4.6)*	34.2 (9.4)*	25.4 (5.4)*
Paper and Allied Products	7.8 (4.0)*	3.8 (1.6)*	15.5 (7.0)*	8.5 (2.9)*	25.7 (6.6)*	29.6 (6.5)*
Other Manufacturing	11.0 (5.0)*	4.7 (1.4)*	8.5 (2.4)*	9.5 (2.2)*	24.8 (6.1)*	16.5 (2.9)*
Transportation Equipment	10.3 (5.1)*	3.0 (1.3)*	4.8 (2.0)*	15.9 (3.8)*	25.6 (8.3)*	27.6 (4.9)*
Wood, Furniture and Fixtures	6.4 (3.0)*	5.1 (2.2)*	5.6 (3.8)*	3.9 (2.2)*	15.9 (5.7)*	11.0 (3.2)*
Food, Beverage and Tobacco	0.6 (0.5)*	1.0 (0.8)*	9.8 (4.5)*	9.4 (2.1)*	9.0 (4.1)*	21.9 (3.0)*
Printing and Publishing	1.9 (1.8)*	0.9 (0.6)*	6.2 (3.5)*	3.6 (2.3)*	39.3(12.5)*	27.1 (6.8)*

* standard error estimates

Table 4

Types of Innovation Introduced

	World-first innovators		Other innovators	
	employment-weighted	company-weighted	employment-weighted	company-weighted
	(percentage)			
Product only innovations	46.2 (8.5)*	37.8 (5.4)*	40.5 (5.6)*	40.7 (2.7)*
Process only innovations	63.0 (8.7)*	53.2 (5.6)*	58.0 (6.8)*	51.1 (2.8)*
Combined product-process	69.6 (8.2)*	61.6 (5.6)*	60.2 (5.5)*	52.7 (2.8)*

* standard error estimates

Table 5

Features of Process Innovations

	World-first innovators		Other innovators	
	employment-weighted	company-weighted	employment-weighted	company-weighted
	(percentage)			
New production techniques	62.9 (8.4)*	54.4 (5.6)*	53.7 (6.9)*	59.6 (2.8)*
New organization	28.9 (8.8)*	18.8 (4.2)*	31.5 (8.0)*	19.6 (2.3)*
Greater degree of automation	26.2 (6.4)*	40.6 (5.7)*	34.9 (5.5)*	38.2 (2.8)*
Other	13.1 (6.3)*	6.2 (2.3)*	4.7 (1.4)*	5.7 (1.2)*

* standard error estimates

Table 6

Features of Product Innovations

	World-first innovators		Other innovators	
	employment-weighted	company-weighted	employment-weighted	company-weighted
	(percentage)			
New functional parts	42.1 (8.7)*	37.8 (5.4)*	21.3 (4.5)*	24.9 (2.6)*
Use of new intermediate products	24.5 (8.8)*	15.9 (4.3)*	6.4 (1.7)*	11.2 (1.8)*
Fundamentally new functions	40.7 (8.5)*	38.8 (5.5)*	24.8 (4.6)*	26.3 (2.5)*
Use of new materials	47.9 (8.4)*	38.4 (5.4)*	27.1 (4.4)*	33.6 (2.7)*
Other	12.1 (6.2)*	8.5 (2.8)*	20.5 (8.5)*	10.6 (1.7)*

* standard error estimates

Table 7

Effects of Innovation

	World-first innovators		Canadian-first innovators		Other innovators	
	employment-weighted	company-weighted	employment-weighted	company-weighted	employment-weighted	company-weighted
	(percentage)					
Extending product range	53.1 (8.8)*	50.5 (5.8)*	45.4(10.2)*	50.5 (4.5)*	66.8 (5.2)*	62.0 (3.8)*
Reduced lead times	9.2 (2.6)*	24.6 (5.1)*	24.3 (7.2)*	29.4 (4.2)*	32.5 (5.5)*	35.6 (3.8)*
Improved working conditions	13.6 (3.8)*	22.9 (4.8)*	19.8 (5.4)*	31.9 (4.3)*	27.7 (4.9)*	31.7 (3.6)*
Improved technological capabilities	56.1 (9.0)*	57.3 (5.8)*	72.5 (7.0)*	48.7 (4.4)*	48.0 (6.2)*	50.0 (3.9)*
Improved quality of products	55.8 (8.8)*	64.5 (5.3)*	52.0(11.2)*	56.1 (4.5)*	57.1 (6.6)*	62.3 (3.9)*

* standard error estimates

Table 8

Improved Interactions with Customers

	World-first innovators		Canadian-first innovators		Other innovators	
	employment-weighted	company-weighted	employment-weighted	company-weighted	employment-weighted	company-weighted
	(percentage)					
Improved interactions with customers	63.3 (9.5)*	72.1 (5.4)*	82.7 (4.9)*	70.7 (4.2)*	74.9 (4.4)*	74.8 (3.3)*

* standard error estimates

Table 9

Market Share and Profitability

	World-first innovators		Canadian-first innovators		Other innovators	
	employment-weighted	company-weighted	employment-weighted	company-weighted	employment-weighted	company-weighted
	(percentage)					
Increased share in domestic market	55.6 (9.0)*	70.0 (5.4)*	68.2 (8.2)*	61.7 (4.5)*	61.7 (5.6)*	66.7 (3.7)*
Increased share in foreign market	44.6 (8.6)*	44.7 (5.7)*	36.6 (8.9)*	36.6 (4.3)*	46.3 (6.5)*	39.5 (4.0)*
Improved profit margin	58.8 (8.9)*	59.0 (5.7)*	56.7(11.9)*	60.4 (4.4)*	65.5 (6.7)*	65.6 (3.8)*

* standard error estimates

Table 10

Internal Innovative Idea Sources

	World-first innovators		Other innovators	
	employment-weighted	company-weighted	employment-weighted	company-weighted
	(percentage)			
Research and Development	85.9 (3.6)*	65.9 (5.5)*	49.2 (6.4)*	39.2 (2.7)*
Production	23.2 (6.0)*	25.9 (4.9)*	33.3 (5.1)*	37.8 (2.8)*
Management	25.8 (6.3)*	43.1 (5.6)*	53.5 (6.2)*	54.4 (2.8)*
Sales/Marketing	37.1 (7.7)*	40.7 (5.5)*	31.9 (5.0)*	43.4 (2.8)*
Other	2.7 (1.3)*	6.1 (2.5)*	3.3 (1.1)*	2.9 (0.9)*

* standard error estimates

Table 11

External Innovative Idea Sources

	World-first innovators		Other innovators	
	employment-weighted	company-weighted	employment-weighted	company-weighted
	(percentage)			
Suppliers	32.3 (8.5)*	30.3 (5.2)*	27.6 (4.4)*	27.9 (2.6)*
Clients or customers	31.3 (7.0)*	37.6 (5.4)*	38.6 (5.6)*	47.7 (2.8)*
Related firms	25.7 (7.5)*	12.2 (2.7)*	31.8 (7.6)*	15.8 (2.0)*
Consultants	21.1 (8.4)*	15.2 (4.0)*	11.6 (3.1)*	12.7 (1.8)*
Private R&D institutions	13.7 (8.2)*	7.4 (3.3)*	4.7 (1.4)*	3.7 (1.1)*
Government development agencies	13.6 (7.4)*	2.5 (1.2)*	1.0 (0.4)*	3.3 (1.1)*
Competitors	4.3 (1.8)*	11.1 (3.6)*	29.0 (5.0)*	30.9 (2.7)*
Trade fairs/conferences/meetings	4.2 (1.4)*	13.6 (3.8)*	14.0 (2.9)*	18.1 (2.2)*
Public R&D institutions	6.6 (4.3)*	5.9 (2.9)*	4.4 (2.4)*	2.4 (0.8)*
Universities/colleges	5.8 (4.2)*	3.9 (2.0)*	1.6 (0.7)*	2.6 (1.0)*
Software houses	5.1 (3.4)*	3.8 (1.7)*	3.6 (1.8)*	3.3 (1.1)*
Patent offices or patent literature	11.5 (5.4)*	8.8 (3.2)*	2.5 (1.5)*	1.3 (0.5)*
Professional publications	4.8 (1.7)*	11.3 (3.4)*	10.1 (2.6)*	12.9 (2.0)*
Government regulations/standards	6.8 (4.9)*	7.7 (3.4)*	6.1 (2.3)*	8.4 (1.6)*
Financial institutions	1.0 (0.9)*	0.2 (0.2)*	0.5 (0.3)*	0.5 (0.4)*

* standard error estimates

Table 12

Internal Technology Idea Sources

	World-first innovators		Other innovators	
	employment-weighted	company-weighted	employment-weighted	company-weighted
	(percentage)			
Experimental development	65.9 (7.8)*	59.8 (5.8)*	54.0 (7.9)*	50.5 (3.2)*
Production engineering	55.3 (8.8)*	47.4 (5.8)*	62.0 (6.4)*	52.4 (3.2)*
Research	68.3 (7.1)*	46.8 (5.8)*	27.0 (5.4)*	28.2 (2.8)*
Other	2.5 (1.6)*	2.9 (1.5)*	1.0 (0.3)*	3.6 (1.0)*

* standard error estimates

Table 13

External Technology Idea Sources for World-First Innovators

	Firms conducting research		Firms not conducting research	
	employment-weighted	company-weighted	employment-weighted	company-weighted
	(percentage)			
Related firm	43.6 (12.0)*	21.5 (6.3)*	45.4 (12.5)*	23.4 (7.6)*
Supplier firms	27.7 (11.7)*	31.9 (7.6)*	31.7 (9.1)*	48.8 (8.3)*
Unrelated firms	21.2 (12.0)*	9.5 (5.2)*	20.6 (7.2)*	30.9 (8.3)*
Consultants and service firms	1.7 (1.0)*	13.7 (6.1)*	17.0 (6.9)*	25.5 (7.7)*
Industrial research firms	17.0 (12.0)*	9.1 (5.5)*	15.6 (9.8)*	8.0 (4.9)*
Government laboratories	13.7 (9.0)*	6.1 (3.3)*	5.5 (3.8)*	4.4 (2.3)*
University laboratories	38.2 (12.5)*	15.5 (6.4)*	0.9 (0.7)*	1.5 (1.0)*
Publications	0.7 (0.4)*	7.4 (4.5)*	11.8 (5.8)*	7.5 (4.1)*
Joint ventures/Strategic alliances	6.2 (4.3)*	7.1 (3.9)*	7.8 (5.0)*	8.3 (4.6)*
Customer firms	4.5 (2.5)*	11.0 (4.7)*	7.2 (4.1)*	3.6 (1.9)*
Trade fairs and conferences	1.4 (0.8)*	6.1 (3.2)*	4.7 (3.6)*	5.9 (4.4)*
Other	0.2 (0.1)*	1.9 (1.6)*	3.8 (3.4)*	0.8 (0.7)*

* standard error estimates

Table 14

External Technology Idea Sources for Non World-First Innovators

	Firms conducting research		Firms not conducting research	
	employment-weighted	company-weighted	employment-weighted	company-weighted
	(percentage)			
Related firms	8.7 (3.1)*	11.4 (3.4)*	15.7 (4.8)*	15.1 (2.7)*
Supplier firms	38.0 (10.3)*	28.0 (5.0)*	29.6 (7.2)*	31.8 (3.7)*
Unrelated firms	22.8 (10.6)*	11.8 (3.7)*	9.9 (2.8)*	14.8 (2.6)*
Consultants and service firms	18.4 (10.6)*	12.3 (4.4)*	10.3 (2.7)*	15.7 (2.7)*
Industrial research firms	4.4 (2.0)*	6.6 (2.7)*	8.2 (3.6)*	3.0 (1.0)*
Government laboratories	5.7 (3.2)*	7.7 (3.1)*	1.1 (0.7)*	1.8 (0.8)*
University laboratories	2.9 (2.0)*	1.4 (0.7)*	3.0 (1.5)*	4.2 (1.8)*
Publications	7.1 (3.0)*	11.5 (3.3)*	5.5 (2.1)*	7.9 (2.1)*
Joint ventures/Strategic alliances	2.5 (1.4)*	2.6 (1.6)*	2.9 (1.3)*	5.2 (1.8)*
Customer firms	7.7 (3.7)*	18.6 (4.8)*	9.0 (2.6)*	14.8 (2.8)*
Trade fairs and conferences	11.5 (4.3)*	17.3 (4.4)*	9.5 (2.7)*	14.7 (2.8)*
Other	0.7 (0.4)*	2.3 (1.2)*	1.2 (0.5)*	5.2 (1.9)*

* standard error estimates

Table 15

External Technology Idea Sources (World-Firsts versus Non World-Firsts)

	World-first innovators		Other innovators	
	employment-weighted	company-weighted	employment-weighted	company-weighted
	(percentage)			
Related firms	44.1 (9.1)*	22.5 (5.0)*	13.8 (3.5)*	14.1 (2.2)*
Supplier firms	29.0 (8.4)*	40.9 (5.8)*	31.9 (6.2)*	30.7 (3.0)*
Unrelated firms	21.0 (8.5)*	20.9 (5.3)*	13.4 (3.9)*	14.0 (2.1)*
Consultants and service firms	6.5 (2.4)*	20.0 (5.0)*	12.5 (3.7)*	14.7 (2.3)*
Industrial research firms	16.6 (8.8)*	8.5 (3.6)*	7.2 (2.6)*	4.0 (1.1)*
Government laboratories	11.1 (6.4)*	5.2 (2.0)*	2.3 (1.1)*	3.4 (1.1)*
University laboratories	26.4 (9.8)*	8.0 (3.2)*	3.0 (1.2)*	3.4 (1.3)*
Publications	4.2 (1.9)*	7.4 (3.0)*	5.9 (1.8)*	8.9 (1.8)*
Joint ventures/Strategic alliances	6.7 (3.4)*	7.7 (3.1)*	2.8 (1.0)*	4.5 (1.4)*
Customer firms	5.4 (2.2)*	7.1 (2.5)*	8.7 (2.1)*	15.9 (2.4)*
Trade fairs and conferences	2.5 (1.3)*	6.0 (2.7)*	10.0 (2.3)*	15.4 (2.3)*
Other	1.3 (1.1)*	1.3 (0.9)*	1.0 (0.4)*	4.4 (1.4)*

* standard error estimates

Table 16

Performance of Research and Development

	World-first innovators				Other innovators			
	employment-weighted		company-weighted		employment-weighted		company-weighted	
	(percentage)							
R&D performed on an ongoing basis	82.0	(4.8)*	68.7	(5.1)*	52.6	(6.1)*	50.1	(2.7)*
R&D performed on an occasional basis	10.7	(3.9)*	24.2	(4.8)*	32.1	(6.7)*	40.0	(2.7)*

* standard error estimates

Table 17

Organization of Research and Development

	World-first innovators				Other innovators			
	employment-weighted		company-weighted		employment-weighted		company-weighted	
	(percentage)							
Firm has a separate R&D unit	73.6	(7.2)*	52.5	(5.8)*	54.1	(6.8)*	36.7	(2.7)*
R&D work is done in other departments	52.0	(8.8)*	56.5	(5.7)*	41.4	(5.9)*	60.3	(2.8)*
R&D work is contracted out	36.4	(8.1)*	35.2	(5.5)*	36.5	(7.6)*	19.5	(2.1)*

* standard error estimates

Table 18

Impact of Innovation on Workers

	World-first innovators				Other innovators			
	employment-weighted		company-weighted		employment-weighted		company-weighted	
	(percentage)							
Decrease in production workers	8.7	(3.1)*	14.5	(4.4)*	16.0	(3.9)*	12.1	(1.8)*
Increase in production workers	32.4	(7.5)*	33.1	(5.3)*	26.2	(4.8)*	36.0	(2.8)*
Decrease in non-production workers	1.1	(0.7)*	4.0	(2.1)*	3.3	(1.1)*	3.9	(1.1)*
Increase in non-production workers	21.1	(5.6)*	30.5	(5.4)*	18.3	(3.6)*	22.0	(2.5)*
Decrease in total workers	6.6	(2.7)*	12.1	(4.1)*	15.7	(3.9)*	12.7	(1.8)*
Increase in total workers	40.1	(8.1)*	43.5	(5.7)*	31.2	(5.3)*	40.4	(2.9)*

* standard error estimates

Table 19

Impact of Innovation on Workers' Skill Requirements

	World-first innovators		Other innovators	
	employment-weighted	company-weighted	employment-weighted	company-weighted
	(percentage)			
Decrease in skill requirements	0.3 (0.2)*	2.3 (2.3)*	1.7 (1.5)*	0.5 (0.5)*
Increase in skill requirements	57.0 (9.0)*	55.4 (5.8)*	63.6 (7.7)*	61.8 (2.8)*
No change in skill requirements	42.8 (9.0)*	42.3 (5.8)*	34.7 (7.8)*	37.7 (2.8)*

* standard error estimates

Table 20

Impediments to Innovation

	World-first innovators		Other innovators	
	employment-weighted	company-weighted	employment-weighted	company-weighted
	(percentage)			
Lack of cooperation from other firms	5.8 (2.5)*	17.3 (5.4)*	9.7 (2.6)*	14.2 (2.2)*
Lack of technology information	8.6 (3.0)*	22.0 (5.4)*	23.5 (5.0)*	32.4 (2.9)*
Lack of external technical services	14.0 (5.1)*	19.8 (5.3)*	13.8 (4.0)*	14.1 (2.0)*
Lack of cooperation with scientific\educational institutions	16.7 (8.0)*	9.1 (4.1)*	5.8 (2.0)*	5.2 (1.2)*
Standards and regulations	31.3 (7.9)*	32.6 (5.8)*	27.6 (5.2)*	21.5 (2.4)*
Lack of market information	38.6 (10.1)*	41.4 (6.3)*	25.3 (5.0)*	26.1 (2.6)*
Lack of skilled personnel	60.3 (8.3)*	49.7 (6.2)*	39.5 (5.9)*	46.5 (3.0)*
Other	35.1 (10.0)*	23.9 (5.5)*	32.6 (8.0)*	20.9 (2.3)*

* standard error estimates

Table 21

Intellectual Property Usage

	World-first innovators				Other innovators			
	employment-weighted		company-weighted		employment-weighted		company-weighted	
	(percentage)							
Patents	69.4	(6.6)*	44.5	(5.4)*	34.2	(5.0)*	24.7	(2.2)*
Trade marks	51.7	(8.2)*	39.8	(5.4)*	34.7	(4.8)*	32.0	(2.5)*
Trade secrets	43.5	(8.6)*	33.2	(5.1)*	31.1	(6.9)*	18.2	(2.1)*
Industrial designs	24.3	(7.0)*	24.4	(4.8)*	15.4	(3.2)*	13.2	(1.9)*
Copyrights	21.1	(8.6)*	17.8	(4.6)*	13.3	(3.3)*	7.5	(1.3)*
Integrated circuit designs	2.5	(1.5)*	4.7	(1.9)*	1.1	(0.5)*	2.3	(0.7)*
Plant breeders' rights	1.2	(1.1)*	0.2	(0.2)*	0.9	(0.5)*	0.7	(0.4)*
Other	2.2	(1.3)*	3.1	(1.9)*	1.5	(0.8)*	1.1	(0.5)*

* standard error estimates