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COMPARING THE INNOVATION PERFORMANCE OF CANADIAN FIRMS AND THOSE OF SELECTED EUROPEAN COUNTRIES: AN ECONOMETRIC ANALYSIS.

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1- **Background**

Innovation is seen by many as one of the major engines of growth, and yet many studies show that innovation rates vary considerably across countries. Using patenting rates (international patents/million of population) as a measure of innovation, Stern and al. (2000) show that from 1975 to 1995 only Switzerland managed to keep pace with the US inventors with more than 150 international patents per capita. Japan caught up with the two leaders towards the end of the 80s and even outpaced them in the 90s. Following these top three countries, Sweden, Finland, Germany and Canada are in the second group with less than 100 int'l patents per capita. Finally, there is a third group with less than 50 international patents per capita, to which France and Spain belong. These findings are corroborated by Trajtenberg (2000) using the same database but for slightly different years.

Other studies use indicators derived from the Innovation Surveys and also find substantial differences in realized innovation performance among OECD countries. For instance, Guellec and Pattinson (2001) look at the result of the Second European Community Innovation Survey (CIS 2). They find that the overall level of innovation (percentage of innovators) for European manufacturing firms is 51%, ranging from 73% in Ireland to 26% in Portugal. Therrien and Mohnen (2002) compare the results of some of these EU countries (Germany, France, Ireland, and Spain) to Canada. They find that Canada, at least in terms of the percentage of innovators leads the pack with more than 80% of innovative firms followed by Ireland (73%), Germany (68%), France (44%) and Spain (30%).

How can we explain these differences in the innovation or patenting rates? The literature on innovation proposes several determinants of innovation – involving both macro- and microeconomic variables. Trajtenberg (2000) finds a strong correlation between former civilian R&D (with a three years lag) and the number of international patents. Focussing on the Canadian situation, he shows that Canada stands in the middle of the pack in regards to patenting. However, because of the weak investment in civilian R&D, he predicts that Canada will hardly be able to improve or even to keep up her position as producer of relevant technology in the near future.

Stern and al. (2000) build an innovation index called "National innovation capacity" providing the expected level of international patents by country. Their index combines factors derived from three major areas of research on innovation: ideas-driven endogenous growth theory (Romer, 1990), cluster-based theory (Porter, 1990) and the national system of innovation concept (Nelson, 1993). This index, based on macroeconomic and political variables, draws a picture of an "economy's potential […] to produce a stream of commercially relevant innovation" and, to some extent, explains differences in innovation (patenting) rate among countries. They find that variables related to the "ideas-driven endogenous growth" and "national innovation system" models – stock of knowledge (GDP per capita or stock of patent), human resources devoted to innovation (full time S&T personal or R&D expenditures), political institutions or policies (IP, openness of market)– are important determinants of innovation. Private R&D funding, R&D performed by universities and the linkages between institutions and industrial clusters – central variables in the cluster theory of innovation – are also important determinants of innovation.

While the macro level policies and institutions set up the general context for innovation, it is ultimately firms that introduce and commercialize innovations. Therefore, it is important to understand the process leading to innovation. Firms must develop an internal innovation capability to generate and develop novel ideas into innovative products or processes. It is firms' innovation capability that will shape the overall country innovative performance.

Several studies have looked at the determinants of innovation at the firm level (see Kleinknecht 1996). From these studies, firms' general characteristics (size, industrial sector) as well as firms' environment (proximity to the knowledge sector, competition faced by firms, demand-pull effect) emerge as important determinants of innovation. Moreover, internal firm's decision regarding innovation (activities linked to innovation, doing R&D on a continuous basis, cooperation, skills, etc.) are also important factors determining the firm's innovation capability. For instance, Crepon and al. (1998), using a French database, use a system of equations that goes from the decision to engage in innovation activities to the impact of innovation outcome in firms' performances. They find that size has a positive impact on the probability to be engaged in innovation activities, but not on the innovation output (measured by the share of innovative sales)[1]. However, innovative sales increase with the research effort (measured by the R&D intensity), demand-pull and technology-push variables. Similar results are obtained by Klomp and van Leeuwen (2000) for the Netherlands and by Lööf and Heshmati (2000) for Sweden, using a similar model.

Papers reviewed above focus on firms in a particular country. Other authors compared firms' innovation performance in different countries. For instance, Mohnen and Dagenais (2000) build an innovation index defined as the expected share of sales form innovation, for Ireland and Denmark, controlling for the usual determinants of innovation (size, industry, R&D intensity, continuous R&D, cooperative R&D). From the innovation index of one country (say Ireland), they take the structure of the other country (Denmark) to compute what would be the expected share of sales from innovation using the industrial structure of the other country. They find that Denmark is slightly more innovative than Ireland using the estimates obtained of either country.

In a more recent paper, Mairesse and Mohnen (2001) refine the innovation comparison between countries using an accounting for innovation framework and distinguishing two different but related measures of innovation: the expected share of sales from innovation and "innovativeness", defined as the difference between the observed and the expected share of innovative sales. Pooling data from seven European countries, they compute what would be the expected intensity of innovative sales for a hypothetical European country (means of the seven countries studied), and derive the impact of selected variables on the difference between the hypothetical country and each European countries. As noted by the authors "The interest of the expected innovation indicator (and the underlying accounting framework) is that it goes beyond merely reporting the observed share of innovative sales, and attempts to explicitly assess the differences which are imputable to the differences in industry, size, R&D effort, economic environment, and so on". Innovativeness, on the other side, acts as the residual of the innovation function, and therefore, measures what we still don't know or can not estimate with the model.

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1 At least, there is no direct impact of size on innovation output, but as innovation output is function of innovation input, which is function of size, there is an indirect impact of size on innovation output.

They find that, even though the model can explain some of the difference between countries, there is still a lot to be explained.

The aim of this paper is to compare the innovation performance of Canadian and European manufacturing firms. Using, as much as possible, the potential determinants of innovation suggested in the literature, we estimate a dichotomous probit determining the probability to innovate followed by an ordered probit on the intensity of innovation. Due to administrative constraint, data from Europe and Canada can not be pooled together. Therefore, using estimates from the model described above, we compute the expected innovation intensities in Canada and in Europe, and then we compare them by making a decomposition of the differences, explaining which factors cause the difference of innovation performance between Canada and the four European countries –Germany, France, Ireland, and Spain. The remainder of the paper proceeds by first describing the databases used and how they are harmonized. We then discuss the model and methodology issues. Discussion of the empirical results will follow in Section 4, and finally, concluding thoughts will be presented in Section 5.

2- **Data**[2]

The comparison of the innovation performance of Canada and selected European countries is based on two separate databases. The Canadian data come from Statistics Canada's 1999 Innovation Survey while the European data come from Eurostat's 2nd wave of Community Innovation Surveys. These two surveys share several characteristics since both of them followed the guidelines of the Oslo manual (OECD, 1997). They use the same definition of innovation and contain the same questions regarding the innovation process (obstacles to innovation, activities related to innovation, etc.) and its outcomes.

Even though international comparability was at the core of both survey designs, there are subtle and some more substantial differences between the two surveys. In a previous paper (Mohnen-Therrien, 2001) we suggest some adjustments regarding industrial classifications, categories of innovative sales, and the definition of the innovation novelty to allow a fair comparison of innovation performance across countries. However, some discrepancies could not be adjusted for. The first one concerns the statistical unit: the European survey is based on a sample of enterprises whereas the Canadian survey is based on a sample of "provincial-enterprises"[3]. After some data analysis we conclude that using the provincial-enterprise (instead of the enterprise) as the statistical unit does not seem to lead to any serious bias. The second major discrepancy regards the years covered by the surveys. The Canadian survey covers the 1997-1999 period, while the European survey covers the 1994-1996 period. We suspect that the later period for the Canadian survey may have favored Canadian small provincial enterprises and those in the low technology intensive industries.[4] It so happens that those firms show a stronger innovation rate than their European counterparts, which is no longer the case if we consider the stronger

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[2] For a complete description and comparison of CIS 2 and the 1999 Survey of Innovation, tests performed and assumption made to harmonize the two databases, see Mohnen-Therrien (2001). For official reports regarding the surveys, see for Canada: Schaan and Nemes (2002) and for Europe: Foyn (1999, 2000).

[3] A "provincial enterprise" consists of all establishments of a given enterprise in the same industry within a province. Using this definition, an enterprise can be represented more than once in the sample.

[4] In Mohnen and Therrien (2001) it is reported that 77% of Canadian firms in the low-technology sectors were innovative while 41% of European firms innovated in these sectors. In the same vein, among small firms 75% of Canadian firms reported an innovation versus 42% in Europe. By contrast 88% of large Canadian firms were innovative versus 82% of large European firms.

definition of first-innovation (which means first in the firm's market for European firms and the aggregation of world-first and Canada-first for Canadian firms). We must keep these results in mind while analyzing results later in this paper. The third discrepancy has to do with the fact that we have microaggregated data for the four European countries and micro-data at the provincial-enterprise level for Canada. Mairesse and Mohnen (2001) showed that for an econometric model close to the one used in this study the microaggregated nature of the data has little bearing on the results.

The core question in these questionnaires is whether new or significantly improved products or processes were introduced in the firm during the three-year period of reference (1994-1997 and 1997-1999 for Europe and Canada respectively). Firms that answered that they had introduced an innovation (be it a product or a process), were asked to fill in the other questions, regarding the innovation process and its outcome. The variable that we consider particularly interesting for the purpose of comparing international innovation performance, and that is unique to the innovation surveys, is the share in sales of innovative products. In Canada only product innovators (which includes product and process innovators and product innovators only, but excludes process innovators only) were asked to answer this question. Also for Canada the percentage in sales of new or significantly improved products is only available in 6 categories (1-5%, 6-15%, 16-25%, 26-50%, 51-75%, and 75%+), while in Europe the variable is available in a continuous manner. Therefore to exploit this variable in the same way in Canada and Europe, we do two things. First, we exclude from the samples all innovators that are only process innovators, which we identify by those that declare to be process innovators and that report no sales of innovative products. Second, we create the same categories of shares in sales of innovative products for Europe as are defined in the Canadian survey.

Both surveys provide data on a set of variables that could explain the share in sales of innovative products. We can get the size of the firm and the main industry it belongs to. We measure the size of the firm by the number of employees (in logarithms). Industries are divided into three groups according to their technological intensity (see appendix). We have a dummy indicating the presence of internal R&D. For Canada, the dummy is set to 1 if a firm performs R&D within the firm in a separate and distinct R&D department or if a firm performs R&D and does not contract it out to other firms. We find information in the datasets on the pursuit of a number of innovation activities. For Canada, these innovation activities are research & development (R&D), acquisition of machinery and equipment, industrial engineering and design, tooling-up, and training related to innovation. The European survey in addition splits R&D into internal and external R&D and distinguishes the additional activity of introducing innovations on the market. We consider the diversity of innovation activities as an indicator of the innovation efforts. We therefore distinguish firms with more than the median number of innovation activities from those with less than the median number of activities. As other explanatory variables we have the presence of one or the other kind of government support for innovation, the presence of cooperation or collaboration in innovation, and the presence of a first-innovation as an indication of innovation strength. Finally, we construct a measure of proximity to science and basic research and a measure of competitive pressure, both of which are expected to foster innovation. The former is constructed as a dummy set to one when the respondent used universities or government laboratories as a source of information for innovation (Canada) or gave a score greater than the median score on a Likert scale to the use of universities or government laboratories as a source of information for innovation (Europe). For Europe, only national universities and national government laboratories are taken into account while for Canada, no distinction is made regarding the national or foreign nature of universities and government labs. Competitive pressure is constructed as a dummy taking the value of one when the objective of "opening up new markets or increasing market share" gets a score above the median. For Canada, the same procedure is applied to the success factor "seeking new markets".

We cleaned the original datasets to remove outliers and to harmonize the Canadian and European data. In order to have comparable data, we deleted all enterprises with less than 165,000 € (or 250,000 $CAN) or less than 20 employees, and all those from the printing and publishing industry.[5] [6] For the European data, missing values for the criterion defining innovators (i.e. having introduced a new product or process) were replaced by zeros, in other words those enterprises were treated as non-innovators, and missing values for the share of innovative sales were also replaced by zeros (with possible elimination of those firms if they declared themselves to be process innovators). Missing values for the dummies underlying the measures of proximity to basic research, competition, competitive pressure and cooperation were assigned a value of zero. This is not an unreasonable assumption and in any case concerns less than 3% of European firms. To remove potential outliers in the European data, we deleted all enterprises where the logarithm of labor productivity was located outside the interval defined by the country mean plus or minus four times the country standard error. Finally for Europe, we also deleted some 30 enterprises with R&D/sales or R&D personnel/total personnel above 50%, which could represent virtual research units.[7] We end up with 4404 observations for Canada and 10407 observations for Europe (constituted respectively of 4434, 1537, 4434 and 382 observations for France, Germany, Spain and Ireland). Weights will be applied to the data to so as to cover the total population.

Table 1 shows that industrial composition is quite similar for Canada and Europe. One third of the firms is located in the low-technology sectors. More than half are located in medium-technology sectors, and the remaining firms are located in the high-technology sectors. However, the percentage of innovative firms is higher in Canada (78%) than in Europe where only 52% of the firms declare to be innovative. One factor that could explain the difference between the Canadian and European innovation performance is the size composition of the two samples. While only 31% of the Canadian population is represented by small firms, small firms represent more than 53% of the European population.[8] As smaller firms tend to be less innovative, the size composition of the sample certainly affects the overall European innovation performance. This is shown in Table 1 where the proportion of small innovative firms in each case is under the proportion of small firms in the whole population, for each community (29% vs. 31% for Canada and 41% vs. 53% for Europe). In the next section, the use of an econometric

[5] The publishing industry is classified differently using the European industrial classification (NACE) or Canadian industrial classification (NAICS). Using the NAICS, publishing industry has been classified outside the manufacturing sector but using the NACE, it is a sub-group of the manufacturing printing industries. Because publishing activities constitute an important share of the printing industry, we exclude the whole "Printing and Related Support Activity industry (NAICS-323 and NACE-22)".

[6] One would recall that the target population of both surveys are firms with more than 19 employees and more than $CAN 250,000 of gross income revenue (€165,000).

[7] We decided not to eliminate observations on the basis of outliers in the turnover or labor productivity growth rates, as we do not use these data in our econometric model.

[8] Small firms have less than 50 employees, medium size firms have between 50 and 250 employees, and large firms have more than 250 employees.

model will help us to separate the effect of size from other potential effects on innovation performance.

3-Model

We base the comparison of the innovation performance in Canada and the four European countries on this output measure of innovation that is unique to the innovation surveys, namely the share in sales due to innovative products. In order to determine the appropriate econometric model to handle these data it is important to make three remarks concerning this variable.

First, given the way the innovation survey questionnaire is set up, we face a censoring problem. Before the question on the share in sales of innovative products, there is a filtering question where firms have to declare whether they introduced a new product or a new process in the last three years. If they answer “no” to both questions, they only have to report some minimal amount of information, essentially their size (in terms of turnover and employment) and their main sector of activity. If they answer “yes” to one of the two questions, they declare themselves to be innovative and only then they are invited to respond to a set of other questions regarding the inputs, the outputs, and the organization of their innovation. Second, some enterprises declare to be innovative but report no share in sales of innovative products. Either those firms are process innovators only or, in the case of European firms, they are innovative but have not been able to commercialize their innovation yet. We have eliminated all pure process innovators and we have put the European product innovators with zero innovative sales in the category of innovators with less than 5% of innovative sales. Third, as mentioned before, we have to work with categorical data and not with continuous data on the share of innovative sales.

Not only do we want to compare countries in terms of their firms’ distribution across categories of innovative sales, we also want to explain what makes the difference in innovation performance. Therefore we need a model. Given the structure of the data, the natural model to estimate in this case is a probit model discriminating between innovating and non-innovating firms followed by and linked to a multinomial ordered probit model (with known bounds) determining the importance of innovative sales. Our econometric model is thus as follows. Let us denote by INNO the binary variable of whether a firm innovates or not and by INNO* the latent variable that underlies this decision. To simplify notation, we shall omit the enterprise index whenever possible. To the binary variable INNO corresponds a latent variable INNO* such that

$$\begin{aligned} &INNO = 1 \qquad \text{if} \qquad INNO^* = X\beta + \varepsilon \geq 0 \\ &INNO = 0 \qquad \text{if} \qquad INNO^* = X\beta + \varepsilon < 0 \end{aligned} \qquad (1)$$

where X is a matrix of explanatory variables, β are the coefficients to be estimated and ε is a random error term with mean zero and unit variance.[9] To a zero response to INNO we associate a negative value for INNO*, and to a unity response to INNO we associate a positive value for INNO*. INNO* is like the threshold beyond which it is worth innovating. This is the traditional probit model discriminating between innovators and non-innovators.

[9] As the variance of ε is not identifiable, we set it equal to one.

About the innovators we also know something about their innovative strength, namely we have some categorical information about their share of innovative sales, denoted by INNO_S. To the observed ordered responses to the variable INNO_S we associate a latent variable

$$ZINNO\_S^{*} = \ln(\text{INNO\_S}/(1-\text{INNO\_S})) = Z\gamma + \sigma_{\eta}\eta \qquad (2)$$

where Z is a matrix of explanatory variables, γ are the corresponding coefficients to be estimated and η is a random error term with mean zero and variance 1. The ordered responses to INNO_S correspond to defined intervals of realization of the latent variable:

INNO_S=1	if INNO* ≥ 0 and $0\% < INNO\_S^{*} \leq 5\%$	or $-\infty < ZINNO\_S^{*} \leq -2.94$	
INNO_S=2	if INNO* ≥ 0 and $5\% < INNO\_S^{*} \leq 15\%$	or $-2.94 < ZINNO\_S^{*} \leq -1.73$	
INNO_S=3	if INNO* ≥ 0 and $15\% < INNO\_S^{*} \leq 25\%$	or $-1.73 < ZINNO\_S^{*} \leq -1.10$	
INNO_S=4	if INNO* ≥ 0 and $25\% < INNO\_S^{*} \leq 50\%$	or $-1.10 < ZINNO\_S^{*} \leq 0$	
INNO_S=5	if INNO* ≥ 0 and $50\% < INNO\_S^{*} \leq 75\%$	or $0 < ZINNO\_S^{*} \leq 1.90$	
INNO_S=6	if INNO* ≥ 0 and $INNO\_S^{*} > 75\%$	or $1.90 < ZINNO\_S^{*} \leq \infty$	(3)

We assume ε and η to be jointly distributed iid according to a standard bivariate normal distribution with correlation coefficient ρ. The logit transformation of the latent variable INNO_S* into ZINNO_S* = ln(INNO_S*/(1-INNO_S*)) stretches its domain of definition from [0,1] to [-∞,+∞]. The thresholds defining the categories t_i (i=1,…,5) are transformed accordingly, e.g. t_i = 0.05 becomes $t_i^{'}$ = ln(0.05/0.95)= -2.94. We estimate the β, γ and ρ parameters by maximum likelihood, i.e. we maximize the likelihood of observing the 0/1 responses on INNO and the categorical responses to INNO_S that we observe on innovators. The log-likelihood function is given by :

$$\begin{aligned}
\ln L = & \textstyle\sum_{INNO=0} \ln(\Phi_1[-X\beta]) + \sum_{INNO=1,INNO_S=1} \ln(\Phi_2[t_1^{*} - Z\gamma^{*}, X\beta, \rho]) + \\
& \textstyle\sum_{INNO=1,INNO_S=2} \ln(\Phi_2[t_2^{*} - Z\gamma^{*}, X\beta, \rho] - \Phi_2[[t_1^{*} - Z\gamma^{*}, X\beta, \rho]) + \\
& \textstyle\sum_{INNO=1,INNO_S=3} \ln(\Phi_2[t_3^{*} - Z\gamma^{*}, X\beta, \rho] - \Phi_2[t_2^{*} - Z\gamma^{*}, X\beta, \rho]) + \\
& \textstyle\sum_{INNO=1,INNO_S=4} \ln(\Phi_2[t_4^{*} - Z\gamma^{*}, X\beta, \rho] - \Phi_2[t_3^{*} - Z\gamma^{*}, X\beta, \rho]) + \\
& \textstyle\sum_{INNO=1,INNO_S=5} \ln(\Phi_2[t_5^{*} - Z\gamma^{*}, X\beta, \rho] - \Phi_2[t_4^{*} - Z\gamma^{*}, X\beta, \rho]) + \\
& \textstyle\sum_{INNO=1,INNO_S=6} \ln(\Phi_2[\infty, X\beta, \rho] - \Phi_2[t_5^{*} - Z\gamma^{*}, X\beta, \rho])
\end{aligned} \qquad (4)$$

where Φ_1 is the cumulative univariate normal distribution, Φ_2 is the cumulative bivariate normal distribution, the indices under the summation signs indicate the observations over which the sums are taken, $t_i^{*} = t_i^{'} / \sigma_{\eta}$ (i=1,…,5) and $\gamma^{*} = \gamma / \sigma_{\eta}$.

For reasons of statistical confidentiality we are not able to pool the European and Canadian data. We thus estimate separately the data of Canada and of the four European countries. Any country heterogeneity in the European data that is not accounted for by the explanatory variables introduced in the model is captured by country fixed effects introduced in the specification of (1) and (2). Dummy variables are introduced to capture industry-group specific effects. The explanatory variables are industry group and size (expressed in logarithms)) for the probit equation. For the ordered probit equation we have in addition a dummy for the presence of internal R&D activities, a dummy for having a number of different innovation activities greater than the median, a dummy for cooperation in innovation activities, a dummy for proximity to basic science, a dummy for competition, a dummy for first-innovator, and finally a dummy for the presence of government support for innovation. Each sample unit in each database is given a weight based on the number of sample units it represents in a given stratum for the population. This weight (inverse of the sampling rate) is applied to each term in the log-likelihood function. In this way, inference can be made about the population.

4- Results

Before turning to the analysis of the model described in the previous section, let us have a look at the distribution of the dependent variable – the share of sales due to innovative products – by our variables of interest. Table 2 shows that a larger proportion of European firms than of Canadian firms has been able to collect a substantial part of revenue from product innovation. The percentage of European firms collecting more than 50% of their revenue from innovation is almost three times as high as the percentage of Canadian firms (44% vs. 15%). One might recall (Table 1) that Canada has a better innovation performance than Europe when comparing the percentage of innovators. That advantage does not seem to hold when comparing the intensity of innovation as measured by the share in sales of innovative products.

These results are consistent with those obtained by Trajtenberg (2000) on international patenting. Looking at the patent rate (international patents per capita), Canada trails Germany but is ahead of France, Ireland and Spain. These results are in line with the good performance of Canada regarding the percentage of innovators. However, other patent indicators -- percentage of patent owned by foreign interest and unassigned patents –show that Canada lags behind the rest of the world[10]. As stated by Trajtenberg: " [T]here is reason for concern […] 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"[11]. Foreign owners could decide to commercialize the innovation product in their home country instead of Canada, which could partly explain why Canada lags behind Europe in terms of sales from innovation[12].

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[10] Here Trajtenberg (2000) compares Canada to the G7 countries and some other countries like Israel and Finland. He has no evidence regarding Spain and Ireland.

[11] Analyzing more in-depth Canada and the US, he draws a dark picture of the Canadian innovation future. For instance, he finds that Canada trails the US in terms of patent quality (measured by citations). Even more troubling is the fact that Canada patents more in traditional fields (such as transportation and agriculture) than in the upcoming field of computer and communication, which is the core of the new general purpose technologies (GPT).

[12] Unfortunately, it is not possible to control for the status of the firm (foreign or national) with our databases.

Both in Canada and in Europe, firms with more than 15% of innovative sales tend to have more than the median number of innovative activities, the opposite holds for small innovators. Innovative firms are not concentrated in large firms. The distribution of innovators among size classes is not greatly affected by the intensity of innovation. The intensity of innovation seems to be correlated with the incidence of R&D activities. Firms with a large share of innovative sales seem to be first innovators. The proximity to basic research and, to a lesser extent, the pressure of competition also seem to boost innovation. The three big differences between Canada and Europe are the level of government support, the proximity to basic research and the percentage of first innovators[13]. In the Canadian sample 63% of firms report some kind of government support against only 21% in Europe. In Europe, on the other hand, twice as many firms receive information for innovation from basic research institutions, i.e. universities and government labs, (32% against 16%) and 45% of European firms are first innovators against only 31% in Canada, which once more reinforces the impression that Canadian firms while more often innovative are in fact less strongly innovative compared to their European counterparts.

Table 3 presents the econometric estimates of the model described in the previous section. The estimates are more precise with European data, which is not surprizing given the greater number of data points in the European sample. In Europe we have additional country dummies to account for missing explanatory variables that would be country-specific. The reference country is Germany. Both in Europe and in Canada the probability to innovate and the intensity of innovation increase with the sectoral technological intensity. The country dummy coefficients reproduce the relative rankings that we have reported in Therrien and Mohnen (2002). The incidence of innovation increases with the number of employees more so in Europe than in Canada. With the European data innovation intensity decreases with the size of the firms and their incidence of internal R&D, whereas in Canada both effects are positive. These findings are not out of line with those from previous studies[14]. All other effects go in the same direction at least when they are significant. The diversity of innovation activities, cooperation in innovation, government support, the proximity to basic research, the pressure of competition, and the novelty of innovation, all favor innovation. These findings corroborate the assumption stating that to be innovative (and to reach profit from innovation), firms must develop their innovation capability, that such capability can not be taken for granted[15]. Therefore, firms must invest in R&D as well as other innovation activities such as acquisition of existing technologies, training, etc, to build their innovation capability. Moreover, proximity to the science sector as well as cooperation with other firms are other channels that strengthen the innovation capability.

Table 4 reports the marginal effects of the main explanatory variables, taken at their mean values, on the various modalities of innovation: not to innovate, or to innovate such that the percentage of innovative sales falls in various brackets, which we have restricted to three: less than 15%, between 15% and 50%, and more than 50%. Notice that the sum of the marginal effects across the different possibilities (i.e. on each line) is equal to zero. The results have to be

13 One might note that for Canada, government support programs for innovation include financial as well as non-financial programs, while in Europe only financial support programs are included the definition.

14 In Crepon et al. (1998) and in Mairesse and Mohnen (2001) size is not significant while in Lööf and Heshmati (2001) size is negatively correlated to the innovation output (innovation sales per employee).

15 See Cohen-Levinthal (1989) or Oerlemans et al.(1998) for a literature review on innovation capability.

interpreted in the following way. First, probabilities to be innovative and to fall into the four categories of innovation behavior are computed at the mean values of the explanatory variables, i.e. at the observed proportions of firms in the various industries, of enterprises doing R&D, or receiving government support and so on. Marginal effects are the change in those probabilities if a firm increases its size by one percent, or shifts from one industry to another, or turns from noncooperative to cooperative in innovation, etc. In other words, what is the additional probability of being in these four categories of innovation behavior that we distinguish in table 4, that come from a change (ceteris paribus) in one selected variable? For instance, in Europe, if a firm switches from a low tech to high tech industry, its probability not to innovate will fall by 21% (0.29-0.50), its probability to be a low-intensive innovator (less than 15% of innovative sales) increases by 1% (0.12-0.11), it increases by 7% its probability to be a medium innovator (between 15% and 50% of innovative sales) and by 13% its probability to be an intensive innovator (more than 50% of innovative sales). The same move in Canada would materialize in a 13% higher probability to innovate , a 1% lesser chance to be a low innovator, a 7% chance to be a medium-intensive innovator and a 6% chance to be a strong innovator.

Size increases the probability to innovate in both regions, much more in Europe than in Canada, with an almost equal distribution across the classes of innovative sales shares. Notice that size has two effects on the intensity of innovation, one indirect effect on the probability to innovate and one direct effect on the intensity of innovation. The net effect is positive for Europe as well as for Canada. Europe is more sensitive than Canada to government support and the novelty of innovation, whereas the characteristics of doing R&D, cooperating in innovation and being active in many ways in innovation have more of an effect on innovative sales in Canada than in Europe.

We now turn to the main purpose of this paper. Table 5 decomposes the difference in innovative performance between Europe and Canada. The analysis is performed once using the estimate obtained from the European data, once using the estimates obtained from the Canadian data. In both cases we can predict from the data and our estimates of the model parameters the expected intensity of innovation for every enterprise in the sample, be it innovative or not, given by

$$E(INNO\_S \mid X, Z) =$$

$$\int_{-X\beta}^{\infty}\int_{-\infty}^{\infty} \exp(Z\gamma + \sigma_\eta \eta)/(1+\exp(Z\gamma + \sigma_\eta \eta))\, f(\varepsilon,\eta)\, d\varepsilon\, d\eta \qquad (5)$$

where $f(\varepsilon,\eta)$ is the bivariate standard normal distribution with correlation coefficient ρ. The conditional mean is evaluated at the estimated values of β, γ, ρ, and σ_η using a Gauss-Legendre quadrature to compute the integrals.

The latter is actually a convolution of two effects, the probability to innovate and the expected intensity of innovation for innovative firms, respectively given by

$$E(INNO^* \mid X) = \int_{-X\beta}^{\infty} f_1(\varepsilon)d\varepsilon \tag{6}$$

$$E(INNO\_S \mid Z, INNO^* \geq 0) = \int_{-\infty}^{\infty} \exp(Z\gamma + \sigma_\eta \eta)/(1+\exp(Z\gamma + \sigma_\eta \eta))\, f_2(\eta)d\eta \tag{7}$$

where $f_1(\varepsilon)$ and $f_2(\eta)$ are respectively the marginal normal distribution functions of ε and η. Notice that (5) is the product of (6) and (7) when ε and η are independent.

The predicted values of these three expressions are evaluated at the mean values (for innovative firms) for the variables in the respective countries. To decompose the difference in prediction into its various components, we take a linear expansion of the predictions, once around the European mean with the gradients evaluated with the European estimates, and once around the Canadian mean with the gradients evaluated with the Canadian estimates.

Not surprisingly, we notice in table 5 that the European estimates, evaluated at the averages of the variables, more closely predict the average European performance and the Canadian estimates the average Canadian performance. If we evaluate the difference with respect to the European estimates, Canada looks more innovative both in probability (column 1) and conditional intensity (column 2), and hence also in the unconditional intensity of innovation (column 3). If we evaluate the difference with respect to the Canadian estimates, our set of explanatory variables still predicts Canada to have a higher proportion of innovating firms (column 4), but no longer to be more innovative in innovation intensity, conditionally on being innovative (column 5) or unconditionally (column 6). What our model allows us to do is to split the difference in predicted innovation performance into what can be attributed to the structural effects, such as differences in size, R&D efforts, competition, and what for lack of a better explanation we attribute to innovativeness. If we had been able to pool the data of all five countries, we would have obtained a unique set of estimates, and any difference between Canada and Europe could have been attributed to differences in the levels of the variables. With two sets of estimates, there will be inevitably differences in predictions and explanations for them. The proper way to interpret the results is then to say: if innovation works as it seems to work in Canada, how does Canada compare to Europe, and *vice versa*, how do the two regions compare if innovation works as it does in Europe?

Both estimates reveal that the sectoral composition of manufacturing output favors innovation in Europe. Europe has a lower proportion of output in what we have classified as low-tech sectors, where innovation occurrence and intensity are lower. Unambiguous too are the effects of size, cooperation in innovation and government support. These factors are more prominent in Canada than in Europe. The order of magnitudes can sometimes differ between the two sets of estimates.

For example, the presence of government support for innovation explains 0.28 percentage points of the difference in unconditional innovation intensity with the Canadian estimates against 1.26 points with the European estimates. Differences in the pressure of competition, in the scope of innovation, measured by the number of innovation activities undertaken, and in the novelty of innovation (i.e. the occurrence of first-to-the market innovations) play in favor of innovation in Europe, that is they are more prevalent in Europe than in Canada. The only two factors on which the two estimates disagree are the proximity to basic research and the incidence of internal R&D. The sum of the structural effects, i.e. of all the predicted differences that we can attribute to explanatory variables, almost add up to the differences in prediction. The small discrepancy is due to the linear approximation error in the decomposition of a nonlinear function. If we look at the bottom of the table, we see that on average almost 80% of Canadian firms innovate against barely 50% in Europe, but that innovating firms are more innovative in Europe than in Canada, and that therefore a firm is on average predicted to be slightly more innovative in Canada. Whatever difference in observed innovation performance is not explained by the model is what Mairesse and Mohnen (2001) coin “innovativeness”. The European estimates reveal that most of the differences in prediction are due to country effects. As such the country effects capture the heterogeneity in the data due to country specificities. They can hardly be qualified as structural effects. We thus add them to the sources of innovativeness. Innovativeness in all three dimensions is thus measured as the difference in observed innovation not explained by the structural effects of the model. Here again the message from the two estimates is consistent: Canadian firms, despite all differences in size, competition and output composition with respect to the European firms, have a greater tendency to innovate, but the typical innovating firm in Canada has a lower share of innovative sales, and because the former effect is more prevalent than the latter, a Canadian firm is expected to be more innovative than a European firm.

5. Conclusion

The Comparison of the European and the Canadian innovation performance in manufacturing from the information provided by the Innovation Surveys of the late 1990s reveals that Canada has a higher proportion of innovating firms but a lower share of innovative sales for their innovating firms, so that in total we expect a typical Canadian firm to have a slightly higher share of innovative sales. This is what the descriptive analysis show. The econometric analysis conducted in this paper has tried to explain part of this difference by the influence of the sectoral composition of output, and the effects of size, competition, and innovation capacity. For doing that we have estimated the structure of innovation from Canadian and European innovation survey data. Both estimates concur to attribute to differences in size, tendencies to cooperate in innovation and the incidence of government support a slight advantage for Canada, and to attribute to the sectoral composition of manufacturing output, to the pressure of competition, the scope of innovation activities and to the novelty of innovation a slight advantage to Europe. These structural effects combined, while informative, are not sufficient to explain the basic pattern of innovation that was visible by just looking at the raw data. Canada looks more innovative than the four European countries (France, Germany, Ireland and Spain) combined.

What future studies should examine in more detail is the representativeness of the country samples: do non-respondents or non-sampled firms behave the same way as respondents do (what we have implicitly assumed in our analysis)? Another source of error could lie in the definition of innovation. Although efforts have been made to define the notion of innovation in the questionnaires, there still is a serious potential measurement error due to a different interpretation of what innovative means and of its order of magnitude. To some extent, we could get a more nuanced picture of country differences in innovation performance if we could have the share of innovative sales split into incremental innovations, first-to-the market innovations, or innovations at different stages of the product life-cycle. It would also be useful to get an idea of the selection bias due to the mandatory/voluntary nature of the surveys. In order to increase our understanding of innovation we should try to increase our set of explanatory variables, which implies the merger of innovation survey data with other firm information data. In the same vein, most explanatory variables used in this paper are of a qualitative nature (dichotomous variables), and the model would gain to use quantitative variables (i.e. using R&D expenses instead of the dichotomous variable performing R&D or not) for refining the estimations. Finally, the explanation might also lie not at the firm level but at the macro level of the national organization of innovation.

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Appendix
Tables of concordance between NAICS and NACE (rev. 1) industrial classifications by technological intensity

<u>Aggregation by technological intensity</u>*:

NAICS code	NACE code (rev. 1)	Corresponding economic activities
		Low-technology
311-312	15-16	Food, beverage and tobacco products
313-316	17-19	Textile mills, textile product mills, clothing, leather and allied products
321-322	20-21	Wood products and paper manufacturing
		Medium-technology
324	23	Petroleum and coal products
326-327	25-26	Rubber and other non-metallic products
331-332	27-28	Basic & Fabricated metal products
333	29	Machinery and equipment
334.5-334.6	33	Navigational, medical, medial and optical equipment
336.1-336.3	34	Motor vehicles, trailers and semi-trailers
337+339	36	Furniture and related products and miscellaneous manufacturing
		High-technology
325	24	Chemicals and chemical products
334.1	30	Computers and peripheral equipment
334.4+335	31	Electrical and electronic machinery and equipment
334.2-334.3	32	Radio, television and communication equipment and apparatus
336.4-336.9	35	Aerospace products and parts, and other transport equipment

*: Taxonomy is drawn from Hatzichronoglou (1997).

Table 1a --CANADA – Distribution of innovators and non-innovators across size and sectors

	Non-innov	Innov	TOTAL
Industrial sect.			
low-tech	39%	32%	33%
med-tech	54%	55%	55%
hi-tech	7%	13%	12%
Size of the firm			
Small	38%	29%	31%
Medium	53%	55%	55%
Large	9%	16%	14%
Observations (weighted)			
Percentage	22%	78%	100%
N	1566	5464	7030

*Pure process innovators are excluded from the sample
Source: Canada: 1999 Survey of Innovation, Statistics Canada

Table 1b --EUROPE -- Distribution of innovators and non-innovators across size and sectors

	Non-innov	Innov	TOTAL
Industrial sect.			
Low-tech	40%	24%	32%
Med-tech	52%	60%	56%
hi-tech	8%	16%	12%
Size of the firm			
Small	65%	40%	53%
Medium	31%	43%	37%
Large	4%	17%	10%
Observations (weighted)			
Percentage	49%	51%	100%
N	35730	34654	70383

*Pure process innovators are excluded from the sample.
Source: CIS 2, Eurostat.

Table 2 Shares of innovative sales--by selected variables of interest, Canada and Europe

	<5%	5-15%	15-25%	25-50%	50-75%	>75%	Total
				Canada			
Industrial sect.							
low-tech	38%	34%	32%	26%	32%	31%	32%
med-tech	52%	56%	55%	58%	46%	53%	55%
hi-tech	10%	11%	13%	15%	22%	16%	13%
Size of the firm							
small	37%	32%	29%	28%	27%	23%	29%
medium	48%	53%	58%	54%	57%	59%	55%
large	15%	16%	14%	17%	17%	18%	16%
Innovation activities							
below median	63%	56%	49%	40%	45%	38%	48%
above median	37%	44%	51%	60%	55%	62%	52%
Other activities related to innovation							
RD internal	60%	55%	67%	71%	64%	76%	64%
Collaboration	33%	31%	37%	42%	39%	42%	36%
Gvt support	62%	59%	62%	68%	70%	67%	63%
Firm and industry characteristics							
Basic	11%	15%	16%	17%	16%	18%	16%
Competition	44%	42%	43%	49%	44%	49%	45%
First innovators	19%	31%	24%	36%	35%	37%	31%
Observations (weighted)							
Percentage	5%	33%	21%	26%	7%	8%	100%
N	247	1817	1168	1397	377	458	5464
				Europe			
Industrial sect.							
low-tech	34%	33%	26%	19%	22%	25%	24%
med-tech	49%	52%	59%	65%	59%	61%	60%
hi-tech	17%	15%	15%	16%	18%	14%	16%
Size of the firm							
Small	43%	40%	34%	36%	46%	45%	40%
Medium	46%	42%	47%	46%	36%	40%	43%
Large	11%	18%	19%	18%	18%	15%	17%
Innovation activities							
below median	68%	51%	40%	30%	35%	41%	40%
above median	32%	49%	60%	70%	65%	59%	60%
Other activities related to innovation							
RD internal	58%	66%	74%	78%	77%	71%	73%
Collaboration	26%	32%	29%	28%	32%	28%	29%
Gvt support	12%	19%	21%	19%	25%	25%	21%
Firm and industry characteristics							
Basic	27%	24%	32%	33%	35%	34%	32%
Competition	46%	65%	66%	54%	49%	56%	56%
First innovator	26%	39%	46%	50%	48%	43%	45%
Observations (weighted)							
percentage	6%	12%	13%	26%	15%	29%	100%
N	2120	3992	4550	8878	5126	9986	34654

Sources: Canada: 1999 Survey of Innovation; EU: CIS 2

Table 3. Estimation of joint probits on probability to innovate and ordered probits on categorical"shares of innovative sales".

	Europe		Canada	
Explanatory variables				
Industrial Sector	*Probit on innovation*			
Low Tech	**-1.311**	(-175.84)	0.030	(0.47)
Medium Tech	**-1.022**	(-149.08)	**0.197**	(3.41)
High Tech	**-0.755**	(-82.85)	**0.472**	(6.15)
Country				
Ireland	**0.234**	(64.26)	--	--
France	**-0.604**	(-79.54)	--	--
Spain	**-0.995**	(-163.37)	--	--
Log of number of employees	**0.355**	(241.59)	**0.139**	(10.28)
	Ordered probit on shares of innovative products			
Industrial Sector				
Low Tech	-0.090	(-0.81)	**-2.135**	(-13.71)
Medium Tech	**0.261**	(2.68)	**-2.066**	(-14.60)
High Tech	**0.296**	(3.21)	**-1.782**	(-13.51)
Country				
Ireland	**-0.824**	(-90.25)	--	--
France	**-1.676**	(-58.10)	--	--
Spain	**-0.422**	(-7.94)	--	--
Log of number of employees	**-0.127**	(-8.98)	**0.052**	(2.85)
Activities related to innovation				
R&D internal	**-0.080**	(-10.71)	**0.252**	(8.98)
Multi-activities	**0.113**	(9.83)	**0.238**	(8.58)
Cooperation	**0.068**	(10.02)	**0.119**	(4.14)
Government support	**0.312**	(55.31)	0.060	(1.12)
Firm and industry characteristics				
Basic	**0.026**	(3.00)	-0.085	(-1.23)
Competition	**0.044**	(2.69)	**0.071**	(2.34)
First-innovators	**0.435**	(82.53)	**0.105**	(3.45)
Sigma	**1.742**	(206.63)	**1.128**	(34.01)
Rho	-0.080	(-1.92)	-0.432	(-1.84)
Log-likelihood	-99364.99		-12568.07	
N (weighted)	34654		5464	
N (unweighted)	10407		4404	

Note: bold = significant at 5% level, Asympotic t-stat in parenthesis.
Sources: Canada: 1999 Survey of Innovation, Statistics Canada; EU: CIS 2, Eurostat.

Table 4. Marginal effects of explanatory variables (in percentage points) on

	Propensity not to innovate		Propensity to have sales from innovative products					
			less than 15%		from 15% to 50%		more than 50%	
	EU	CND	EU	CND	EU	CND	EU	CND
Sector								
Low Tech	0.50	-0.01	-0.12	0.49	-0.19	-0.14	-0.20	-0.34
Medium Tech	0.39	-0.06	-0.13	0.50	-0.16	-0.12	-0.11	-0.33
High Tech	0.29	-0.14	-0.11	0.48	-0.12	-0.07	-0.07	-0.28
Ireland	-0.09	-----	0.11	-----	0.06	-----	-0.08	------
France	0.23	-----	0.12	-----	-0.04	-----	-0.31	------
Spain	0.38	-----	-0.05	-----	-0.13	-----	-0.20	------
Log (nb. empl)	-0.14	-0.04	0.05	0.01	0.05	0.02	0.03	0.01
R&D internal	-----	-----	0.01	-0.06	0.00	0.02	-0.01	0.04
Multi-activities	-----	-----	-0.01	-0.05	0.00	0.02	0.01	0.04
Cooperation	-----	-----	-0.01	-0.03	0.00	0.01	0.01	0.02
Basic	-----	-----	0.00	0.02	0.00	-0.01	0.00	-0.01
Competition	-----	-----	-0.01	-0.02	0.00	0.00	0.01	0.01
Gvt support	-----	-----	-0.03	-0.01	-0.01	0.00	0.04	0.01
First-innovators	-----	-----	-0.03	-0.02	-0.02	0.01	0.06	0.02

Evaluated at means of the variables for innovative firms.

Sources: Canada: 1999 Survey of Innovation, Statistics Canada; EU: CIS 2, Eurostat.

Table 5. Comparison between Europe and Canada of the predicted probability to innovate, intensity of innovation for innovators, and intensity of innovation for all firms

	Using European estimates			Using Canadian estimates		
	Prob. to innovate All	Intensity of innovation Innovators	Intensity of innovation All	Prob. to innovate All	Intensity of innovation Innovators	Intensity of innovation All
Predictions of … at the averages of the variables in …						
Canada	70.51%	49.51%	34.12%	79.25%	25.82%	17.83%
Europe	60.56%	41.14%	24.06%	79.18%	26.13%	18.04%
Decomposition of the predicted difference (Canada – Europe)						
Sectoral composition						
Low Tech	-3.43%	-0.10%	-1.49%	0.06%	-2.13%	-1.57%
Medium Tech	1.79%	-0.19%	0.63%	-0.27%	1.48%	1.01%
High Tech	0.65%	-0.11%	0.21%	-0.26%	0.51%	0.29%
Firm & market characteristics						
Log (nb. empl)	1.85%	-0.27%	0.61%	0.54%	0.10%	0.25%
Competition		-0.08%	-0.05%		-0.12%	-0.09%
Internal innovation capacity						
R&D internal		0.11%	0.07%		-0.35%	-0.26%
Multi-activities		-0.15%	-0.09%		-0.30%	-0.22%
Cooperation		0.08%	0.05%		0.13%	0.10%
Basic		-0.07%	-0.04%		0.21%	0.15%
Gvt support		2.09%	1.26%		0.37%	0.28%
First-innovators		-0.86%	-0.51%		-0.20%	-0.15%
Sum of struct. effects	0.86%	0.45%	0.63%	0.07%	-0.31%	-0.21%
Country effects (reference country=Germany)						
Ireland	-0.30%	0.44%	0.14%			
France	5.74%	6.60%	6.36%			
Spain	4.13%	0.73%	2.16%			
Observed averages of … in …						
Canada	78.59%	29.60%	23.26%	78.59%	29.60%	23.26%
Europe	51.58%	39.38%	20.31%	51.58%	39.38%	20.31%
Canada – Europe	27.01%	-9.78%	2.95%	27.01%	-9.78%	2.95%
Innovativeness	26.15%	-10.23%	2.32%	27.08%	-9.47%	3.16%