Is Canada Missing the "Technology Boat"? Evidence from Patent Data

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Abstract

Canada has been lagging in terms of productivity growth in recent years. A possible cause might be poor performance in R&D and technical change. This paper is an attempt to shed light on this issue, by examining innovation in Canada for the past 30 years with the aid of highly detailed patent data. I use for that purpose all Canadian patents taken in the US (over 45,000), as well as US patents and patents from other countries for comparative purposes. Canadian patenting is highly correlated with lagged R&D, and with worldwide developments in technology as reflected in total US patenting. Canada stands mid-way among the G7 in terms of patents per capita and patents/R&D, but in recent years it has been overtaken by a group of "High Tech" countries Finland, Israel and Taiwan, with South Korea closing-in fast. The technological composition of Canadian innovations is rather out of step with the rest of the world, with the share of traditional fields still very high in Canada, whereas the upcoming field of Computers and Communications has grown less in Canada than elsewhere. Given that Computers and Communications is the dominant "General Purpose Technology" of the present era, weakness in this field may impinge on the performance of the whole economy. Another source of weakness lies in the patterns of ownership on the intellectual property represented by patents: less than 50% of Canadian patents are owned by Canadian corporations, a much lower percentage than all other G7 countries. In terms of the relative "quality" of Canadian innovations as measured by the number of citations received, it is significantly lower than the quality of patents awarded to US inventors, particularly in Computers (but not in Communications), and in Medical Instrumentation (but not in Drugs).

Key words: Patents, Canadian economy, Productivity.

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I. Introduction

Canada stands out as a highly advanced economy in terms of income per capita as well as various measures of quality of life, and yet in recent years it has stalled and even lost ground relative to other countries (particularly the US) in terms of productivity and growth (see e.g. Trefler, 1999). This seemingly incongruent predicament has elicited a great deal of attention, and motivated research aimed at understanding the sources of the current "malady". One of the possible lines of inquiry in this respect is to investigate the performance of the Canadian economy in terms of R&D, innovation and technical change. After all, these are the key factors that have traditionally propelled productivity growth in the industrialized world.

This paper is an attempt to shed light on the innovative performance of Canada with the aid of highly detailed patent data, drawn from all patents granted in the US to Canadian inventors, and to US patents granted to other countries. I shall address questions such as: How does Canada fare vis a vis other countries in terms of patenting activity? What is the technological composition of its innovations? Who actually owns the intellectual property rights, and to what extent can the Canadian economy expect to benefit from the innovations done by Canadian inventors? How do Canadian innovations compare to those of other countries in terms of their "importance" as reflected in patent citations? In addressing these questions we hope not only to shed light on the case of Canada, but also to demonstrate the power of this type of data for studying innovation in great detail and, in particular, for examining in a comparative fashion the innovative performance of countries and regions.

Why the focus on Canadian patents in the US? Several reasons account for that. First, according to Rafiquzzaman and Whewell (1998), "Canada has one of the lowest propensities to file patents at home of any of the major industrialized countries, with only 6.6% of national patent applications originating from residents in 1992" (p. 5). Thus, a natural place to look for the outcomes of innovative activity in Canada is in the patenting abroad by Canadians. The lion share of patent applications abroad has traditionally gone to the US (well over half for most of the period studied), due primarily to the high level of economic integration between Canada and the US.[1] Second, even though Canadian patenting in other G7 countries has increased significantly over the years (see Rafiquzzaman and Whewell, Table 2), it is often the case that patents are sought first and foremost in the US, where the standards for patentability are more stringent that in most European countries. Thus, one can hopefully learn a great deal about innovation in Canada by analyzing the Canadian patents granted in the US. From the mid 1960s through 1997 Canada-based inventors received over 45,000 patents in the US. This is a large (absolute) number, and it placed Canada as the 5th largest foreign recipient of US patents.

Adam Jaffe and I have developed in recent years a methodological approach that allows one to study innovation in great detail with the aid of patent data, and not just to rely on patent counts.[2] In particular, building both on detailed information contained in patents and on patent citations, we can compute for each individual patent quantitative indicators of notions such as the "importance", "generality", and "originality" of patents (see Trajtenberg, Jaffe and Henderson, 1997). We can also trace the "spillovers" stemming from each patent, and analyze their geographical and temporal patterns (e.g. are spillovers geographically localized? See Jaffe, Henderson and Trajtenberg, 1993). Moreover, we have constructed a large data bank containing information on all US patents granted from 1965 to 1996,[3] that allows us to compute this sort of measures for any subset of patents. This is a powerful capability that greatly enhances our ability to do empirical research in the area of the Economics of Technical Change.

The paper is organized as follows: Beginning with a concise discussion of the data in section II, we then examine in sections III and IV the main trends in Canadian patenting, both in itself and in comparison to two groups of countries, the other G7, and a "reference group of countries" consisting of Finland, Israel, South Korea and Taiwan. Section V deals with the technological composition of Canadian innovations, relative to

[1] However, this percentage has been dropping in recent years: it stood at 62% in 1978, and dropped to 49% in 1992.
[2] Rebecca Henderson of MIT also participated in the initial stages of this endeavor, and Bronwyn Hall of Berkeley and Oxford has been involved in it for the past few years.
[3] With the assistance of Michael Fogarty and his team at Case Western University.

that of other countries. In section VI we look at the distribution of Canadian assignees, thus addressing the issue of who controls the rights to the intellectual property embedded in these patents, and hence who can expect to benefit from it. Section VII undertakes to examine the relative "importance" or "quality" of Canadian patents vis a vis patents granted to US inventors, in terms of citations received. Finally, Section VIII summarizes the main points and attempts to draw policy implications.

II. Data

A patent is a temporary monopoly awarded to inventors for the commercial use of a newly invented device. For a patent to be granted, the innovation must be non-trivial, meaning that it would not appear obvious to a skilled practitioner of the relevant technology, and it must be useful, meaning that it has potential commercial value. If a patent is granted, an extensive public document is created. The front page of a patent contains detailed information about the invention, the inventor, the assignee, and the technological antecedents of the invention, all of which can be accessed in computerized form (see Figures 1 and 2).

These extremely detailed and rich data have, however, two important limitations: first, the range of *patentable* innovations constitutes just a sub-set of all research outcomes, and second, patenting is a *strategic* decision and hence not all *patentable* innovations are actually *patented*. As to the first limitation, consider an hypothetical distribution of research outcomes, ranging from the most applied on the left to the most basic on the right. Clearly, neither end of the continuum is patentable: Maxwell's equations could not be patented since they do not constitute a device (ideas cannot be patented). On the other hand, a marginally better mousetrap is not patentable either, because the innovation has to be non-trivial. Thus, our measures would not capture purely scientific advances devoid of immediate applicability, as well as run-of-the-mill technological improvements that are too trite to pass for discrete, codifiable innovations.

The second limitation is rooted in the fact that it may be optimal for inventors *not* to apply for patents even though their innovations would satisfy the criteria for patentability.

For example, until 1980 universities in the USA could not collect royalties for the use of patents derived from federally funded research. This limitation greatly reduced the incentive to patent results from such research, which constitutes about 90% of all university research in the USA. Firms, on the other hand, may elect not to patent and rely instead on secrecy to protect their property rights.[4] Thus, patentability requirements and incentives to refrain from patenting limit the scope of analysis based on patent data. It is widely believed that these limitations are not too severe, but that remains an open empirical issue.

Our working hypothesis here is that, whereas these limitations may affect ***level*** comparisons across fields/industries and perhaps also across countries ***at a point in time***, they do not affect the analysis of trends and changes over time. In other words, if we observe for example a surge in the *share* of US patents in the field of Computers and Communications and a concomitant decline in the share of Chemicals, it is hard to believe that these changes are due to underlying changes in the relative propensity to patent in these two sectors. Rather, the assumption is that these trends reflect true changes in the amount of innovation done in those fields.

The data that we use here were assembled from various sources. First, from our own massive data bank, which consists as said of all US patents and their citations, granted form 1965 through 1996, I extracted the following subsets: (1) All patents granted during that period to Canada, and to a random sample of 1/50 of US patents; (2) for all those patents I added all the patent citations that they received over the same period; (3) patent counts by application year for all the comparison countries (the other G7 and the 4 countries in the reference group). Second, I updated the patent counts with data extracted from the US Patent Office site in the Internet (see Notes to Appendix 1). Third, I extracted from the same site data on "raw applications" for all these countries, and added data on population for the comparison countries and Canada, data on R&D for the G7, and a variety of other data from the NSF and other sources.

[4] There is a large variance across industries in the reliance on patents versus secrecy: see Levin et al, 1987.

III. Basic facts about Canadian patenting in the US

Figure 3 shows the number of successful Canadian patent applications in the US over time, starting in 1968. Patenting was essentially flat for the first 15 years and then started to climb up, but not in a smooth way: the number of patents grew fast during the 1986-89 period, and then again in 1992-95, with stagnant periods in between. We have to be careful with the timing though: patent applications reflect (successful) R&D conducted ***prior*** to the filing date, with lags varying greatly by sector. Thus, the number of patents in a particular year should be attributed to investments in R&D carried out in the previous 2-3 years at least, and in some sectors (such as pharmaceuticals) further back (see Figure 4).

What accounts for the observed path of Canadian patenting over time? I shall not attempt to conduct here an in-depth analysis of such trajectory (that is beyond the scope of the present study), but rather I'll content myself with examining the most salient factors. First of all, there is the input side, namely R&D: the more resources a country devotes to research and other forms of inventive activity, the more we would expect to see innovative outputs, and certainly patents among them. I shall use for these purposes *real, non-defense* R&D spending, as reported by the National Science Foundation (NSF, 1998).[5] Second, there are fluctuations in world-wide patenting quite likely reflecting changes in technological opportunities (and perhaps also in patenting practices), that may influence patenting by Canadian inventors. Moreover, given the proximity to the US, Canadian patenting patterns may be particularly sensitive to patenting by US inventors (they account for about ½ of all US patents). In order to ascertain the importance of these factors, I run simple regressions of the yearly number of Canadian patents as dependent variable, with lagged R&D and patents by US inventors as regressors, all in logs.[6]

[5] There are of course other indicators such as number of scientists and engineers in R&D, business sector R&D, etc. I have chosen real non-defense R&D primarily for reasons of data availability and consistency across countries.

[6] I experimented with various lags for R&D (recall that this is non-defense Canadian R&D), and the best fit obtains for a lag of 2 years. However, the results using a 3-year lag are very similar.

	Dep. Var: log(Canadian patents) – 1981 - 97				
Regressors *(in logs)*	**(1)**	**(2)***	**(3)**	**(4)***	**(5)** ***1981-95****
constant	4.36 (27.8)	-3.51 (-1.49)	0.88 (0.44)	-0.36 (-0.18)	1.94 (2.15)
R&D lagged 2 years	1.62 (20.3)		1.02 (2.92)	0.67 (1.8)	1.32 (3.3)
Patents to US inventors		1.02 (4.74)	0.43 (1.75)	0.61 (2.43)	0.28 (1.04)
AR(1)		0.64 (2.37)		0.16 (0.56)	
Obs	15	16	15	14	13
R^2	0.969	0.966	0.976	0.975	0.976
DW	1.88	2.34	1.61	2.08	1.98

t-statistics in parenthesis
* *Corrected for serial correlation.*
*** The patent figures for 1996 and 1997 are preliminary estimates, hence this run.*

As we can see, the pair-wise correlations between Canadian patents and *each* of the regressors are very high. When put together in the regression lagged R&D prevails in some of the runs, but the data are too sparse and too collinear to be able to reach definite conclusions. That is, on the one hand the behavior over time of Canadian patent applications resembles that of patenting by US inventors, apparently responding to global economic and technological forces. On the other hand, Canadian patents follow very closely the amount of resources devoted in Canada to civilian R&D. Of course, it could be that expenditures on R&D in Canada respond to the same underlying global forces that drive total patenting (e.g. technological opportunities), and hence a more elaborate model would treat R&D as endogenous. Regardless of the "race" between regressors, the fact is that innovative output in Canada, as reflected in the number of patent applications in the US, seems to be highly responsive to civilian R&D performed 2-3 years earlier. Thus, fluctuations in the level of R&D resources invested do manifest themselves after a while in the number of patented innovations produced.

Beyond the statistical analysis, a closer look at the series, and in particular at the *growth rates* of patents and of R&D, reveals a number of discrete periods along the time trajectory, which seem to follow a 3-year cyclical pattern:

Period	Growth rate of patents	Growth rate of R&D (3-year lag)
1968 - 83	~ 0%	na
1983 - 86	9.2%	4.4%*
1986 - 89	13.2%	7.6%
1989 - 92	-0.7%	1.5%
1992 - 95	6.4%	4.2%

*Computed for 1981-83 only

The correspondence between the two series is quite striking (recall Figure 4), and raises questions about the "political cycle" that may have induced the observed fluctuations in R&D spending.

IV. International Comparisons

Whereas the detailed analysis of Canadian patenting is revealing in itself, we resort to international comparisons in order to put in perspective the overall level and trend over time in Canadian patenting. We have chosen for that purpose two groups of countries:

1. ***The (other) G7***: France, Germany, Italy, Japan, UK and USA.
2. A ***"Reference Group":*** Finland, Israel, South Korea and Taiwan.

The Reference Group consists of countries that have fast-growing High Tech sectors, which have turned pivotal for their economic performance and in particular for growth. Thus, they provide a benchmark in terms of patenting in economies that are geared towards innovation as they try to catch up with the richer G7-type countries.

Appendix 1 contains detailed patent figures for each country, Figures 5-6 show the time patterns of patents per capita for Canada versus each of the above groups of countries,[7] and Figure 7 does the same in terms of patents/R&D, for the G7 only.[8] As the figures reveal, Canada holds a respectable mid-place vis a vis the G7, both in terms of patents per capita and in terms of patents per R&D dollars: it lies well below the US and Japan, nearly on par with Germany (higher in terms of patents/R&D), and above France, the UK and Italy. In the early seventies Canada was even ahead of Japan, but then Japan took off and is now closing in even on the US. Notice that 1983 proved to be a turning point for ***all*** of the largest countries at the same time (USA, Japan, Germany, and to a lesser extent also for Canada); this is an interesting fact in itself, that remains to be explained.

The comparison with the Reference Group shows a very clear picture: Canada was well ahead of the four countries in the group throughout the seventies, but in the course of the eighties Israel and Finland caught up, surpassing Canada by the mid nineties. Taiwan experienced a meteoric rise since the early eighties, bursting ahead of the pack by 1997. South Korea is climbing up extremely fast as well, and will probably surpass Canada by 2,000. It is thus clear that the countries in the Reference Group are experiencing much faster rates of innovation than Canada, reflecting for the most part conscious policies of encouragement of Industrial R&D and of the High Tech sector.

Table 1 summarizes the main statistics for all these countries, including their "success rates" and growth rates in patenting, over the whole period (1968-97) and for the past 5 years. The picture that emerges is mixed: on the one hand Canada experienced healthy growth rates in patenting, as compared to the other G7 countries: for the past 30 years it was second only to Japan, and for the past 5 years it has the highest growth rate among the G7. On the other hand it still stands mid-way in terms of patents per capita (compared again to the other G7), and second to last in the absolute number of patents. In order to improve its standing in those terms Canadian patenting would have to growth significantly faster than present rates. The reference group offers a good perspective in

[7] We chose to normalize the number of patents by population, simply because this is a widely available and accurate statistic that provides a consistent scale factor.

[8] The R&D data for the countries in the reference group are spotty and less reliable.

that respect: notice that their growth rates in the past five years have been 2 to 5 times faster than Canada's!

Table 1 reveals also that Canada has a relative weakness in terms of "success rates", that is, the proportion of patent applications that result in patent grants: it stands second to last vis a vis the other G7 countries (only the UK has a worse record), and below 3 of the 4 countries in the Reference Group (only Taiwan is lower). To understand the implications of these differences, if Canada were able to reach the average of the G7 countries ahead of it (61%) from the present 55%, that would represent an increase of about 11% in the annual number of patents granted. This would be like an increase in the productivity of the R&D process, rather than an increase in the overall level of resources devoted to inventive activity.

It is important to note that in the present context the *absolute* number of patents remains key (similarly to the absolute level of R&D expenditures, rather than its ratio to GDP). In order to establish a viable, self-sustaining High Tech sector, a country has to achieve a critical mass in terms of pertinent infrastructure, skills development, managerial experience, testing facilities, marketing and communication channels, financial institutions, etc. Similarly, it is clear by now that spillovers, and in particular ***regional*** spillovers, are extremely important in fueling the growth of this sector. Once again, the amount of spillovers generated, and the ability to capture external spillovers is a function of ***absolute***, not relative size. If we take the number of patents as indicative of the absolute size of the innovative sector, Canada still has a long way to go, considering that it stands below all of the other G7 countries except for Italy, and that by 1997 Taiwan and South Korea have already moved ahead of Canada (see Appendix 1).

Recall from the discussion in section 3 that there is a tight relationship between R&D spending in Canada and patenting. Comparing Canada to OECD countries in terms of R&D/GDP ratios, and in terms of R&D per capita (see Figures 8a and 8b), we can see that Canada devotes relatively few resources to R&D.[9] Thus, it is quite clear that the somewhat precarious standing of Canada in terms of innovative outputs reflects to a large extent its weak commitment to R&D. Moreover, the implication of a ***low*** R&D/GDP ratio is even more problematic for Canada, considering once again that in this area the ***absolute*** amount of resources is what counts, and that Canada's economy is much smaller than the leading G7 countries. Thus, Canada's GNP in 1997 was 38% that of France, 25% that of Germany, 12% that of Japan, and 8% that of the US. These (much larger) countries devoted 2.0 – 2.8% of GDP to civilian R&D, as opposed to 1.5% for Canada.

V. The Technological Composition of Canadian Patented Innovations

The US Patent Office has developed over the years a very elaborate classification system by which it assigns patents to technological categories. It consists of over 400 main patent classes, and over 150,000 patent subclasses. The main patent classes have been traditionally aggregated into 4 fields: chemical, mechanical, electrical and other. We have developed recently a new classification scheme, by which we assigned these 400 patent classes into 35 technological "sub-categories", and these in turn are aggregated into 6 categories: Computers and Communications, Electrical and Electronics, Drugs and Medical, Chemical, Mechanical and Others. This classification allows one to study in detail the technological composition of the flow of patented innovations. In particular, one can compare the technological portfolio of any country with world-wide trends, which is what I intend to do here with respect to Canada.

Figure 9 shows the distribution of patents by these six technological categories over time for all US patents, and Figure 10 does the same for patents granted to Canadian inventors (appendix 2 shows these distributions for patents granted to US inventors, and to non-US inventors). Figure 9 is supposed to reflect the main trends in worldwide, cutting-edge technology. The pattern is quite clear: for the first decade or so (i.e. 1967 ~ 1978) there is little change - just a slow decline in Mechanical patents,[10] and a concomitant small increase in the share of Drugs and Medical. The three traditional fields

[9] Other indicators such as number of researchers per worker (47/10,000 in Canada) provide further evidence to that effect.

[10] There is also a slight decline in Chemical patents for non-US inventors – see appendix 2.

(Mechanical, Chemical and Others) stand highest throughout this initial period, with shares of about 25% each. Both Drugs and Medical and Computers and Communications accounted for a very small fraction back then: 3% – 6% each.

Starting in 1979 this mostly static picture changes quite dramatically: all three traditional fields lose ground, whereas Computers and Communications (C&C) surges forward doubling its share (from 7% in 1979 to 14% in 1994), and Drugs and Medical also increases rapidly from 6 to 10% (12% in the US). As to Electrical and Electronics, it increases slightly during this period, from 16% to 18%. It is important to remark that these changes in shares are all the more significant in view of the fact that there has been an equally dramatic increase in the ***number*** of patents issued (starting in about 1983). Thus for example, the actual number of patents in C&C experienced a ***threefold*** increase worldwide in 1979-94, whereas the total number of patents increased just by 54%.

It is clear that these figures faithfully capture the crucial technological development of the last two decades, namely, the advent of Computers and Communications as the dominant "General Purpose Technology" (GPT) of our era.[11] As to Drugs and Medical, it would seem that its rise is demand driven, following the continuous increase in the share of GDP devoted to healthcare in industrialized nations, and in the US in particular. Moreover, current developments in Biotechnology may well turn this field into one of the dominant General Purpose Technologies of the next century. General Purpose Technologies play the role of "engines of growth", and thus their importance goes far beyond their weight as a sector. As the General Purpose Technology improves and spreads throughout the economy, it prompts complementary advances in user sectors, bringing about generalized productivity gains. A thriving, innovative General Purpose Technology sector (in this case C&C) is thus a crucial factor determining the growth potential of advanced economies.

[11] See Bresnahan and Trajtenberg (1995) and Helpman and Trajtenberg (1998) for discussion of the notion of "General Purpose Technologies", and an analysis of their implication for growth.

Figure 11 compares the technological composition of all US patents with that of Canadian inventors, for the period 1980-94. The picture that emerges is quite disturbing: Essentially Canada seems to be "missing the boat" in terms of the prevailing General Purpose Technology, Computers and Communications, and instead it continues to innovate in traditional fields. Thus, the share of C&C patents in Canada barely changed during this period (from 7% to 9%), as opposed to the ***doubling*** of the C&C share for all patents (from the same initial base of 7% to 14%). It is also worrisome that the share of Electrical and Electronics (E&E), that stood at 18% for all patents by 1994, was only 12% for Canadian patents. This category embeds both mature E&E fields, but also newer semiconductor technologies, which are important in themselves and also support the C&C sector. Taken together, C&C and E&E accounted for a third of all patents by 1994, whereas in Canada they made just 21%.

The flip side of Canada's disadvantage in C&C and in E&E is the high shares of two of the three traditional patent categories: Others, which accounts for almost 1/3 of all Canadian patents (versus 20% worldwide), and to a lesser extent Mechanical (the third field, Chemical, is actually lower in Canada that in the rest of the world). In order to look more in detail into this matter, Table 2 shows the top 20 technological sub-categories for Canadian patents granted during 1991-96, and compares their ranking with that of the patents granted to US inventors during the same period.[12] The most glaring differences are as follows. Canadian inventors patent relatively ***much more*** (once again, in terms of ranking) than US inventors in the following fields:

- Transportation *(rank 3 in Canada, 8 in the US)*
- Furniture and House Fixtures *(rank 4 in Canada, 14 in the US)*
- Agriculture, Husbandry and Food *(rank 5 in Canada, 15 in the US)*
- Earth Working and Wells *(rank 9 in Canada, 18 in the US)*

Canadians patent ***much less*** than their US counterparts in:

- Computer Hardware and Software *(rank 2 in the US, 15 in Canada)*
- Surgery and Medical Instrumentation *(rank 3 in the US, 13 in Canada)*

[12] The table excludes the "miscellaneous" sub-categories from each of the main categories (i.e. there is a miscellaneous sub-category in Computers and Communications, in Chemical, Mechanical, etc.).

- Resins *(rank 6 in the US, 16 in Canada)*
- Power Systems *(rank 7 in the US, 14 in Canada)*

Thus, the differences in the share of Computers and Communications are due not to Communications (in that sub-category Canadian patents rank almost as high as US patents), but to Computer Hardware and Software, where the disparity is very large.[13] Likewise, the (much smaller) difference in Drugs and Medical is due to Medical Instrumentation, not to Drugs.[14]

Why is the divergence in the technological composition of Canadian patents an issue?

One could argue that the technological composition of Canadian patents reflects a series of well-grounded economic factors, and hence that its divergence vis a vis other countries does not necessarily carry normative implications. That may well be the case, and indeed the top technological sub-categories seem to correlate to some extent with some notion of comparative advantage, relative size of sectors, idiosyncratic technological needs, etc.

The problem is that Computers and Communications (or, more generally, Information Technology, IT), the area where Canadian patents are lagging the most in relative terms, is not just a field like any other, but as said before it is the dominant General Purpose Technology (GPT) of our times. Of course, not every country needs to excel technologically in the prevalent GPT in order to benefit from it. Information Technologies are spreading rapidly and becoming a powerful economic force all over the industrialized world (and to a lesser degree also in less developed countries), and not just in those countries that are innovators in that field. However, in order for an economy to be able to reap the economy-wide benefits and tap the full potential of a GPT for growth, it *does* need to innovate in it. That is so not so much because the innovations per se are going to impact growth, but because by innovating in the GPT area, a country ***develops and enhances its capabilities to harness the GPT for growth***.

[13] In fact, the number of Canadian patents in Communications was 2.6 times the number in Computers (2,156 versus 816), whereas for US inventors the factor was just of 1.3.

[14] Canadian inventors took more patents in Drugs than in Medical instrumentation (942 versus 781, with an additional 371 in Biotech), whereas the opposite was true for US inventors.

The argument here echoes the notion of "absorptive capacity" in the context of basic research (see Cohen and Levinthal, 1989). This notion was raised *inter alia* as a response to the puzzle - why do for-profit firms engage in basic research, given that they cannot appropriate most of the returns from such research? The answer is that in order for those firms to be able to benefit from the basic research done elsewhere (e.g. in academia), they need to engage in such activity themselves. Thus, the scientists working at Xerox's PARC serve *inter alia* as a bridge between worldwide advances in science, and the particular technological needs (or opportunities) at Xerox. The world of IT moves too fast for an economy to be able to adopt a passive stance and still benefit from it. Only those that are in the race themselves can hope to cope with the speed of advances of the leading runners.

It is important to emphasize that the problem lies as said with ***Computers Hardware and Software***, not with ***Communications***. As we shall see in Section VII, this view is reinforced when examining the "quality" of Canadian patents relative to US patents: in Computers there is a big gap in the quality of Canadian patents in favor of US patents, in Communications the gap is much smaller (see Figure 13).

VI. Who Owns What? A View at the Distribution of Canadian Patents Assignees

By way of introduction, we need to describe the different "players" related to any given patent. First there are the inventors, that is, those individuals directly responsible for carrying out the innovation embedded in the patent. Second there is the assignee, that is, the legal entity (corporation, government agency, university, etc.) that owns the patent rights, assigned to it by the inventor(s). However, there are individual inventors that work on their own and have not yet assigned the rights of the patent to a legal entity at the time of issue, in which case the patent is classified as "unassigned".[15] For most patents the inventors are typically employees of a firm, in which case the assignee is the firm itself.

[15] In a small number of cases the patent is "assigned to individual, that is, the inventor herself may appear as the legal entity that owns the patent rights.

According to the conventions of the US Patent Office, the "nationality" of a patent is determined by the address (at the time of application) of the ***first inventor***. That is, if a patent has many inventors and they are located in a variety of countries, the location of the first inventor listed on the patent determines to which country it is deemed to belong. Likewise, if the assignee is located in a country different from that of the first inventor, it is once again the location of the latter that determines the nationality of the patent. Notice for example that the patent displayed in Figure 2 is regarded as Canadian even though there is a second inventor that is not, and the assignee is Rolls Royce, UK.[16]

The data that we have presented so far (e.g. number of patents by countries) were compiled according to this convention: Canadian patents are those for which the address of the first inventor was in Canada, regardless of the identity and location of the assignees or of the other inventors, and similarly for the other countries. The important question now is, who actually owns the rights to these inventions? Keeping in mind that for patents labeled "Canadian" it was indeed Canadian scientists and engineers that were responsible for the "innovative act" that led to these patents,[17,18] the question is: which entity, commercial or otherwise, is in a position to reap the economic benefits from these inventions?

At the upper level of aggregation there are 3 possibilities: (*i*) That there is no assignee (i.e. the inventor herself retains the rights to the patent), and hence it is not clear if and when the patent will be commercially exploited; (*ii*) that the assignee is also Canadian, that is, that the location of the entity owning the rights to the patent is in Canada; (*iii*) that the assignee is foreign. Even the seemingly sharp distinction between (*ii*) and (*iii*) is not quite as clear. There are on the one hand Canadian corporations that

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[16] Clearly, this convention is completely inconsequential for anything but the compilation of statistics about international patenting activity.
[17] At least in part, since as said patents classified as "Canadian" may include also other inventors located in different countries.
[18] The reason we have to be careful with the wording here is as follows: suppose that an Canadian scientist goes to a sabbatical to MIT in Cambridge, MA, and carries out a project in a lab there that results in a patented invention (there are quite a few of these in the data). Such a patent would be labeled as Canadian, but the assignee would be MIT. Now, the invention was made possible not only by the ideas and efforts of the Canadian scientist, but also by the facilities, physical and otherwise, of the host institution. The end result is no doubt a function of both.

have established subsidiaries or otherwise related firms in other countries, and they may choose to assign the patents (done is Canada) to their "foreign" subsidiaries (but in fact we should regard them as Canadian). On the other hand, there are multinational corporations that have established subsidiaries in Canada, and some may choose to assign the locally produced patents to the Canadian subsidiary, even though the multinational retains effective control over the property rights.

The distinction between these 3 categories, unassigned, Canadian ("local") and foreign, is then telling of the extent to which the country can expect to benefit from "its" patents. The unassigned patents may of course find their way to successful commercial applications (and many do), but they typically face much higher uncertainty than corporate assignees that own from the start the patents issued to their employees. Moreover, corporations are in a better position to capture internally the spillovers generated by those innovations. Thus, the higher is the percentage of unassigned patents, the less would be the economic potential of a given stock of patents. The distinction between foreign and local assignees is presumably informative of the probability that the *local economy* would be the prime beneficiary of the new knowledge embedded in the patent. One can draw various scenarios whereby foreign ownership may be as good if not better in that respect than local ownership of the patent rights (e.g. the foreign multinational offers marketing channels for the innovation that would be inaccessible to local firms). Still, we are rapidly moving in many technological areas to an era where the prime asset is the effective control of intellectual property, and presumably that is correlated with the ownership of patent rights. However, we do not need to take a strong stand in this respect, only to agree that this distinction is informative and quite likely important for understanding the potential value for a country of its stock of patents.

Table 3 shows the distribution between unassigned, "local" and foreign assignees, for Canada, the G7 and the Reference Group.[19] As we can see, the percentage of local

[19] These figures do not come from the same database as those presented so far: (1) The number of patents assigned to a country in table 3 include all patents in which ***any*** of the inventors resides in that country; (2) the period covered in table 3 is 1976-98 for granted patents, as opposed to 1968-97 for applied patents in all

assignees in Canada is much lower than that of all other G7 countries, due primarily to a high share of unassigned patents. As to the Reference Group, Finland and South Korea have much higher shares of local assignees than Canada, Israel a slightly higher share, and Taiwan a lower one. Taiwan has indeed a very low percentage of local assignees (due to an extremely high share of unassigned, 64%!), whereas South Korea has an extremely high share of them (topped only by Japan). These differences are clearly related to the industrial organization of these countries: Taiwan has a very large number of small enterprises, and an extremely high rate of turnover of firms, whereas South Korea is dominated by huge, stable *chaebol* (this is a topic worth of further investigation). The contrast between the latest figures (for 1998) and those for the whole period 1976-98 reveal that the G7 countries are quite stable, whereas the countries in the Reference Group increased the share of local assignees, particularly Taiwan and South Korea.

What characterizes Canada vis a vis other countries is that ***both*** the shares of unassigned and of foreign are relatively high: the percentage of unassigned in Canada is the second highest (after Taiwan), and the percentage of foreign is the third highest (after the UK and Israel). Thus, there is reason for concern in this respect, in that a full half of Canadian inventions may not fully benefit the Canadian economy, either because they are done by individuals that may have a hard time commercializing them, or because they are owned by foreign assignees.

VII. The Relative "Importance" of Canadian Patents

Simple patent counts are a very imperfect measure of innovative activity, simply because patents vary a great deal in their technological and economic "importance" or "value", and the distribution of such values is extremely skewed. Recent research has shown that patent citations can effectively play the role of proxies for the "importance" of patents, as well as providing a way of tracing spillovers (see Trajtenberg, 1990, and Henderson, Jaffe and Trajtenberg, 1998). By citations I mean the references to previous patents that appear in the front page of each patent (see Figures 1 and 2).

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other tables. Both are due to limitations of the search capabilities in the Internet site of the US Patent Office.

Patent citations serve an important legal function, since they delimit the scope of the property rights awarded by the patent. Thus, if patent 2 cites patent 1, it implies that patent 1 represents a piece of previously existing knowledge upon which patent 2 builds, and over which 2 cannot have a claim. The applicant has a legal duty to disclose any knowledge of the prior art, but the decision regarding which patents to cite ultimately rests with the patent examiner, who is supposed to be an expert in the area and hence to be able to identify relevant prior art that the applicant misses or conceals.[20]

I use data on patent citations here in order to examine the "quality" of Canadian patents vis a vis patents awarded to US inventors. That is, I ask to what extent Canadian patents are more or less frequently cited than US patents, controlling for various effects, and analyze how these differences vary over technological categories. Thus, I regress the number of citations received by each patent on control variables (dummies for 5 technological classes as well as for grant years), and a dummy for the US. The sign and magnitude of this latter coefficient is telling of the extent to which Canadian patents receive more or less citations on average than US patents, controlling for technological composition and age of patents. The results for the benchmark regression are as follows:[21]

Number of obs	= 95473
F(6, 95433)	= 387.46
Prob > F	= 0.0000
R-squared	= 0.1194
Adj R-squared	= 0.1190
Root MSE	= 5.0802

[20]Because of the role of the examiner and the legal significance of patent citations, there is reason to believe that patent citations are less likely to be contaminated by extraneous motives in the decision of what to cite than other bibliographic data such as citations in the scientific literature. Moreover, bibliometric data are of limited value in tracing the *economic* impact of scientific results, since they are not linked to economic agents or decisions.

[21] The data for these regressions consist of all Canadian patents, as well as a sample of 1/50 of patents awarded to US inventors.

	Coefficient	Std. Error	t-statistic
constant	3.143	0.035	90.496
US dummy	***0.614***	0.033	18.403
Dummies for Tech Categories:			
Chemical	0.217	0.049	4.467
Drugs&Medical	2.003	0.077	26.165
Comp&Comm	2.145	0.068	31.376
Mechanical	-0.258	0.045	-5.685
Elec&Electronics	0.296	0.053	5.605

gyear F(33,95433) = 337.883 0.000
(34 categories)

Thus, US patents are "better" than Canadian patents by about 20% (the coefficient of 0.614 for the US divided by the constant term of 3.14). Table 4 presents the results of the analysis for each technological category, and Figure 12 shows them graphically. The columns represent, in percentages, the extent to which Canadian patents received lower citation rates than US patents, e.g. in Drugs and Medicine the average number of citations received by Canadian patents was 4.41 (see Table 4), whereas the average for US patents was 4.4+1.2=5.6. Thus, the "disadvantage" of Canadian patents was 4.4/5.6 1 = -22%. As can be seen in Figure 12, the biggest disadvantage of Canadian patents vis a vis the US resides in Drugs and Medical and in Computers and Communications; the smallest in Mechanical and Others. Once again, this is quite worrisome: the former two are the leading technologies of our time, the latter two are declining traditional fields.

However, a closer look at Computers and Communications reveals a wide disparity between the two components (see Table 4 and Figure 13): in Communications the disadvantage was just of -9.5% whereas in Computers it stands at –19%. That is, Canada suffers from a large gap in the "quality" of patents in ***Computers*** vis a vis the US, but in ***Communications*** the disadvantage is much smaller, and in fact it is even lower than in Mechanical and Others, the two traditional fields with the least disadvantage. This is good news, recalling that the rank of patents in Communications (in terms of absolute numbers) is almost as high in Canada as it is in the US. That is, Canadians inventors patent a great deal in Communications, and these patents are of relatively high "quality" still below that of US patents in the same field, but only by a small factor. Thus, the problem that we have identified earlier on in terms of the relatively low share of Canadian patents in the dominant GPT of our time, Computers and Communications, is first and foremost a problem in Computers, not in Communications.

Likewise, a detailed examination of the "quality" of patents in Drugs and Medical reveals that the disadvantage of Canadian patents vis a vis the US lies primarily in Medical Instrumentation (see again Table 4 and Figure 13). In Drugs the gap with the US is much smaller (-8.3%) and not quite significant from a statistical point of view. As said before, Canadian inventors took more patents in Drugs than in Medical Instrumentation (the opposite is true for US inventors), and hence here again the news are good in that sense.

VIII. Concluding Remarks and Policy Implications

Before summing up, it is important to emphasize once again that the forgoing analysis was conducted entirely on the basis of data contained in Canadian and other patents issued by the US Patent Office. Clearly, not all Canadian innovations are reflected in those patents (the same is true for the comparison countries), and hence the results should be qualified accordingly. However, there is reason to believe that Canadian patents issued in the US are indeed representative of the main technological trends and patterns in Canada. That is so both because of the large number of such patents relative to domestic patent applications, and because of fragmentary supporting evidence from other sources on some of the findings (such as the good standing of the field of Communications in Canada).

The picture that emerges from the forgoing analysis is mixed at best, and points at a series of weaknesses in Canadian innovative performance:

1. In terms of relative measures of innovative outputs such as patents per capita and patents/R&D ratios, Canada stands mid way vis a vis the other G7 countries, but it has been overtaken in recent years by a group of countries geared towards the High Tech sector (Finland, Israel, Taiwan, with South Korea closing-in).

2. Canada stands well below the other G7 (except for Italy) in terms of the relative amount of resources devoted to innovation, with a R&D/GDP ratio of 1.5%, as opposed to 2.0-2.8% for Germany, Japan and the US.
3. Because of the importance of indivisibilities and critical mass in this area, what ultimately counts is both the absolute amount of R&D, and the absolute number of patents received. Thus, the medium to poor showing in the ***relative*** measures mean a very poor standing in ***absolute*** terms, and carry potentially serious implications for economic performance.
4. Canadian patenting is highly correlated with lagged R&D spending in Canada as well as with worldwide trends in patenting. The latter are exogenous but the amount of resources devoted to R&D is not. Thus, a current policy shift in favor of R&D spending may boost innovative outputs in 2-3 years.
5. The "rate of success" of Canadian patent applications in the US is low relative both to the other G7 and to the Reference Group. It is not clear what accounts for the gap - insufficient selectivity, poor overall "quality" of the applications, procedural difficulties, etc. It is worth examining this area more in detail, since an increase in the success rate may act like a productivity boost to the innovation process.
6. The technological composition of Canadian patents is out of step with the rest of the world: in Canada two of the three traditional fields (Mechanical and Others) still comprise the lion share of patents, whereas the fields of Computers and Communications (C&C) and of Electrical and Electronics are well below the world mark.
7. Close examination reveals that the problem lies with Computers (Hardware and Software), and not with Communications. This is true also in terms of the "quality" of Canadian patents in these fields, vis a vis US patents.
8. The lagging of Canadian innovation in Computers may have dire consequences for the economic performance of the economy as a whole, since C&C constitute the leading "General Purpose Technology" of our times.
9. The patterns of ownership of Canadian patents are also troubling: less than half of Canadian patents are owned by Canadian assignees, 35% are unassigned (the second highest % among the G7), and 19% are owned by foreign assignees. Thus, half of

Canadian inventions may not fully benefit the Canadian economy, either because they are done by individuals that may have a hard time commercializing them, or because they are owned by foreign assignees.

10. There is a significant gap of about 20% in the "quality" or "importance" of Canadian patents versus patents of US inventors, as measured by the number of citations received. The largest disadvantage was in Drugs and Medical (-22%) and in Computers and Communications (-19%), whereas in two of the traditional fields Canadian patents exhibited the least disadvantage. A close-up look reveals that the quality gap resides first and foremost in Computers, not in Communications, and in Medical Instrumentation, not in Drugs.

Clearly, there is a great deal of room for improvements both in the rate and in direction of innovative activity in Canada. According to most indicators, Canada does possess the human capital and the infrastructure needed to benefit from and innovate successfully in cutting edge technologies. Whether or not it will do so depends as much on allocative decisions (e.g. R&D spending) as on institutional factors affecting innovation and entrepreneurship. Both are to some extent within the realm of economic policy.

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Appendix 1
Issued Patents by Application Year 1968-97

Country	1968-72	1973-77	1978-82	1983-87	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Canada	1,106	1,180	1,147	1,345	1,876	2,029	1,938	2,052	1,984	2,274	2,472	2,781	2,564	2,709
France	1,929	2,164	2,199	2,397	2,940	2,925	3,051	2,980	2,926	2,926	3,062	3,449	3,035	3,220
Germany	4,874	5,745	6,167	6,660	7,621	7,759	7,504	6,920	6,966	6,775	7,431	8,180	7,869	8,403
Italy	660	718	819	971	1,267	1,232	1,283	1,250	1,267	1,184	1,268	1,415	1,356	1,393
Japan	4,062	6,385	9,359	13,979	19,866	21,650	22,104	22,811	22,714	22,066	25,352	26,659	25,906	27,386
UK	2,764	2,709	2,357	2,429	2,704	2,811	2,594	2,341	2,265	2,474	2,819	3,086	2,743	2,946
USA	45,150	41,894	38,222	37,990	46,968	50,190	53,266	53,790	56,690	59,264	65,384	74,610	64,947	73,182
Finland	70	103	143	212	262	310	350	352	329	361	460	503	544	580
Israel	58	102	137	211	281	318	325	316	355	422	578	605	566	650
South Korea	4	9	20	74	205	409	510	795	906	1,026	1,587	2,029	2,851	3,302
Taiwan	1	33	87	279	557	725	932	1,116	1,260	1,567	1,908	2,197	2,688	3,097

See Notes in following page.

Notes to Appendix 1
Sources of Data on Yearly Patent Counts by Countries

The difficulty in obtaining accurate patent counts by ***application year*** stems from the lag between application and grant, that causes truncation in the figures for recent years. That is, we have the complete figures for patents by grant year up to 1998, but not by application year. However, one can estimate these figures relying on the previous percentage of "successful" applications (since we do have the number of raw applications for recent years) and other data. In particular, the figures showed in Appendix 1 (and used throughout the paper) were compiled and/or estimated as follows:

- Up to 1989: from our data file.
- For 1990-94: taken from the latest TAF-USPTO report as given there. These figures are based upon patents granted up to the end of 1998, but since over 99% of patents are examined by the forth year after application, these figures may be regarded as essentially complete.
- For 1995: (patents applied in '95 and granted up to '98)/(ratio of '95 patents whose examination was completed by '98=0.98).
- For 1996, average of the following two estimates: (*i*) (patents applied in '96 and granted up to '98)/(ratio of '96 patents whose examination was completed by '98=0.84); (*ii*) (number of raw applications in '96)*("national success ratio": percentage of patents applied for in '94 and '95 that were eventually granted, out of raw applications in those years).
- For 1997: (number of patent applications filed in '97)*(estimated national success ratio for '96). The later was computed as: (estimated number of patents granted in '96)/(number of applications in '96).

Appendix 2
Total *non-defense* R&D expenditures in G7 Countries
(in constant 1992 billion $)

Country	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Canada	5.15	5.56	5.61	6.11	6.62	6.99	7.02	7.14	7.31	7.75	7.90	8.21	8.68	9.00	9.13
France	13.38	14.46	15.24	16.14	16.87	16.97	17.51	18.32	19.70	20.48	21.15	22.42	22.03	21.73	21.72
Germany	22.95	23.69	24.05	24.70	27.07	27.96	29.92	31.03	32.37	32.58	35.04	35.84	34.45	34.35	34.22
Italy	6.77	7.06	7.45	8.01	9.09	9.44	10.31	10.80	11.38	12.38	12.74	13.13	11.90	11.30	11.54
Japan	34.83	37.38	40.31	43.25	48.00	48.76	52.07	56.20	61.55	66.58	67.94	68.91	66.55	65.63	69.74
UK	13.66	13.39	13.12	13.84	14.56	15.65	16.18	17.13	17.61	17.97	16.57	17.83	17.80	17.99	17.17
USA	81.41	82.55	86.25	93.88	100.36	101.90	103.34	107.79	113.79	120.92	127.83	129.36	126.28	128.58	138.35

Notes:
Data taken from NSF site, "National Patterns of R&D Resources: 1997 Data Update" (table b8.xls).
Canada figures for 1992 and 1994 were calculated from total R&D of Canada for that year by taking the average ratio of previous and next years ratio of non-defense R&D to total R&D.
For UK in 1982 and 1984 we took the average of previous and next year ND R&D.
For France in 1995 we took the non-defense R&D to total R&D ratio of previous year.

Table 1
Canada, the G7 and the Reference Group: Basic Patent Statistics – 1967 - 97

Country	Patents per Year		Patents per Capita		Success Rate		Annual Growth Rate	
	1967-97	***1992-97***	**1967-97**	***1992-97***	**1967-97**	***1992-97***	**1967-97**	***1992-97***
Canada	1,552	*2,560*	6.2	*8.6*	56%	*55%*	3.6%	*6.4%*
Other G7:								
France	2,466	*3,138*	4.6	*5.4*	66%	*63%*	2.2%	*1.9%*
Germany	6,422	*7,732*	9.9	*9.5*	65%	*63%*	2.6%	*3.8%*
Italy	959	*1,323*	1.7	*2.3*	59%	*58%*	3.2%	*1.9%*
Japan	13,515	*25,474*	11.8	*20.3*	65%	*61%*	8.6%	*3.8%*
UK	2,603	*2,814*	4.5	*4.8*	55%	*51%*	0.2%	*5.4%*
USA	47,153	*67,478*	19.8	*25.6*	62%	*59%*	1.7%	*5.2%*
The Reference Group:								
Finland	223	*490*	4.7	*9.6*	57%	*58%*	9.1%	*12.0%*
Israel	232	*564*	5.2	*10.0*	54%	*56%*	10.0%	*12.9%*
South Korea	472	*2,159*	1.1	*4.8*	61%	*62%*	34.3%*	*29.5%*
Taiwan	602	*2,291*	3.1	*10.7*	44%	*47%*	24.9%*	*19.7%*

* For South Korea and Taiwan the average growth rates are for the last 20 years.

Table 2

Top Canadian Technological Sub-Categories *
Canada vs. US 1987-96

Technological Sub Category	Number of Canadian Patents	Canada Rank	USA Rank
Mat. Proc & Handling	1303	1	4
Communications	1090	2	1
Transportation	796	***3***	8
Furniture,House Fixtures	745	***4***	14
Agriculture,Husbandry,Food	719	***5***	15
Drugs	596	6	5
Metal Working	566	7	11
Measuring & Testing	548	8	9
Earth Working & Wells	528	***9***	18
Receptacles	525	10	12
Motors & Engines + Parts	498	11	13
Electrical Devices	483	12	10
Surgery & Med Inst.	470	13	***3***
Power Systems	466	14	***7***
Computer Hardware & Software	405	15	***2***
Resins	383	16	***6***
Liquid Purification or Separation	337	17	26
Amusement Devices	336	18	21
Heating	328	19	27
Apparel & Textile	307	20	25

* Excluding Miscellaneous in each Technological Category

Table 3
Distribution of Assignee Types – International Comparison
1976-98

	Number of Patents				Percentages		
Country	**Unassigned**	**Foreign**	***Local***	**Total**	**Unassigned**	**Foreign**	**Local***
Canada	15,756	8,614	21,175	45,545	**35%**	**19%**	**46% *(50%)***
Other G7							
France	6,567	8,883	49,500	64,950	10%	14%	76% *(75%)*
Germany	13,147	17,060	117,660	147,867	9%	12%	80% *(77%)*
Italy	3,957	3,904	19,293	27,154	15%	14%	71% *(72%)*
Japan	9,003	6,950	341,854	357,807	3%	2%	96% *(95%)*
UK	5,812	15,698	37,693	59,203	10%	27%	64% *na*
USA	296,191	19,546	887,308	1,203,045	25%	2%	74% *(76%)*
Reference Group							
Israel	1,815	1,807	3,443	7,065	26%	26%	49% *(52%)*
Finland	834	422	4,739	5,995	14%	7%	79% *(81%)*
South Korea	1,154	531	10,666	12,351	9%	4%	86% *(92%)*
Taiwan	13,296	991	6,362	20,649	64%	5%	31% *(44%)*

* Numbers in parenthesis: the percentages for 1998.

Table 4
Regressions by Technological Categories

	Chemical	Computers & Communications	Drugs & Medical	Electrical & Electronic	Mechanical	Others
Constant	3.44 *(55.2)*	4.75 *(37.6)*	4.41 *(26.3)*	3.45 *(55.1)*	3.02 *(79.5)*	3.23 *(93.3)*
US Dummy	0.64 *(7.7)*	1.08 *(6.5)*	1.24 *(5.6)*	0.58 *(7.1)*	0.48 *(8.9)*	0.49 *(9.6)*
R^2	0.086	0.178	0.139	0.14	0.095	0.123
# of obs.	18,511	7,020	5,372	14,105	23,353	27,090
Canadian disadvantage	-15.7%	-18.5%	-21.9%	-14.5%	-13.8%	-13.1%

Sub-Categories within Computers and Communications

	Computers & Communications	Computers	Communications
Constant	4.75 *(37.6)*	5.16 *(19.1)*	4.71 *(35.3)*
US. Dummy	1.08 *(6.5)*	1.2 *(3.7)*	0.49 *(2.6)*
R^2	0.178	0.225	0.156
# of obs.	7,020	2,767	4,253
Canadian disadvantage	-18.5%	-18.9%	-9.5%

Sub-Categories within Drugs and Medical

	Drugs & Medical*	Medical Instrumentation	Drugs	Bio Tech
Constant	4.41 *(26.3)*	6.08 *(19.4)*	3.29 *(13.8)*	2.71 *(9.6)*
US Dummy	1.24 *(5.6)*	2.02 *(5.1)*	0.3 *(0.9)*	0.62 *(1.6)*
R^2	0.139	0.218	0.082	0.246
# of obs.	5,372	2,081	2,020	767
Canadian disadvantage	-21.9%	-25.0%	-8.3%	-18.7%

* includes, besides the three subcategories shown, a "misc." category

t-statistics in parenthesis

Figure 1

United States Patent	**5,946,313**
Allan, et. al.	**Aug. 31, 1999**

Mechanism for multiplexing ATM AAL5 virtual circuits over ethernet

Abstract

The invention provides for a E-Mux and a method for encapsulating/segmenting ATM cells into/from an Ethernet frame at the boundary between an ATM and an Ethernet network. An Ethernet end-station on the E-Mux is addressed using multiple MAC level identifiers, which are dynamically assigned according to the ATM virtual circuits which terminate on that end station, and have only transitory significance on the Ethernet. A unique ATM OUI identifies the frames carrying ATM-traffic.

Inventors: **Allan; David Ian** (Ottawa, CA); **Casey; Liam M.** (Ottawa, CA); **Robert; Andre J.** (Woodlawn, CA).
Assignee: **Northern Telecom Limited** (Montreal, CA).
Appl. No.: **821,145**
Filed: **Mar. 20, 1997**

Intl. Cl. :	**H04Q 11/04**
Current U.S. Cl.:	**370/397**; 370/401
Field of Search:	**370**/397, 395, 398, 401, 471, 473, 474

References Cited | [Referenced By]

U.S. Patent Documents

5,457,681	Oct., 1995	Gaddis et al.	**370**/56
5,490,140	Feb., 1996	Abensour et al.	**370**/397
5,490,141	Feb., 1996	Lai et al.	**370**/397
5,732,071	Mar., 1998	Saito et al.	**370**/401

Figure 2

United States Patent	**5,941,683**
Ridyard, et. al.	**Aug. 24, 1999**

Gas turbine engine support structure

Abstract

A bearing support structure for a gas turbine engine comprises an annular array of stator vanes and a radially inner bearing support portion which are interconnected by an annular array of radially extending U-shaped cross-section parts. The U-shaped cross-section parts are interconnected at their radially outer extents and are arranged so that adjacent parts are open in generally opposite axial directions. Such a bearing support structure can carry service pipes with good accessibility and be produced by casting, thereby reducing its cost.

Inventors:	**Ridyard; Philip** (Mississauga, CA); **Foster; Alan G** (Derby, GB).
Assignee:	**Rolls-Royce plc** (London, GB).
Appl. No.:	**25,109**
Filed:	**Feb. 17, 1998**
Intl. Cl. :	**F01D 25/16**
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Field of Search:	**415**/142, 209.2, 209.3, 209.4, 210.1; **416**/244 A, 245 R; **60**/226.1

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4,979,872	Dec., 1990	Myers et al.	**415**/142
4,987,736	Jan., 1991	Ciokajlo et al.	**60**/39.31

Figure 3
Canadian Patents in the US -1968-1997

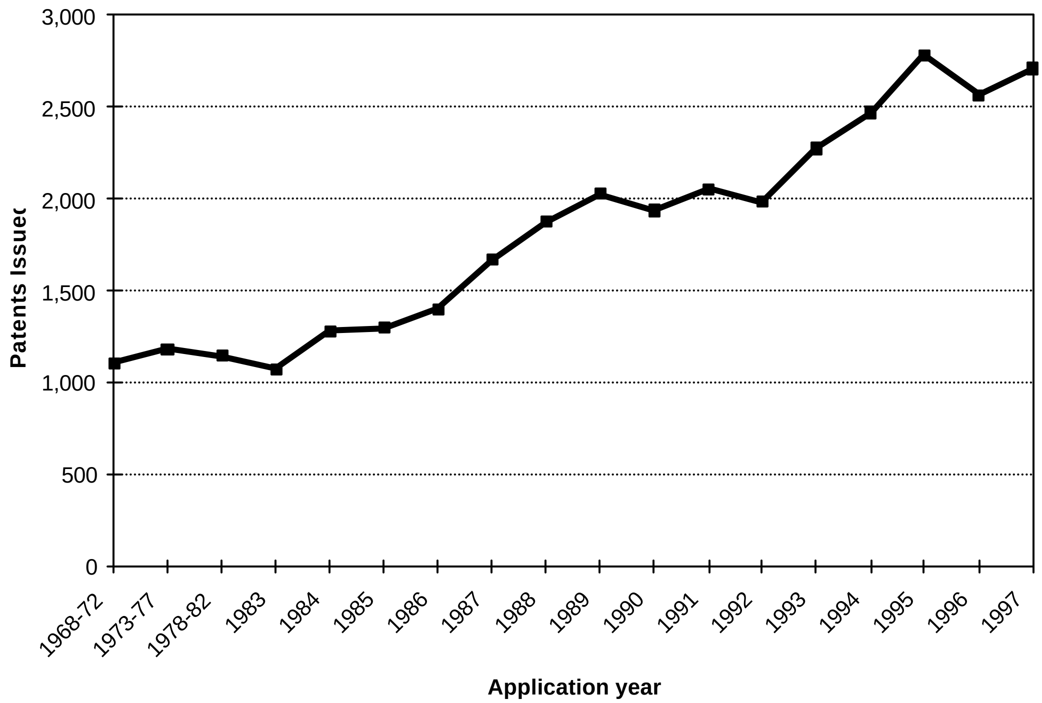

Figure 4
Canadian Patents and Civilian R&D Expenditure
in billions of 1992 dollars (3-year lag)

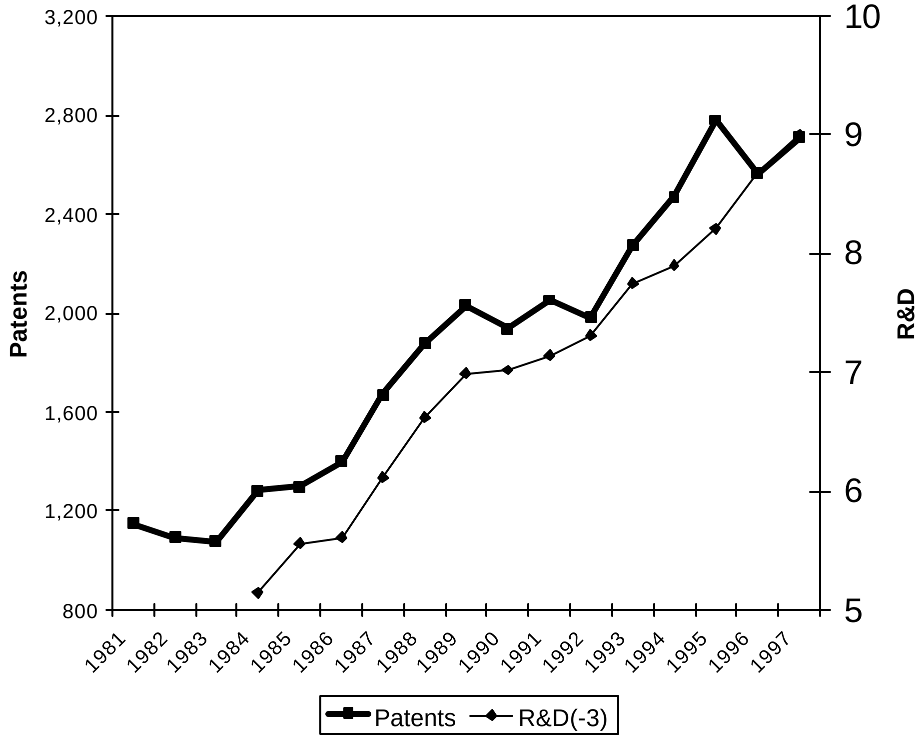

Figure 5
Patents per Capita: Canada vs. the G7
(patents per 100,000)

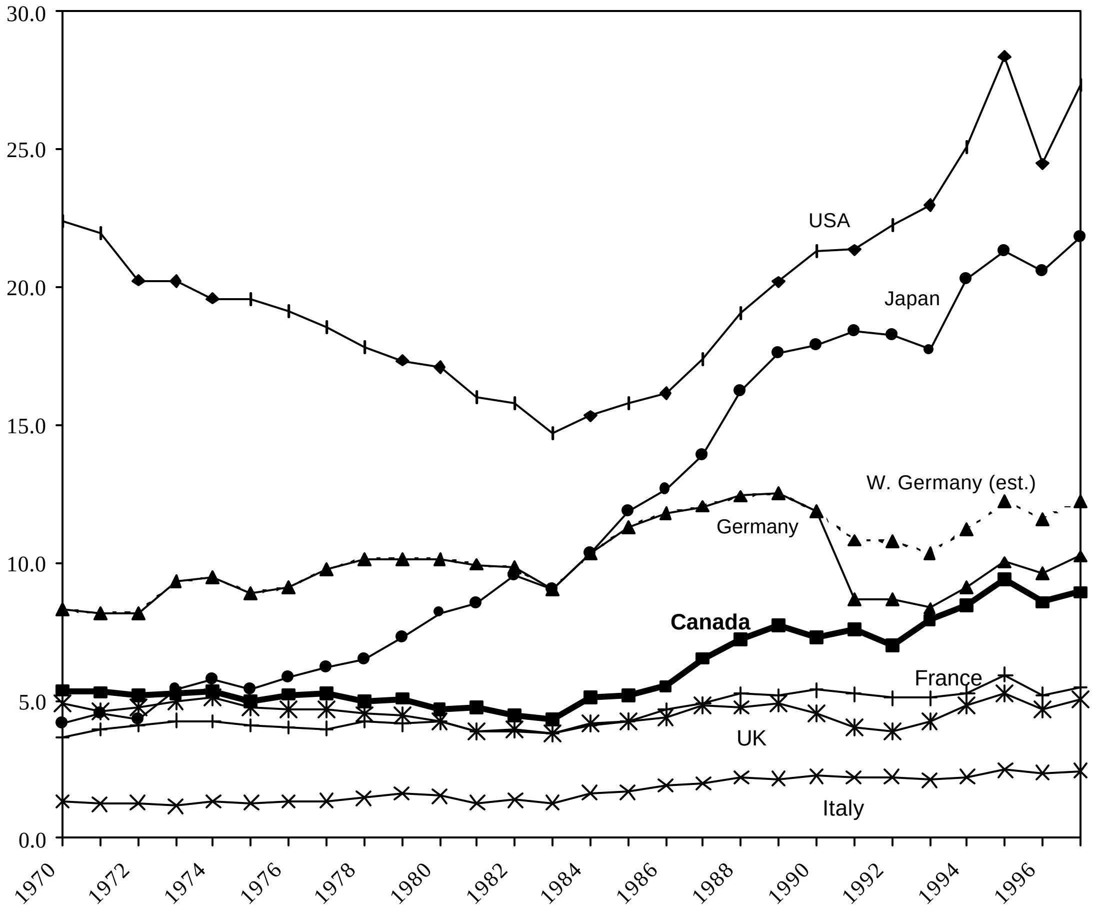

Figure 6
Patents Per Capita: Canada vs. the Reference Group

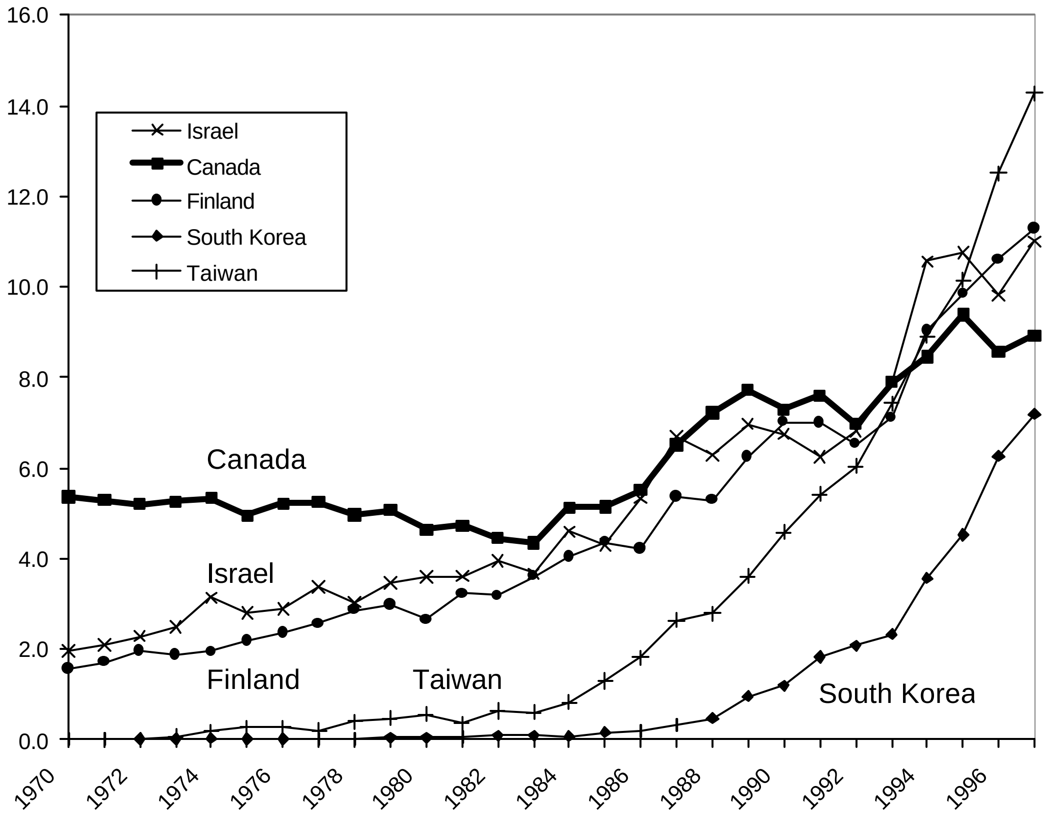

Figure 7
Patents/ Non-Defense R&D - G7
(patents per100M$ R&D)

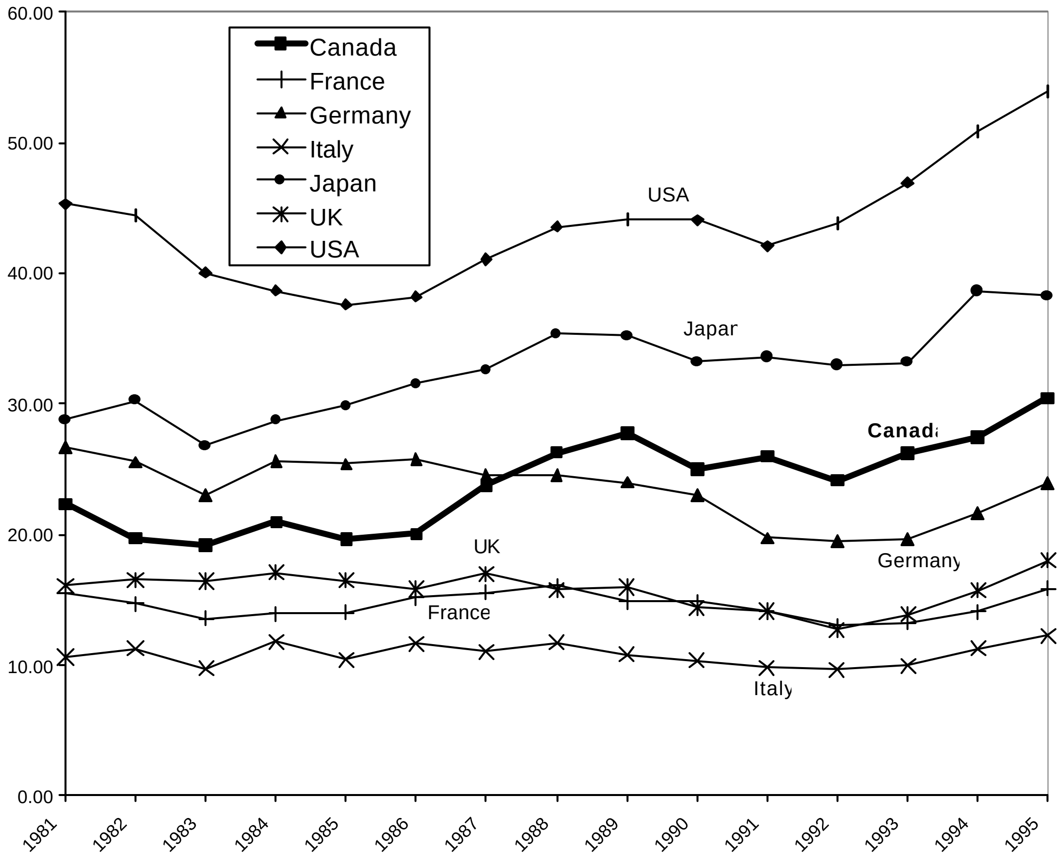

Figure 8a
Civilian R&D as % of GDP in 1996
OECD Countries

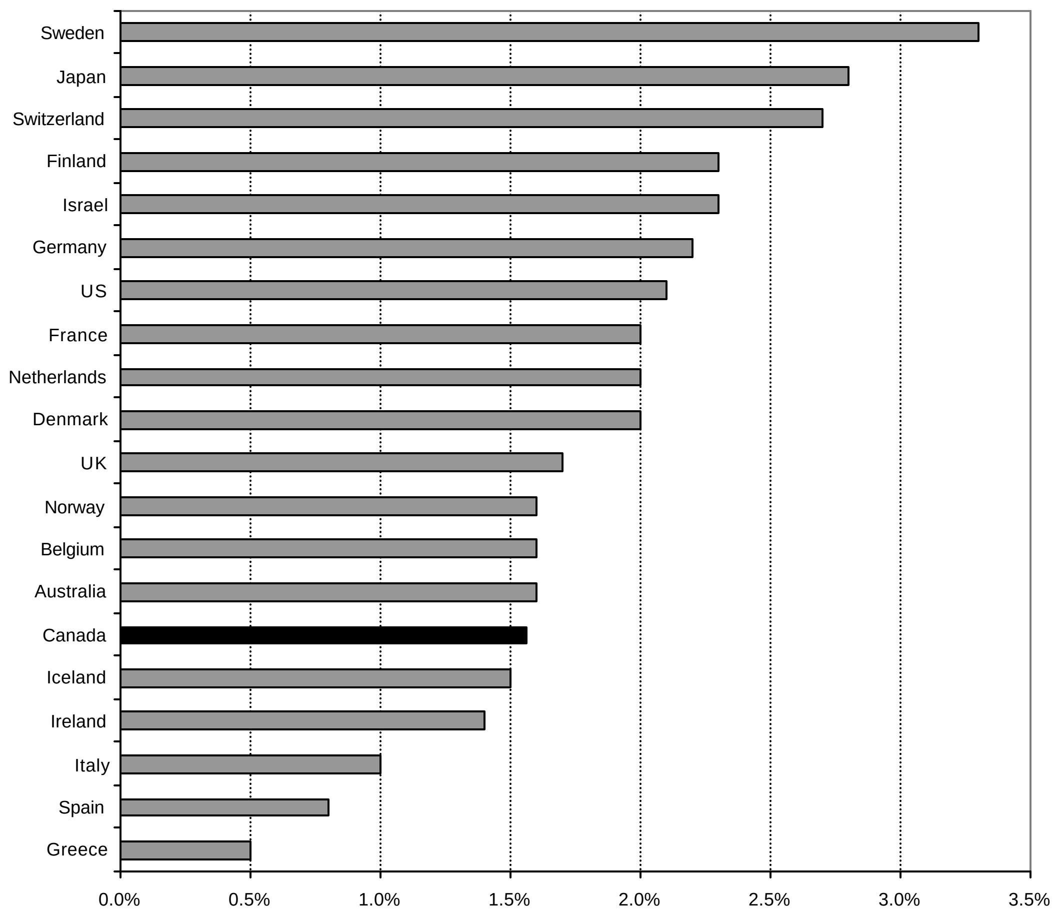

Figure 8b
Civilian R&D Per capita in (PPP) dollars 1996
OECD Countries

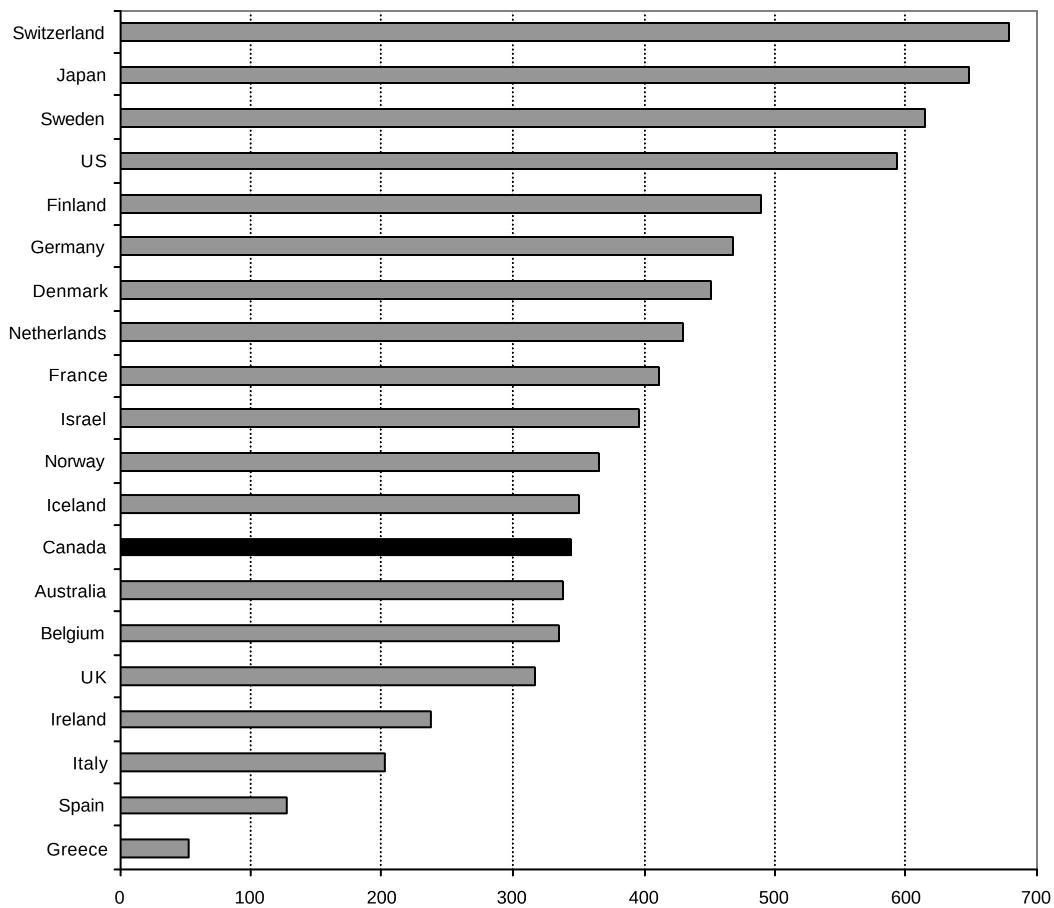

Figure 9
Distribution of Patents by Technology Categories - All US Patents

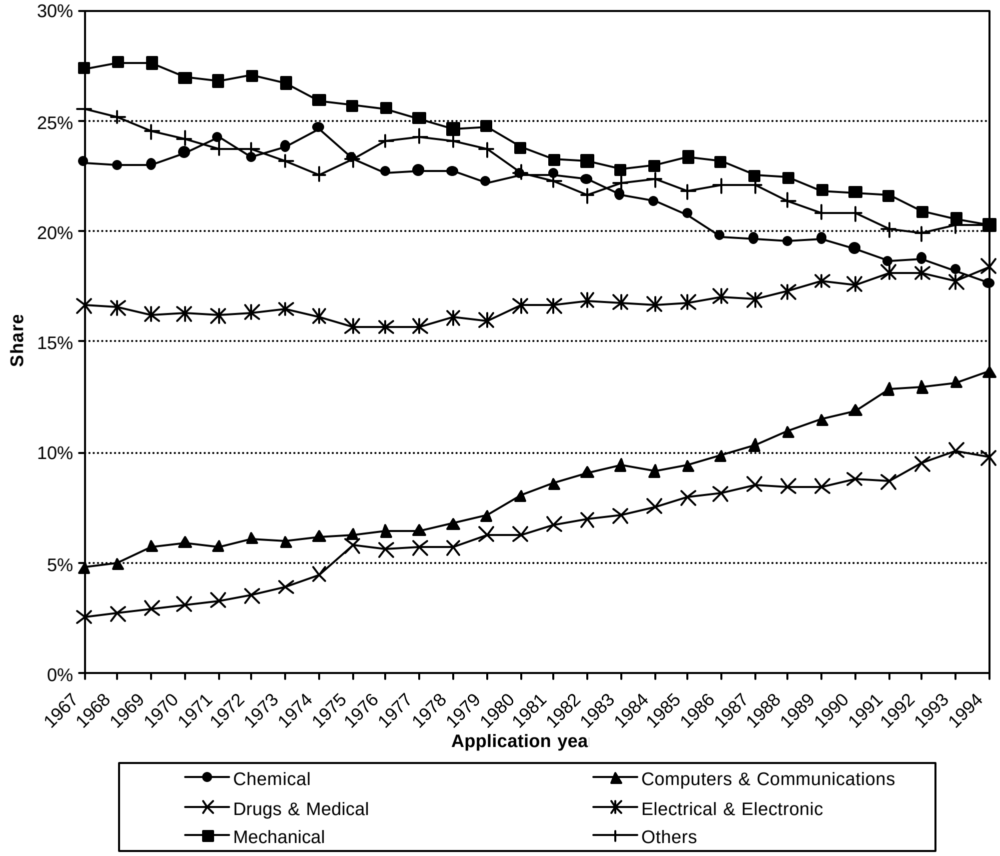

Figure 10
Distribution of Patents by Technological Categories - Canadian Inventors

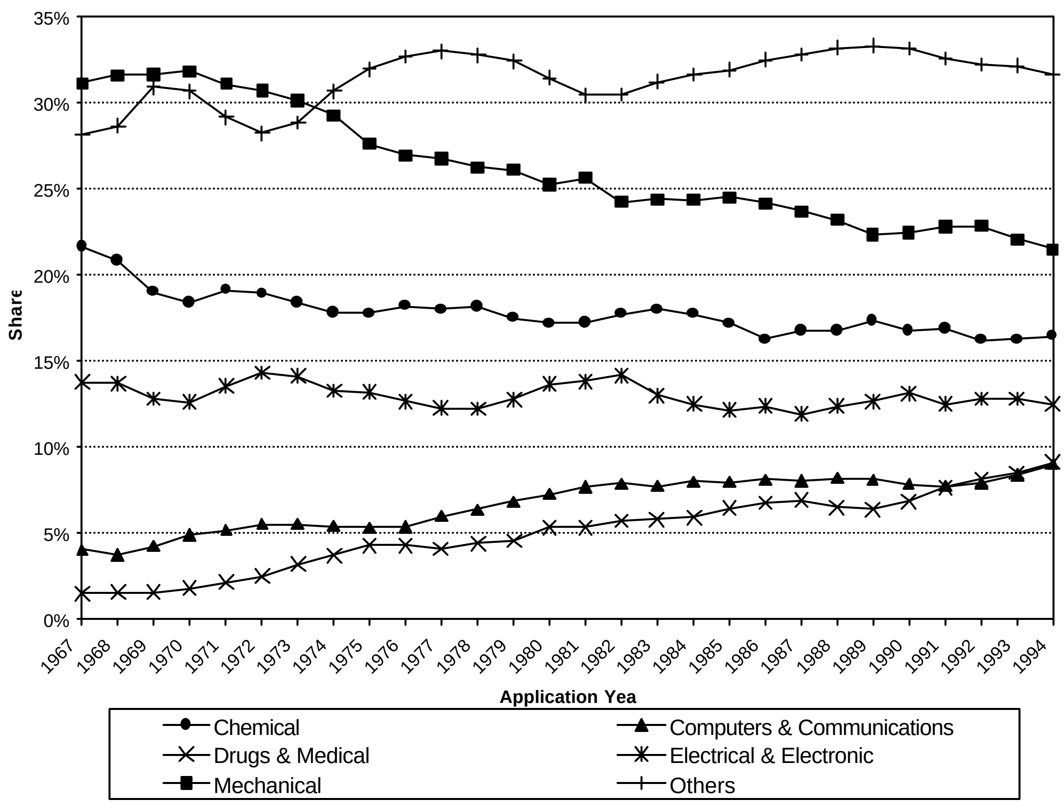

Figure 11
Distribution of Patents by Technological Categories - 1980-1994

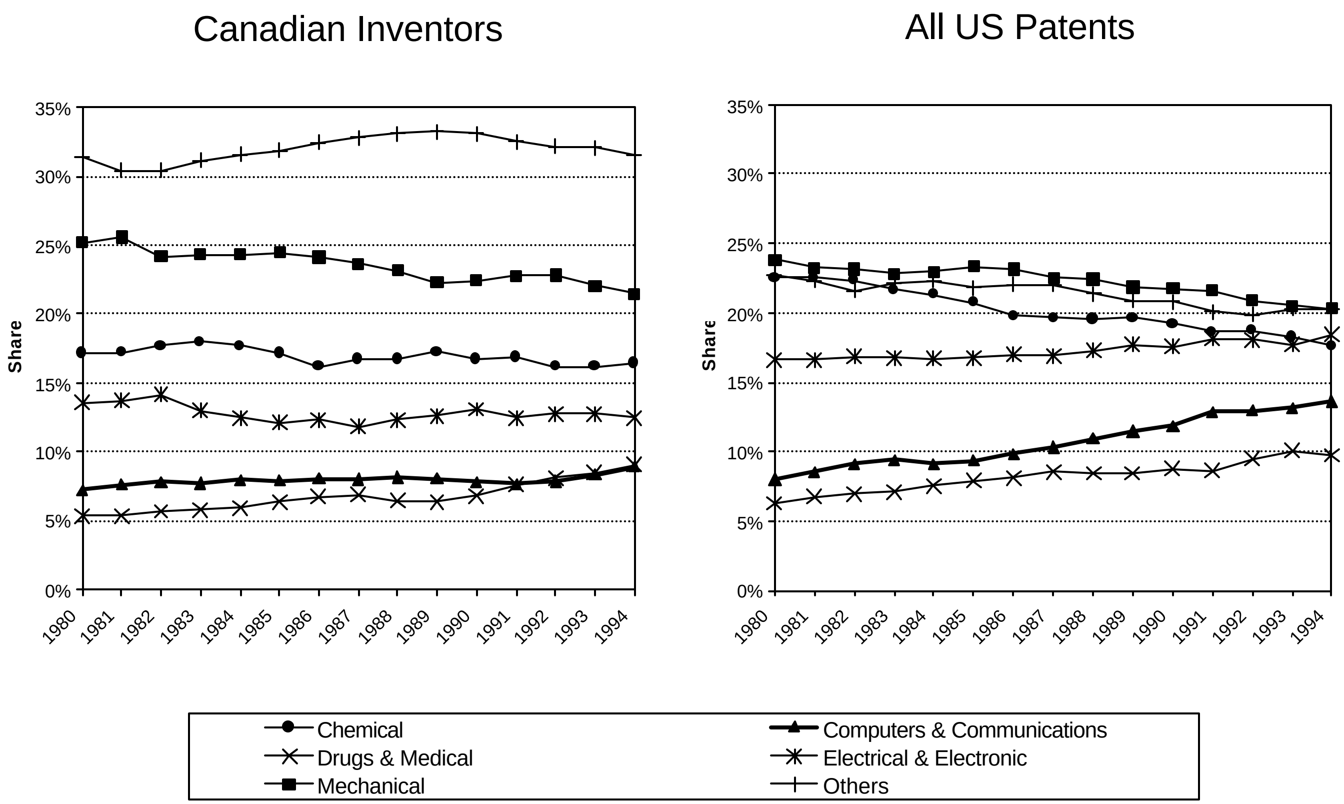

Figure 12
Relative "Importance" of Canadian vs. US Patents
by Technological Category

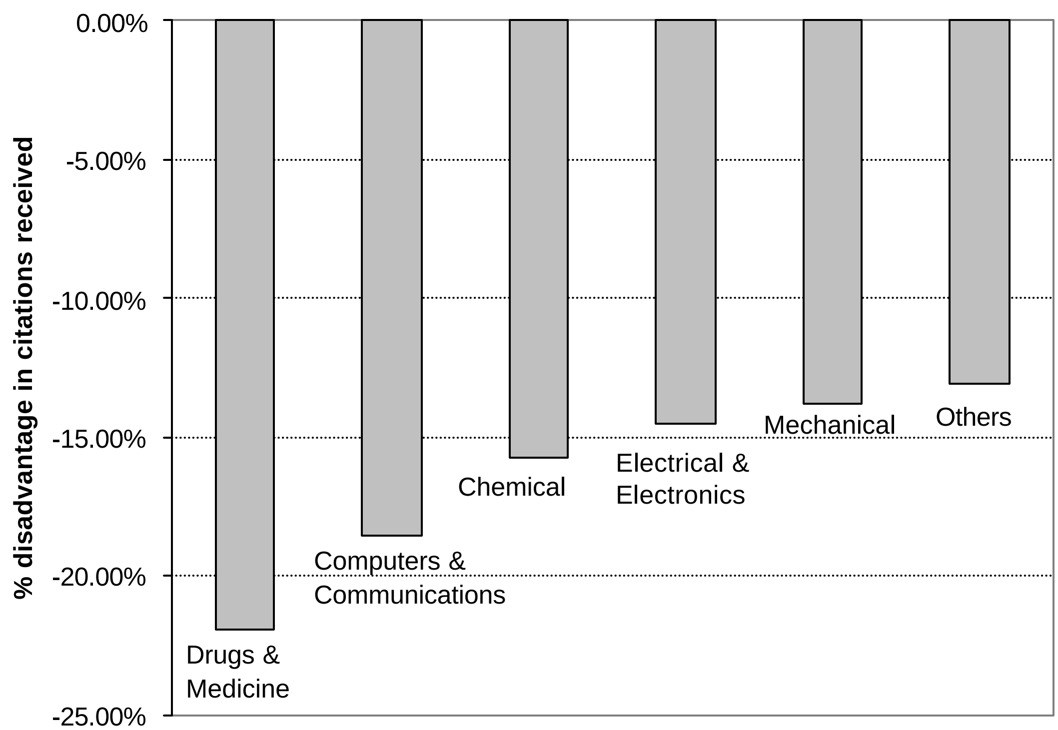

Figure 13
Relative "Importance" of Canadian vs. US Patents
Selected Sub Categories