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RECENT JUMPS IN PATENTING ACTIVITIES: COMPARATIVE INNOVATIVE PERFORMANCE OF MAJOR INDUSTRIAL COUNTRIES, PATTERNS AND EXPLANATIONS

By Mohammed Rafiquzzaman and Lori Whewell,
Industry Canada

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Comments should be addressed to:

Someshwar Rao
Director
Strategic Investment Analysis
Micro-Economic Policy Analysis
Industry Canada
5th Floor, West Tower
235 Queen Street
Ottawa, Ontario
K1A 0H5

Tel.: (613) 941-8187
Fax: (613) 991-1261
E-mail: rao.someshwar@ic.gc.ca

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ABSTRACT

In recent years, Canada has experienced an increase in patenting activities. Canadians are filing patent applications at an ever-increasing rate, both at home and abroad. Further, patent applications abroad by Canadian inventors have grown at a faster rate than patent applications in Canada from abroad, thereby widening the gap between the outflow and inflow of patent applications. All these trends are direct reflections of an increase in inventive activity in Canada. This paper analyses the nature, pattern and causes of these shifts in patenting activities in Canada.

The paper has five objectives: (1) to investigate whether the recent surge in patenting activities is a global phenomenon or something unique to Canada, and to examine the causes of these increases; (2) to examine Canada's inventive performance vis-à-vis that of other G-7 countries; (3) to demonstrate the trend in the flow of patent applications to and from Canada; (4) to understand the factors that determine international patenting activities of inventors from one country in another country; and (5) to identify the most innovative and dynamic industries within the Canadian manufacturing sector.

Trends in patenting activity indicate that Canadian inventors are well positioned in the field of innovation vis-à-vis those of the other six G-7 countries (the United States, Japan, Italy, Germany, France and the United Kingdom). Canadian inventors have been gaining ground in the development of technology more quickly than nationals of most other industrialized countries. We find that the propensity of Canadian inventors to patent in the other six countries has changed over time, as has the patenting activity of inventors from these countries in Canada. In particular, dramatic changes have occurred in cross-border patenting between Canada and the United States. While Canada still receives the largest share of its foreign patents from U.S. inventors, and the United States receives the highest share of foreign patents from Canadians, each of these shares has been falling over time. Canadians are increasingly applying for patent protection in countries other than the United States; in addition, Canada is becoming a more attractive place in which to seek patent protection for nationals of foreign countries other than the United States.

The paper considers two competing hypotheses to explain the causes of the recent increase in Canadian patenting activity: first, the *pro-patent hypothesis*, associated with changes in patent policy that have benefited patent holders and thereby increased the propensity to patent; second, the *fertile technology hypothesis*, related to the current technological revolution and innovation in the high-technology sector, particularly in the fields of biotechnology, information technology and software industries. The result has been an increase in the filing of patent applications related to these specific technologies. The findings of the paper suggest that, although both hypotheses are at work, the fertile technology hypothesis can better explain the recent increase in patenting activity in Canada.

Further, the paper finds that the characteristics of both technology source and destination countries, along with national patent systems, play important roles in international patenting decisions. Source country characteristics, such as research intensity and home country bias, are significant determinants of international patenting activity. Destination country characteristics, such as human capital, imports, market size, degree of intellectual property protection, and geographic proximity, tend to induce inventors from the source country to patent in the destination country. However, the cost of patenting was not found to be an important determinant of international patenting activity.

Finally, the paper finds that increases in patenting activity have not been uniformly distributed across all industrial sectors within Canadian manufacturing. The largest concentration of applications for manufacturing patents is found in the science-based industries. The science-based sector, which is the smallest sector within Canadian manufacturing, remains the most innovative, and a handful of industries within the science-based sector have become increasingly dynamic over time.

INTRODUCTION

Over the past two decades, most of the industrialized countries have experienced an increase in patenting activity. Foreign patenting has grown more rapidly than domestic patenting. Both foreign patenting and patenting abroad have gone up, and at the same time the diffusion-dependency ratio has increased, thereby widening the gap between the outflow and inflow of patent applications.[1] The implication is that the propensity to patent abroad is increasing, reflecting the upward trend in value of patentable inventions (Kortum 1997) and the fact that countries are exporting (transferring) more technologies abroad than they are importing (Eto and Lee 1993). Although the pattern of these changes is well documented (see, e.g., Bosworth 1984, French 1987, Eto and Lee 1993, Eaton and Kortum 1996, Kortum and Lerner 1997), there is very little research about the causes of these changes. Three hypotheses have been offered to explain them: the *pro-patent policy hypothesis* (Merges 1992, 1995), the *fertile technology hypothesis* (Greenwood and Yorukoglu 1997, Arora and Gambardella 1994, Kortum and Lerner 1997) and the *regulatory capture hypothesis* (Lerner 1995).

Merges (1992) has suggested that the jump in patenting activity reflects an increase in the propensity to patent inventions, driven by changes in the legal environment for patent holders. The recent surge in patent applications may be a direct consequence of a major institutional change.[2] Since the eighth General Agreement on Tariffs and Trade (GATT) round, industrialized countries have changed their standards for protecting intellectual property via patents. The changes have not only broadened the rights of patentees but have also strengthened the protection of intellectual property rights (Maskus 1993, 1998).[3] These changes have been widely regarded as "pro-patent" and are expressed particularly in the increase in patent filing (Merges 1992, Kortum and Lerner 1997).

A different explanation for the recent jump in patenting stresses the type of technological revolution that has been widening the set of technological opportunities (Greenwood and Yorukoglu 1997). Connected with this is the explosion of new firm formation and innovation in the high-technology sector, particularly in the biotechnology, information technology and software industries. Further, the application of information technology to the discovery process itself may have substantially increased the productivity of research and development, or R&D (Arora and Gambardella 1994). Another possibility is that changes in the management of R&D facilities, in particular a shift to more applied activities, has increased the yield of patentable innovations (Rosenbloom and Spencer 1996). Still another possibility is that the increased level of patenting activity is the result of an overall increase in inventive input (higher levels of R&D and/or changes in the composition of R&D).[4] This set of ideas can be grouped together as the fertile technology hypothesis to explain why patenting has surged (Kortum 1997, Kortum and Lerner 1997).

In recent years, the rates of both foreign patenting by Canadians and of patenting by foreigners in Canada have been rising. Patent applications by Canadian inventors abroad have grown at a faster rate than patent applications in Canada originating from abroad. As a result of this change, the diffusion-dependency ratio has been growing at a faster rate. This suggests that Canadians are becoming more innovative and more technologically advanced than in the past. The observed trends in patenting activity imply that Canada is relatively less dependent on foreign technologies and that the patentable inventions of Canadians have become more valuable.[5]

A question naturally arises: why do we care about the reasons for the jump in Canadian patenting? First, Canadians have traditionally been pictured as less innovative. They are viewed as being technologically far behind their counterparts in other industrialized nations and they file fewer patent applications, both domestically and internationally, than citizens of other industrialized nations. If the number of patents filed by a firm, sector or country is a direct reflection of inventive intensity, then whatever may be the cause, a surge in filing by Canadians is a direct reflection of an increase in inventive activity.[6] Therefore, a jump in research productivity, as suggested by the fertile technology hypothesis, signals accelerated technological change, which yields productivity growth as more inventions are adopted — a favourable outlook for Canada. Second, if the increase in patenting is due to policy changes, it raises important public policy issues. A long series of economic models (Nordhaus 1969, Rafiquzzaman 1987 and 1988, Tirole 1989, Gilbert and Shapiro 1990, Klemperer 1990, de Laat 1996) have been used to argue that the patent system is designed to encourage innovation by providing inventors with a legally guaranteed monopoly on the products or processes that are the outcomes of their innovations. This incentive to invent must be balanced against the fact that it is socially optimal to encourage diffusion of innovations after their invention. This is true because monopolies do not maximize social welfare after an innovation has occurred. Managing this trade-off efficiently has been the subject of research that looks at the optimal length and optimal scope of patents. If the system of protection is substantially broadened and strengthened — as proposed by the pro-patent hypothesis — a careful analysis of the resulting impact on welfare is required.

This paper analyses the nature, pattern and causes of the shifts in patenting activities in Canada in light of the above hypotheses. It also investigates whether the recent surge in patenting is a global phenomenon or something unique to Canada. It therefore compares patenting performance, as measured by the growth in patenting activity across the Group of Seven (G-7) countries (Canada, the United States, Japan, Italy, Germany, France and the United Kingdom). It employs multivariate analysis to model international patenting decisions of inventors, in order to further explain the shifts. Finally, the paper investigates whether increases in patenting activity have been uniformly distributed across all industrial sectors or concentrated in certain fields of technology, as suggested by the fertile technology hypothesis. To do so, the paper makes use of international patent data collected by the Organization for Economic Co-operation and Development (OECD) and Canadian Patent Data (PATDAT) administered by the Canadian Intellectual Property Office (CIPO) over the period 1978–1992.[7]

Patterns in international patenting and the inventive performance of major industrial countries are described and compared in the following section of the paper, entitled “Patenting Activity: Inter-Country Comparisons.” The section on “International Patenting by Canadians” demonstrates the flow of patent applications to and from Canada. “A Model of Patenting” presents an empirical framework for modelling patenting decisions of inventors internationally. It also specifies an econometric model for international patenting, describes the sources of data, estimates the model and discusses the results. The following section breaks down the total variation in the international patenting data into source country by year effects and destination country by year effects, in order to investigate whether the recent jump in Canadian patenting is attributable to the pro-patent hypothesis or to the fertile technology hypothesis. “Inter-Sectoral Patenting Activities in Canada” presents the concentration of patenting activity across different industries within Canadian manufacturing, in order to identify the most dynamic and innovative industries. The final section summarizes the discussion and presents the conclusions.

PATENTING ACTIVITY: INTER-COUNTRY COMPARISONS

In recent years, patenting activities in most industrialized countries have been growing at a faster pace than ever before. Foreign patenting and patenting abroad have recently been rising more rapidly than domestic patenting. This implies that policy makers and entrepreneurs increasingly recognize the importance of foreign patenting as well as patenting abroad. For example, while the international transfer of technological know-how is recognized as an important dimension of the diffusion of new technologies, foreign patenting is often ignored in studies of international technology transfer (Slama 1981, Bosworth 1984, Reddy and Zhao 1990).[8] Foreign patenting has been overlooked partly because of the lack of readily available, internationally comparable patent data. The growth in foreign patenting and patenting abroad also implies that inventors increasingly recognize the global importance of their innovations as their value has been rising both domestically and internationally (Eaton and Kortum 1996).

Across countries there are institutional differences in national patent systems which generate asymmetries between patent application procedures and patent granting procedures. Although both patent applications and patent grants are considered indicators of inventive activity, the former procedures are more unified internationally than the latter. Therefore, data on applications may be better for cross-national comparisons than data on patent grants, despite the merits of the latter in several respects (Soete 1987, Eto and Lee 1993).

While most industrialized countries are experiencing increases in patenting activity, are some countries showing a superior inventive performance? Are traditionally less innovative countries increasing their patenting activities? To investigate these questions, this section compares and contrasts the patenting activity of inventors in the seven major industrialized countries (the United States, the United Kingdom, Germany, France, Japan, Italy and Canada), using the OECD's *Basic Science and Technology Statistics* on patents (OECD 1995).[9] According to the data, in 1987 these countries together shared 75.1 percent of the world's patent applications abroad (i.e., patents applied for outside the applicant's country of residence). On average, the major countries accounted for 84.1 percent of patent applications in their domestic patent markets in that year. Hence it can be claimed that the major countries account for a large proportion of all patents in the world.

Trends in domestic patenting

To assess the importance of domestic patenting, foreign patenting and patenting abroad, the average annual growth rates of patenting activities for the periods 1978–1984 and 1985–1992 are presented in Table 1. Patenting activity as a whole increased between 1978–1984 and 1985–1992 across all nations, and particularly in Canada. Over the period 1978–1984, the average annual growth rate in domestic patenting ranged from a low of -0.10 percent in the United Kingdom to 10.44 percent in Japan. A comparison of the periods 1978–1984 and 1985–1992 shows that domestic patenting increased during the second period in all countries except Germany, Japan and Britain. The largest increase occurred in the United States (5.1 percentage points), followed by Canada (3.7 percentage points) and France (1.4 percentage points).

While previous studies (e.g., French 1987) indicated that Canada has a low relative propensity to file for domestic patents compared to other nations, the above statistics indicate that, on average, the propensity to file for domestic patents has grown in Canada at a faster rate than in many other industrialized countries over both periods. The pace of growth has increased since the mid-1980s. Although the United States experienced the highest increase in growth in the propensity for domestic patenting, Canada followed close behind. The propensity for domestic patenting declined in other countries, with the exception of France.

Table 1: Growth Rates of Patenting Activities between 1978–1984 and 1985–1992 (%)

	1978–1984					1985–1992				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Country	Domestic patents[a]	Patents from abroad[b]	National patents[c]	Patenting abroad[d]	Diffusion-dependency ratio[e]	Domestic patents[a]	Patents from abroad[b]	National patents[c]	Patenting abroad[d]	Diffusion-dependency ratio[e]
Canada	1.69	1.37	1.37	6.44	5.06	5.37	6.58	6.44	22.52	14.73
France	-0.01	6.22	4.63	7.57	1.30	1.34	6.03	5.12	8.72	2.48
Germany	1.11	5.66	3.52	7.74	1.97	0.86	5.32	3.50	7.83	2.37
Italy	—	—	6.01	7.85	—	—	—	10.27	11.30	—
Japan	10.44	3.61	9.54	12.98	9.05	3.55	5.42	3.75	9.65	4.08
U.K.	-0.10	5.29	3.49	7.39	2.04	-0.15	5.46	4.00	13.62	7.83
U.S.	0.16	4.87	2.14	8.57	3.78	5.27	7.49	6.31	14.00	6.13

Notes

a Total number of patent applications by residents of each country.

b Total number of patent applications by residents of foreign countries (non-resident applications).

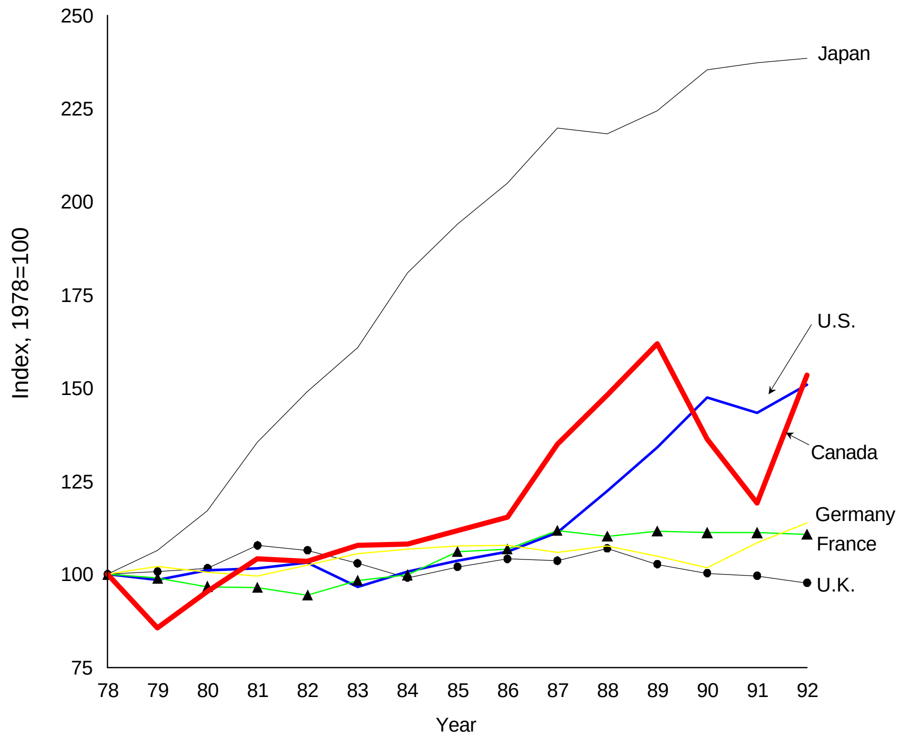
c Sum of resident and non-resident patent applications.

d Total number of patent applications by residents of a given country for patent protection in foreign countries.

e Ratio of the number of foreign-bound patent applications from a country to the inflow of applications from other countries (patenting abroad divided by patents from abroad).

A dash (—) indicates that data were not available.

Figure 1: Domestic Patent Applications, 1978–92



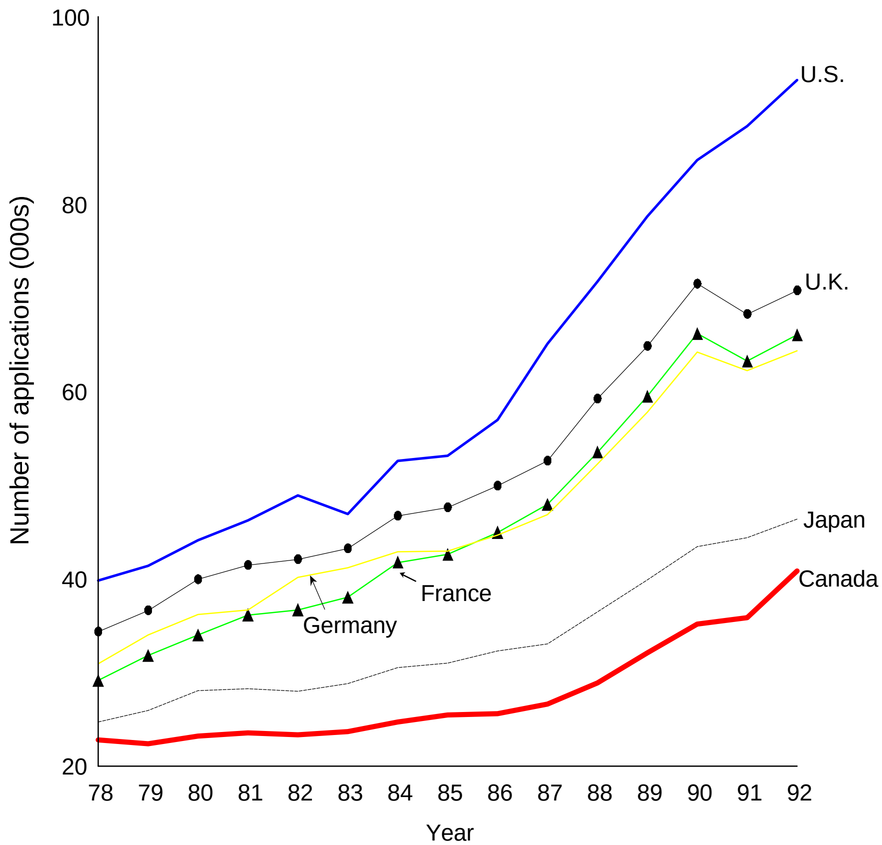
The pattern in domestic patenting in Canada compared to that in the United States, France, Germany, Japan and the United Kingdom is shown graphically in Figure 1. The figure shows that the three European countries have experienced different patterns in domestic patenting. Britain witnessed a cyclical pattern with peaks in 1981 and 1988, and a sharp decline thereafter. In contrast, both France and Germany display an upward trend until 1986. Since 1987, domestic applications have been essentially flat in France. On the other hand, there has been a recent upswing in domestic patent applications in Germany.

Canada has one of the lowest propensities to file patents at home of any of the major industrialized countries, with only 6.6 percent of national patent applications originating from residents in 1992; this figure contrasts, for example, with 16.1 percent in France and 49.8 percent in the United States (OECD 1995). Nevertheless, Canada shows an upward trend in domestic patenting over the 1978–1992 period, a phenomenon also evident in the United States and Japan (see Figure 1). Japan witnessed a steep upward trend throughout the 1970s and 1980s, but a relatively slower growth rate in the 1990s. In Canada and the United States, however, domestic applications exhibited strong growth between 1986 and 1989, and more recently between 1991 and 1992. Overall, domestic patenting activity has grown at a faster rate in Canada than in any other country except the United States (see Table 1).

Trends in foreign patenting activity

The intensification of trade flows in high-technology products and the transfer of technology by means of licensing agreements have led to an increase in non-resident firms' requests for protection of intellectual property in foreign markets. Figure 2 shows that patent applications by non-residents have been increasing in

Figure 2: Non-Resident Patent Applications by Host Country, 1978–92



all the G-7 countries. However, there are country-to-country differences in the growth rate of non-resident applications (see Table 1, columns 2 and 7). For example, over the period 1978–1984, foreign applications grew at an average rate of 1.37 percent per year in Canada, compared to a rate of 6.2 percent in France. Between 1978–1984 and 1985–1992, the rate of growth increased in the United States, the United Kingdom, Japan and Canada. The largest increase occurred in Canada (6.58 percent, up from 1.37 percent, or an increase of 5.2 percentage points) followed by the United States (up by 2.6 percentage points) and Japan (up by 1.8 percentage points), France (0.19 percentage points) and the United Kingdom. (0.16 percentage points). Germany suffered a decline over the same period.

The above statistics indicate that while Canada, the United States and Japan experienced rapid growth in the number of foreign applications in the period 1985–1992, France and the United Kingdom. experienced slower growth in the number of patent applications of foreign origin during the same period.

The increased growth in filings from non-nationals contributed to the increased growth in total filings (sum of domestic and non-resident filings) across all nations (see Table 1, columns 3 and 8). The growth accelerated in the period 1985–1992 in all countries except Japan and Germany. The most rapid growth in total filings occurred in Canada, followed by Italy and the United States. Japan suffered a large decline over the same period, mainly because domestic patenting declined at a rate of more than 6.0 percentage points per year.

Trends in patenting abroad

As in the case of foreign patenting, the intensification of trade flows in high-technology products and the transfer of technology by means of licensing agreements have also led to an increase in patenting abroad by technology-producing countries. Since the value of many of these innovations has been increasing worldwide, inventors from technology-producing countries are increasingly seeking protection for intellectual property on foreign markets.

The increase in patenting abroad is more dramatic than that in either domestic or foreign patenting. All nations experienced a very rapid average annual rate of growth in patenting abroad during the period 1978–1984 (see Table 1, columns 4 and 9). A comparison of 1985–1992 with 1978–1984 shows that the growth rate accelerated in all countries except Japan, where patenting abroad has grown more slowly. Canada experienced the largest increase (16.08 percentage points), with the United Kingdom a distant second (6.23 percentage points).

Figure 3 compares patenting activity abroad by inventors of all G-7 countries between 1978 and 1992. The four European countries and the United States display an upward trend, with a slight upturn in the late 1980s. In contrast, Japan witnessed an upward trend until the late 1980s, with activity essentially flat thereafter. While Figure 3 illustrates that Canada files fewer patents abroad than the other G-7 countries, Figure 4 shows that, relative to the other countries, Canada has performed remarkably well in terms of growth since 1978. Patenting in foreign countries by Canadian inventors has been rising since 1978, with a sharp upswing beginning in 1989. The data demonstrate that Canada switched its relative position with other countries in the late 1980s, reflecting the larger growth in patenting abroad by Canadian inventors compared with those of other countries.

Figure 3: Patenting Abroad by Country, 1978–92

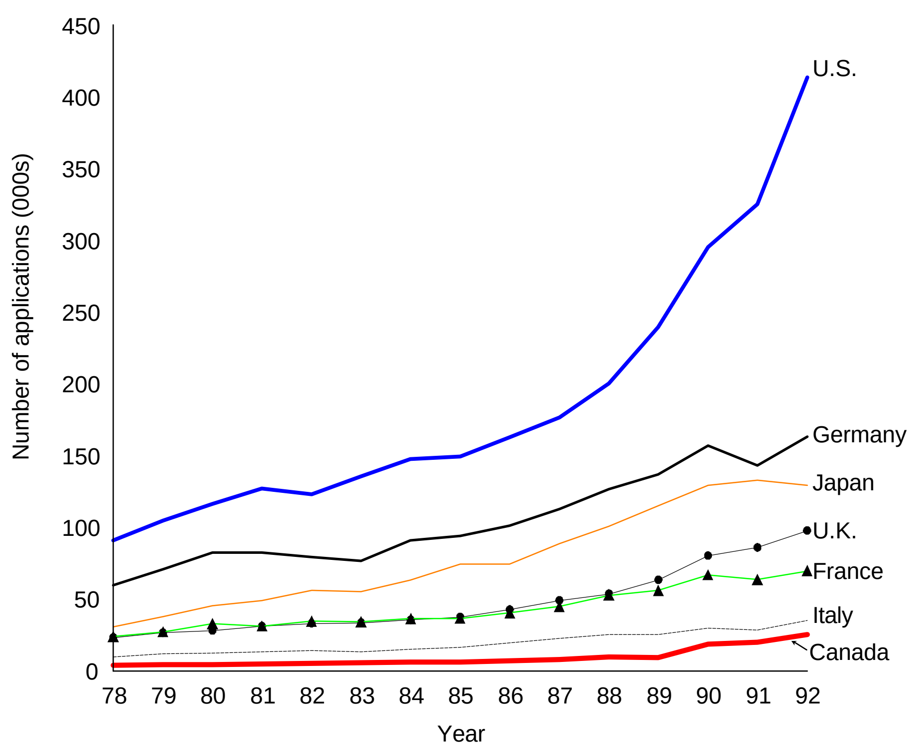
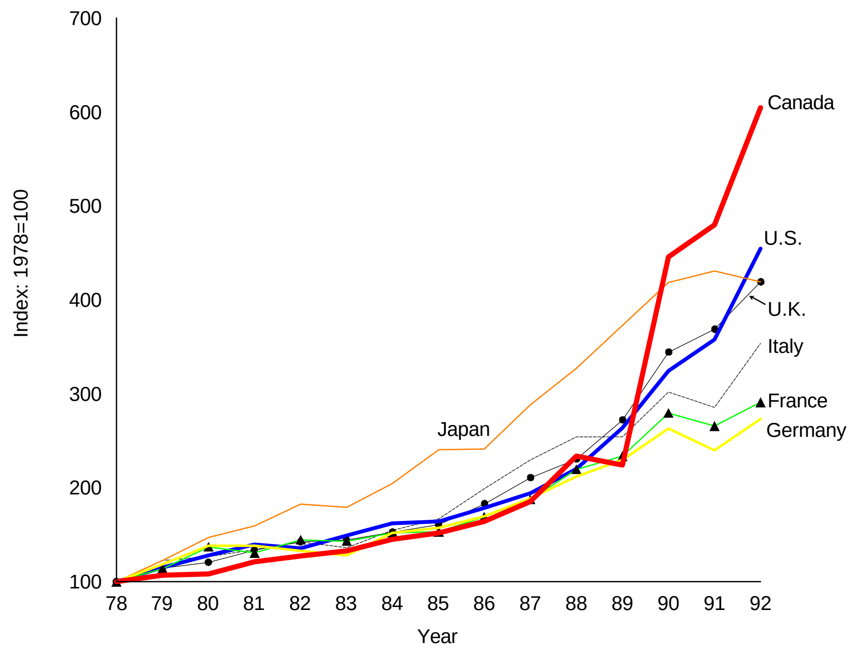


Figure 4: Patenting Abroad by Country, 1978–92 (1978=100)



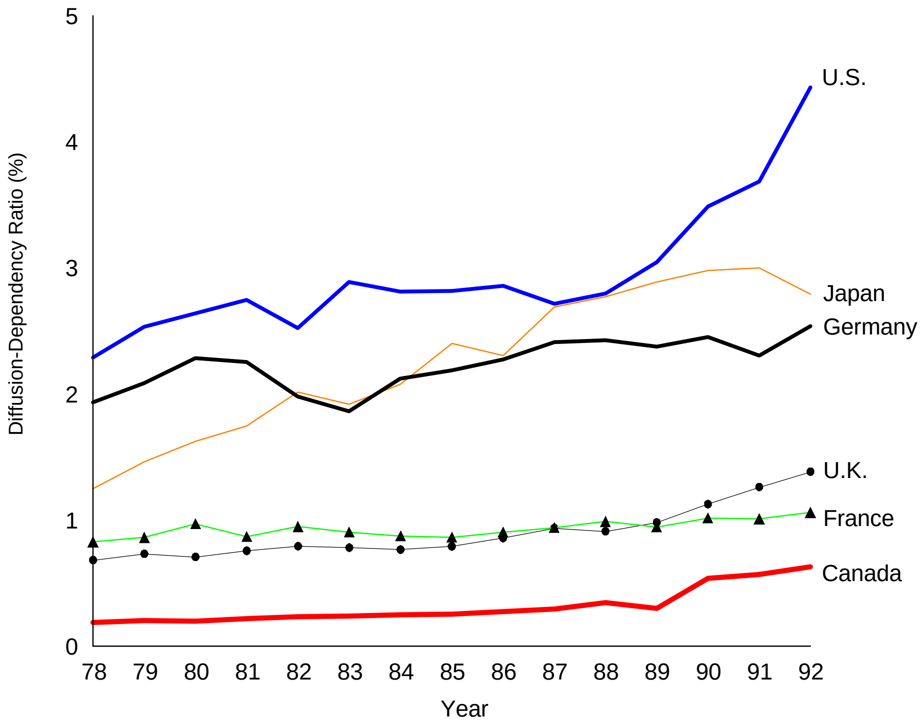
Trends in the diffusion-dependency ratio

Although both foreign patenting and patenting abroad have grown in most of these countries during both periods under study, patenting abroad has grown at a faster rate. This is further shown by the rapid growth in the diffusion-dependency ratio across all countries (see Table 1, columns 5 and 7). The growth rate accelerated in all countries over the periods 1978–1984 and 1985–1992; the exception was Japan, where the ratio declined at a rate of about 5.0 percentage points per year. Canada experienced the largest increase (9.7 percentage points per year) over the same periods.

The pattern of change in the diffusion-dependency ratio is graphically depicted in Figure 5. Both Canada and the United States experienced an upward trend in the diffusion-dependency ratio throughout the time period, with a sharp increase since 1989. The ratio clearly increased for all other countries as well — again with the exception of Japan, where the ratio declined from the beginning of the 1990s.

In summary, four facts become apparent from the analysis of different dimensions of patenting activities in G-7 countries. First, most of these countries experienced a rapid growth in all dimensions of patenting activities during the periods 1978–1984 and 1985–1992. The growth accelerated in all countries over the period 1985–1992, except Japan. In that country, the growth rate for most of the dimensions of patenting activities declined in the second period; the one exception was patenting abroad, which grew at a faster pace than during the period 1978–1984. Second, there are substantial differences in the growth of all dimensions of patenting activities across countries. Third, Canada and the United States experienced larger increases in growth for all dimensions of patenting activities than did other countries. Fourth, over the periods 1978–1984 and 1985–1992, Canada enjoyed a larger increase in growth in foreign patenting, national patenting, patenting abroad and the diffusion-dependency ratio than did the United States. The United States was ahead of Canada only in domestic patenting. Therefore, if innovativeness is measured in terms of the growth in patent applications instead of levels, Canada is becoming more inventive, and at a faster rate than many other countries.

Figure 5: Diffusion-Dependency Ratio by Country, 1978–92



INTERNATIONAL PATENTING BY CANADIANS

It was demonstrated above that patenting by Canadians abroad has been rising at a faster rate than foreign patenting in Canada. As a result, the diffusion-dependency ratio has also been rising at a faster rate. This suggests that although Canada relies on foreign technology more than most countries do, this dependency has been decreasing over time. On the other hand, as a source country, Canada has been diffusing technology abroad at a high rate, as evidenced by the rapid growth in patenting abroad by Canadian inventors — suggesting that the value of Canadian innovations abroad has been rising. In this section we investigate the relative importance of a target country to Canadians in patent terms. We also contrast the degree of attractiveness of Canada as a target country for filing patent applications from the same foreign countries. Proximity, market size, degree of economic integration and the strength of intellectual property protection play an important role in the patenting activity of a country, including both foreign patenting and patenting abroad.

Canadians patenting abroad

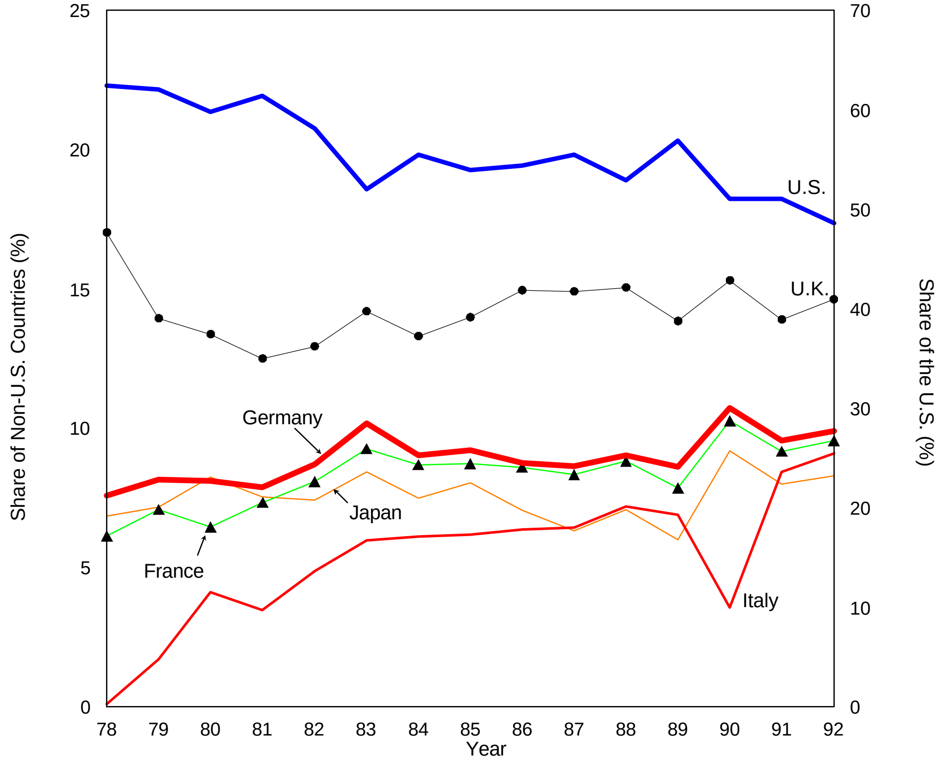
The intensity of interest of Canadians in patenting abroad with respect to six major industrial markets of the world is shown in Table 2. The intensity of interest of Canadians in filing in any of these foreign markets is measured by that country's share of the total patent applications filed by Canadians in the six countries — the United States, Japan, Germany, France, Italy and the United Kingdom. In 1978, the United States received the primary share of attention for Canadian patenting, followed by Germany, Japan, Britain, France and Italy. Between 1978 and 1992, the intensity of interest by Canadians increased in France, Germany, Italy and Japan, while it declined in the United States and the United Kingdom., with the largest decline occurring in the United States (13.8 percentage points). While the United States has become a less attractive country for Canadian patents over the years, it still receives the largest share of attention from Canadian inventors. This is due to the larger market size of the United States and the high level of economic integration between the two countries. By the end of 1992, France, Germany, Italy and Japan received equivalent levels of attention from Canadians, while the United Kingdom received slightly more attention.

Table 2: Foreign Country's Share of Total Patent Applications Filed by Canadians Abroad, 1978 and 1992

Country	1978	1992	Difference
	(percent)		
France	6.11	9.53	3.42
Germany	7.58	9.90	2.32
Italy	0.09	9.09	9.00
Japan	6.85	8.28	1.43
U.K.	17.01	14.61	-2.39
U.S.	62.37	48.58	-13.78
Total number of applications in those countries[a]	3 278	8 192	
Total number of applications in OECD countries[b]	4 233	25 585	

a Total number of applications filed by Canadians in the six industrialized countries.
b Total number of applications filed by Canadians in all OECD countries.

Figure 6: Share of Canada's External Patent Applications by Destination Country, 1978–92



The pattern in the composition of Canada's patent applications in each of other G-7 countries is graphically depicted in Figure 6. The shares of Germany, France and Japan increased until the early 1980s, remained essentially flat until the end of the 1980s, and then went through a slight upturn. Italy witnessed a distinct upward trend throughout the period, with the exception of 1989–1990. The United Kingdom generally exhibited a downward trend across the 1978–1992 period. The most dramatic change occurred in the United States: a sharp decline throughout the entire period.

Foreign patenting in Canada

In order to compare the relative activity of the nationals of the same six countries in filing patents in Canada with the levels of patent applications filed by Canadians in these countries, the above figures may be contrasted with corresponding data on the share of patent applications in Canada filed by nationals of these countries. In 1978, the United States enjoyed the largest share of patenting in Canada originating from those countries, while the share of foreign patenting in Canada by the other major industrialized countries ranged from a low of 1.9 percent for Italy to a high of 9.1 percent for Germany (see Table 3). The relatively higher rate of filings originating from the United States is probably due to proximity and the high degree of integration of the Canadian and U.S. markets. Moreover, larger countries may be expected to produce more innovations and therefore more foreign filings than smaller countries. Between 1978 and 1992, all countries increased their share of patenting activities in Canada, with the exception of the United States. The largest increase was for Japan (4.2 percentage points). Although the patenting activity in Canada by the United States declined (8.5 percentage points), Canada remained the most attractive country in which to seek a patent for American inventors.

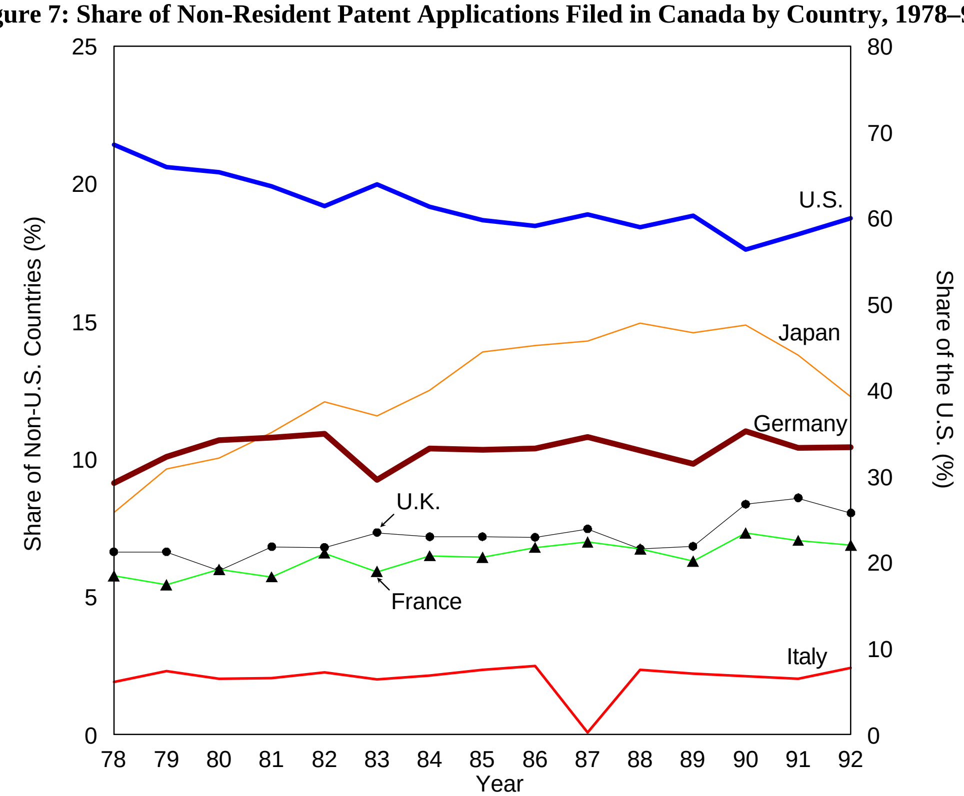
Table 3: Share of Patent Applications in Canada Filed by Foreigners, 1978 and 1992

Country	1978	1992	Difference
		(percent)	
France	5.75	6.88	1.12
Germany	9.14	10.43	1.29
Italy	1.91	2.42	0.52
Japan	8.07	12.26	4.19
U.K.	6.63	8.04	1.41
U.S.	68.51	59.97	-8.53
Total number of applications from these countries[a]	19 848	34 970	
Total number of applications from OECD countries[b]	22 809	40 856	

a Total number of applications filed in Canada by the nationals of the six industrialized countries.
b Total number of applications filed in Canada by the nationals of all OECD countries.

The share of non-resident patent applications in Canada from each country is plotted in Figure 7. Traditionally, the United States accounted for the largest share of non-resident patents in Canada, followed by Japan and Germany. While the share of applications for Canadian patents from U.S. inventors has steadily declined, Japan showed a distinct upward trend until the end of the 1980s and then went through a sharp downturn. It is evident from Figure 7 that the shares of patent applications from the four European countries remained virtually flat throughout the period of the study, though they show a slight upward trend beginning in 1989 for the United Kingdom, Germany and France. Patent applications by Italian inventors do not show any trend and represent the smallest share of foreign patenting activity in Canada.

Figure 7: Share of Non-Resident Patent Applications Filed in Canada by Country, 1978–92



A MODEL OF PATENTING

In the previous sections, similarities and differences in the cross-country patterns of patent filings were examined, and evidence of cross-country differences was found. It also became apparent that both foreign patenting and patenting abroad have gone up, and that patenting abroad has risen more rapidly than foreign patenting. The purpose of this section is to explain these changes. We utilize regression analysis, first to investigate the factors that influence firms to decide to patent internationally, and then to explain plausible causes of the recent increase in patenting activities. A multivariate analysis permits examination of the importance of the characteristics of both source countries (e.g., research efforts of the source country) and destination countries (destination country's market size, or human capital), innovation (quality, use) and the national patent system (e.g., strong versus weak patent protection) in international patenting decisions.

While data on international patenting indicate where innovations occur and where their inventors think they might be adopted, they do not indicate how an invention occurs and how the inventor decides where to patent. To address these issues, we incorporate the inventor's decision to patent in different countries into a model of research and technology diffusion.

While the production of inventions depends mainly on the proportion of the labour force engaged in R&D, as well as per-capita expenditure on R&D, the main driving force toward patenting an invention in a country is the potential appropriation of the rent from the invention in that country. When an invention is generated in a country, the inventor appropriates the rent it earns there as long as (1) no better invention has rendered it obsolete and (2) it has not been successfully imitated (Eaton and Kortum 1994). Patent protection reduces the hazard of imitation.[10] Therefore, when an invention is generated and patented, the return to patenting is determined by the characteristics of the invention and the characteristics of national economies and patent systems.

The movement of patented know-how between countries is influenced by factors that affect the profitability of technology diffusion/transfer — in particular, by the supplies of new technology available within the potential source country and by the propensity of firms within the source country to transfer technology. Thus the observed flows are influenced by forces that can be traced to characteristics of both the source and destination countries.

Eaton and Kortum (1996) argue that there are several dimensions of an invention that affect its level of returns: its quality, the sector in which it is used and the time it takes to diffuse to each country. The quality of an invention is important in that the owner can earn a profit only after the invention has been adopted and only before it has been surpassed by a more advanced technology. The quality of an invention is also important because inventions do not diffuse immediately. An invention discovered at a given time in a particular country will diffuse to another country with a time lag. The higher the quality of the invention, the faster the speed of diffusion, and thus the sooner returns accrue on the invention. Moreover, the potential profit depends on whether or not the invention is patented. Finally, even if an invention diffuses in a country in a timely manner, there will be no economic value to the invention until it is adopted in the country. Adoption will take place if the quality of the invention is as good as, or better than, the existing state-of-the-art technology in the relevant sector.

The decision to patent in a destination country will depend on several characteristics of that country. They include the cost of patenting in the destination country and the expected value of patent protection in that country, the market size of the destination country, the average level of productivity of the destination country, and the speed at which the destination country absorbs inventions into its technology.

Eaton and Kortum (1996) and Kortum and Lerner (1997) developed models that capture the patenting decisions of inventors of a source country (i) with respect to a destination country (n). For the purpose of this paper we adopt the Eaton-Kortum-Lerner approach. They assume that the level of patenting by the source country *i* in the destination country *n* depends upon three factors: (1) the rate at which the source country generates patentable inventions; (2) the probability that an invention developed in the source country is applicable in the destination country; and (3) the propensity to patent, i.e., the fraction of inventions applicable in the destination country that the source country chooses to patent in the destination country.

We denote the rate at which the source country *i* generates patentable inventions at time *t* by θ_{it}. If ε_{nit} is the probability that an invention that occurred in country *i* is applicable in country *n* at date *t*, then the rate at which inventions flow into country *n* from country *i* is $\varepsilon_{it}\theta_{it}$. Then ε_{nit} is an indicator of international technology diffusion, representing the technology diffusion at time *t* in country *n*. Given that f_{nit} is the propensity to patent by country *i* in country *n* at time *t*, then, following Eaton and Kortum (1996),[11] the number of patent applications from country *i* for protection in country *n* at time *t*, or P_{nit}, is:

$$P_{nit} = \varepsilon_{nit} \theta_{it} f_{nit}. \quad \textbf{(1)}$$

We assume that the rate at which a country produces patentable inventions (i.e., the country's inventiveness) depends upon the number of researchers in that country.[12] Technology diffusion — the probability that an invention from country *i* will be adopted in country *n*, or ε_{nit} — depends on whether (1) *n* or *i* are the same country or not, (2) the distance between *n* and *i*, (3) the level of human capital in *n* (the adopting country), and (4) the level of country *n*'s imports from country *i* relative to country *n*'s gross domestic product (GDP). The first factor allows ideas to flow more freely within than between countries (Eaton and Kortum 1996). The second factor, distance, reflects possible geographical impediments to the free flow of ideas. The third factor tests whether a country's level of human capital increases its ability to absorb ideas either from domestic or foreign sources (Benhabib and Speigel 1994). The fourth factor examines whether imported goods are a vehicle for the diffusion of technology (Coe and Helpman 1995). Our specification of technology diffusion is

$$\ln\varepsilon_{nit} = \delta_1 DUMMY_{ni} + \delta_2 DIST_{ni} + \delta_3 DIST_{ni}^2 + \delta_4 \ln HK_{nt} + \delta_5 \ln IM_{nit} \quad \textbf{(2)}$$

where $DUMMY_{ni}$ is a dummy variable that equals 1 if $n = i$, and 0 otherwise. $DIST_{ni}$ is the distance in kilometres from *n* to *i*, $DIST^2_{ni}$ is the square of the distance, HK_{nt} is the level of human capital in country *n* at time *t*, and IM_{nit} is *n*'s imports from *i* relative to *n*'s GDP at time *t*.

The propensity to patent, f_{nit}, depends upon several factors: (1) the cost of patenting in country *n* by country *i* at time *t*, (2) the destination country's market size, and (3) the strength of intellectual property protection provided by the destination country.

Assuming that $\theta_{it} \propto R_{it}$ (where R_{it} is the number of research workers in country *i* at time *t*), from equations (1) and (2) we may approximate the equation for patenting per country *i* worker in country *n* at time *t* as

$$\ln(P_{nit}/L_i) = \ln\alpha_0 + \alpha_1 \ln(R_i/L_i) + \ln\varepsilon_{nit} + \alpha_2 C_{nit} + \alpha_3 IP_{nt} + \alpha_4 \ln M_{nt}, \quad \textbf{(3)}$$

where (P_{nit}/L_i) is the number of patent applications per country *i* worker in country *n*, ε_{nit} is the probability of diffusion of inventions of country *i* in country *n*, (R_i/L_i) is country *i*'s research intensity, C_{nit} is the cost of patenting in country *n* by country *i*, IP_{nt} is the level of intellectual property protection in country *n*, and M_{nt} is the size of the market of the destination country. Applying (2) into (3), we get

$$\ln(P_{nit}/L_i) = \ln\alpha_0 + \alpha_1\ln(R_i/L_i) + \alpha_2 C_{nit} + \alpha_3 IP_{nt} + \alpha_4 \ln M_{nt} + \delta_1 DUMMY_{ni} + \delta_2 DIST_{ni} + \delta_3 DIST_{ni}^2 + \delta_4 \ln HK_{nt} + \delta_5 \ln IM_{nit} + \delta_6 (DUMMY_{ni})*(HK_{nt}) + \delta_7 (C_{nit})*(IP_{nt}) + u_{nit}, \quad \textbf{(4)}$$

where u_{nit} is an error term. In (4) we have added two interaction terms, $(DUMMY_{ni})*(HK_{nt})$ and $(C_{nit})*(IP_{nt})$. The first term allows us to investigate whether the response to changes in human capital on international patenting differs between destination and source countries. The second term captures the effect of patenting costs in a destination country at a given level of intellectual property protection in that country.

Variables used in the model

Research intensity of the source country (R_i/L_i)

The rate of patenting in a destination country depends on the source country's degree of inventiveness — that is, the rate at which inventions are generated in the source country. Continuous generation of inventions, in turn, depends on the intensity of research in the source country. The greater the research intensity, the higher the rate of invention and thus the higher the rate of patenting. It is then hypothesized that the research intensity will be positively associated with the source country's patenting activity. This is measured by the proportion of workers who are doing research (R&D scientists and engineers) out of the total work force.

Human Capital (HK_n)

A key variable of the model is a country's level of human capital that facilitates international patenting activity. It has been well articulated that human capital, or the average years of schooling of the labour force, affects the output and growth of an economy (Romer 1990). An educated labour force is better at creating, implementing and adopting new technologies, and thus at increasing productivity.[13] Human capital also affects the speed of technological catch-up (Romer 1990) and the diffusion of technology between countries (Nelson and Phelps 1966). A higher level of education enhances not only the ability of a country to develop its own technological inventions, but also its ability to adopt and implement technologies developed elsewhere (Benhabib and Spiegel 1994, Engelbrecht 1997). The implication is that a country's level of human capital is a measure of its ability to absorb ideas and inventions either from domestic or foreign sources, and thus to increase the speed of technological diffusion and patenting activity in that country. It is then hypothesized that a country's level of human capital will be positively related to patenting activity. Human capital in a destination country is measured as the average number of years of schooling in that country.

Geographical proximity ($DIST_{ni}$, $DIST^2_{ni}$)

Another key variable of the model is the distance separating the countries between which patent flows occur. Distance reflects possible geographical impediments to the free flow of ideas. It is assumed that distance has a negative effect on international patenting activity. It is measured as the distance in miles between the capital cities of the source and destination countries.

Imports (IM_{ni})

The long-term economic growth of nations is related to the ability to generate new knowledge domestically and the ability to apply this knowledge, as well as knowledge generated abroad, in the economy (Verspagen 1997). Traded goods represent one of the channels through which spillovers of knowledge between countries occur — a channel that is especially stressed in the open-economy endogenous growth models. The idea is that the higher the share of imports in a country's GDP, the more that country benefits from foreign R&D. Coe and Helpman (1995) show the empirical relevance of this idea and suggest that imported goods are a vehicle for the diffusion of technology. It is therefore assumed that imports are positively related to technology diffusion and patenting activity.[14] Imports are measured as the value of goods imported by a destination country from a source country, relative to the destination country's GDP.

Cost of applying for a patent (C_{ni})

The patenting of an invention in a destination country entails various costs. These consist of outlays for filing fees, agents' fees and translation costs. To the extent that these costs are important factors in the inventor's decision to patent in a destination country, they should decrease the patenting activity. The cost of applying for a patent in a destination country is defined as the sum of filing fees, agents' fees and translation costs in that country.

Level of intellectual property protection (IP_n)

Differences in international patent laws have been a concern in international patenting decisions. The level of intellectual property protection in a destination country is an important determinant of patenting by inventors of a source country because it is correlated with the appropriability of the rent from inventions. Lack of property rights is a barrier to appropriability, because innovators lose the returns from R&D and imitators gain at innovators' expense. It is therefore hypothesized that stronger intellectual property protection in the destination country will enhance the patenting activity of the inventors of the source country.

Market size of the destination country (M_n)

The market size of the destination country can affect the flow of technology in two ways. First, in the extreme case, there may be some threshold size of economy below which it is not profitable to exploit the latest technologies. Second, small economies may tend to be relatively specialized and may offer little scope for a wide variety of product and process inventions. In the first case, the degree to which patenting is profitable varies with the absolute size of the market; in the second case, the degree to which patenting is profitable increases with the absolute size of the economy. On this point, in deciding on where to patent, the head of General Electric's foreign patenting operations has made the following suggestion:

> Where only a limited investment is needed to manufacture the product, greater emphasis should be given to covering the major market countries rather than the manufacturing countries, since it would be easy for competitors to shift manufacture in order to avoid a patent. (Eaton and Kortum 1996, p. 254).

Therefore, it is hypothesized that patent protection is sought in countries with large markets. Market size is measured as the GDP of the destination country.

Free flow of inventions between countries (Dummy)

The decision to acquire a new technology depends on the availability, cost, quality, and the flow of information about the technology. Acquiring reliable and timely information is an important element in the adoption process. The flow of information varies substantially according to the proximity of suppliers. Information is less costly to obtain and process when it has to be transmitted over short distances. It is then hypothesized that technology, ideas and inventions flow more freely within countries than between countries, indicating that an invention will be adopted in the source country earlier than in the destination country. To capture the effect stemming from the fact that inventions flow more freely within countries than between countries, a dummy variable is included; it equals 1 if the source country is also the destination country ($i = n$) and 0 otherwise.

Data and sources

The empirical estimation of the model is based on a cross-section of six industrialized countries over the period 1978 to 1992. We estimate equation (4) using data on patent applications for each year from 1978 to 1992 in Canada, Germany, France, the United Kingdom, Japan and the United States by inventors from these six countries.[15]

Patent data are taken from the OECD's *Basic Science and Technology Statistics* data base.[16] Our dependent variable represents the number of patent applications in each country by inventors from each country.[17] Data on R&D personnel are also taken from the *Basic Science and Technology Statistics* data base. Total labour force data come from the OECD's *Economic Outlook*. The source for GDP data is the OECD's *International Sectoral Data Base*. Information on imports comes from the International Monetary Fund's *Direction of Trade Statistics Yearbook* (various issues).

Our data on human capital are from Kyriacou (1991). Human capital is estimated as the average number of years of schooling in each country. We use Kyriacou's estimates for 1975, 1980 and 1985 to construct a continuous variable of average years of schooling for the remaining years in the sample period.[18] The distance between cities is taken from Famighetti (1998). It is measured as the air distance between the capital cities of different countries in statute miles.

Helfgott (1993) constructed a measure of the cost of applying for a patent in different countries that includes filing fees, agents' fees and translation fees. We use Helfgott's measure scaled by GDP. An index of the strength of intellectual property protection in different countries was constructed by Rapp and Rozek (1990). The value of the index, which ranges from 1 to 5 according to the strength of intellectual property protection provided by different countries, was adjusted by Maskus and Penubarti (1995); it is this adjusted index which is used in this paper.

Results

The parameter estimates of the patent equation model (4) are presented in Table 4. The equation explains about 77 per cent of the total variation in international patenting per source-country worker. It exhibits consistent signs on each of the explanatory variables.[19] The coefficients have the expected signs and are generally significant at the 5-per-cent level or higher. The coefficient on $\ln(R_i/L_i)$ is positive and highly significant. The positive coefficient on $\ln(R_i/L_i)$ indicates that an increase in the source country's research intensity increases its inventiveness and thus increases its international patenting activity. The elasticity of patentable idea production with respect to research employment is close to unity.

Table 4: Determinants of International Patenting

Variable[1]	Parameter estimate	S.E.[a]
Constant	-21.2298***	1.7719
$\ln(R_i/L_i)$	1.0369***	0.1012
$\ln(HK_n)$	8.6404**	4.0729
$\ln(IM_{ni})$	0.0450	0.0548
$DIST_{ni}$	-0.0004***	0.0001
$DIST^2_{ni}$	2.9093 x 10^{-8}***	0.01 x 10^{-8}
C_{ni}	0.0006	0.0007
IP_n	2.0373***	0.3848
$\ln(M_n)$	0.6427***	0.0747
$DUMMY_{ni}$	6.8288***	0.7179
$(C_{ni})*(IP_n)$	-0.0002**	0.0001
$(DUMMY_{ni})*(HK_n)$	-0.5734***	0.0681
Adjusted R^2	0.769	
F(11,356)	108.44***	

[1] To avoid notational complexity, subscript *t* is excluded from the variables.

[a] Standard error. *** Significant at 1% level or less. ** Significant at 5% level or less. * Significant at 10% level or less.

Imported goods have sometimes been cited as vehicles for the diffusion of technology (Coe and Helpman 1995). The results only weakly support this hypothesis. The positive but insignificant coefficient on $\ln(IM_{nit})$ implies that imports are not an important vehicle for technology diffusion — a result that is consistent with that of Eaton and Kortum (1996).

The positive and significant coefficient of the home dummy ($DUMMY_{ni}$) indicates that ideas diffuse more within countries than between them. This reflects the fact that the home country is always the most popular country in which to seek protection; foreign patents provide very little protection.

The coefficient of the variable human capital, $\ln(HK_{nt})$, is positive and highly significant, demonstrating the increasing ability of a destination country to absorb technology. This suggests that an increase in a destination country's level of human capital (in terms of a higher level of schooling) increases its ability to absorb technology from either domestic or foreign sources, and thus facilitates patenting activity in the destination country by source-country inventors. When the human capital variable is interacted with the domestic dummy variable, the dummy interaction variable ($DUMMY_{ni} * HK_{nt}$) is significantly negatively associated with the number of patent applications from the source country in the destination country. This implies that a higher level of human capital in the destination country reduces the number of patent applications in the source country. Patenting becomes more attractive in the foreign country than in the home country.

Our data show that the geographical (physical) distance between countries is a major determinant of international flows of patent applications. The highly significant negative coefficient on *DIST* indicates that technological diffusion between countries falls as the distance between them increases. However, the value of the coefficient is very small, reflecting the fact that proximity is less important. In addition, the effect of geographical distance is reduced as indicated by the positive but less significant coefficient on $DIST^2$, reinforcing the conclusion that proximity is of lesser importance.

As expected, the strength of patent protection plays a significant role in determining international patenting activity. The coefficient on IP_{nt} is positive and highly significant, indicating that countries providing strong protection are more attractive destinations for foreign patents.

Contrary to our expectations, the parameter of the cost of patenting variable (C_{nit}) is of the wrong sign but the effect is not significant, suggesting that patenting cost in the destination country does not matter. However, when the cost of patenting variable is interacted with the strength of protection provided by the destination country, the interaction term ($C_{nit} * IP_{nt}$) negatively affects the international patenting activity, and the effect is highly significant. This indicates that, given a level of intellectual property protection, a higher cost of patenting will lower patenting activity.

As expected, the coefficient of the market size variable ($\ln M_n$) is positive and significant, reflecting the fact that the patenting activity of the source country increases with the market size of the destination country. Countries with larger GDP tend to receive more applications than do countries with lower GDP. The reaction of patent applications to changes in GDP is considerably stronger for international patent flows. The value of elasticity (0.64) indicates that a 1-per-cent increase in the GDP of the destination country produces a close to 0.64-per-cent rise in the patenting activity of the source country in the destination country.[20]

THE RELATIVE IMPORTANCE OF THE PRO-PATENT AND THE FERTILE TECHNOLOGY HYPOTHESES

The previous section demonstrates the factors that influence the international flow of patents. It does not, however, explain the causes of the recent jump in international patenting activity. The purpose of this section is to shed some light on the plausible causes of the changes.

Applications for Canadian patents by Canadian inventors have risen more in the years since 1985 (both in absolute and percentage terms) than at any time in the 1970s and 1980s (see Figure 8).[21] During the same period, patent applications in Canada by inventors from foreign countries have also risen (see Figure 9). For example, patenting by foreigners has been rising since the beginning of 1979, and the increase has been sustained over the entire period of the 1980s and 1990s, with strong evidence of a more rapid increase beginning in the mid-1980s.

Figure 10 plots the applications for foreign patent protection by Canadian inventors. The data indicate that patent applications by Canadian inventors in foreign countries have grown at a faster pace than foreign applications in Canada, thereby causing the diffusion-dependency ratio to trend upward from the beginning of 1978, with a sharp increase in the ratio since 1989 (see Figure 11).[22] This suggests that the rate of diffusion of Canadian technologies abroad has been increasing at a faster rate than the rate of diffusion of foreign technologies in Canada. Moreover, the value of inventions by Canadian inventors has increased abroad. For example, in 1978 the ratio of patent applications by Canadian inventors abroad to patent applications by foreign inventors in Canada (diffusion-dependency ratio) was 18.6 per cent. This ratio increased by 8.5 percentage points between 1978 and 1986, and by 35.5 percentage points between 1986 and 1992.

This section seeks to explain these phenomena by asking two questions. First, does the jump in patenting reflect an increase in the propensity to patent inventions, driven by changes in Canadian patent policy that have strengthened intellectual property rights and broadened the rights of patentees? If this is so, then the *pro-patent policy* is the cause of the sudden increase in patenting activity (Merges 1992, 1995).

Second, the jump in patenting may reflect widening technological opportunities, which have generated inventions in the high-technology sector and particularly in the biotechnology, information technology and software industries. The technological revolution in these industries may have increased the yield of patentable inventions. Further, application of advanced technologies (e.g., information technologies) to the discovery process itself has substantially increased the productivity of R&D (Arora and Gambardella 1994), and a shift in R&D facilities to more applied activities may also have increased the yield of patentable inventions. When lumped together, this set of ideas is referred to as the *fertile technology hypothesis* (Kortum and Lerner 1997). The question then is whether this hypothesis can explain the recent increase in patenting activity in Canada.

Figure 8: Canadian Patent Applications by Canadian Inventors, 1978–92

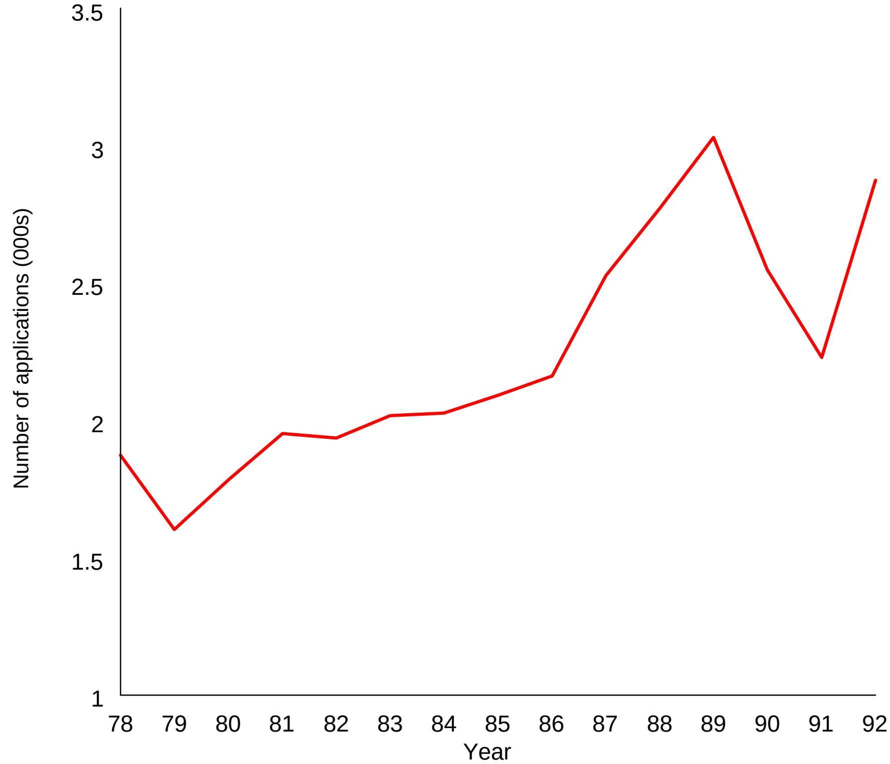


Figure 9: Canadian Patent Applications by Foreign Inventors, 1978–92

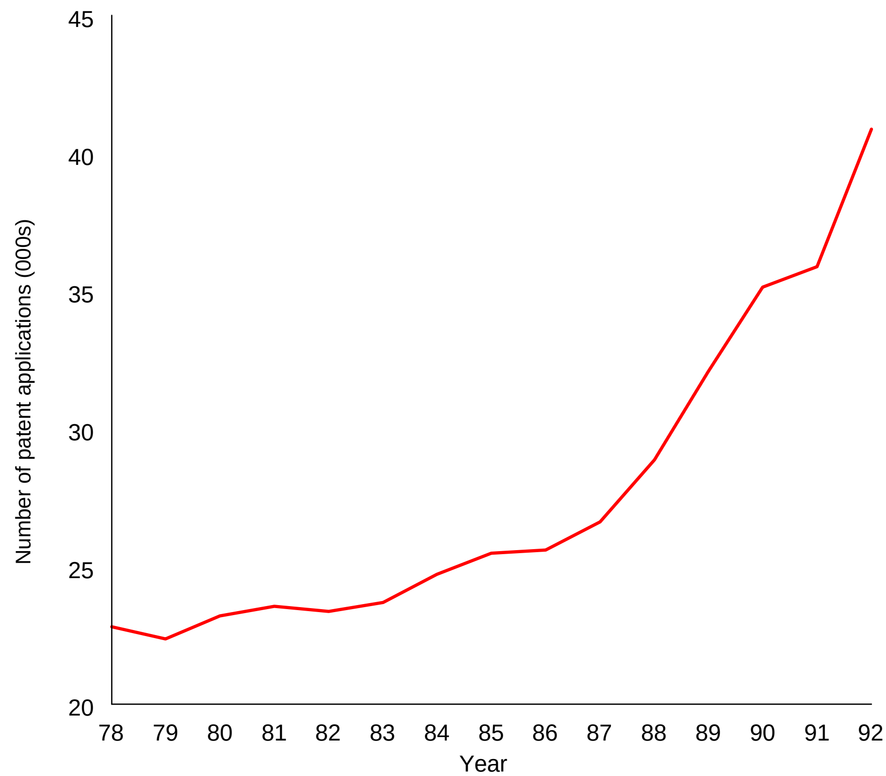


Figure 10: Patent applications Filed by Canadians in Foreign Countries, 1978–92

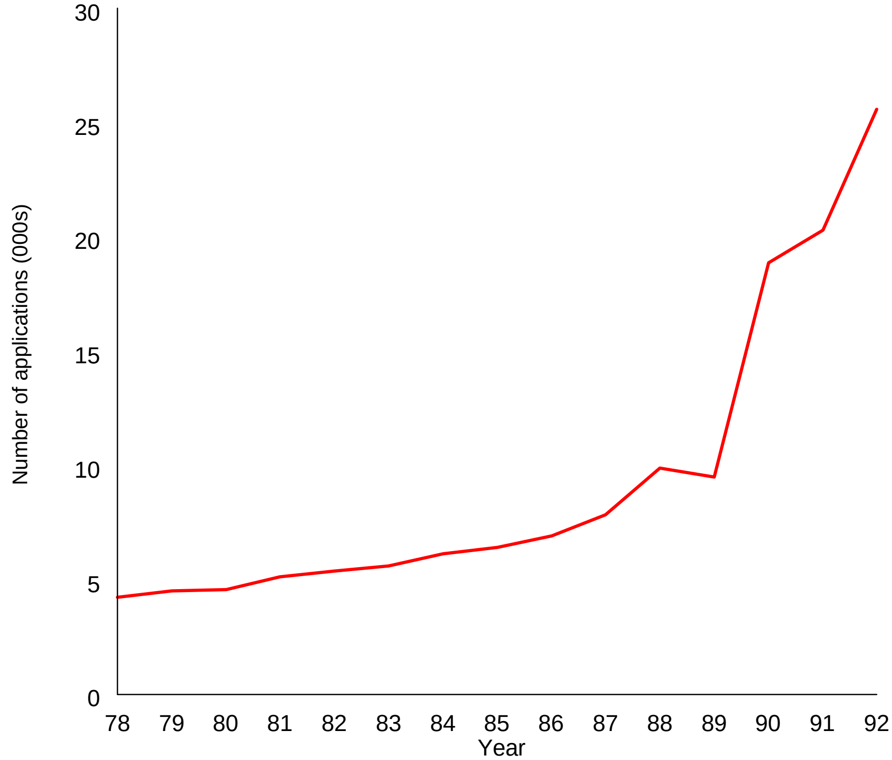
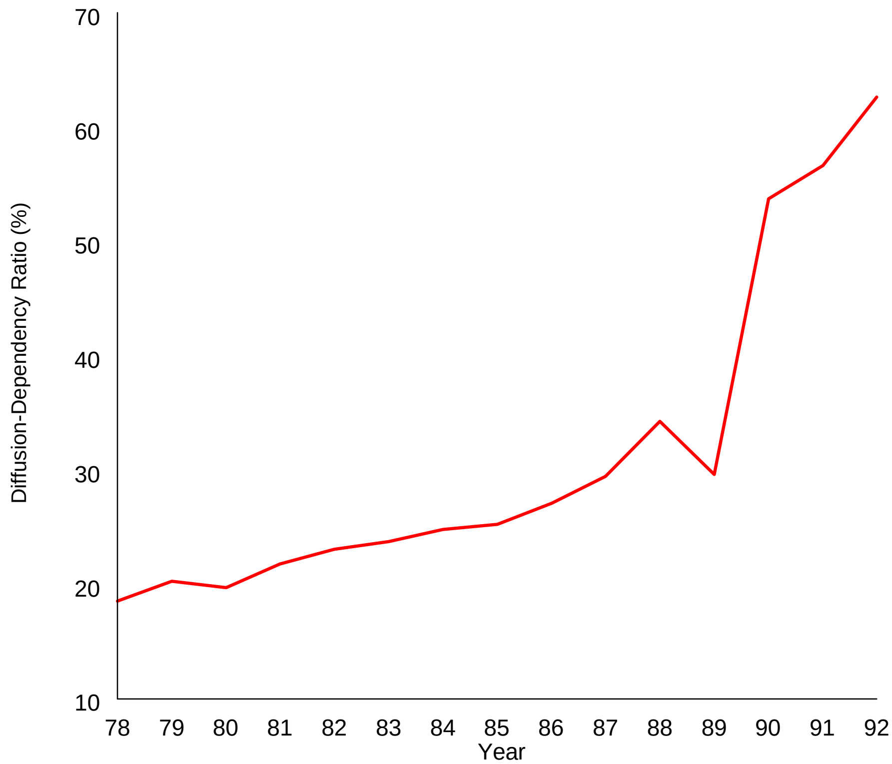


Figure 11: Diffusion-Dependency Ratio for Canada, 1978–92



If the pro-patent policy hypothesis is valid, the changes in Canadian patent policy in the mid-1980s should increase the desirability of patent protection in Canada for both domestic and foreign inventors. That is, Canada should be an attractive destination for both domestic and foreign patents. In the international context, for example, the strengthening of patent protection in Canada would stimulate Canadian applications by German inventors and Canadian applications by Canadian inventors (see Table 5). There is little reason, however, to expect such a strengthening to alter either German applications by German inventors or German applications by Canadian inventors.

The fertile technology hypothesis implies quite a different pattern. An increase in technological opportunities in Canada would increase the production of inventions in Canada, and thus Canada would become a source of inventions. This would lead to an increase in Canadian and German applications by Canadian inventors (see Table 5, column 4).

Technological opportunities and the technological revolution are not unique to Canada. If the improvement in technological opportunities is a global phenomenon — that is, if the fertile technology hypothesis is applicable to other countries — we would also expect an increase in Canadian and German applications by German inventors (see Table 5, column 5).

Table 5: Hypotheses with Respect to the Increase in Patenting Activity

	Pro-patent hypothesis		*Fertile technology hypothesis*	
	Canadian inventors	German inventors	Canadian inventors	German inventors
Canadian applications	↗	↗	↗	↗
German applications	✕	✕	↗	↗

Note: "↗" denotes increasing; "✕" denotes no change.

Our descriptive analysis of international patent data demonstrates that, between 1978–1984 and 1985–1992, Canada experienced generally larger changes in growth in all aspects of patenting activity than did other countries (see Table 6). Domestic patenting activity in Canada grew at a rate of 3.7 percentage points per year. In the same period, Canada experienced an increase in growth in both patenting abroad and foreign patenting, with the former growing more rapidly than the latter. This indicates that in recent years Canadians are increasingly filing patent applications at home and abroad, and that the recent increase in patenting activity in Canada is more strongly related to the outcome of the fertile technology hypothesis. The implication is that Canada's potential as a source of patentable inventions has increased while its attractiveness as a destination country for patent applications has declined.

This should not be interpreted to mean that an increase in technological opportunities, as suggested by the fertile technology hypothesis, is the only factor at work. It is also possible that the pro-patent policy has played an important role in increasing the patenting activity of Canadian inventors.

In order to explain the relative importance of the sources of change, we break down the variation in international patenting decisions into the source country by year effect and the destination country by year effect. If the variation due to the source country by year effect is larger than the variation due to the destination country by year effect, then the fertile technology hypothesis is the predominant explanation of the recent jump in patenting activity. In the opposite case, the pro-patent policy is the predominant explanation.

Table 6: Changes in the Growth Rate of Patenting Activity* between 1978–84 and 1985–92

	Domestic patents	Patents from abroad	National patents	Patenting abroad	Diffusion-dependency ratio
Canada	3.68	5.21	5.01	16.08	9.67
France	1.35	0.19	0.48	1.15	1.18
Germany	-0.25	-0.33	-0.02	1.00	0.39
Italy	N/A	N/A	4.27	3.45	N/A
Japan	-6.89	1.82	-5.79	-3.33	-4.97
U.K.	-0.05	0.16	0.51	6.23	5.79
U.S.	5.10	2.63	4.17	5.43	2.35

* Entries are the difference between the average annual growth rates of patent applications in 1978–84 and 1985–92 (see Table 1).

Following Kortum and Lerner (1997), the decomposition of the total variation in international patenting is provided by equation (1). The idea is to estimate that equation in order to see which effect is more dominant in explaining the variation in Canadian patenting activity. If the fertile technology hypothesis is predominant, then the variation due to the source country by year effect (θ_{it}) should be larger than the variation due to the destination country by year effect (f_{nit}). The pro-patent hypothesis predicts that the larger portion of the variation should be attributable to the destination country by year effect.

In order to measure source- and destination-country effects, we estimate the log of equation (1). Including a multiplicative error term u, and taking logs in (1), our patent equation becomes

$$\ln P_{nit} = \ln \varepsilon_{nit} + \ln \theta_{it} + \ln f_{nit} + \ln u_{nit} \quad \textbf{(5)}$$

We estimate equation (5) using patent application data for the period 1981–1992 in Canada, France, Germany, Japan, the United Kingdom and the United States by inventors from each of these countries. This gives us 432 observations (12 years for 6 source countries and 6 destination countries). As in Kortum and Lerner (1997), our dependent variable is the natural log of patent applications, while the explanatory variables are sets of dummy variables. Three sets of dummy variables are used: destination country and year specific for f_{nit}; source country and year specific for θ_{it}, and destination and source country specific for ε_{nit}.

The basic fit of equation (5) and the explanatory power of each set of dummy variables are presented in Table 7. The results in Table 7 also separate the one-dimensional effects from the two-dimensional effects. The model picks up almost all the variation in the dependent variable, $\ln P_{nit}$. The year by source-country dummies account for much of the variation in the data; the year by destination country dummies do not. The small variation in the international patent data due to the destination country by year effects indicates that it is uncommon to have inventors from different countries applying for patents in a given country. This finding suggests that the fertile technology hypothesis is more significant than the pro-patent policy hypothesis.[23]

Table 7: Explanatory Power of the Sets of Dummy Variables

Set of dummy variables	Number of parameters	Sum of squares
Destination country	5	55.81
Source country	5	350.92
Year	11	17.39
Source country by destination country	25	24.55
Destination country by year	55	43.27
Source country by year	55	315.71
Total explained		807.65
Unexplained		33.02
Total variation		840.67

INTER-SECTORAL PATENTING ACTIVITIES IN CANADA

We have demonstrated above that the international patenting data do not support the theory that inventors from different countries have been seeking patents in a given destination country. The year by source-country dummies account for much of the variation in the data. These findings provide more evidence in favour of the fertile technology hypothesis than the pro-patent hypothesis.

If the fertile technology hypothesis is correct, one would expect to see that applications for Canadian patents are concentrated in a handful of industries. The industries must be those that are undergoing structural changes, increasing in importance, adopting new technologies, becoming increasingly dynamic and experiencing rapid growth in inventions. For the purposes of this paper, we will consider the Canadian manufacturing sector. The principal aim of this section is to investigate whether patenting activities are uniformly distributed across all industries or are concentrated in certain industries — in particular, whether the progressive but smaller sectors have been gaining greater shares of patent applications.

In order to examine the extent to which patenting activity has become concentrated across industries, the manufacturing sector is aggregated into five major sectors*:* the natural resource–based sector, the labour-intensive sector, the scale-based sector, the product-differentiated sector and the science-based sector.[24]

In recent years Canada's manufacturing industries have undergone important structural changes (Baldwin and Rafiquzzaman 1994). As part of the changes, manufacturing employment has shifted from declining industries to growing industries. The importance of some sectors within manufacturing has increased, while that of others has diminished. Baldwin and Rafiquzzaman (1994) found that product-differentiated and science-based sectors within manufacturing were the smallest sectors in 1970. Although both remained the smallest at the end of 1990, they had increased in importance by then. In 1970, the share of production employment was 31.6 per cent in the scale-based sector, 25.5 per cent in the labour-intensive sector, 24.9 per cent in the natural resource–based sector, 10.0 per cent in the product-differentiated sector and 8.1 per cent in the science-based sector. Between 1970 and 1990, the share of employment in the labour-intensive sector declined (by 4.5 percentage points). All other sectors increased their share, with the largest increase occurring in the product-differentiated sector (2.01 percentage points), followed by the natural resource–based sector (1.35 percentage points) and the science-based sector (1.07 percentage points). The scale-based sector remained virtually unchanged.

While the above evidence suggests that the natural resource–based, product-differentiated and science-based sectors increased in importance over the period in terms of employment, it is not clear whether these sectors have become equally innovative. In order to investigate this, we consider the patterns of patent applications by firms across these industries. In doing so, we have relied on the PATDAT data base maintained by the Canadian Intellectual Property Office (CIPO) at Industry Canada. Several questions are examined: Is patenting activity in the Canadian manufacturing sector uniformly distributed across all industrial sectors or concentrated in some industries? Which industrial sectors have higher patenting activity? What has happened to patenting activity over time across industries? Are increases in patenting activity concentrated in sectors that have increased in importance? Does patenting activity relate to industry size? This section seeks to investigate these questions, using the number of patent applications in different sectors within Canadian manufacturing.

Table 8 presents the share of patent applications in each sector for the years 1975, 1985 and 1990. Given the significant annual variation in the number of patent applications over the 1988–1990 period, the comparison is based on a three-year average rather than a single year. The share for patent applications for 1975 is calculated as the average share of 1975, 1976 and 1977; that for 1985 is calculated as the average of 1984, 1985 and 1986; and that for 1990 is calculated as the average of 1989, 1990 and 1991.[25]

The table shows that in 1975, most patent applications in the Canadian manufacturing sector came from firms in product-differentiated industries (34.7 per cent), followed by firms in science-based (31.3 per cent), scale-based (18.4 per cent), labour-intensive (10.7 per cent) and natural resource–based industries (4.9 per cent). Between 1975 and 1985, the share of patent applications declined in the labour-intensive, scale-based and product-differentiated sectors. It declined further in two of these three sectors — the labour-intensive and product-differentiated sectors — between 1985 and 1990. Over the same period, the natural resource–based and scale-based sectors made a small gain. The number of patent applications by firms in science-based industries increased between 1975 and 1985, and between 1985 and 1990. The science-based sector remained the largest source of applications (35.4 per cent) at the end of 1990, followed by the product-differentiated (30.0 per cent), scale-based (18.8 per cent), labour-intensive (8.0 per cent) and natural resource–based (7.8 per cent) sectors.

The above statistics indicate that while Canada has experienced a surge in patenting activity, the increase is not uniformly distributed across all industries within the manufacturing sector. The science-based sector, which is the smallest manufacturing sector in Canada, remains the most innovative, as indicated by the concentration of the number of patent applications in this sector. That sector has become increasingly dynamic as the concentration of filings for patent applications has increased over time.

Table 8: Share of Patent Applications* in the Canadian Manufacturing Sector by Industrial Sector, 1975–1990

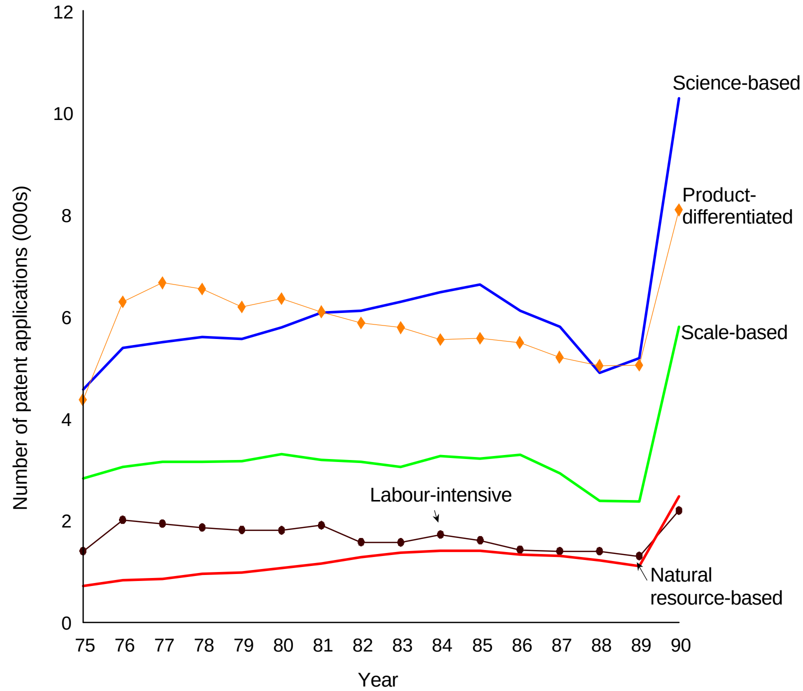
Industrial sector	1975	1985	1990
		(per cent)	
Natural resources	4.90	7.63	7.79
Labour-intensive	10.73	8.71	7.96
Scale-based	18.38	17.95	18.79
Product-differentiated	34.68	30.47	30.02
Science-based	31.31	35.24	35.44

* The PATDAT data base contains the number of patents granted in each sector by year of application. Since not all patent applications are granted, the data represent a lower bound on the actual number of patent applications for each year.

Source: PATDAT (CIPO).

The pattern of change is graphically depicted in Figure 12, which presents the total number of patent applications for the natural resource–based, labour-intensive, scale-based, product-differentiated and science-based sectors. It shows that inventors in the science-based sector generally account for the highest number of applications. The number of applications are traditionally small in all other sectors, being lowest in the labour-intensive and natural resource–based sectors. The science-based sector experienced an upward trend throughout, with a jump starting from the beginning of 1989. The number of applications in the product-differentiated and labour-intensive sectors shows a downward trend until 1989, and a steep upward trend thereafter. The natural resource–based sector also experienced an upward trend over the period 1975–1989. Although both the natural resource-based and science-based sectors showed an upward trend in filing patent applications over the period 1975–1990, the largest number of filings occurred in the science-based sector throughout the period. This also suggests that, over the period studied, patenting activity in Canadian manufacturing has been concentrated mainly in the science-based sector.

Figure 12: Patent Applications in the Manufacturing Sector in Canada* by Industrial Sector, 1975–90



* The data represent the number of applications in each year only for those patents that were subsequently granted.

The industrial breakdown of patent applications within the science-based sector

The previous section demonstrated that patenting activity in the manufacturing sector of Canada is concentrated mainly in the science-based sector. This section identifies which industries within the science-based sector are more innovative.

The industrial breakdown of firms applying for patents shows that certain industries within the science-based sector predominate: electronic parts and components; other communication and electronic equipment; other electrical and industrial equipment; pharmaceuticals and medicines; other chemical products industries, not elsewhere classified (n.e.c.); and indicating, recording and controlling instruments. In each of these industries, on average, more than 300 applications per year were filed in the periods 1975–1984 and 1985–1990 (see Table 9).

When comparisons are made over time, it turns out that the average number of patent applications per year increased substantially between 1975–1984 and 1985–1990, with an average growth of 42 per cent (Table 9). This large increase is explained by the expansion in the number of applications by firms in a handful of dominating as well as non-dominating industries. Between 1975–1984 and 1985–1990, patent applications rose in all the communication and other electronic equipment industries, the pharmaceuticals and medicines industry, the paint and varnish industry, and the adhesives industry (Table 9). Between the same periods, in the electrical industrial equipment industry group, the number of applications increased only in the electrical switchgear and protective equipment industry. In the scientific and professional equipment group, both the indicating, recording and controlling instruments, and other instruments and related products industries registered gains in the number of patent applications, although the former experienced a very marginal gain. Other industries experienced a decline in the number of applications (Table 9).

In industries where the number of applications grew between 1975–1984 and 1985–1990, the growth rate ranges from 1.6 per cent to 226 per cent. However, the sectoral disparity in the rise in patent applications is of interest here, more than the growth rate. The handful of industries that have shown themselves the most dynamic are, paradoxically, those that tended to file the least in 1975–1984. For example, firms in the telecommunication equipment, electrical switchgear and protective equipment, and adhesives industries ranked quite low in applications filed in the period 1975–1984. Over the next six years, they became extremely dynamic with a growth in patent filings of 175 per cent, 54 per cent and 84 per cent, respectively. Of the seven industries recording the largest number of patent applications in the first of the two periods, four different types of evolutions can be distinguished: rapid in the case of pharmaceuticals and medicines, and other instruments and related products; medium for electronic parts and components, and other communication and electronic equipment; slower for indicating, recording and controlling instruments; and a decline for other electrical and industrial equipment, and other chemical products (n.e.c).

Table 9: Number of Patent Applications in the Science-Based Sector by Industry

Industry	1975–1984	1985–1990	Change (%)
Aircraft and Aircraft Parts Industry			
Aircraft and Aircraft Parts	56	51	- 8.93
Record Player, Radio and Television Receivers Industry			
Record Player, Radio and Television Receivers	181	145	- 19.89
Communication and Other Electronic Equipment Industries			
Telecommunication Equipment	111	305	174.77
Electronic Parts and Components	508	745	46.65
Other Communication and Electronic Equipment	646	899	39.16
Electrical Industrial Equipment Industries			
Electrical Transformers	17	14	- 17.65
Electrical Switchgear and Protective Equipment	92	142	54.35
Other Electrical Industrial Equipment	462	363	- 21.43
Pharmaceuticals and Medicines Industry			
Pharmaceuticals and Medicines	442	964	118.10
Paint and Varnish Industry			
Paint and Varnish	116	124	6.90
Other Chemical Products Industries			
Adhesives	38	70	84.21
Other Chemical Products Industries n.e.c.	656	594	- 9.45
Scientific and Professional Equipment Industries			
Indicating, Recording and Controlling Instruments	708	719	1.55
Other Instruments and Related Products	360	1172	225.56
Clock and Watch	14	10	- 28.57
Ophthalmic Goods	55	33	- 40.00
Total	4 460	6 349	42.35

Source: PATDAT (CIPO).

In sum, while the science-based sector has become increasingly dynamic within the manufacturing sector, not all industries within the science-based sector have become equally dynamic. In fact, over time, the number of patent applications by firms in some industries within the science-based sector has declined. On the other hand, rapid growth in filing has occurred in the telecommunication equipment, pharmaceuticals and medicines, adhesives, and other instruments and related products industries. Medium growth in filings has occurred in the electronic parts and components, other communication and electronic equipment, and electrical switchgear and protective equipment industries. Other industries have shown either slower growth or a decline in filings.

SUMMARY AND CONCLUSIONS

Canadians have traditionally been pictured as less innovative; they are viewed as being technologically far behind their industrial counterparts; and they file far fewer patent applications, both domestically and internationally, than residents of other industrial nations. Such observations on the low performance of Canadians are overstated, and are mainly attributable to the measure of innovation and technological performance employed. When invention and technological performance are measured by the growth in patenting activities, a completely opposite picture emerges.

In this paper we present an analysis of innovative performance, as measured by the growth in patenting activities IN seven major industrial countries (Canada, the United States, France, Germany, Italy, the United Kingdom and Japan). We also consider the propensity to patent by Canadian inventors in these countries, and that by inventors of these countries to patent in Canada. We then focus on the determinants of international patenting decisions in order to further explain cross-country differences in patenting activities. We also seek to explain the recent surge in patenting activities, both domestic and foreign, in Canada in the light of two competing theories, which have been identified in the literature as the pro-patent policy and the fertile technology hypotheses. Our results can be summarized as follows.

Patenting activity: inter-country comparisons

- The assessment of performance by individual country reveals that all countries increased their patenting activities. Foreign patenting has grown more rapidly than domestic patenting. Patenting abroad has risen at a faster rate than foreign patenting, and at the same time the diffusion-dependency ratio has increased.

- Most of these countries experienced a rapid growth rate in all dimensions of patenting activities in the periods 1978–1984 and 1985–1992. The growth accelerated in all countries over the period 1985–1992, except Japan. In that country, the growth rate for most of the dimensions of patenting activities declined in the second period, except for patenting abroad, which grew at a faster pace than during the period 1978–1984. Among the four European countries considered, the United Kingdom and France were most successful in all dimensions of patenting activities, while Germany was slightly behind. Italy's performance was close to the United Kingdom's in the areas of national patenting and patenting abroad. All European countries, however, were behind Canada and the United States.

- Of the countries considered, Canada and the United States experienced the largest increases in growth in all aspects of patenting activities. Over the periods 1978–1984 and 1985–1992, Canada enjoyed larger increases in the growth of foreign patenting, national patenting, patenting abroad and the diffusion-dependency ratio than did the United States and other countries. The United States was ahead of Canada only in domestic patenting. Therefore, if inventiveness is measured by the growth in patenting activities instead of absolute numbers, it is apparent from our analysis that Canada's performance, when compared with that of other countries, is most impressive in that Canadian inventors are not lagging in the development of technology.

- There are substantial differences in the growth of all aspects of patenting activities across countries.

International patenting by Canadians

- The assessment of inventive performance across the seven countries reveals that all dimensions of patenting activities by Canadians have been expanding at a faster rate than activities by residents of the other nations. It follows from our analysis that Canada has been gaining: it has been catching up to other countries in filing external patent applications. Although Canadian technology has been diffusing abroad at a faster rate, Canada still remains an absolute importer of technology, a fact suggesting that technologies from foreign countries are also being diffused in Canada.

- Over the years there have been changes in the intensity of interest of Canadians in patenting abroad in the six principal industrial markets of the world. Although over the years the United States has become a relatively less attractive country for Canadian patents, it still receives the largest share of attention from Canadian inventors.

- The propensity to patent in Canada by inventors of these six countries has also changed. Over time, nationals of all countries except the United States increased their patenting activities in Canada. The largest increase was posted by nationals of Japan, followed by those of the United Kingdom, Germany, France and Italy. Although patenting activity in Canada by nationals of the United States declined, Canada remains the most attractive country in which to patent for American inventors.

The determinants of international patenting

In order to explain the differences in patenting activities across nations, we developed and estimated a model of international patenting decisions of inventors. The main driving force toward patenting an invention in a destination country for a source-country inventor is the appropriation of the rent from the invention in the destination country. There are, however, other factors associated with the characteristics of both the source and the destination countries (e.g., research efforts of the source country; market size and human capital of the destination country), with invention (quality, use), and with the national patent system (e.g., strong versus weak patent protection) that influence the flow of inventions from source to destination countries.

The results show that a characteristic of the source country — its research intensity — is an important factor affecting the rate at which it generates patentable inventions. An increase in the source country's research intensity increases its innovativeness, thereby increasing its international patenting activity. The results also show that the home country is always the most popular country in which to seek protection. This suggests that inventions diffuse more within than between countries.

The characteristics associated with the destination country play an important role in patenting activities by inventors of the source country. The paper tested the impact on the patenting activity of several variables relating to the characteristics of the destination country. Geographic proximity is an important factor in the patenting decision. If the destination country is close to the source country, source country inventors tend to patent in the destination country more — although the effect is comparatively weak.

Coe and Helpman (1995) advocate the theory that imported goods are a vehicle for the diffusion of technology which facilitates international patenting. Our results only weakly support this hypothesis in that they do not show imports as an important vehicle for technology diffusion — a finding that is consistent with that of Eaton and Kortum (1996).

The paper also tested the impact of the destination country's market size on the patenting activity of the source country. The patenting activity of the source country increases with the market size of the destination country. For example, a 1-per-cent increase in the GDP of the destination country produces close to a 0.64-per-cent rise in the patenting activity of the source country in the destination country.

The empirical results show that both human capital and the strength of patent protection in the destination country are strongly associated with international patenting activity. An increase in the destination country's level of human capital increases its ability to absorb technology from foreign sources and thus facilitates patenting activity in the destination country by source-country inventors. The results also show that countries providing strong intellectual property protection are more attractive destinations for foreign patent applications.

Contrary to expectations, our data show that the cost of patenting in the destination country does not matter in international patenting activity. However, the cost does matter when it is interacted with the level of intellectual property protection. This indicates that given a level of intellectual property protection, a higher cost of patenting will lower the patenting activity.

The pro-patent versus the fertile technology hypothesis

A more detailed picture of patenting activity is produced when we seek to explain the recent surge in patenting activity in Canada. Two competing views, the pro-patent and the fertile technology hypotheses, have been identified in the literature to explain the causes of this change. Our analysis leads us to conclude that, although both hypotheses are at work, the recent jump in patenting has been driven mainly by the exploitation of technological opportunities. This further suggests that the recent increase in patenting activity in Canada is the outcome more of the fertile technology hypothesis than the pro-patent hypothesis. The implication is that Canada's potential as a source of patentable inventions has increased while its attractiveness as a destination for patent appliactions has declined.

Inter-sectoral patenting activities in Canada

If the fertile technology hypothesis accounts for the recent increase in patenting activity in Canada, one would expect to see that applications for Canadian patents are concentrated in only a handful of industries. The industries must be those undergoing structural changes, increasing in importance, adopting new technologies, becoming increasingly dynamic and experiencing rapid growth in inventions. In the case of the Canadian manufacturing sector, that is indeed the finding of this paper. The surge in patenting activities in Canada is not uniformly distributed across all industries within the manufacturing sector. The science-based sector, which is the smallest sector within Canadian manufacturing, has increased in importance over time. The largest number of applications for manufacturing patents is concentrated in science-based industries. This suggests that the science-based sector remains the most innovative sector in Canadian manufacturing and has become more dynamic as the concentration of patent applications has increased over time.

While the science-based sector as a whole has become the most innovative and dynamic within Canadian manufacturing, not all industries within the science-based sector are equally innovative and dynamic. An examination of science-based industries reveals that a few industries within this sector are highly innovative: electronic parts and components; other communication and electronic equipment; other electrical and industrial equipment; pharmaceuticals and medicines; other chemical products industries, n.e.c.; and indicating, recording and controlling instruments. The assessment of performance by industry reveals that over time these as well as some other science-based industries have become increasingly dynamic. Rapid growth in patent applications has occurred in telecommunication equipment, pharmaceuticals and medicines, adhesives, and other instruments and related products industries. Medium growth in filings has occurred in the electronic parts and components, other communication and electronic equipment, and the electrical switchgear and protective equipment industries. Other industries have shown either slower growth or a decline in filings.

NOTES

1 There is a distinction between "patenting abroad" and "foreign patenting." "Patenting abroad" denotes total applications by residents of a given country *i* for patent protection in another country *j*. "Foreign patenting" in a particular country *i* denotes applications by residents of a foreign country *j* for patents in country *i*. The diffusion-dependency ratio in a particular country is defined as the ratio of the outflow of patent applications from the country to the inflow of patent applications to the country from elsewhere.

2 For example, patents have received stronger protection in the United States since the 1982 creation of the Court of Appeals of the Federal Circuit (see, e.g., McConville 1994). Through a series of legislative amendments adopted during the period from 1987 to 1993, Canada has modernized and improved the practice applicable to patent protection in Canada. The most significant change came from the 1987 amendments to the Canadian Patent Act, R.S.C. 1985, c. P-4. With this change, which took effect October 1, 1989, Canada moved from a "first-to-invent" to a "first-to-file" system. For details see Barrigar (1997) and MacOdrum (1997).

3 The initiatives for changes have been formulated within the context of international trade policy. Indeed, intellectual property rights and trade have been linked in both bilateral and multilateral trade policy. For example, Trade Related Intellectual Property Rights (TRIPs) arrangements have been made in the Canada–U.S. Free Trade Agreement (FTA), the North American Free Trade Agreement (NAFTA), the Uruguay Round Agreement of the GATT, and between members of the Asia-Pacific Economic Co-operation (APEC) forum. On this point see WIPO (1991), WTO (1995) and Hirshhorn (1996).

4 This point was suggested by a referee. For example, the Gross Domestic Expenditure on R&D in Canada from 1984 to 1991 increased (in real terms) by 22.4 per cent (Statistics Canada 1997).

5 Although criticisms of the use of patent data as an indicator of inventive activity are well known, recently Griliches (1990, p. 1702) has pointed out that "Patent statistics remain a unique source for the analysis of the process of technical change. Nothing else even comes close in the quantity of available data, accessibility, and potential industrial, organizational, and technological detail."

6 Traditionally, most statistical and econometric research considered the patent to be a measure of innovation. The number of patents filed by a firm, sector or country is a direct reflection of innovative intensity. This method permits international comparisons for which patent counts provide the sole indicator of innovation output available at this level. In addition, for the purposes of international comparisons, it is appropriate to compare patent application statistics since the applications filed in any given year probably represent essentially the same inventions. On this see French (1987), Griliches (1990), and Malerba, Orsenigo and Peretto (1997). Aside from patents, there are other measures of innovativeness that take into account resources devoted to innovative activity (for example, R&D employment or expenditures).

7 There are two reasons for selecting the period 1978–1992: first, data on cross-country patent applications (foreign patenting and patenting abroad) were not available from the OECD source before 1978 or after 1992; and second, the Canadian Patent Act, R.S.C. 1985, c. P-4 was amended through a series of legislative amendments in the period from 1978 to 1993. In order to compare the pattern of changes in growth in patenting activities before and after the amendments to the Patent Act, R.S.C. 1985, the period of study was divided into two parts: 1978–84 and 1985–92.

8 There are a number of other channels of technology transfer: the international movement of goods and services, foreign direct investment, the migration of skilled and educated workers, and the establishment of foreign production facilities based on secret know-how or unpatented know-how. See Pavitt (1985) on this topic.

9 Certain data for Italy are not available in the OECD data base prior to 1992. For this reason, Italy is excluded from some of the international comparisons of patenting activity in this section.

10 Patent protection need not provide perfect protection from imitation, nor is imitation necessarily immediate if the inventor fails to patent. Patent protection nevertheless does have real effects in that it influences the return to R&D.

11 Our model differs from that of Eaton and Kortum (1996). Their model is a cross-sectional, while our model incorporates both time series and a cross-section of countries.

12 Under the assumption that research workers, R_i, are drawn from a Pareto distribution of talent in country i and that the most talented researchers engage in R&D activity, the rate at which the country i will produce inventions is given by $\alpha R_i^{\beta} L_i^{\ 1 - \beta}$, where α, β are parameters, $L_i = L_i^{\ P} + R_i$ and L_i^P is the non-research workers and L_i is the total labour force in country i.

13 These are the assumptions of endogenous growth theory as pioneered by Grossman and Helpman (1991).

14 As a determinant of patenting activity, Schiffel and Kitti (1978) also suggested the imports of goods and services. Their reasons are different from those of Coe and Helpman (1995) and Engelbrecht (1997). Bosworth (1984) summarizes the reasons provided by Schiffel and Kitti.

15 Italy was excluded from the survey because of a lack of data on domestic applications for the years under study.

16 The OECD data on patent applications by country of application and residence of inventor were compared with the World Intellectual Property Organization (WIPO) data. There was no difference between the two sets of data.

17 Since patent law requires that an inventor apply for a patent in any other country within a year of the first (or priority) application, patent applications rather than patent grants better capture the inventors' decisions to patent. Moreover, applications rather than grants are more comparable across countries.

18 To obtain measures for the variable between 1978 and 1980, we allow the 1975 value to grow at the average annual growth rate between 1975 and 1980; similarly, for 1981–84, the 1980 value grows at the average annual growth rate between 1980 and 1985; and to find values for 1986–92, we assume that average schooling continues to grow at the 1980–85 rate.

19 The only real exception to this is the coefficient on C_{ni}, which is positive but insignificant.

20 In order to compare the international patenting activity by Canadian inventors with those of the other G-7 countries, equation (4) was re-estimated without Canada. The results showed no difference in the signs and levels of significance of the parameter estimates with and without Canada. However,

the magnitude of the impact of all parameters is generally larger when Canada is excluded. For example, when Canada is excluded, the elasticity of patentable idea production with respect to research employment increases by 3.0 per cent. On the other hand, a 1-per-cent increase in GDP in the destination country increases the patenting activity of the source country in the destination country by only about 0.41 per cent, representing a 36.7-per-cent decline when Canada is excluded. (Other results are available from the authors on request.)

21 Similar trends can be observed in the United States.

22 Another reason for the sharp increase in the diffusion-dependency ratio may be related to institutional changes, such as the establishment of the Patent Co-operation Treaty (PCT) in 1970. Since the introduction of the PCT, inventors resident in member countries, including Canada, have increasingly been using this system to obtain patents for several countries at once, instead of filing separate applications in each patent office serving those countries. Under the PCT system, the filing of separate patent applications can be avoided through the filing of an “international” or “PCT” application (Bogsch 1995). Because of this institutional change, it is possible that Canadians are using the PCT system more intensively than their counterparts in other industrialized countries; as a result, there is an increasing trend for Canadians to patent abroad and the diffusion-dependency ratio has been rising.

23 Similar observations are made by Kortum and Lerner (1997). They do not, however, include Canada in their analysis.

24 The classification is taken from a taxonomy developed by the OECD (1987) to investigate structural change in member states. The OECD classification was verified for its applicability to the Canadian situation using discriminant analysis, and was modified slightly. For details, see Baldwin and Rafiquzzaman (1994, 1995). For a listing of industries classified under each sector, see the Appendix.

25 We are thankful to one of the referees for suggesting this methodology.

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APPENDIX: DEFINITION OF INDUSTRY GROUPS IN THE CANADIAN MANUFACTURING SECTOR

Natural resource-based

1011 - Slaughtering and Meat Processors
1012 - Poultry Processors
1021 - Fish Products
1031 - Fruit & Vegetable Canners & Processors
1032 - Frozen Fruit & Vegetable Processing
1041 - Dairy Products
1049 - Dairy Products
1051 - Flour & Breakfast Cereal Products
1052 - Flour & Breakfast Cereal Products
1053 - Feed Industry
1061 - Vegetable Oil Mills
1071 - Biscuit Manufacturers
1072 - Bakeries
1081 - Cane & Beet Sugar Processors
1082 - Confectionery Manufacturers
1083 - Confectionery Manufacturers
1091 - Miscellaneous Food Processors
1092 - Miscellaneous Food Processors
1093 - Miscellaneous Food Processors
1094 - Miscellaneous Food Processors
1099 - Confectionery Manufacturers
1111 - Soft Drink Manufacturers
1121 - Distilleries
1131 - Breweries
1141 - Wineries
1211 - Leaf Tobacco Processors
1221 - Tobacco Products
1611 - Plastics Fabricating Industry (n.e.s.)[1]
1621 - Plastics Fabricating Industry (n.e.s.)
1631 - Plastics Fabricating Industry (n.e.s.)
1691 - Plastic Bag Industry
1711 - Leather Tanneries
1992 - Textile Dyeing & Finishing Plants
2511 - Shingle Mills
2521 - Veneer & Plywood Mills
2522 - Veneer & Plywood Mills
2541 - Pre-fabricated Buildings (Wood Frame)
2542 - Kitchen Cabinets
2543 - Sash, Door & Other Millwork (n.e.s.)
2549 - Sash, Door & Other Millwork (n.e.s.)
2581 - Coffin & Casket Industry
2592 - Manufacturers of Particle Board
2593 - Manufacturers of Particle Board

2599 - Miscellaneous Wood Industries (2599 & 2592)
2692 - Hotel & Restaurant Furniture & Fixtures
2699 - Other Furniture & Fixtures
2791 - Miscellaneous Paper Converters
2792 - Miscellaneous Paper Converters
2793 - Miscellaneous Paper Converters
2799 - Miscellaneous Paper Converters
2831 - Publishing Only
2839 - Publishing Only
2951 - Smelting & Refining
2959 - Smelting & Refining
2961 - Aluminum Rolling, Casting & Extruding
2971 - Copper & Copper Alloy Rolling
3511 - Clay Products Manufacturers (from Domestic Clay)
3521 - Cement Manufacturers
3541 - Concrete Pipe Manufacturers
3542 - Manufacturers of Structural Concrete Products
3549 - Concrete Products Manufacturers (n.e.s.)
3551 - Ready-mix Concrete Manufacturers
3581 - Lime Manufacturers
3591 - Refractories Manufacturers
3592 - Miscellaneous Non-metallic Mineral Products (n.e.s.)
3593 - Miscellaneous Non-metallic Mineral Products (n.e.s.)
3594 - Miscellaneous Non-metallic Mineral Products (n.e.s.)
3599 - Stone Products Manufacturers
3611 - Petroleum Refining
3612 - Manufacturers of Lubricating Oils & Greases
3699 - Miscellaneous Leather Products Manufacturers
3971 - Signs & Displays Industries

Labour-intensive

1712 - Shoe Factories
1713 - Miscellaneous Leather Products Manufacturers
1719 - Boot & Shoe Findings Manufacturers
1811 - Fibre & Filament Yarn Manufacturers
1821 - Wool Yarn & Cloth Mills
1829 - Cotton Yarn & Cloth Mills (1832 & 1810)
1831 - Knitted Fabric Manufacturers
1911 - Fibre & Felt Mills (1851 & 1852)
1921 - Carpet, Mat & Rug Industry
1931 - Canvas Products Manufacturers
1991 - Narrow Fabric Mills
1993 - Household Products of Textile Materials
1994 - Hygiene Products of Textile Materials
1995 - Tire Cord Products
1999 - Textiles (1899/1893/1871/1840/1891)
2431 - Men’s Clothing - Coats
2432 - Men’s Clothing - Suits & Jackets

2433 - Men's Clothing - Pants
2434 - Men's Clothing - Shirts
2435 - Men's Clothing Contractors
2441 - Women's Clothing Factories
2442 - Women's Clothing Factories
2443 - Women's Clothing Factories
2444 - Women's Clothing Factories
2445 - Women's Clothing Contractors
2451 - Children's Clothing Industries
2491 - Other Knitting Mills
2492 - Miscellaneous Clothing Industries (n.e.s.)
2493 - Leather Gloves Factories
2494 - Hosiery Mills (2310 & 2491)
2495 - Fur Goods Industry
2496 - Foundation Garment Industry
2499 - Men's Clothing (2431 & 2492)
2561 - Wooden Box Factories
2591 - Wood Preservation Industry
2611 - Furniture Re-upholstery (2611 & 2619)
2612 - Household Furniture Manufacturers (n.e.s.)
2619 - Household Furniture Manufacturers (n.e.s.)
2641 - Office Furniture Manufacturers
2649 - Miscellaneous Furniture & Fixtures
2691 - Bed Spring and Mattress
3011 - Boiler & Plate Works
3021 - Boiler & Plate Works (3010 & 3020)
3022 - Fabricated Structural Metal Industries (1320 & 1310)
3023 - Fabricated Structural Metal Industries
3029 - Fabricated Structural Metal Industries
3031 - Metal Door & Window Manufacturers
3032 - Ornamental & Architectural Metal Industries
3039 - Ornamental & Architectural Metal Industries
3041 - Metal Coating Industries
3042 - Metal Stamping & Pressing Industries
3049 - Other Stamped & Pressed Metal
3091 - Miscellaneous Metal Fabricating Industries
3092 - Miscellaneous Metal Fabricating Industries
3099 - Miscellaneous Metal Fabricating Industries
3257 - Automobile Fabric Accessories
3281 - Boatbuilding & Repair
3332 - Electric Lamp & Shade Manufacturers
3333 - Electric Lamp & Bulb Manufacturers
3921 - Jewellery & Silverware
3922 - Jewellery & Silverware
3991 - Broom, Brush & Mop Manufacturers
3992 - Button, Buckle & Fastener Manufacturers
3993 - Floor Tile, Linoleum & Coated Fabrics
3994 - Sound Recording & Musical Instrument
3999 - Miscellaneous Manufacturing Industries (3999/3915/3996/3998)

Scale-based

1511 - Rubber Products Industries
1521 - Rubber Products Industries
1599 - Other Rubber Products
2512 - Sawmills & Planning Mills
2711 - Pulp & Paper Mills
2712 - Pulp & Paper Mills
2713 - Pulp & Paper Mills
2714 - Pulp & Paper Mills
2719 - Pulp & Paper Mills
2721 - Asphalt Roofing Manufacturers
2731 - Folding Carton & Set-up Box Manufacturers
2732 - Corrugated Box Manufacturers
2733 - Paper & Plastic Bag Manufacturers
2811 - Commercial Printing
2819 - Commercial Printing
2821 - Platemaking, Typesetting & Trade Bindery
2841 - Publishing & Printing
2849 - Publishing & Printing
2911 - Iron & Steel Mills
2912 - Iron & Steel Mills
2919 - Iron & Steel Mills
2921 - Steel Pipe & Tube Mills
2941 - Iron Foundries
2999 - Metal Rolling, Casting & Extruding (n.e.s.)
3051 - Wire & Wire Products Manufacturers (n.e.s.)
3052 - Wire & Wire Products Manufacturers (n.e.s.)
3053 - Wire & Wire Products Manufacturers (n.e.s.)
3059 - Wire & Wire Products Manufacturers (n.e.s.)
3231 - Motor Vehicle Manufacturers
3241 - Truck Body Manufacturers
3242 - Commercial Trailer Manufacturers
3251 - Motor Vehicle Parts & Accessories Manufacturers
3252 - Motor Vehicle Parts & Accessories Manufacturers
3253 - Motor Vehicle Parts & Accessories Manufacturers
3254 - Motor Vehicle Parts & Accessories Manufacturers
3255 - Motor Vehicle Parts & Accessories Manufacturers
3256 - Vehicle Plastics Parts & Accessories
3259 - Motor Vehicle Parts & Accessories Manufacturers
3261 - Railroad Rolling Stock Industry
3271 - Shipbuilding & Repair
3299 - Miscellaneous Vehicle Manufacturers
3512 - Clay Products Manufacturers (from Imported Clay)
3561 - Glass Manufacturers
3562 - Glass Products Manufacturers
3571 - Abrasives Manufacturers
3711 - Industrial Chemicals (Inorganic) Manufacturers
3712 - Pigments & Dry Colours Manufacturers

3721 - Industrial Chemicals (Organic) Manufacturers
3722 - Mixed Fertilizers Manufacturers
3729 - Other Agricultural Chemicals Manufacturers
3731 - Plastics & Synthetic Resins Manufacturers
3791 - Printing Inks Manufacturers

Product-differentiated

3061 - Hardware, Tool & Cutlery Manufacturers
3062 - Hardware, Tool & Cutlery Manufacturers
3063 - Hardware, Tool & Cutlery Manufacturers
3069 - Hardware, Tool & Cutlery Manufacturers
3071 - Heating Equipment Manufacturers
3081 - Machine Shops
3111 - Agricultural Implement Industry
3121 - Commercial Refrigeration & Air Conditioning
3191 - Miscellaneous Machinery & Equipment
3192 - Miscellaneous Machinery & Equipment
3193 - Miscellaneous Machinery & Equipment
3194 - Miscellaneous Machinery & Equipment
3199 - Miscellaneous Machinery & Equipment
3243 - Non-commercial Trailer Manufacturers
3244 - Non-commercial Trailer Manufacturers
3311 - Small Electrical Appliances Manufacturers
3321 - Major Appliances Manufacturers
3331 - Lighting Fixtures Manufacturers
3361 - Office & Store Machinery Manufacturers
3362 - Office & Store Machinery Manufacturers
3369 - Office & Store Machinery Manufacturers
3381 - Electric Wire & Cable Manufacturers
3391 - Battery Manufacturers
3392 - Miscellaneous Electrical Products Manufacturers (n.e.s.)
3399 - Miscellaneous Electrical Products Manufacturers (n.e.s.)
3771 - Toilet Preparations Manufacturers
3931 - Sporting Goods Manufacturers
3932 - Toys & Games Manufacturers

Science-based

3211 - Aircraft & Aircraft Parts Manufacturers
3341 - Household Radio & TV Receivers Manufacturers
3351 - Communications Equipment Manufacturers: Telecommunication Equipment
3352 - Communications Equipment Manufacturers: Electronic Parts and Components
3359 - Communications Equipment Manufacturers: Other Communication and Electronic Equipment
3371 - Electrical Industrial Equipment: Electrical Transformers Manufacturers
3372 - Electrical Industrial Equipment: Electrical Switchgear and Protective Equipment Manufacturers
3379 - Electrical Industrial Equipment: Other Electrical Industrial Equipment Manufacturers

3741 - Pharmaceuticals & Medicines Manufacturers
3751 - Paints & Varnish Manufacturers
3761 - Soap & Cleaning Compounds Manufacturers
3792 - Miscellaneous Chemical Industries: Adhesives (n.e.s.)
3799 - Miscellaneous Chemical Industries (n.e.s.)
3911 - Instrument & Related Products Manufacturers: Indicating, Recording and Controlling Instruments
3912 - Other Instruments & Related Products
3913 - Clock & Watch Manufacturers
3914 - Ophtalmic Goods Manufacturers

n.e.s. : Not elsewhere specified.
Source: Baldwin and Rafiquzzaman (1995).

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Fax: (613) 991-1261
E-mail: fumerton.cheryl@ic.gc.ca