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Science, Innovation and Electronic Information Division

Regional disparities of research and development in the business services sector

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This paper represents the views of the author and does not necessarily reflect the opinions of Statistics Canada.

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The science and innovation information program

The purpose of this program is to develop **useful indicators of science and technology activity** in Canada based on a framework that ties them together into a coherent picture. To achieve the purpose, statistical indicators are being developed in five key entities:

- **Actors**: are persons and institutions engaged in S&T activities. Measures include distinguishing R&D performers, identifying universities that license their technologies, and determining the field of study of graduates.
- **Activities**: include the creation, transmission or use of S&T knowledge including research and development, innovation, and use of technologies.
- **Linkages**: are the means by which S&T knowledge is transferred among actors. Measures include the flow of graduates to industries, the licensing of a university's technology to a company, co-authorship of scientific papers, the source of ideas for innovation in industry.
- **Outcomes**: are the medium-term consequences of activities. An outcome of an innovation in a firm may be more highly skilled jobs. An outcome of a firm adopting a new technology may be a greater market share for that firm.
- **Impacts**: are the longer-term consequences of activities, linkages and outcomes. Wireless telephony is the result of many activities, linkages and outcomes. It has wide-ranging economic and social impacts such as increased connectedness.

The development of these indicators and their further elaboration is being done at Statistics Canada, in collaboration with other government departments and agencies, and a network of contractors.

Prior to the start of this work, the ongoing measurements of S&T activities were limited to the investment of money and human resources in research and development (R&D). For governments, there were also measures of related scientific activity (RSA) such as surveys and routine testing. These measures presented a limited picture of science and technology in Canada. More measures were needed to improve the picture.

Innovation makes firms competitive and we are continuing with our efforts to understand the characteristics of innovative and non-innovative firms, especially in the service sector that dominates the Canadian Economy. The capacity to innovate resides in people and measures are being developed of the characteristics of people in those industries that lead science and technology activity. In these same industries, measures are being made of the creation and the loss of jobs as part of understanding the impact of technological change.

The federal government is a principal player in science and technology in which it invests over five billion dollars each year. In the past, it has been possible to say only *how much* the federal government spends and *where* it spends it. Our report **Federal Scientific Activities, 1998 (Cat. No. 88-204)** first published socio-economic objectives indicators to show *what* the S&T money is spent on. As well as offering a basis for a public debate on the priorities of government spending, all of this information has been used to provide a context for performance reports of individual departments and agencies.

As of April 1999, the Program has been established as a part of Statistics Canada's Science, Innovation and Electronic Information Division.

The final version of the framework that guides the future elaboration of indicators was published in December, 1998 (**Science and Technology Activities and Impacts: A Framework for a Statistical Information System,** Cat. No. 88-522). The framework has given rise to **A Five-Year Strategic Plan for the Development of an Information System for Science and Technology** (Cat. No. 88-523).
It is now possible to report on the Canadian system on science and technology and show the role of the federal government in that system.

Our working papers and research papers are available at no cost on the Statistics Canada Internet site at http://www.statcan.ca/cgi-bin/downpub/research.cgi?subject=193.

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1. Introduction

The Canadian economy is characterized by the size of the service sector. One of the economy's important characteristics is its capacity to carry out research and development (R&D). Most of the R&D in the service sector is conducted by the business services industries.[1] Elsewhere, the research and development activity contribute to the growth of the economy. Paradoxically, research and development is sometime considered as an activity performed mostly by the fabrication sector.

In this document, we define the "economic dynamic" as the process that characterizes the evolution of a country's or a region's industrial structure. That structure is likely to change in time and space. Accordingly, it makes sense to examine whether disparities in the geographic distribution of jobs and R&D spending persist or disappear. The main purpose of this article is to address this question and to shed light on the importance of efforts dedicated to research and development in the business services sector.

The regional convergence of industrial structure is nothing new. It is a very broad issue that turns up regularly on the political agenda. It is an important question for economic decision-makers because it can influence political choices on matters of regional development and resource reallocation. The subject has been studied thoroughly for the manufacturing sector, where most R&D is done. However, studies of regional convergence are much less numerous in the service sector, particularly on the topic of R&D. Traditionally, most R&D is attributed to the manufacturing sector. Yet R&D is not foreign to the service sector. Like innovation, it simply manifests itself in a different, non-technical form, Djellal, Francoz, Gallouj and Jacquin (2003). Since our national economy consists largely of tertiary activities, we felt it was important to measure R&D effort in that sector.

It would not be an overstatement to say that regional economic convergence is one of the most common topics in economic literature. A number of researchers have studied the spatial convergence of income and employment extensively for many years. Solow (1956), with his neoclassical growth model, was the first to link economic growth and technological progress. The residual variable in Solow's model was largely attributable to innovation and more specifically to the knowledge held by human capital. Subsequently, Romer[2] (1990) provided clarification on the endogenization of R&D in economic growth. Baumol (1986) looked at how quickly the per capita income gap narrowed between 16 industrialized countries in order to test the idea of convergence on an international level. Barro (1991) and Barro and Salaa-I-Martin (1990, 1992) studied the phenomenon of regional and international catch-up in employment. Blanchard and Katz (1992) continued this work in a national context, and for them, the main mechanism for adjusting the allocation of economic activities was labour mobility.

Other researchers focused on the regional and international integration of trade. In particular, Krugman (1991) developed a model of oligopolistic equilibrium that explained why economic activity gravitates to one specific area while other areas are stripped of their industries and become what he calls peripheral regions. In the same vein, Calmette (1994) and Hanson (1998) made empirical estimates of Krugman's (1991) model. Hanson's parametric results show that demand varies with the distance parameter and that income in one locality can affect wages and employment in another locality. Calmette, on the other hand, made an indirect (non-parametric) estimate of Krugman's model. She produced intra-industry trade indexes and compared her results with the explanation provided by the theoretical model. She concluded that the equilibrium of employment distribution between regions is unstable and depends on the initial state of the model's parameters. In a now famous article, McCallum (1995) analyzed the impact that borders and distance have on Canada's national and international trading patterns. He determined that borders had a substantial effect on convergence and trade patterns since trade tends to be east-west rather than north-south.

[1] The business services industry performs 61% of all R&D in the service sector (see Rosa and Gault, 2003).
[2] Robert Solow received the 1987 Nobel Prize in Economics for his work on economic growth.

Finally, the neo-Schumpeterian theories of innovation analyzed the models of convergence and growth of economic structures in terms of technological level and human capital. For example, the theories of technological change and innovation proposed by Dosi and Freeman (1998) show that they generate structural transformations in the economy's components. More recently, Keller (2002) demonstrated that the convergence of economic structures in different countries depends in part on the effects of the spread (or spillover) of local technological knowledge and that those effects decrease with distance.

This brief overview of the literature shows that to analyze the issue of economic integration, one needs a good understanding of technological catch-up either at the international or the regional level. Less advanced regions or countries benefit from the transfer of knowledge through the spread of technology spillovers. This leads to the phenomenon of so-called technological convergence (or catch-up); in other words, the less developed regions gradually narrow the gap. The phenomenon of convergence in a national context is at the very core of the analysis in this article.

More specifically, this paper centres on the neo-Schumpeterian theoretical approach mentioned above. We will analyze the formative impact that technological change has on the regional economy. First we will develop a descriptive portrait of the regional disparities that characterize R&D performers in the business services sector. Then, we will analyze the structure of R&D expenditures and employment using R&D specialization, competitiveness and diversification indexes. These indexes are intended to reflect the various forms of knowledge spillovers.[3] To round out our analysis, we will assess the convergence of regional disparities in R&D spending per employee over the period from 1990 to 2000. As a result of that assessment, we will provide a summary on the source of regional differences in R&D effort. Comparison of these efforts will provide a more direct picture of the nature of the competition between regions and industries in the business services sector.

Keywords: Business services sector, specialization indexes, competitiveness index, diversity index, knowledge spillover, regional disparities.

2.0 Data source

The data in this paper are from Statistics Canada's Survey of Research and Development in Canadian Industry. Statistics Canada has been collecting data on research and development by commercial enterprises since 1955. The survey data used in this article are from a census rather than a sample survey. The survey covered all R&D activities in Canada. It gathered data on each company's revenues, R&D expenditures, R&D personnel by degree, sources of funds for R&D, and payments for R&D on behalf of other organizations such as universities and other companies. This article may serve as a reference document for future users of the survey data; it will also serve as an initial attempt to present the data on services in a chronological context.

[3] A knowledge spillover is the result of any process that facilitates the spread and transmission of information, new ideas and tacit know-how among companies and individuals. Through geographic proximity, the company contributes involuntarily to the knowledge pool. That contribution is called a knowledge spillover Aagrawl (2002).

This study covers the period from 1990 to 2000 and focuses on the business services sector.[4] The findings of this study apply only to companies that reported R&D expenditures. For data quality and confidentiality reasons, we don't go back farther than 1990. However, this period still presents some methodological problems associated with the survey. In 1996, Statistics Canada stopped surveying companies with expenditures of less than $1 million to reduce the response burden. It started using administrative data from the Canada Customs and Revenue Agency (CCRA) to cover small R&D performers. This change in collection methodology improved the coverage of small firms. Adjustments were made in the two years preceding the change for all variables collected. Unfortunately, only revenues and expenditures could be adjusted for the whole period.

Such a change in the database inevitably affected the analysis. It is impossible to study directly for all observations the increase in a variable such as employment over a period that includes the year in which the methodology changed (i.e., before and after 1993). To overcome – or, more correctly, alleviate – the effects of this problem, we retained companies that spent more than $1 million on R&D for the entire period from 1990 to 2000. Statistics Canada surveys such companies directly, using a questionnaire. In some tables, we will present the results for all companies, both those which completed the full questionnaire and the ones (small performers) for which data were provided by the CCRA. For the latter, only the period from 1993 on is covered.

Another important point is that not all the variables were corrected or distributed according to the province in which the companies operated. For example, a company's total revenues and total workforce include all of its operations, no matter where they were located. For our study, we needed those variables broken down by province. As a result, for firms operating in more than one province, we had to distribute the revenues and workforce in proportion to R&D expenditures. This assumption means that if a firm has 30% of its R&D expenditures in a particular province, it will also have 30% of its revenues and workforce there. It seems to be a reasonable assumption, especially since only about 7% of the firms in the business services sector operate in more than one province, which essentially means that their effect on our conclusions about those variables is negligible.

2.1 Methodology

A traditional way of analyzing changes in industrial structure is to describe the reasons for the convergence, or the disappearance of some disparities, between industries or within a particular industry at the regional level for R&D, for example. These disparities can be interpreted through the emergence of agglomerations based on the existence of comparative advantages or spillovers (the company's involuntary contribution to the pool of knowledge). It is widely accepted in the economic literature on endogenous growth (Lucas, 1988; Romer, 1986) that technology and knowledge spillovers are the main forces leading to innovation and sustainable growth. Some forms of industrial organization can be more conducive to the spread of such spillovers than others. For example, we might wonder whether industrial specialization or industrial diversity has the greater influence on the spread of knowledge. We deal with this issue in sections 4.0 and 4.1, explaining how the industrial fabric of the various regions has changed between 1990 and 2000.

[4] The SIC-E codes for business services are: Computer and related services (7721-7722); Architectural, Engineering and others scientific and technical services (7751-7752-7759); Management consulting services (7771); other business services (7711-7712-7731-7739-7741-7742-7743-7749-7761-7791-7792-7793-7794-7795-7796-7799). This last category include: (Employment agencies and personnel suppliers; Accounting and bookkeeping services; Advertising services; Offices of lawyers and notaries; Other business services).

However, the study would seem incomplete if we identified structural change without specifying its cause. In section 5, we perform a decomposition analysis of the ratio of R&D expenditures to number of employees. That ratio is a measure of R&D effort at the company level. The assumption here is that change in industrial structure is partly attributable to R&D effort. As we will see later in the article, the R&D effort between 1990 and 2000 resulted in a reallocation of activities in the business services sector. While we will not provide formal, direct proof of this statement, we show that R&D expenditures and the number of graduates engaged in R&D increased during the period, and that the differences in regional specialization in these two variables diminished.

In the next section, we provide a brief overview of the industrial and regional structure of the resources allocated to R&D in the business services sector. This overview will help us situate the conceptual framework that serves as the starting point for our analysis. We will put the level of resources devoted to R&D in the business services sector into context.

3.0 The industrial and regional structure of the business services sector

Table 1 shows the number of employees engaged in R&D, R&D expenditures and the number of locations where R&D is performed[5], by 3-digit Statistics Canada Standard Industrial Classification (SIC-E) for the business services sector. Computer and related services and architectural, engineering and other scientific and technical services are by far the most active industries in the business services sector. In 2000, they accounted for 94% of R&D jobs, 95% of R&D expenditures and 86% of all business services reporting R&D.

Looking at growth in the sector (companies with R&D expenditures of more than $1 million) between 1990 and 2000, we find that total number of locations performing R&D rose from 155 to 342, the number of R&D jobs climbed from 5,669 to 16,765, and R&D spending grew from $490 million to $1.5 billion, increases of 120%, 195% and 208% respectively.

In 2000, firms reporting over $1 million in R&D spending accounted for 74% of the total R&D expenditures in business services, but only 59% of the jobs.

[5] In our tables “R&D performers’ unities” correspond to the location where the enterprises declared their R&D expenditure.

Table 1
Number of employees engaged in R&D, intramural expenditures (in thousands of dollars) and number of locations performing R&D in business services, by industry

		Companies spending over $1 million on R&D				All companies performing R&D	
		1990	1994	1998	2000	1994	2000
Computer and related services	Employees engaged in R&D	1,842	3,775	5,907	9,175	7,912	15,896
	Total R&D expenditures	135,308	307,492	442,696	671,791	503,077	965,521
	R&D Performers unities	56	105	125	184	1,429	1,697
Architectural, engineering and other scientific and technical services	Employees engaged in R&D	3,524	5,458	6,603	7,106	8,562	10,540
	Total R&D expenditures	326,013	532,566	727,147	792,396	710,051	963,022
	R&D Performers unities	87	134	130	140	1,360	1,194
Management consulting services	Employees engaged in R&D	155	397	198	147	1,074	493
	Total R&D expenditures	13,275	37,382	19,973	13,825	71,121	28,895
	R&D Performers unities	7	15	6	6	281	154
Other business services	Employees engaged in R&D	148	415	508	337	1,106	1,194
	Total R&D expenditures	15,749	30,936	45,949	32,503	63,116	70,120
	R&D Performers unities	5	11	14	12	291	309
Total, business services sector	Employees engaged in R&D	**5,669**	**10,045**	**13,216**	**16,765**	**18,654**	**28,123**
	Total R&D expenditures	**490,345**	**908,376**	**1,235,765**	**1,510,515**	**1,347,365**	**2,027,558**
	R&D Performers unities	**155**	**265**	**275**	**342**	**3,361**	**3,354**
All industries in Canada	Employees engaged in R&D	43,170	52,792	61,887	72,905	78,883	100,892
	Total R&D expenditures	4,532,603	6,220,465	8,511,545	10,799,918	7,567,176	12,174,504
	R&D Performers unities	673	934	1,027	1,207	11,338	10,667

Source: Survey of Research and Development in Canadian Industry

The regional distribution of R&D in the business services sector is also highly concentrated, as indicated by the data in Appendix Table 3. R&D is heaviest in Ontario, with Quebec close behind and British Columbia and Alberta a distant third and fourth respectively. In 2000, Quebec and Ontario together accounted for 78% of R&D jobs, 80% of R&D expenditures and 72% of the locations performing R&D in the business services sector. The corresponding figures for 1994 were 67%, 66% and 64%. Hence, if we look at the business services sector as a whole, the trend toward geographic concentration of R&D activity accelerated between 1994 and 2000.

The R&D in the business services sector accounts for 28% of R&D jobs, 17% of R&D expenditures and 31% of locations that perform R&D (Table 1). Though not trivial, these percentages may seem rather modest relative to the figures for the manufacturing sector. In 10 years, the growth of R&D in the business services sector was rather remarkable. Companies that spent at least $1 million on R&D accounted for 23% of total R&D jobs in the economy in 2000, compared with just 13% in 1990. Growth in R&D expenditures was more modest, as they edged up from 11% in 1990 to 14% in 2000.

While we must acknowledge that R&D remains primarily a manufacturing activity, the business services sector has certainly improved its importance in that area. This is particularly true for British Columbia, as 39% of its R&D jobs are in the business services sector (this figure was computed from the data in Appendix Tables 3 and 4).

3.1 Human resources engaged in research and development

People employed in R&D need a high level of skill and knowledge. By the nature of the work, most R&D jobs are highly skilled in the sense that they generally require a university education. Not surprisingly, therefore, R&D work absorbs many postsecondary graduates. Table 2 below presents the percentage of employees with postsecondary degrees relative to the total number of employees engaged in R&D, by industry. A postsecondary graduate is someone who has a bachelor's, master's or doctoral degree.

Between 1990 and 2000, the proportion of employees with postsecondary degrees engaged in R&D increased steadily in the business services sector. For companies in the sector that spent more than $1 million on R&D, the proportion rose from 11% in 1990 to 20% in 2000.[6] When all companies are included, the figures are slightly lower (see Table 2).

For the business services sector as a whole, the average proportion of employees with postsecondary degrees engaged in R&D was 16% in 2000. For companies in the sector that spent more than $1 million on R&D, the proportion was 20%. The corresponding figures for all industries in Canada are 4% and 5%. This indicates that the proportion of postsecondary graduates engaged in R&D is much higher in the service sector than in the rest of the economy. We can therefore observe that the business services sector is very intensive in terms of R&D employment.

In 2000, computer and related services and architectural, engineering and other scientific and technical services had the highest proportions of postsecondary graduates (17% in each case). If we confine ourselves to companies that reported R&D expenditures of more than $1 million, management consulting services had the largest proportion of postsecondary graduates (43%).

[6] By way of comparison, 20% of the full-time labour force had a university degree in 2000 (source: CANSIM matrix 282-0004).

Table 2
Employees with postsecondary degrees engaged in R&D as a percentage of total employment in business services,[7] by industry

		Highly skilled employees (bachelor's, master's, doctorates) / Total employment		Total (bachelor's, master's, doctorates, technicians and other) / Total employment	
		Companies spending over $1 million on R&D	**All companies performing R&D**	**Companies spending over $1 million on R&D**	**All companies performing R&D**
Computer and related services	1990	14	14	24	25
	1994	19	17	28	26
	1998	26	18	36	26
	2000	19	17	27	26
Architectural, engineering and other scientific and technical services	1990	12	11	25	20
	1994	20	11	36	19
	1998	18	14	33	24
	2000	20	17	30	25
Management consulting services	1990	6	7	12	12
	1994	22	13	34	20
	1998	26	13	46	20
	2000	43	10	60	15
Other business services	1990	3	4	4	7
	1994	4	5	6	8
	1998	18	4	25	7
	2000	17	8	23	13
Total, business services sector	1990	**11**	**11**	**21**	**19**
	1994	**17**	**12**	**28**	**20**
	1998	**22**	**14**	**34**	**22**
	2000	**20**	**16**	**28**	**24**
All industries in Canada	1990	2	2	4	4
	1994	3	3	5	5
	1998	4	3	6	5
	2000	5	4	7	7

Source: Survey of Research and Development in Canadian Industry

However, management consulting services employ very few R&D personnel (only 493 out of 28,123 total jobs in 2000). This is as a reminder that it is important to exercise caution when interpreting percentages. In addition, the substantial fluctuations in the figures for the industry are due to the small number of companies it contains. Of the six firms surveyed in 1998 and 2000, only one remained for the whole period; the rest are new or have disappeared.

While both industries have high proportions of postsecondary graduates, together they have only 6% of all employees engaged in R&D.

4.0 Structures and technology spillovers in the business services sector

In the preceding sections, we observed that R&D employment and expenditures increased during the last decade in the business services sector. At this point, it makes sense to ask whether that growth had a significant impact on the regional structure.

[7] This percentage is equal to the number of employees with postsecondary degrees engaged in R&D over the company's total number of employees for the industry considered. As previously noted, this includes only those companies which reported performing R&D.

The sectoral structure of R&D employment and expenditures reflects more than mere information about economic aggregation; it provides a picture of the composition of a region's industrial fabric and an overview of its evolution in time and space. The evolution of the structure of R&D employment and expenditures is an indicator of the economy's ability to adapt to change. Information about levels of specialization, diversity and competition in the regional R&D production structure helps governments formulate regional development policy.

The speed with which the structure of R&D employment or expenditures in the business services sector responds to change will determine the sector's ability to adapt to competition. A region in which the dominant industry has a rapidly evolving technological structure may show that the industry is healthy and dynamic, particularly in relation to competing industries whose employment structures are much less volatile.[8]

In this section, we provide some structural indicators of R&D employment and expenditures. These indicators will not only provide us with an overview of the business services sector's R&D composition by region but also help us establish a link with theoretical explanations of spillovers.

Let start with the following question: What is the relationship between technological structure and technology spillover?

Indeed, the link between technological structure and knowledge spillover is not new. In the literature, Romer (1986) and Lucas (1988) putted forward the idea that technology spillover is the main factor leading to innovation. Knowledge spillovers are due to the growth and accumulation of the knowledge pool. This accumulation of knowledge is enhanced by geographic proximity, which facilitates the transfer of knowledge, new ideas and tacit know-how between companies and individuals. Hence there is a direct relationship between the spatial distribution of industries and the efficiency with which knowledge is transmitted and circulated among companies and individuals. That relationship provides the justification for our interpretation of the structural indicators of R&D employment and expenditures. The index values are presented in appendix tables. For a detailed interpretation, explanation and description of the structural indicators, see Box A.

In general, two types of spillovers are discussed in economic literature: location spillovers, which are sector-specific, and agglomeration spillovers, which are common to all companies (Maurel, 1996). The former type is based on the work of Marshall (1890), Arrow (1962) and Romer (1986, 1990) (MAR to abbreviate). Those authors focus on the concept of human capital as the source of knowledge spillovers. Under those conditions, local monopoly promotes the transfer of knowledge. There are variations on this approach, such as that of Porter (1990), who sees competition, not local monopoly, as the main engine of growth. The second type, location spillovers, refers to the work of Jacobs (1969), who views spillovers as a product of the diversity of the industrial fabric.

[8] However, it is important to exercise caution in interpreting these indexes. Because the population is small, they can be affected dramatically by the disappearance or creation of just one firm. We encountered this problem primarily in the data for all business services industries on the Prairies and to a lesser extent in the data for management consulting services and other business services in the Maritimes and Alberta.

Box A

All the indexes defined below are indicators that help understand the economic structure of research and development in the business services sector.

1. Indexes of sectoral specialization (Balassa Index and Aquino Index)

The Balassa Index reflects what economists call the technology spillovers of location or the knowledge spillovers. Marshall (1890), Arrow (1962) and Romer (1990) (often abbreviated MAR in the literature) have shown that the more important a sector is in a local economy, the more it promotes the region's development and growth. In other words, the authors predict that local monopoly is better for economic growth than competition is. In their view, local monopoly internalizes knowledge spillovers better than the competition system does.

Definition of the specialization index (Balassa):

$$Let\ B_i^k = \frac{\dfrac{L_{i,k}}{L_k}}{\dfrac{L_{i,I}}{L_I}}$$

Where $L_{i,k}$ is the number of R&D jobs (or R&D expenditures) in industry i (business services sector) in region k, and L_k is the total R&D employment (or expenditures) in region k. Finally, $L_{i,I}$ represents R&D employment (or expenditures) in the business services sector in Canada, and L_I represents total R&D employment (or expenditures) in Canada. When the index is greater than 1, it indicates a high level of specialization in business services in region k, while a value of less than 1 indicates a low level of specialization in business services in the region.

2. Indexes of intrasectoral competitiveness

This index also reflects location spillovers, but in Porter's approach (1990), the competition system – not local monopoly – maximizes the spillovers by encouraging imitation and the transmission of innovative ideas.

$$Let\ P_{i,k} = \frac{\dfrac{E_{i,k}}{L_{i,k}}}{\dfrac{E_{i,I}}{L_{i,I}}}$$

Where $E_{i,k}$ is the number of companies in industry i (business services) in region k, and $L_{i,k}$ is the number of R&D jobs in industry i in region k. The denominator represents the same quotient at the national level. When the index is greater than 1, it means that industry i is more competitive in region k than the same industry at the national level.

3. Indexes of intrasectoral diversity (Herfindahl Index)

This index reflects the idea that the most important spillovers are those which relate to the diversity of the economic environment. Jacobs (1969) used this approach, considering that industrial diversity stimulates growth and the spread of ideas.

$$H_i^k = \sum_{j \neq i} s_{jk}^2$$

Where s_{jk} is the share of business services industry j relative to all other business services industries in region k except industry i. An increase in this index can be interpreted as an increase in local concentration, or a decrease in the region's intrasectoral diversity (a case specific to our study, since we are focusing exclusively on the business services sector). Conversely, a decline in the index means that the region has a high level of intrasectoral diversification.

4.1 Industrial structure and spread of knowledge in the business services sector

In this study, we computed structural indexes reflecting the various forms of spillovers mentioned in the previous section, using the formulas described in Box A. The detailed results of these indexes are presented in the Appendix (Tables 5 through 10).

An analysis of the tables provide a number of important observations. An initial overview of Appendix Table 5 indicates that British Columbia is the most specialized province with respect to R&D jobs in business services. The Maritime provinces also seem to be highly specialized in R&D jobs in business services compared with the rest of the R&D jobs in the economy. Quebec appears to have been more specialized in such jobs than Ontario between 1990 and 2000. During that period, the level of specialization of the provinces remained relatively stable, though there was a slight upward trend in R&D labour specialization in Quebec and a significant decline in British Columbia. The relatively rapid change in British Columbia's R&D employment structure clearly points to some kind of disruption in the sector. There was probably a sectoral reallocation of R&D jobs. As a result, the regional levels of specialization showed a tendency to converge over the course of the decade.

The Maritimes had proportionally more intrasectoral competition in R&D employment in business services, according to the indexes in Appendix Table 6. The Prairies and Alberta also had a high level of competition in this sector. Over the period from 1990 to 2000, the level of competition remained relatively stable in all provinces except the Maritimes, which exhibited a downward trend. Once again, the results suggest that provincial levels of competition in the sector were converging.

The Herfindahl diversity index for employment, shown in Table 7, produces some very interesting results. Ontario had the highest diversification index in 2000, and the province's index was on an upward trend over the period from 1990 to 2000. This suggests that Ontario is moving toward industrial concentration in the business services sector, particularly in computer and related services. The trend for Quebec and British Columbia appears to be in the opposite direction. Between 1990 and 2000, both provinces showed an increase in industrial diversity in this sector.[9]

The indexes for R&D expenditures are presented in Tables 8, 9 and 10. The pattern of R&D expenditures is nearly identical for the specialization and competitiveness indexes. In other words, the provincial patterns of R&D employment and R&D expenditures provide the same information. What is surprising is the result for the diversity index of R&D expenditures in Ontario. As indicated above, Ontario was observed to have a significant level of intrasectoral concentration in R&D employment. In R&D expenditures, however, Ontario exhibited a high level of intrasectoral diversity (see Table 10). This means that Ontario's R&D employment structure is heavily concentrated in computer and related services, whereas its R&D expenditures are spread more evenly across the various industries.

Overall, the indexes that we have described here show that the business services sector's organizational structure changed substantially between 1990 and 2000. The number of R&D jobs and the amounts spent on R&D grew exponentially. The reallocation and creation of R&D jobs certainly was (and continues to be) an important issue for Canada, and it took place very quickly, as shown by the rapid change in the structure of the business services sector.

In British Columbia, specialization in R&D jobs in the business services sector would be the industrial structure that best explains the spread of knowledge in the province (the MAR approach). In the Maritimes, on the other hand, industrial competition in business services would promote the spread of knowledge in the sector (Porter's approach). In Quebec and Alberta, the spread of knowledge is spurred by industrial

[9] The occasional sharp variations in this index for Alberta, the Maritimes and the Prairies are due to the small number of observations in management consulting services and other business services.

diversity in the business services sector (Jacobs's approach). In short, we cannot determine which form of industrial structure in the business services sector would do most for the spread of R&D knowledge. The mechanism of R&D knowledge transfer is not the same across Canada; rather, it appears to be based on region-specific organizational structures.

5.0 Regional convergence of R&D effort

We have just shown how the regional structure of R&D employment can reflect the transfer of knowledge. To some extent, the structural indexes have also provided an overview of the evolution of the regional composition of R&D employment and expenditures between 1990 and 2000. However, the indexes provide no information about R&D effort and even less about regional differences in R&D effort.

The R&D spending effort partly reflects the comparative advantages of one region over another in the business services sector. In this section, we will not focus on the level of R&D spending effort in each province, but rather on the evolution and composition of the cumulative differences in that effort over the 1990-2000 period. This information will give us a good idea of the extent of the disparities between provinces and how those disparities expanded or shrank during the period.

To support our argument, we will use the decomposition method. This means building an equation in which the ratio of R&D spending to the number of employees is equal to the product of a number of other ratios. (For more details, see equation (1) in Box B.) Then we compute the ratio's variance (see equation (2) in Box B) and the variances of the decomposition terms. This method helps us identify the source of the variation in R&D spending effort. Coulombe and Day (1999) used the method in an article on income disparities between Canada and the United States.

Chart 1 illustrates the differences in the decomposition of the R&D effort ratio. There is a remarkable convergence in R&D spending per employee in the business services sector. It appears that over the 10-year period, the disparities between regions became much smaller.

Early in the decade, the covariations of the decomposed ratios explained most of the differences between provinces. This means that for example, when the financial effort committed to R&D varies, the human resources effort committed to R&D varies in the same direction. In other words, if the covariations are important in explaining regional differences in R&D effort per employee, it means that the joint contributions of the ratios of R&D expenditures to revenues, revenues to R&D employment, and R&D employment to total employment explain most of the differences. The disparities were probably reduced by a combined effort in R&D employment and R&D expenditures rather than by separate efforts for each variable.

Appendix Table 11 provides a good overview of R&D spending per employee. In 2000, Alberta, British Columbia and the Maritimes spent between $34,000 and $40,000 per employee on R&D in the business services sector. The Prairies spent $61,000. All regions increased their expenditures over the decade. Although these amounts are considerably lower than the $100,000 spent per employee in manufacturing, R&D is still growing steadily in the business services sector.

Box B

Formulation of the equation:

$$\frac{T\_DEPRD}{T\_EMP} = \frac{T\_DEPRD}{T\_REV} \bullet \frac{T\_REV}{T\_EMPRD} \bullet \frac{T\_EMPRD}{T\_EMP} \qquad \textbf{Equation (1)}$$

$$var(A) = var(B) + var(C) + var(D) + 2cov(B,C) + 2cov(B,D) + 2cov(C,D) \qquad \textbf{Equation (2)}$$

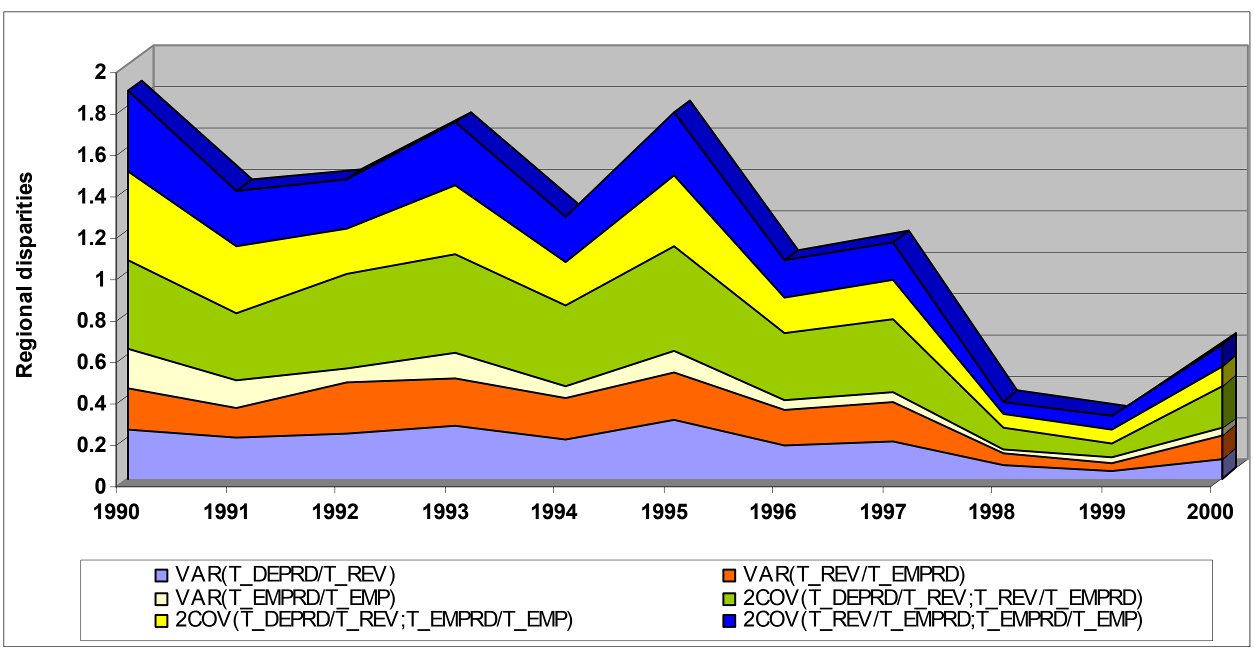
Where $A = LOG\left(\frac{T\_DEPRD_i}{T\_EMP_i}\right)$ $B = LOG\left(\frac{T\_DEPRD_i}{T\_REV_i}\right)$

$C = LOG\left(\frac{T\_REV_i}{T\_EMPRD_i}\right)$ $D = LOG\left(\frac{T\_EMPRD_i}{T\_EMP_i}\right)$; Index i indicates the province.

The first ratio in equation (1) reflects the intensity of R&D expenditure, that is, the **R&D effort per employee**. This intensity can in turn be broken into various components. The first component represents R&D expenditures as a percentage of the company's total revenue, which reflects the **financial effort committed to R&D**. The second component is a return-on-investment ratio for R&D jobs. The third component is R&D jobs as a percentage of the company's total workforce, that is, a ratio of the **human resources effort committed to R&D**.

Chart 1 below clearly shows the evolution and source of differences in R&D spending effort. The convergence in R&D effort is notable. As indicated in Chart 3, the absolute difference declined from more than 2.5 to less than 1.1.

Chart 1: Variation of the ratio of R&D expenditures to total employment during the period 1990-2000.



6.0 Conclusion

This article has described the growth and level of research and development in the business services sector. In 2000, over $2 billion was spent on R&D and over 28,000 employees were engaged in R&D. We have also shown that there are disparities in R&D employment and expenditures not only between industries but also between provinces.

The following are some of the highlights of our study.

In 2000, the business services sector accounted for 28% of all jobs in research and development, 17% of all such spending and 31% of firms that perform R&D.

R&D performers in the business sector that spend at least $1 million on R&D accounted for 23% of total R&D jobs in the economy in 2000, compared with just 13% in 1990. These performers accounted for 14% of R&D spending in 2000, up from 11% a decade earlier.

R&D activity in the business services sector is highly concentrated. Most of it occurs in Quebec and Ontario in computer and related services and architectural, engineering and other scientific and technical services.

The proportion of postsecondary graduates (bachelor's, master's or doctoral degrees) engaged in R&D is higher for architectural, engineering and other scientific and technical services than for the other three industries in the sector. At the national level in 2000, the proportion of employees engaged in R&D for companies reporting R&D in the sector was over 16%, compared with just 4% at the national level.

The structure of R&D employment in the business services sector can be explained through various conceptual models. British Columbia is relatively specialized in the business services sector. The Maritimes has a more competitive R&D employment structure than any other part of Canada. In the Maritimes, competitiveness between industries in the business services sector is a model that encourages the transfer of knowledge. Ontario has the highest concentration of industries in the sector. In Quebec, the Maritimes and to a lesser extent British Columbia, the industries in the sector became more diverse between 1999 and 2000.

Over the 10-year period (from 1990 to 2000), provincial differences in R&D spending effort in the business services sector declined appreciably. Geographic disparities diminished over the course of the decade. Combined changes in financial effort, profitability and human resources engaged in R&D accounted for most of the decrease in regional differences in R&D spending.

Appendix

Table 3
Number of employees engaged in R&D, intramural expenditures (in thousands of dollars) and number of locations for companies performing R&D, in the business services sector, by region

		Companies spending over $1 million on R&D				All companies performing R&D	
		1990	1994	1998	2000	1994	2000
Maritimes	Employees engaged in R&D	94	167	178	234	469	695
	Total R&D expenditures	6,378	11,985	11,112	15,575	28,943	34,724
	R&D Performers unities	10	10	8	9	141	136
Quebec	Employees engaged in R&D	1,539	2,800	4,721	6,537	5,513	10,678
	Total R&D expenditures	136,301	256,682	415,425	592,656	384,877	785,955
	R&D Performers unities	28	59	76	114	970	1,203
Ontario	Employees engaged in R&D	2,538	3,844	5,265	6,757	6,910	11,225
	Total R&D expenditures	208,969	349,329	491,077	640,567	510,880	841,278
	R&D Performers unities	74	113	124	144	1,177	1,200
Saskatchewan and Manitoba	Employees engaged in R&D	91	357	196	245	580	458
	Total R&D expenditures	7,521	29,418	30,488	19,136	39,539	28,357
	R&D Performers unities	5	13	5	8	104	97
Alberta	Employees engaged in R&D	478	875	741	584	1,767	1,578
	Total R&D expenditures	39,765	70,391	59,336	47,163	114,844	92,821
	R&D Performers unities	15	23	21	15	375	328
British Columbia	Employees engaged in R&D	929	2,002	2,115	2,408	3,415	3,489
	Total R&D expenditures	91,411	190,571	228,327	195,418	268,282	244,423
	R&D Performers unities	23	47	41	52	594	390
Total, business services sector	Employees engaged in R&D	**5,669**	**10,045**	**13,216**	**16,765**	**18,654**	**28,123**
	Total R&D expenditures	**490,345**	**908,376**	**1,235,765**	**1,510,515**	**1,347,365**	**2,027,558**
	R&D Performers unities	**155**	**265**	**275**	**342**	**3,361**	**3,354**

Source: Survey of Research and Development in Canadian Industry

Table 4
Number of employees engaged in R&D, intramural expenditures (in thousands of dollars) and number of locations for companies performing R&D, in all sectors combined, by region

		Companies spending over $1 million on R&D				All companies performing R&D	
		1990	**1994**	**1998**	**2000**	**1994**	**2000**
Maritimes	Employees engaged in R&D	523	732	726	841	1,630	1,947
	Total R&D expenditures	64,840	77,156	71,161	85,879	125,249	135,233
	R&D Performers unities	41	40	51	63	451	455
Quebec	Employees engaged in R&D	11,499	14,856	18,733	23,259	23,731	34,486
	Total R&D expenditures	1,246,622	1,638,563	2,332,096	3,008,495	2,056,172	3,554,551
	R&D Performers unities	138	229	270	332	3,697	4,492
Ontario	Employees engaged in R&D	25,436	29,092	33,595	38,274	38,826	48,780
	Total R&D expenditures	2,558,209	3,572,503	4,912,724	6,199,160	4,111,579	6,721,060
	R&D Performers unities	304	411	445	501	4,053	3,508
Saskatchewan and Manitoba	Employees engaged in R&D	787	1,156	1,261	1,482	2,283	2,322
	Total R&D expenditures	71,959	116,134	144,586	166,452	172,111	206,576
	R&D Performers unities	46	62	59	68	528	404
Alberta	Employees engaged in R&D	2,132	2,762	3,037	2,527	4,815	4,412
	Total R&D expenditures	306,534	401,831	536,269	486,280	508,812	581,843
	R&D Performers unities	68	87	85	90	993	777
British Columbia*	Employees engaged in R&D	2,793	4,194	4,535	6,522	7,598	8,945
	Total R&D expenditures	284,439	414,278	514,709	853,652	593,253	975,241
	R&D Performers unities	76	105	117	153	1,616	1,031
All industries in Canada	Employees engaged in R&D	**43,170**	**52,792**	**61,887**	**72,905**	**78,883**	**100,892**
	Total R&D expenditures	**4,532,603**	**6,220,465**	**8,511,545**	**10,799,918**	**7,567,176**	**12,174,504**
	R&D Performers unities	**673**	**934**	**1,027**	**1,207**	**11,338**	**10,667**

Source: Survey of Research and Development in Canadian Industry
* For reasons of confidentiality, Yukon, the Northwest Territories and Nunavut are included with British Columbia. The figures for the territories are negligible.

Table 5. Specialization index (Balassa) for R&D employment

	MARI	QC	ONT	PRAI	ALB	BC
1990	1.4	1.0	0.8	0.9	1.7	2.5
1991	1.8	1.0	0.7	1.5	1.5	2.9
1992	1.4	0.9	0.7	2.1	2.1	2.4
1993	1.5	0.9	0.8	1.2	1.8	2.5
1994	1.2	1.0	0.7	1.6	1.7	2.5
1995	1.1	1.1	0.6	1.1	1.5	2.0
1996	1.2	1.2	0.7	1.0	1.7	2.0
1997	1.7	1.3	0.6	0.8	1.7	2.2
1998	1.1	1.2	0.7	0.7	1.1	2.2
1999	1.4	1.2	0.7	0.7	1.2	2.1
2000	1.2	1.2	0.8	0.7	1.0	1.6

Source: Survey of Research and Development in Canadian Industry

Table 6. Competitiveness index (Porter) for R&D employment

	MARI	QC	ONT	PRAI	ALB	BC
1990	3.9	0.7	0.1	2.0	1.1	0.9
1991	3.3	0.7	0.1	1.0	1.2	0.9
1992	3.3	0.8	0.1	1.3	0.9	0.9
1993	2.8	0.8	0.1	2.0	0.9	0.8
1994	2.3	0.8	0.1	1.4	1.0	0.9
1995	2.3	0.7	0.2	1.2	1.1	0.9
1996	2.2	0.8	0.2	1.4	1.0	1.0
1997	2.2	0.8	0.1	2.0	1.0	1.0
1998	2.2	0.8	0.2	1.2	1.4	0.9
1999	1.9	0.8	0.2	0.8	1.3	1.0
2000	1.9	0.9	0.2	1.6	1.3	1.1

Source: Survey of Research and Development in Canadian Industry

Table 7. Diversification index (Herfindahl) for R&D employment

	MARI	QC	ONT	PRAI	ALB	BC
1990	2.2	8.2	1.6	4.4	29.8	6.2
1991	2.0	3.9	1.4	1.2	139.1	4.3
1992	3.2	3.3	1.4	0.8	278.1	2.5
1993	2.2	5.8	1.4	6.1	28.7	3.7
1994	2.1	5.0	1.7	1.3	14.0	2.7
1995	3.2	6.4	2.7	1.3	13.0	4.2
1996	2.1	3.3	2.5	1.5	10.7	3.3
1997	4.3	4.0	1.6	50.2	4.7	1.3
1998	2.2	3.8	2.8	0.0	3.6	1.9
1999	16.1	6.2	3.3	0.0	1.6	2.9
2000	5.5	2.5	9.3	7.8	2.2	1.7

Source: Survey of Research and Development in Canadian Industry

Table 8. Specialization index (Balassa) for R&D expenditures

	MARI	QC	ONT	PRAI	ALB	BC
1990	0.9	1.0	0.8	1.0	1.2	3.0
1991	1.4	0.9	0.7	2.7	1.3	3.4
1992	1.0	0.9	0.7	2.2	1.5	3.2
1993	1.2	0.9	0.8	1.9	1.2	3.0
1994	1.1	1.1	0.7	1.7	1.2	3.2
1995	1.1	1.2	0.7	0.9	1.1	2.9
1996	1.0	1.3	0.6	0.9	1.1	2.8
1997	1.4	1.2	0.7	1.3	1.2	3.0
1998	1.1	1.2	0.7	1.5	0.8	3.1
1999	1.1	1.2	0.7	0.9	0.9	3.0
2000	1.3	1.4	0.7	0.8	0.7	1.6

Source: Survey of Research and Development in Canadian Industry

Table 9. Competitiveness index (Porter) for R&D expenditures

	MARI	QC	ONT	PRAI	ALB	BC
1990	5.0	0.6	1.1	2.1	1.2	0.8
1991	4.7	0.8	1.1	0.6	1.1	0.8
1992	5.0	0.9	1.1	1.2	1.0	0.7
1993	3.4	0.8	1.1	1.5	1.1	0.8
1994	2.9	0.8	1.1	1.5	1.1	0.8
1995	2.9	0.8	1.1	2.0	1.3	0.8
1996	2.9	0.8	1.2	2.1	1.2	0.8
1997	3.3	0.8	1.1	1.4	1.1	0.8
1998	3.2	0.8	1.1	0.7	1.6	0.8
1999	3.0	0.9	1.1	0.7	1.6	0.8
2000	2.6	0.8	1.0	1.8	1.4	1.2

Source: Survey of Research and Development in Canadian Industry

Table 10. Diversification index (Herfindahl) for R&D expenditures

	MARI	QC	ONT	PRAI	ALB	BC
1990	1.9	19.1	1.4	2.9	55.8	15.3
1991	2.3	5.7	1.3	7.0	180.1	5.8
1992	1.9	5.1	1.4	1.8	273.8	3.2
1993	2.2	5.7	1.4	19.1	42.3	9.8
1994	2.2	4.0	1.4	1.5	20.7	6.8
1995	2.5	5.1	1.6	1.8	11.5	10.6
1996	2.2	4.3	1.6	2.1	9.9	5.8
1997	2.5	6.3	1.2	32.3	4.9	2.3
1998	2.0	8.2	1.6	0.0	3.1	4.3
1999	11.0	10.4	1.9	0.0	1.7	12.9
2000	14.7	6.8	3.1	7.0	2.1	1.9

Source: Survey of Research and Development in Canadian Industry

Table 11. R&D expenditures per employee in the business services sector, for companies spending more than $1 million on R&D

	T_DEPRD/T_EMP					
	MARI	QC	ONT	PRAI	ALB	BC
1996	35,916	34,943	19,472	35,894	10,379	47,855
1997	39,207	33,247	31,586	72,587	11,280	38,806
1998	36,795	27,414	32,932	107,731	36,402	33,922
1999	31,419	19,111	29,099	97,701	30,583	43,836
2000	39,732	22,158	25,955	61,137	34,226	34,212

Source: Survey of Research and Development in Canadian Industry

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