Innovation and Productivity in Canadian Manufacturing Establishments

Pierre Therrien and Petr Hanel[♦]

Abstract: This paper builds on the Canadian contribution to the OECD Innovation Microdata Project, which analyzes the impact of innovation on labour productivity using firm-level data from national innovation and administrative surveys. We use an expanded data set with additional information on manufacturing establishments from the Canadian Survey of Innovation 2005 linked with the Annual Survey of Manufactures and Logging (ASML). The estimated econometric model controls for selection bias, simultaneity, size of firm and industry effects. The main findings are as follows: (1) Exporting to non-US markets, size of the firm and use of government support increase the probability to innovate and having positive innovation sales. (2) Exporting (both to the U.S. and other markets), cooperation with other firms and organizations, and a high share of firm revenues coming from sales to a firm's most important client correlate with higher innovation expenditure per employee. Firms with a higher market share at the beginning of the period tend to spend more on innovation by the end of the period. (3) Firms with higher innovation expenditure per employee generate more innovation sales per employee. Other factors increasing innovation sales are human and physical capital and introduction of process innovations. (4) Finally, firms generating more innovation sales per employee achieve higher labour productivity, even when size of firm, intensity of human and physical capital, and labour productivity at the beginning of the period are taken into account. The results add to, and are in line with, the findings based on the simpler model applied in the 18-country OECD study. The paper concludes with a discussion of policy implications.

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1. Introduction

The standard of living and the quality of life in a country are closely related to its level of labour productivity. Improving labour productivity not only supports increased wages but is also the best guarantor of capacity to provide public services such as health care, education, and environmental initiatives, the top priorities of Canadians. However, both the level and growth rate of Canada's labour productivity have been a source of concern for some time (Hanel, 2008). Innovation is one of the principal sources of productivity growth and is also an area where Canadian industry lags behind many of its competitors according to the European Innovation Scoreboard (Pro-Inno, 2008)[1]. Accordingly, Canada has joined research efforts of other OECD countries to reach a better understanding of the process from the decision to innovate up to the effect of innovation on productivity and other performance indicators.

To understand what is behind the aggregate statistics, it is necessary to examine innovation and productivity at the firm level. After all, it is there that labour and capital—the principal factors of production—are put to work more or less efficiently. By introducing new and improved products and production processes, innovating firms expand existing and create new markets, as well as improve the efficiency of their production and marketing activities—i.e., improve their productivity.

The analysis of microdata using innovation surveys, which started in the 1990s, has focused on the innovation process, its characteristics, and the conditions that encourage or impede innovation[2]. However, use of microdata for international

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[1] According to the European Innovation Scoreboard 2007, Canada ranks in the middle of the OECD, with a Summary Innovation Index reading just below that of the EU 27. Note that Canada's score is based mostly on R&D-related variables; innovation survey-related factors were not taken into account, due to issues of data availability.

[2] The OECD in collaboration with EUROSTAT launched, in the early 1990s, a concerted effort to collect information on the whole innovation process at the firm level (Community Innovation Survey in Europe, Innovation Surveys in Australia, Canada, etc). Availability of data on

comparisons is hampered by national laws that protect confidentiality of firm-level information. To get around this problem, the OECD launched in 2006 the Innovation Microdata Project (OECD, 2009). As part of this project, research teams from 18 OECD countries used a common methodology first introduced by Crépon, Duguet and Mairesse (CDM) to analyze the impact of innovation on labour productivity using firm-level data from their national innovation and administrative surveys.

This paper extends the Canadian model used for the OECD project. It follows the same methodology as the OECD model but uses to the full extent all information available on manufacturing establishments from the Canadian Survey of Innovation 2005 (linked with the Annual Survey of Manufactures and Logging (ASML). The extended Canadian model tests and refines relationships found in the OECD project and focuses on the policy implications of the Canadian results.

This paper is organized as follows: Section 2 reviews the literature dealing with the issue of innovation and productivity at the firm level, including a summary of the main results of the OECD project with particular emphasis on the Canadian results. The third section presents in more detail the proposed refinement of the econometric model for application to Canada, while Section 4 analyzes the results from the extended Canadian model. Finally, Section 5 concludes by considering policy implications of the results and by proposing alternative avenues for future research.

2. Overview of the literature

2.1 Background and CDM model

Initially, the difficulty of measuring technical progress directly led economists studying the link between innovation and

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innovation spurred new research aimed at understanding the innovation process, its sources, results and effects. For examples of such studies see Kleinknecht (1987 and 1989); for specifically Canadian studies, see Baldwin and Hanel (2003) and Gault (2003).

productivity at the firm level to focus their attention on research and development (R&D), an input into the innovation process. However, as Mairesse and Sassenou (1991) who surveyed these studies noted, the methodological difficulties faced in modeling the complex relationships involved, in addition to the issues of obtaining high quality data, made it quite challenging to arrive at satisfactory interpretations and conclusions.

The introduction of innovation surveys in most OECD countries[3] in the early 1990s provided data that enabled researchers to statistically document the multiple sources of innovation, the variety of types of innovation, and their relationship with the expected and achieved impact of innovation results on the performance of innovating firms. Crépon, Duguet and Mairesse (1998), inspired by earlier work of Pakes and Griliches (1984), integrated these relationships into a single system of three stages with four recursive equations:

(i) The first stage captures the firm's decisions regarding research activities—i.e., whether to engage in R&D and, if yes, what level of resources to allocate to this purpose. The Heckman selection equation estimates the probability that the firm performs R&D activities. Given that a firm engages in R&D, the second equation in the first stage estimates the intensity of these activities.

(ii) The second stage models innovation as a function of R&D and other variables. Innovation outcomes are measured by patents in one variant of this equation and by the percentage of innovation sales in a firm's total sales in another variant.

(iii) The third stage of the model expresses productivity as a function of innovation output—measured either by the expected number of patents per employee or by the share of

[3] The notable and unfortunate exceptions are the U.S. and Japan, the two countries whose statistical agencies have not yet conducted nationwide innovation surveys. However, U.S. academic researchers have produced two very influential survey-based studies (Levin, Klevorick, Nelson and Winter, 1987; and Cohen, Nelson and Walsh, 2000) that in many ways laid the groundwork for innovation surveys.

innovative sales over total sales—and other determinants of productivity, including capital, labour and skill composition, using an augmented Cobb-Douglas production function.

The estimating model uses appropriate methods to deal with selection bias, the endogenous nature of innovation and R&D and the statistical properties of the underlying data. The CDM results show, for French manufacturing firms, a clear link between the innovation input intensity (R&D capital intensity), innovation output (patents or innovation sales), and firm productivity:

> "The probability of engaging in research (R&D) for a firm increases with its size (number of employees), its market share and diversification, and with the demand pull and technology push indicators. The research effort (R&D capital intensity) of a firm engaged in research increases with the same variables, except for size (its research capital being strictly proportional to size). The firm innovation output, as measured by patent numbers or innovative sales, rises with its research effort and with the demand pull and technology indicators, either directly or indirectly through their effects on research. Finally, firm productivity correlates positively with a higher innovation output, even when controlling for the skill composition of labour as well as for physical capital intensity" (Crépon, Duguet and Mairesse, 1998).

2.2 Variants of the CDM model

The CDM model has inspired several similar studies, all based on the harmonized innovation survey data collected according to guidelines provided by the Oslo Manual for collecting and interpreting innovation data. Interesting variants of the CDM framework are found in: Lööf and Heshmati (2006), who examine the link between innovation and labour productivity in Swedish manufacturing and services firms; Griffith et al. (2006), who compare the innovation-labour productivity nexus for France, Germany, Spain and the UK; and Van Leeuwen and

Klomp (2006), who estimate the contribution of innovation to multifactor productivity growth in the Netherlands.

The Swedish study is of particular interest. It uses the CDM model as the theoretical framework but adopts a different econometric strategy to overcome the problem of endogenous explanatory variables, using instrumental variable analysis instead of the asymptotic least squares method used by CDM. As well, the study conducts various types of sensitivity analysis, including by using, *inter alia*, different data sources, different classifications of firms' performance, different classifications of innovation and by estimating models in growth terms as well as well as in level terms. Results show that various productivity measures such as sales per employee, value added per employee, growth of value added per employee, growth of sales, growth of profit per employee, growth of employment and, to a lesser degree, sales margins are all positively linked to innovation; of course, the estimated elasticity coefficients vary. In contrast to earlier studies that considered R&D as the sole innovation expenditure, the innovation input variable in this study includes expenditures on all aspects of innovation. The elasticity of labour productivity to innovation sales in manufacturing and in services is found to be rather similar, respectively 0.12 and 0.09. A debatable feature of the study is the inclusion of various obstacles to innovation in the vector of exogenous variables. By definition, in the case of innovating firms, obstacles to innovation are not independent from innovation; thus, this specification potentially results in a simultaneity bias in the coefficient estimates.

Griffith et al. (2006) analyze 1998-2000 data from innovation surveys in France, Germany, Spain and the UK. In contrast to the original CDM, this study estimates separate innovation functions for process and product innovations. Product innovation has a positive effect on labour productivity (measured as sales per employee) in three out of four countries (Germany being the exception). Process innovation appears to have a positive effect only in the case of French firms. Another original feature of this application of the CDM model is the inclusion of local, national and EU funding of R&D in the equation modeling the decision to engage in R&D. However, only national funding appears to affect R&D intensity[4].

Finally, Van Leeuwen and Klomp (2006) examine the impact of innovation on multifactor productivity (MFP) growth using data for the Netherlands. Among other features, this study models the feedback from firms' sales back to innovation activity. The authors argue that revenue per employee is a more appropriate basis for assessing the link between the results of the innovation process and firm performance because the results of innovation are measured in revenue terms rather than in value added terms. The study also finds that the estimation of return on innovation investment benefits from the inclusion of more information on the technological environment of the firm.

2.3 The OECD variant of the CDM model to benchmark countries

Using the Lööf and Heshmati (2006) variant of the three stage, four equation CDM approach, teams of researchers from 18 OECD countries, including Canada, estimated a simplified common model[5]. The requirement of estimating a common model for all participating countries limited the choice of available variables. The OECD model used the standard dependent variables related to innovation input (innovation expenditures per employee); innovation output (innovation sales

[4] In the case of France, national funding appears with a negative coefficient while EU funding comes with a positive one.

[5] The results of this unique joint research initiative were coordinated in a series of workshops by the WPIA-NESTI (OECD) with econometric programming and coordination by Chiara Criscuolo from the London School of Economics. A short summary of results has been published in Chapter 5 of the OECD's *Science, Technology and Industry Outlook 2008* and detailed analysis can be found in OECD (2009), Chapter 3. We present in Appendix 1 summary results for the 18 countries. See Therrien and Hanel (2008) for more information on preliminary results for Canada. Therrien and Hanel (2009) present an overview of extensions of the 'core' model for the United Kingdom, Germany, the Netherlands and Canada.

per employee) and labour productivity (measured by sales per employee). However, owing to unavailable data in some countries, it was impossible to include in the productivity equation the usual factors of production (such as intermediate inputs and human and physical capital) or alternatively to use a better dependent variable (value added per employee). Nonetheless, the main independent variables in the four equations (such as firm size, exporting, cooperation, government support for innovation, etc.) were included in the model. Selection bias and endogeneity issues between innovation sales and productivity were taken into account.

The main finding of the OECD initiative is that innovative firms in all participating countries seem to behave in similar ways. Exporting, large size and being part of a group are characteristics that increase the probability that a plant or firm is innovating. These characteristics, in addition to cooperating on innovation and receiving public financial support, determine the intensity of investment in innovation. Sales of innovative products contribute significantly to labour productivity. The main elasticities—between innovation expenditures and innovation sales and between innovation sales and labour productivity—are usually positive and within the same broad range.

Looking more specifically at each stage and comparing Canada to other countries (see Appendix 1 for the specification of the model and summary tables), the following results emerge:

First stage – decision to innovate and investment in innovation

In Canada, as in the other countries, the decision to innovate is positively correlated with exporting and firm size (as measured by number of employees); however, in contrast to most OECD countries, being part of a larger group results in Canadian plants being less likely to innovate.

The intensity of investment in innovation is, in most OECD countries, increased by exporting, group membership, cooperation in innovation activities with other firms and research institutions, and by government financial support for innovation. In Canada, as in most countries, the largest effect on investment in innovation—as measured by innovation expenditures per employee—comes from sales to foreign markets (regression coefficient of 0.45). The next most significant determinant is use of government support (0.18), followed by cooperating (0.17) and being part of a larger enterprise (0.15). In most countries, including Canada, selection bias has been detected and corrected following Heckman's procedure by including the Mills ratio in the innovation output and productivity equations.

Second stage – Innovation production function

The log of innovative sales per employee is positively correlated with innovation expenditures per employee in all countries except Switzerland, meaning that firms spending more per employee on innovation activities have more innovative sales per employee. The coefficients range from 0.14 for Denmark to 0.52 for New Zealand; the estimated elasticity for Canada is in the mid-range (0.37)[6]. In Canada, as in some other countries (Finland, France and the UK for instance), firms that introduced process innovations in addition to product innovations have higher innovative sales per employee. Other factors, including the size of firm, membership in a group and collaboration with others, do not have any consistent effect on innovation sales across the OECD countries.

Third stage – contribution of innovation to productivity

Labour productivity is positively correlated with innovation sales. Firms with high innovation sales per employee have a higher productivity level than other firms. The estimated elasticity for all countries ranges from 0.23 to 0.86, with Canada's coefficient (0.44) in the middle of the range. Larger firms have somewhat higher productivity, but the effect of size is modest. Being part of a group is also associated with higher productivity. More surprising is the negative, often statistically

[6] With the exception of Austria, the elasticity of innovation sales to innovation expenditures is statistically significant at the 1% level for all countries. Note that the positive and statistically significant coefficients hold only when the endogeneity between innovation expenditures and innovation sales is rejected. The endogeneity issue when using Canadian data is addressed in the next section.

significant, coefficient of process innovation. Process innovation appears to have a positive effect on productivity only indirectly through its positive correlation with innovation sales in the 2nd stage equation.

Summarizing the Canada results, the OECD model suggests that exporting firms are more likely to introduce new and improved products and that they invest more in innovation than non-exporters. Firms that cooperate in innovation and those that receive financial support from government spend more on innovation per employee than others, but the effect of these two variables is notably smaller and less significant in Canada than in other countries. The innovation sales equation shows that higher innovation expenditures and cooperation with private partners are linked to better performance on product innovation, which in turn is linked to higher labour productivity. Larger firms are significantly more likely to innovate and to achieve higher productivity than smaller firms. In Canada, as in most countries, process innovation enhances productivity only indirectly through its positive impact on product innovation; the direct effect of process innovation on productivity appears to be small and, contrary to expectations, negative.

Overall, when statistically significant, the estimated regression coefficients are remarkably similar for all countries, not only for the productivity equation but also for the elasticity of innovation sales to innovation expenditures and for the equation describing investment in innovation and the decision to innovate as well. Thus, in spite of the constraints on the range and choice of variables imposed for the sake of international comparability, the estimated model yields broadly comparable results for the OECD countries included in the sample.

Nonetheless, because of data constraints, the results from the OECD model must be interpreted with caution. The obvious examples of sub-optimal aspects in the OECD-wide study are: the use of a sub-optimal productivity measure (value added or total factor productivity variables would have been better candidates for the productivity measure than total turnover per employee); the specification of the equation would have been improved by inclusion of important production factors such as human and physical capital; and the use of binary variables when quantitative ones were available for some countries (e.g., percentage of sales exported).

In addition, the lack of robustness of important elasticities (those between innovation output and innovation input, and between productivity and innovation output) calls for further analysis and correction of potential biases that might be caused by endogeneity between innovation-related variables. Finally, further work is needed before accepting the puzzling negative coefficients of process innovation in the productivity equation.

In the following sections, the model is refined in order to assess whether the results obtained with the OECD model hold for Canada when important relationships are added and better suited variables are used.

3. The extended Canadian model

By using Canadian data not constrained by the imperatives of international comparability, we are able to introduce a more complete model, including all relevant available variables, to get more reliable results. The modifications of the core OECD model include:

- a better measure of productivity (value added per employee instead of revenue per employee);
- human and physical capital variables in the productivity equation;
- whenever possible, replacement of binary variables with quantitative variables; and
- addition of other relevant control variables such as outsourcing R&D.

We perform in-depth econometric tests to assess robustness of core results on the links between innovation input, innovation output and firms' productivity (by testing the potential "endogeneity" problems between these variables that would bias results). Finally, we test different variables and different models to assess the counter-intuitive preliminary result of a negative coefficient of process innovation on firms’ productivity.

3.1 The model

The extended Canadian model includes additional and refined relationships at each stage of the analysis, and a better modeling of the productivity equation. The specification of each equation is presented below:

(A0) $\text{innov\_strict} = \beta_0^0 + \sum_n \beta_n^0 X_n^0 + \varepsilon^0$
If innov_strict = 1:
(A1) $\log(\text{inn\_exp/emp}) = \beta_0^1 + \sum_m \beta_m^1 X_m^1 + \varepsilon^1$
(A2) $\log(\text{inn\_sale/emp}) = \beta_0^2 + \beta^2 \log(\text{inn\_exp/emp}) + \beta_{MR} MR + \sum_l \beta_l^2 X_l^2 + \varepsilon^2$
(A3) $\log(\text{VA/emp}) = \beta_0^3 + \beta^3 \log(\text{inn\_sale/emp}) + \beta_{MR} MR + \sum_i \beta_i^3 X_i^3 + \varepsilon^3$

The dependent variables in these equations are defined as follows:

(A0)	innov_strict	= 1 if inn_exp>0 and inn_sale>0; otherwise = 0
(A1)	LRTOTPE log(inn_exp/emp)*	= log(total innovation expenditures per employee)
(A2)	LISPE log(inn_sale/emp)*	= log(innovation sales per employee)
(A3)	LVAPE log(value added/emp)	= log(total revenue per employee)

*Potentially endogenous variables

Explanatory variables for each equation are set out below:

For equation A0, the vector of explanatory variables X_n^0 includes:
- employment in log form (*LEMP);*
- percentage of sales exported to the U.S. (*EXPORT_US);*
- percentage of sales exported to other foreign markets (*EXPORT_OT)*;
- share of total revenue from other plants in the group (*INTRA_SALE);*
- government support by grant *(GRANT)* or by R&D tax credit *(GTXC);*

and important success factors such as:
- seeking new markets (*FAC_NEW)*;
- satisfying existing customers (*FAC_EXIST);*
- developing custom designed products *(FAC_CUSTOM);*
- plant's market share at beginning of period *(MKTSH02);*

and
- industry dummy variables *(SIC_stan).*

For equation A1, the vector of explanatory variables X_m^1 includes:
- employment in log form (*LEMP) or* log of employment at the *beginning* of period (*LEMP02*);
- percentage of export to U.S. (*EXPORT_US);*
- percentage of export to other foreign markets (*EXPORT_OT*);
- share of total revenue from sales to the most important customer or client which is not part of the firm (*MIC);*
- cooperation on innovation (*COOP);*
- government support by grant *(GRANT)* or by R&D tax credit *(GTXC);*
- plant's market share at beginning of period *(MKTSH02);*
- R&D contracted-out *(RD_OUT)*; and
- industry dummy variables *(SIC_stan).*

For equation A2, the vector of explanatory variables X_l^2 includes:
- employment in log form (*LEMP);*
- the plant is part of a group, *(GP)*;
- innovation expenditures per employee in log form (*LRTOTPE**);
- introduction of a process innovation (*PROCESS)*;
- sources of information on innovation from public institutions *(S_PUB)*, from market sources (*S_MARKET)*, or in-house *(S_INTRA)*;
- human capital (*HC)*;
- physical capital per employee in log form (*LGIPE);*
- Mills ratio (*MR); and*
- industry dummy variables (*SIC_stan)*;

For equation A3, the vector of explanatory variables X_j^3 includes:
- employment in log form (*LEMP);*
- the plant is part of a group, *(GP*);
- log of innovation sales per employee (*LISPE*)*;
- introduction of a process innovation (*PROCESS);*
- Mills ratio (*MR);*

- human capital (*HC)*;
- physical capital per employee in log form (*LGIPE);*
- labour productivity at the beginning of the period (2002) *(LVAPE02);* and
- industry dummy variables (*SIC_stan)*.

The instrumental variable for innovation sales, *LISPE,* in equation A3 is:
Z (LISPE) = [*LRTOTPE*, *S_INTRA; S_PUB; S_MARKET*]

For estimation purposes, we use the two-stage Heckman procedure (Heckit) for equations A0 and A1. The Mills ratio variable estimated from the first stage (equation A0, which models selection into innovation) is used to correct for selection bias in modeling innovation expenditure in equation A2. Equation A2, which models innovation sales, is estimated using simple OLS, as the hypothesis of exogeneity of innovation expenditures as a determinant of innovation sales could not be rejected[7]. Therefore, there was no need to introduce an instrument for innovation expenditures in this equation. In contrast, tests showed that innovation sales were endogenous in the productivity equation (A3). Therefore, the latter equation was estimated using a two-stage least squares procedure with an instrumental variable used for innovation sales. The Mills ratio generated in the first stage is included as an explanatory variable in equation A3 as well.

A brief discussion of the exogenous variables used in the four equations follows.

[7] An earlier version of this paper (Therrien-Hanel, 2008) described all the tests performed to assess whether the potential endogeneity between innovation expenditures and innovation sales was important enough to require using IV regression. Suffice to say for now that tests showed no need to use IV regression. More details on tests and results are provided in the next sections. Exhaustive results are available upon request.

Decision to innovate and innovation inputs

Instead of merely identifying export activity by a dummy variable as in the OECD core model, data from the Canadian Survey of Innovation 2005 allow for the use of the actual percentage of sales to the U.S. market (*EXPORT_US)* and to other foreign markets (*EXPORT_OT)*. In general, exporters tend to be more innovative (Becker and Egger, 2007) and more productive (Tybout, 2001; Wagner 2007). This is partly due to the *selection effect* since only the most competitive firms can challenge foreign competition and succeed in exporting. Owing to Canada's close integration with the U.S. economy, sales to the U.S. market may present less of a challenge than exports to other areas. The latter may require more specific competencies, including the capacity to innovate. As well, consistent with the *learning by exporting* hypothesis, there is evidence that participation in foreign markets allows firms to acquire new knowledge that makes them more efficient (De Loecker, 2006). According to Baldwin and Gu (2003), Canadian-owned exporters of manufactured products, especially new entrants to foreign markets and young firms, appear to benefit from both of these effects.

Previous results (OECD 2008, Peters, 2008) show that establishments that are part of a larger entity are more likely to innovate and to spend more on innovation. This may be the case for many smaller establishments that can tap into a firm's resources and expertise. We test whether the "strength" of the link with the larger enterprise plays a role in an establishment's behaviour with regard to innovation and innovation spending. The strength of the link is expressed as the share of total revenue that comes from other establishments of the enterprise (*INTRA_SALE*).

Finally, as stressed in the management literature, choosing to focus on one important client or to diversify the number of clients is believed to have an impact on the innovation behaviour of establishments. Firms generating a high proportion of total revenue from their most important client *(MIC)* are likely to face less incertitude with regard to the adoption of their innovation by their dominant client. Often, the innovation may have been created in collaboration with, or in response to the demand of, their most important client. The hypothesis behind this variable can be traced back to the characterization of the customer and specialized supplier relationship in Pavitt (1984).

Factors that are deemed by a firm to be responsible for its success (i.e., in terms of ranking "high" on the Lickert scale) are likely to be related to the decision to innovate. The active search for new markets (*FAC_NEW),* satisfying existing customers (*FAC_EXIST),* and developing custom-designed products *(FAC_CUSTOM)* are success strategies believed to be closely associated with the decision to innovate[8].

Government support reduces the marginal cost of innovation and hence reduces one of the principal obstacles to innovation (Czarnitzki, Hanel and Rosa, 2005). The decision to innovate may be induced by government support as is the case in some European countries (Griffith et al., 2006). Two dummy variables identifying whether a firm claimed R&D tax credits (*GTXC)* and/or received R&D grants (*GRANT)* are included in the selection and innovation expenditure equations[9].

Establishments, especially smaller ones that do not conduct regular R&D activity, may contract out specific research and development tasks to private or public R&D institutes. On the other hand, access to external R&D may complement a firm's internal R&D competencies. Thus, it is not *a priori* clear whether contracting out R&D is a substitute for, or a complement to, intensity of innovation expenditures. In case the firm contracts out R&D, the sign and statistical significance of the regression coefficient of the dummy variable (*RD_OUT)* indicate whether and how strongly this strategy affects the firm's investment in

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[8] The inclusion of those variables also serves another purpose. To identify and separate innovative and non-innovative firms (for the selection equation), information on all firms is required and unfortunately, few questions in innovation surveys are met with responses from both innovative and non-innovative firms. Success factors are one of the few questions answered by both types of firms; using them was helpful in getting a better result for the entire model.

[9] Unfortunately, quantitative information on the amounts of the subsidies and tax credits are not available from our data base.

innovation activity. The profitability of innovation is expected to be higher the greater the firm's market share *(MKTSH02).*

Innovation output equation

The output of innovation is measured by the log of sales of new and improved products and services per employee *(LISPE).* The specification of explanatory variables in this equation is similar to the OECD core model. In addition to the log of innovation expenditures per employee (*LRTOTPE)* and the log of firm employment (*LEMP),* it includes three specific sources of information on innovation (*S_INTRA, S_PUB,* and *S_MARKET)* in replacement of the four specific cooperation variables that did not perform very well for Canada in the OECD core model. Earlier studies show that innovation feeds not only on R&D competencies, but also often on ideas and suggestions from other internal sources such as management (especially in smaller firms without a regular R&D division) and sales and marketing and production staff, as well as from various external sources. Since the measure of innovation outcomes (*LISPE)* is the value of new and improved product sales per employee, it is expected that it is closely associated with information from market partners such as clients and suppliers and from public research institutions (Baldwin and Hanel, 2003; Landry and Amara, 2003).

Productivity equation

We measure labour productivity as value added per employee, a more appropriate measure of labour productivity than total revenue per employee as used in the OECD core model. We further improve on the OECD model by including in the productivity equation, in conformity with production function theory, both human capital, which is represented by the proportion of university graduates in the firm's total employment (*HC)*, and physical capital, which is represented by the cost of fuel and energy per employee (*LGIPE)* in log form[10].

[10] Due to data constraints, we used expenditure on power and fuel in manufacturing activities as a proxy for physical capital. Energy consumption

A firm's labour productivity is also expected to be affected by its innovation activity—i.e., by the outcome of product innovation (*LISPE)* and of process innovation (*PROCESS*). Firms with higher productivity at the beginning of the period (*LVAPE02)* are likely to report higher productivity at the end of the period.

3.2 The data

The data are from the Canadian Survey of Innovation 2005 on manufacturing and logging industries (reference period 2002 to 2004) linked to the Annual Survey of Manufactures and Logging[11]. The target population of the survey is establishments with more than 19 employees and at least $250,000 in revenues according to Statistics Canada's Business Register (June 2005 version). The linked survey has a total of 6,109 observations.

From the 6,109 observations, we kept only those in the manufacturing sector with positive revenue and with more than 9 employees according to data from the Annual Survey of Manufactures and Logging to standardize the target population in accordance with criteria adopted for all OECD countries[12]. The Canadian final sample thus consisted of 5,355 observations.

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is closely related to physical capital and has been successfully used as a surrogate for capital (e.g., Hillman and Bullard, 1978).

[11] The Statistics Canada Survey of Innovation 2005 does not survey services firms. The innovation survey data are linked to principal statistics from the Annual Survey of Manufactures and Logging, 2002 and 2004. For more information on the survey, go to http://www.statcan.ca/english/sdds/4218.htm

[12] Some firms with less than 20 employees (and also less than 9 employees) were found in the database. The survey population was defined using the June 2005 version of Statistics Canada's Business Register. The annual Survey of Manufactures and Logging includes data from 2002 and 2005.

Box 1: List of variables

Symbol	Description
COOP	Plant co-operated on innovation activities
EXPORT_OT	Percentage of plant's total revenue exported to other destinations
EXPORT_US	Percentage of plant's total revenue exported to the U.S.
FAC_CUSTOM	Developing custom-designed products is the most important factor for plant's success
FAC_EXIST	Satisfying existing clients is the most important factor for plant's success
FAC_NEW	Seeking new markets is the most important factor for plant's success
INTRA_SALE	% of plant's total revenue in 2004 from other plants in the firm
GP	Operations of plant are part of a larger firm
GRANT	The plant (firm) used government R&D grants
GTXC	The plant (firm) used R&D tax credits
HC	Human capital (percentage of full-time employees with university degree)
LEMP (*LEMP02)*	Log of employment (Log of employment for beginning of period (2002))
LGIPE	Proxy for physical capital (Cost of energy and fuel per employee), in log form
LISPE	Log of innovation sales per employee
LRTOTPE	Log of total innovation expenditures per employee
LVAPE	Log of value added per employee
LVAPE02	Log of value added per employee at beginning of period (2002)
MIC	% of plant's total revenue in 2004 from the most important customer
MKTSH02	Plant's market share at beginning of period (share of plant's output over industry output)
PROCESS	Plant introduced a new or significantly improved production process, distribution method, or support activity for its goods or services
RD_OUT	R&D contracted out
S_INTRA	Information on innovation from internal sources
S_PUB	Information on innovation from public sources
S_MARKET	Information on innovation from market sources

INDUSTRY	Industry dummy variables are included in all equations.
Food + Tobacco	Food and Tobacco (NAICS: 311-312)
Textile	Textile, Clothing and Leather (NAICS: 313-316)
Wood	Wood products (NAICS: 321)
Paper	Paper and Printing (NAICS: 322-323)
Petro + Chem	Petroleum, Chemical and Plastics & Rubber (324-326)
Non-metal	Non-metal products (NAICS: 327)
Fab-metal	Primary metal and Fabricated metal products (NAICS: 331-332)
M&E + Telecom	Machinery, Electrical, Electronic computer and communication (NAICS: 334-335)
Transport	Transportation (including aerospace) (NAICS: 336)
NEC	Furniture and NEC manufacturing industries (NAICS: 337-339)

3.3 Comparison of innovating and non-innovating firms

Before turning to the analysis of the econometric results, we first provide a brief descriptive analysis of the data presented in Table 1. First, 66% of the Canadian establishments described themselves as innovators in terms of having introduced either a new or improved product or process in the previous three years. The average productivity level *(VAPE)* of the innovators is 11% higher (i.e., $10,000 value added per employee higher) than for non-innovators[13].

As regards firm characteristics, innovators tend to be larger (*EMP:* average of 109 employees for innovators versus 70 employees for non-innovators) and more likely to be part of a larger enterprise (*GP*: 37% vs. 31%). Innovators have, on average, a higher share of university graduates in their workforce (*HC:* 10% vs. 7%). There is, however, no statistically significant difference in physical capital intensity (*GIPE*) between the two groups. Innovators are also more exposed to

[13] Note: the result of innovative firms being more productive than non-innovative firms also holds when computing a simple regression model where firm size and human and physical capital are taken into account.

the international market by exporting a higher share of their products (to the United States as well as to other foreign markets) than non-innovators. Regarding firms' business strategies, both innovators and non-innovators devote a similar share of sales to their most important client (*MIC*: at a little less than 30% of their sales); but innovators are more likely to see the active search for new markets *(FAC_NEW)* and developing custom-designed products *(FAC_CUSTOM)* as important success factors than non-innovators. Satisfying existing clients is seen as equally important for innovators and non-innovators.

Table 2 provides information on the sub-sample of firms and plants that are considered to be innovators in the "strict sense"—i.e., that reported both innovation expenditures and innovation sales. This is the sub-sample that is used in the econometric model (more specifically in equations A1 through A3). The average labour productivity of "strict" innovators is slightly lower (103.76) than productivity (106.99) of all firms that declared to have innovated (cf. Column 1 in Table 1). Strict innovators spent on average 11% of their total expenditures on innovation activities and 22% of their total sales came from sales of innovative products[14].

The comparison with all innovators shows that a slightly larger proportion of the "strict" innovators used various government support programs; however, only the difference with respect to R&D tax credits is statistically significant. The average log of innovation sales per employee (*LISPE*) is 3.21 or roughly $25,000 per employee[15]. More than one out of four firms cooperated on innovation activities with other firms and institutions and almost one in five contracted out R&D.

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[14] According to a Statistics Canada protocol, it was not possible to publish the average spending on innovation activities per employee (coefficient of variation of this descriptive variable too high). We therefore present the average share of innovation expenditures and innovation sales. Note, however, that the intensity of innovation expenditures and sales by employee in dollar terms was used in the regressions.

[15] See footnote above. The same issue (Statistics Canada protocol) prevented us from presenting a more precise figure.

4. Interpretation of the estimated model

The results of the three stage, four equation model using the expanded Canadian dataset are presented in Table 3. Four variants of the model are estimated.

The first two, presented in columns (1) and (2), are based on a data set that includes firms of all sizes. The main difference between these two variants is the use in variant (2) of variables (employment, market share and productivity level) describing firms' characteristics *at the beginning of the period*. Introducing the productivity level at the beginning of the period (*LVAPE02*) among the explanatory variables separates the effect of innovation on productivity in 2004 from the effect of the pre-existing level of productivity in 2002, while adding the firm's market share (*MKTSH02)*[16] gives useful information on whether the firm has a dominant position in the Canadian market. Note, however, that not all firms are in both the 2002 ASML and the 2004 ASML. Using the data for the years 2002 and 2004 thus results in a loss of about one thousand observations. This is why the results obtained using the whole sample are also presented and analyzed.

Finally, since other studies suggest that the size of the firm matters both for innovation and for productivity, separate estimates were also made for small and medium sized firms (SMEs), those employing less than 150 persons, and the large ones; these results are presented in columns (3) and (4) respectively. The interpretation of these variants follows the discussion of the first two.

[16] Note that the denominator of that variable is the 2002 gross output (in current prices) by industry, sourced from Statistics Canada "Industry Productivity KLEMS 1961-2003", a data base made available to researchers under the Data Liberation Initiative on a CD support (January 2008).

4.1 *Overview of estimation results: model variants with firms of all sizes*

The probability that a firm is a strict innovator increases with the size of firm as measured by employment. This corroborates findings from other Canadian innovation studies (Baldwin and Hanel, 2003; Baldwin and Gellatly, 2003; Gault, 2003).

According to the OECD core model, exporters are more likely to innovate than non-exporters[17]. The more detailed data on export activity used in the present model show, however, that the probability of a firm being a strict innovator increases only with the proportion of exports to destinations other than the familiar U.S. market. This presumably suggests that exporting to overseas markets is more demanding but also more rewarding.

The integration of the plant within the firm matters as well, even though its effect on innovation is limited. Plants that generate an important proportion of their revenues from sales to other plants of their firm (*INTRA_SALE)* are marginally more likely to be strict innovators.

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[17] The relationship between exporting and innovating is very likely endogenous. Exporting firms benefit in their innovation activities from knowledge spillovers from foreign markets and exporting provides both incentives to innovate by extending the market size on which to sell innovations and the competitive stimuli which often makes innovation a *sine qua non* condition for survival and expansion on the export market. On the other hand, a firm may be in the export market thanks to former or current innovations that opened new markets and/or increased its productivity and foreign competeviness. Causality certainly goes both ways and our model does not attempt to disentangle the complex relationship between exporting and innovation. A study of a large sample of Dutch firms found that a firm's export intensity has a positive impact on the probability of, and the intensity of, R&D activity. The other direction of causality was found as well. A firm's R&D activity (but in this case not the intensity of this activity) increases the probability of exporting (Kleinknecht and Oostendorp, 2002). In Canada, Baldwin and Gu (2003) have shown that learning through exporting is particularly present for Canadian-owned and 'young' firms. Exporting is also found to improve productivity, especially in domestically controlled plants.

The strategic orientation of a firm is an important determinant of innovation. Firms that attribute their success to strategies based on the search for new markets are more likely to innovate, as are firms that develop custom-designed products. In contrast, firms that focus their strategies on satisfying existing clients are less likely to innovate.

Public support for innovation through R&D tax credits or grants encourages R&D activity and increases the probability of a firm being a strict innovator.

Finally, the statistically significant value of *rho* (the correlation coefficient between the error terms of the selection and outcome equations) shows the importance of correcting for selection bias by using the Heckit procedure.

Results from Model (2) show that the positive effect of size on the probability of being a strict innovator almost vanishes (the coefficient is barely statistically significant at the 10% level) when we control for the size of the firm at the beginning of the period. Other than the reduced coefficient of the employment variable, and some changes in the effect of exporting on the decision to innovate, there is not much difference between the two models.

Innovation input equation

The equation (A1) is the outcome equation of the Heckman procedure that models firm's innovation expenditures per employee. The estimated regression coefficients are presented in the second block of Table 3.

Since investment in innovation is to a large extent a fixed cost, the intensity of investment in innovation as measured by total innovation expenditures per employee is understandably decreasing with the size of employment.

The strong link between exporting outside the U.S. and investment in innovation is confirmed. However, even firms that export to the U.S. market spend more per employee on innovation than non-exporters.

Firms that cooperate on innovation are more likely to spend more on innovation than those that do not. This suggests that cooperation is unlikely to be undertaken as a cost-saving measure, but rather to increase the scope of the project or to complement the firm's competency.

Similarly, contracting out R&D does not seem to be a cost-reducing strategy. The positive elasticity estimate suggests that firms with higher innovation expenditure intensity are also more likely to contract out R&D instead of using R&D contracts as substitutes for their own innovation activities.

Interestingly, while fiscal incentives and direct subsidies to innovation are positively associated with the probability of being a strict innovator (cf. the interpretation of the selection equation above), they are not associated with greater innovation expenditure intensity[18].

As suggested by microeconomic analysis, firms with a larger market share at the beginning of the period invest in innovation more per employee than those with a smaller market share.

<u>Innovation output equation</u>

The innovation output equation shows the contribution of various variables to innovation output (*LISPE)* measured as the value of new and improved products—product innovations—per employee. This equation assesses, among other factors, the importance of innovation expenditures (*LRTOTPE*) for innovation sales. The elasticity of *LISPE* with respect to *LRTOTPE* is 0.33, very similar to the elasticity estimated by the OECD core model (0.37)[19].

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[18] When using the OECD model, the coefficient of public R&D financial support for Canada was positive and significant but with a weaker correlation (significant at the 10% level only) than for other countries (see Appendix 1 for details). The effect vanished when we use the extended model. It should be noted that quantitative variables (real amount of R&D grants and tax credit) would be needed to get a better idea of the real causal effect on firms' innovation expenditure intensity. As noted before, such data were not available with the database used.

[19] The innovation expenditure variable (*LRTOTPE)* is potentially endogenously determined with the innovation sales variable (*LISPE)*. However, tests (the "difference-in-Sargan C statistic" and a manual test regressing the estimated residuals of *LRTOTPE* on *LISPE*) indicate that the hypothesis of exogeneity cannot be rejected. Furthermore, the Stock-Yogo relative bias test shows that the potential bias introduced by using the OLS

Several other variables have an important effect on the output of innovation. First of all, only innovations inspired by ideas from market partners (customers, suppliers, competitors, consultants and commercial R&D laboratories) enhance the commercial success of innovation. This finding corroborates earlier results by Baldwin and Hanel (2003), underlining the importance of the commercial orientation of innovation. The fact that sources of information internal to the firm (sales, marketing, production) do not seem to contribute to innovation sales may be interpreted as an indication that their contribution is already included in total innovation expenditures.

More capital-intensive firms, especially those with high levels of human capital, are more successful at commercializing innovations.

As well, innovating firms that introduce process as well as product innovations derive more sales from innovation than those introducing only product innovations.

Finally, firms with a higher productivity level at the beginning of the period (model variant (2)) derive more sales from innovation at the end of period than those with a lower initial productivity level. This means that firms that were already outperforming other firms in terms of productivity are more likely to be successful innovators (measured by innovation sales) in the next period. Also, it is interesting to note that adding productivity at the beginning of the period does not change the sign and impact of other core variables; in particular, the impact of innovation expenditure intensity remains similar.

Productivity equation

Finally, the productivity equation shows that firms with higher innovation sales per employee (*LISPE*) obtain higher labour productivity expressed as log of value added per employee

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procedure would still be lower than the bias introduced by using the IV regression. Therefore equation (3) was estimated by OLS using the observed rather than the instrumented *LRTOTPE* variable.

(*LVAPE*). The elasticity of the instrumented[20] variable (*LISPE*) is positive and statistically significant; its value of 0.21 is about half that estimated in the OECD core model. Productivity increases slightly with the size of establishment and when the establishment is part of a larger enterprise. Conforming to economic theory, both human and physical capital intensity are important co-determinants of labour productivity.

As in the core model, firms introducing a process innovation in addition to a product innovation have lower labour productivity than other innovative firms[21]. While this result is counterintuitive and stands in contrast with other studies (see Griliches, 1998 for the U.S.; Criscuolo and Gaskell, 2003 for the UK; and Hanel, 2000 and Baldwin and Gu, 2004 for Canada), some explanations can be proposed. First, the model used focuses primarily on product innovators, and therefore the

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[20] According to the tests (the "difference-in-Sargan C statistic" and a manual test regressing the estimated residuals of *LISPE* on *LRTOTPE*), *LISPE* and value added per employee *LVAPE* are endogenous. Therefore the productivity equation is estimated as a 2SLS system with *LISPE* instrumented in the 1st stage.

[21] In the OECD core model, the estimated regression coefficient of the *PROCESS* innovation dummy variable is negative and statistically significant for all countries. To explore further the relationship between labour productivity and process innovation we experimented by replacing *PROCESS* by specific forms of process innovation such as:

(i) new or significantly improved method of producing goods or services;
(ii) new or significantly improved logistic, delivery or distribution methods;
(iii) new or significantly improved supporting activities for firm's processes such as maintenance system, or operations for purchasing, accounting or computing;
(iv) process innovation increased flexibility of production; and
(v) process innovation increased speed of supplying and/or delivering goods and services.

Among the first three types of process innovation, only the new or improved manufacturing method (i) has a significantly negative correlation coefficient. The other two types of process innovation are not correlated with labour productivity. When labour productivity is regressed on the specific effects of process innovations such as increased production flexibility and increased speed of delivery of goods and services, the correlation is still negative and statistically significant.

negative coefficient on productivity is relative to product innovators that do not introduce process innovation. It is therefore possible to think that firms introducing both product and process innovations are introducing complex change (and maybe more radical innovations) in their manufacturing processes, leading to a short-term negative impact on labour productivity. Second, the effect of process innovation is not as well captured in the Canadian survey as the effect of product innovation. To mirror the measurable effect of product innovation (as measured by sales per employee from innovative products), we would need a variable that would assess the cost saving from process innovation[22]. Without such a variable, it is hard to assess the effect of process innovation that would lead directly to productivity gains.

Finally, including labour productivity at the beginning of the period as an additional explanatory variable (model variant (2)) does not change the results discussed above. Even though labour productivity in 2002 is an important determinant of productivity in 2004, it does not significantly change the effect of innovation sales on labour productivity. The estimated elasticity of productivity on innovation sales is slightly lower (0.17), but within the same range as the elasticity estimated in the first model (0.21) with contemporaneous variables.

In conclusion, the better specification and improved estimation procedures of the extended Canadian model provide robust results that confirm, with added detail, the principal conclusions of the OECD core model. These results show, in no uncertain terms, that product innovation contributes significantly to higher productivity.

4.2 Overview of estimation results for SMEs and large firms

Previous studies suggested that the size of firm is an important determinant of innovation and that SMEs do not innovate in the

[22] The elasticity of productivity on the cost saving from process innovation, an estimate of which is available in the German innovation survey, is positive and statistically significant (see Peters, 2008).

same way as large firms (Acs and Audretsch, 1988; Baldwin and Hanel, 2003; Baldwin and Gellatly, 2003). This raises the question of whether the effect of innovation on productivity is also different between the two groups. To determine to what extent the size of firm matters, the model was estimated separately for small and medium sized firms employing less than 150 persons and for the larger firms.

The results for SMEs and large firms are presented respectively in the 3rd and 4th columns in Table 3; they indeed show some notable differences between the two size categories. First, since most large firms export, exporting does not discriminate between innovators and non-innovators and investment in innovation for large firms.

Similarly, human capital does not have a significant effect on innovation sales and labour productivity in large firms. In contrast, human capital increases innovation sales, but not labour productivity, in SMEs.

While the elasticity of innovation sales to innovation expenditures is comparable between the two groups, the elasticity of labour productivity to innovation sales per employee (*LISPE)* is twice as large in big firms (0.35) as in the SME group (0.18).

5. Conclusions and Policy Implications

This paper extends and refines the Canadian model applied in the 18-country OECD study of the relationship between innovation and productivity performance at the firm level (OECD STI-Outlook 2008, Chapter 5; see Appendix 1 for details). Results from both models (the simpler model used for benchmarking Canada internationally and the more robust model using all available information from the Canadian database presented here) show that higher innovation expenditure intensity is conducive to better innovation outcomes (higher innovation sales per employee); and in turn highly innovative firms are more productive. The main difference between the two models is that both the estimated elasticity of innovation output to innovation input and the elasticity of labour productivity to innovation sales are smaller, though still positive and statistically significant in the more robust model run exclusively on Canadian data. Therefore, the coefficients from the OECD model should be used with caution and treated as upper bound values.

Our model also confirmed, with more detail, the main factors leading to higher innovation and productivity performance. Factors directly contributing to higher productivity are: a skilled workforce; higher physical capital intensity; and, as noted above, higher intensity of innovation sales. Results from this study also showed that high innovation expenditure intensity is the best predictor of high innovation sales. Finally, factors contributing indirectly (through innovation expenditure intensity) to higher productivity are: tapping into global markets as shown by export variables, cooperation to access external expertise, and relying on market-oriented external sources of information to guide innovation activity.

Our main results suggest that export (only outside of the U.S. market), size of firm, and use of direct or indirect government support are factors increasing the probability to innovate and having positive innovation sales.

Exports (both to the U.S. and outside of the U.S. market), cooperation with other firms and organizations, and a high share of the firm's revenue coming from sales to its most important client are all factors correlated with higher innovation expenditures per employee. Moreover, firms with a higher market share at the beginning of the period tend to spend more on innovation by the end of the period.

Firms with higher innovation expenditures per employee also generate more innovation sales per employee (an increase of 1% of innovation expenditures per employee is linked with an increase of 0.33% of innovation sales per employee). Firms introducing both product and process innovations also generate more innovation sales per employee than those introducing only product innovations. Other factors increasing innovation sales are human and physical capital and introduction of process innovations.

Finally, results from the model show that more successful product innovators (those generating more innovation sales per employee) achieve higher labour productivity, even when the size of firms and intensity of human and physical capital are taken into account (an increase of 1% of innovation sales per employee is linked to an increase of labour productivity of 0.22%). It is worth noting that firms that are more productive at the beginning of the period derive more sales from innovation and are also still more productive by the end of the period.

The policy implication of these results is certainly interesting given that aggregate productivity growth in the Canadian business sector has been considered weak in recent years (with multi-factor productivity being the main culprit). New evidence (OECD, 2007) confirms results highly publicized a few years ago (Government of Canada, 2002) which show that Canada has a high percentage of innovators (using a broad definition, including technology adopters) but realizes lower innovation sales than most OECD countries. This weak performance in selling innovative products seems to be an important barrier for higher productivity performance as shown by this study.

Also of interest is the result that highly successful innovative firms (those that have high innovation sales per employee) devote more resources to innovation. Transposing this firm-level result to the country level, it is hard not to make the link between the sub-par Canadian performance in business R&D and weak productivity performance in international comparison. R&D is only one, though often the most important, of several activities leading to successful innovation. According to Statistics Canada (Schelling and Gault, 2006) a large percentage of firms reporting R&D activity and claiming R&D tax credits spend less than $100,000 per year, an amount barely covering the wage cost of one full time equivalent senior researcher. This suggests a suboptimal level of R&D activity, below the critical mass of human and complementary resources needed for successful innovation and its commercialization.

In conclusion, this study confirms the importance of innovation to productivity at the establishment level. However, some results require further investigation. First, Canadian firms do not increase their innovation expenditure intensity as much as firms in other OECD countries when collaborating or when receiving public funding. This could be symptomatic of weak coordination/design of existing government programs involving collaboration or support to business innovation and cooperation.

Second, our results suggest that past productivity performance improves both subsequent innovation sales and productivity. More investigation is needed to understand why some firms started with higher productivity performance than others. Would this be because these are firms permanently engaged in innovation or because of the complementarities between different business strategies? Would it be the case that firms with higher productivity at the beginning of the period started by being cost effective before turning to a more innovation-based business strategy? Answers to these questions would be relevant to policymakers, so it is necessary to research more on the causes of higher productivity level at the beginning of the period.

Third, results for Canada and for most OECD countries show that firms introducing product and process innovation have a lower productivity performance in the short term than those that introduced only a product innovation. Partial explanations for this counter-intuitive result have been proposed, one suggestion being that firms introducing complex changes in manufacturing processes suffer a short-term negative impact on labour productivity. Whether or not this effect would be reversed in the long run would also be relevant information for policymakers.

New and better firm-level databases would be needed to answer these questions. Panel data (data linking innovation survey databases in time) and information on different business strategies (other than those based on innovation) are examples of the types of data needed to better explore the complex issue of innovation and productivity in the long term.

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Table 1: Comparison of Innovators and Non-Innovators

	Innovators		*Non-innovators*		*Mean difference*
Variable	*Mean*	*SE*	*Mean*	*SE*	*p-value**
VAPE	107.00	2.00	96.27	2.20	**0.000**
INNOV_STRICT	61.09	1.00	0.00	0.00	**0.000**
EMP	109.10	2.70	70.14	2.10	**0.000**
EXPORT_US	0.29	0.00	0.21	0.00	**0.000**
EXPORT_OT	0.06	0.00	0.03	0.00	**0.000**
GP	0.37	1.20	0.31	1.60	**0.001**
INTRA-SALE	0.06	0.50	0.04	0.50	**0.001**
HC	0.10	0.00	0.07	0.00	**0.000**
GIPE	7.09	0.40	6.73	0.60	0.303
MIC	0.27	0.50	0.29	0.80	**0.008**
GTXC	0.52	1.20	0.15	1.20	**0.000**
GRANT	0.12	0.80	0.02	0.50	**0.000**
FAC_NEW	0.40	1.20	0.24	1.40	**0.000**
FAC_EXIST	0.88	0.80	0.89	1.10	0.325
FAC_CUSTOM	0.45	1.20	0.28	1.50	**0.000**
FOOD + TOBACCO	0.12	0.50	0.11	0.90	0.290
TEXTILE	0.05	0.20	0.09	0.40	**0.000**
WOOD	0.08	0.50	0.10	0.80	**0.014**
PAPER	0.09	0.30	0.08	0.50	0.116
PETRO + CHEM	0.13	0.40	0.10	0.70	**0.000**
NON-METAL	0.04	0.20	0.04	0.40	0.415
FAB-METAL	0.15	0.70	0.20	1.30	**0.001**
M&E + TELECOM	0.19	0.50	0.11	0.90	**0.000**
TRANSPORT	0.06	0.30	0.06	0.60	0.315
NEC	0.10	0.40	0.12	0.70	**0.010**
No. of obs.**	3,629		1,726		

*P value from critical Z score at one tail; bold means significant at the 5% level.

**Because of missing data and the use of logs, the number of observations used in the econometric model for VAPE is 3,611 (instead of 3629) for the sub-sample of innovators.

Source: Authors' calculations based on Statistics Canada Survey of Innovation 2005.

Table 2: Comparative Data for "strict" Innovators

Variable	*Mean*	*SE*
VAPE	103.76	1.56
LISPE	3.21	0.04
LRTOTPE	2.42	0.04
EMP	111.22	2.89
EXPORT_US	0.29	0.01
EXPORT_OT	0.07	0.00
GP	0.37	1.30
INTRA-SALE	0.06	0.55
HC	0.11	0.00
GIPE	5.62	0.17
MIC	0.27	0.67
GTXC	0.61	1.40
GRANT	0.14	1.00
COOP	0.27	1.30
RD_OUT	0.19	1.10
PROCESS	0.72	0.73
S_INTRA	0.23	1.20
S_PUB	0.03	0.40
S_MARKET	0.20	1.10
FAC_NEW	0.45	1.40
FAC_EXIST	0.86	1.00
FAC_CUSTOM	0.51	1.40
FOOD + TOBACCO	0.13	0.90
TEXTILE	0.05	0.20
WOOD	0.06	0.50
PAPER	0.08	0.50
PETRO + CHEM	0.14	0.60
NON-METAL	0.04	0.40
FAB-METAL	0.13	1.00
M&E + TELECOM	0.22	0.90
TRANSPORT	0.05	0.50
NEC	0.11	0.50
No. of obs.**	2,273	

**Because of missing data and the use of logs, the number of observations used in the econometric model for VAPE is 2,261 (instead of 2273) for the sub-sample of innovators.

Source: Authors' calculations based on Statistics Canada Survey of Innovation 2005.

Table 3: Econometric Results

Equation A0: Decision to innovate (Innovation "strict") – Two-stage Heckman (Heckit) Procedure

	without lag (1)	*with lag (2)*	*SME only (3)*	*Large only (4)*
LEMP (LEMP02)	0.0657**	0.0613*	0.0493	0.1161
EXPORT_US	-0.1611	-0.2233*	-0.1572	-0.3018
EXPORT_OT	0.5300**	0.4425*	0.6892***	-0.2507
INTRA-SALE	0.0033**	0.0033*	0.0037*	0.0003
FAC_NEW	0.4380***	0.4211***	0.4539***	0.3617***
FAC_EXIST	-0.156*	-0.156	-0.126	-0.1808
FAC_CUSTOM	0.4112***	0.4396***	0.3434***	0.7966***
GTXC	0.8129***	0.8217***	0.8741***	0.6409***
GRANT	0.3161***	0.3100***	0.2350**	0.7248***
MKTSH02		-0.0011		
rho	-0.27**	-0.33**	-0.351**	0.001
N (unweighted)	5,355	4,312	4,417	938

Equation A1: Innovation input – Log (Innovation expenditures/employee) (LRTOTPE)

	without lag (1)	*with lag (2)*	*SME only (3)*	*Large only (4)*
LEMP (LEMP02)	-0.1255***	-0.1957***	-0.1914***	0.0398
EXPORT_US	0.2745**	0.3717***	0.4192***	-0.1588
EXPORT_OT	1.055***	1.055***	1.1223***	0.4933
MIC	0.0034**	0.0049**	0.0042**	-0.0001
COOP	0.1534**	0.1415*	0.1302	-0..2318
GTXC	-0.1041	-0.2089	-0.159	-0.025
GRANT	0.091	0.041	0.0813	0.2261
RD_OUT	.2349***	0.1443	0.2018**	0.2841*
MKTSH02		0.057***		
N (unweighted)	2,273	1,789	1,786	476

Equation A2: Innovation output – Log (Innovation sales/employee) (LISPE)

	without lag (1)	*with lag (2)*	*SME only (3)*	*Large only (4)*
GP	0.006	0.0108	-0.0175	0.1454
LEMP	-0.0438	-0.03	-0.0659	-0.077
PROCESS	0.2257**	0.3558***	0.1756**	0.2718
HC	0.6730**	.5723*	0.5855**	0.6802
LGIPE	0.2710***	0.2462***	0.2654***	0.2415***
S_INTRA	0.1236	0.2041*	0.2131**	-0.1123
S_PUB	-0.0237	-0.0976	-0.0429	-0.0402
S_MARKET	0.3565***	0.3942***	0.3200***	0.3919**
LRTOTPE	0.3256***	0.3108***	0.3259***	0.3649***
LVAPE02		0.131*		
N (unweighted)	2,243	1,745	1,755	476

Equation A3: Productivity – Log (Value Added/employee) (LVAPE)

	without lag (1)	*with lag (2)*	*SME only (3)*	*Large only (4)*
GP	0.1618***	0.1360***	0.1516***	0.1264
LEMP	0.0328**	-0.0191	-0.0001	0.1038*
LISPE	0.2214***	0.1777**	0.1778***	0.3500***
PROCESS	-0.1134***	-0.089**	-0.077**	-0.224**
HC	0.1495**	0.2132*	0.1539	0.1294
LGIPE	0.1795**	0.1501***	0.1826***	0.1625***
LVAPE02		0.2689***		

Source: Authors' calculations based on Statistics Canada Survey of Innovation 2005.

Appendix 1:
Results from the OECD model (results from 18 countries)

Several OECD countries including Canada combined their research efforts in order to reach a better understanding of the process from the decision to innovate up to the effect of innovation on productivity and other performance indicators.

To ensure the international comparability of results, as far as possible given the data constraints, each team used the same variables from national innovation surveys and applied the same methodology. Based on the data collected by a near-identical survey design and questionnaire and analyzed by means of a common econometric methodology, the joint project yields internationally comparable results of interest to innovating firms, policy makers and academic researchers.

The following models were estimated for each country:

Specification of the OECD core model

(B0) innovator strict = $\beta_0^0 + \sum_n \beta_n^0 X_n^0 + \varepsilon^0$

If innovator strict=1:
(B1) log(inn_exp/emp) = $\beta_0^1 + \sum_m \beta_m^1 X_m^1 + \varepsilon^1$
(B2) log(inn_sale/emp) = $\beta_0^2 + \beta^2$ log(inn_exp/emp) + $\beta_{MR}MR + \sum_l \beta_l^2 X_l^2 + \varepsilon^2$
(B3) log(total rev/emp) = $\beta_0 3 + \beta^3$ log(inn_sale/emp) + $\beta_{MR}MR + \sum j\ \beta^{j3} X^{j3} + \varepsilon^3$

The dependent variables are:
(B0) innovator strict = 1 if innovation expenditures and innovation sales are positive;
(B1) log(inn_exp/emp)* = log(total innovation expenditures/employee),
(B2) log(inn_sale/emp)* = log(share of innovation sales in total revenue/employee)
(B3) log(total rev/emp) = log(plant's total revenue per employee),

The independent variables are:
X_n^0 = log(employment); part of a group; export sales; industry;
X_l^1 = part of a group; export sales; cooperation on innovation; government support for innovation; industry;
X_m^2 = log(employment); part of a group; process innovation; four types of cooperation; industry;
X_j^3 = log(employment), part of a group; innovation process, human capital; log(physical capital per employee); industry
MR= Mills ratio
*Potentially endogenous variable

B0 (Selection Equation): Which firms are more likely to be innovative?

	Belonging to a group	Operating in a foreign market	Being large (size)	Barriers related to knowledge (1)	Barriers related to markets (2)	Barriers related to costs (3)	Rho (4)	No. Obs.	P-value (5)
Australia	0.352***		0.153***	0.232***	0.207***	0.348***		3 697	0.522
Austria	0.213*	0.454***	0.253***	-0.0765	-0.182	-0.00122	0.223	1 001	0.226
Belgium	0.198***	0.617***	0.267***	0.0427	-0.05	0.455***	0.41	2 695	0.0012
Brazil	0.424***	-0.264***	0.123***	0.152***	0.131***	0.032	2.019***	9 384	0
Canada	-0.105*	0.290***	0.140***				1.005***	5 355	0
Denmark	0.186**	0.637***	0.253***	0.243**	0.0288	0.391***	0.324**	1 729	0.0202
Finland	0.0649	0.532***	0.254***	0.190**	0.259***	-0.0266	0.477***	2 155	0.00178
France	0.227***	0.778***	0.204***	0.201***	0.0678***	0.227***	0.643***	18 056	0
Germany	0.144***	0.529***	0.0884***	0.0144	-0.107	0.173***	0.256**	3 242	0.0656
Italy	0.203***	0.478***	0.185***	0.110***	-0.0680**	0.0908***	0.753***	15 915	0
Korea	-0.064		0.202***	0.201***	0.006	0.136*	0.662	1 335	0.007
Luxembourg	0.267*	0.314**	0.248***	0.191	-0.101	0.359*	0.192	545	0.701
Netherlands	0.164***	0.546***	0.213***	0.175***	-0.111**	0.0123	0.727***	6 858	0
NZ	0.113**	0.349***	0.0785***	0.0892*	0.027	0.138***	1.337***	3 426	0
Norway	-0.0724	0.643***	0.320***	0.301***	0.0478	0.301***	0.739***	1 852	0
Sweden	0.173***	0.576***	0.09***	0.556***	0.16***	0.119**		2 954	0.563
Switzerland		0.312***	0.045*	0.075	0.201*	-0.065	0.927***	1 964	0
UK	0.174***	0.464***	0.0468***	0.287***	0.0883**	0.0883**	-0.04	11 162	0.261

* significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.

Source: OECD STI Outlook, 2008, p.242

Notes:
Coefficients reported are marginal effects, i.e. they predict the likelihood of being innovative. For example, an Austrian firm operating on a foreign market is 45% more likely to be innovative than an Austrian firm only active in the local market. For Canada and Brazil the regressions are weighted to the population. Results are based on 2004 innovation surveys (CIS-4 for European countries), except for Austria which used CIS3 data and Australia where the innovation survey has 2005 as the reference year. For Australia the group variable is imputed. Switzerland does not have information on whether firms belong to groups; Australia does not have information on whether firms serve a foreign market and in Canada the survey does not ask about obstacles to innovation.

(1) Knowledge factors are defined e.g. as lack of qualified personnel, lack of technological and/or market information or lack of co-operation partners).

(2) Market factors refer e.g. to market dominated by established enterprises or uncertain demand for innovative goods or services.

(3) Cost factors refer e.g. to lack of internal funds, lack of external finance and costs of innovation too high). All three variables are defined as a 0/1 dummy that equals one if any of the factors included was a very important obstacle.

(4) "rho" is the correlation coefficient between the error terms of the selection and outcome equation.

(5) The p-value is used to test whether correction for selection bias is necessary or not. The null hypothesis, rho = 0, assumes that there is no link between the selection and outcome equations. The null hypothesis is rejected at the 10% level in most countries, hence correcting for selection improves the model, except for Australia, Austria, Luxembourg and the United Kingdom. Industry dummies included but not reported.

B1 (Innovation Input Equation): Which firms spend more on innovation?

	Belonging to a group	Operating in a foreign market	Being engaged in co-operation	Receiving financial public support	No. Obs.
Australia	0.443**		-0.161	-0.0334	3 697
Austria	0.161	0.737***	0.408***	0.746***	1 001
Belgium	0.233*	0.524***	-0.0205	0.714***	2 695
Brazil	0.875***	-0.204*	0.384***	0.332***	9 384
Canada	0.145*	0.448***	0.173**	0.183*	5 355
Denmark	0.477***	0.762***	0.182	0.735***	1 729
Finland	0.260**	0.361*	0.495***	0.460***	2 155
France	0.231***	1.158***	0.427***	0.683***	18 056
Germany	0.0538	0.610***	0.402***	0.469***	3 242
Italy	0.268***	0.511***	0.310***	0.412***	15 915
Korea	-0.167		0.079	0.407***	1 335
Luxembourg	0.212	0.434	0.102	0.352	545
Netherlands	0.247***	0.675***	0.389***	0.569***	6 858
NZ	0.664***	0.740***	0.225***	Confidential	3 426
Norway	-0.0436	0.706***	0.354***	0.657***	1 852
Sweden	0.173***		0.576***		2 954
Switzerland		-0.717**	0.370**	-0.128	1 964
UK	0.0508	0.513***	0.377***	0.537***	11 162

* significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.
Source: OECD STI Outlook, 2008, p.244

Notes:

Coefficients reported are marginal effects for the co-operation and financial support variables but not for the group and foreign markets variables because the latter enter both the selection (probability to innovate) and the outcome (innovation intensity) equation. When variables enter both the selection and outcome equations their marginal effect can be broken down into two parts: the first is the direct effect on the mean of the dependent variable (which is reported in this table) and the second comes from its effect through its presence in the selection equation.

For Canada and Brazil, the regressions are weighted to the population. Results are based on 2004 innovation surveys (CIS-4 for European countries), except for Austria which used CIS3 data and Australia where the innovation survey has 2005 as the reference.

Belonging to a group; operating in a foreign market; being engaged in co-operation and receiving financial support are 0/1 dummies.

For Australia the group variable is imputed from responses to the question about whether the enterprise collaborated with other members of their group and is underreported as it omits enterprises that are part of an enterprise group but did not collaborate.

For New Zealand information on innovation expenditure is codified as a categorical variable; to transform it to a continuous variable midpoints of each range are used and multiplied by total reported expenditure.

Industry dummies included but not reported.

B2 (Innovation output Equation): Does spending in innovation inputs translate into sales from product innovation?*

"Investing in innovation increases sales from product innovation in all countries except Switzerland. The impact on sales is greater than 40% in Australia, New Zealand and Norway and ranges from 14 to 35% for the other countries."

"The preliminary analysis provides mixed results [for other factors]: size is positively correlated, negatively correlated or not correlated with sales from product innovation depending on the country. Economies of scope and scale and knowledge flows within the firm (the group variable) seem to play a role in commercialisation in most countries, but not in all. Finally, there is little evidence that firms that engage in collaboration with different partners have significantly more innovative sales."

** No econometric tables were provided for the Innovation Output Equation in the OECD STI-Outlook so we provided the text associated with the equation.*

B3 (Productivity Equation): What is the impact of product innovation on labour productivity?

	Belonging to a group	Being large (Size)	Having implemented a process innovation	Log innovation sales per worker (product innovation)	No. Obs.
Australia	0.12	0.144***	-0.089	0.557***	509
Austria	0.182**	0.0111	0.0443	0.312***	359
Belgium	0.303***	0.002	-0.119**	0.543***	718
Brazil	0.183**	0.140***	-0.211***	0.647***	1 954
Canada	0.250***	0.0772**	-0.122**	0.436***	2 273
Denmark	0.186**	0.0732***	-0.0405	0.345***	584
Finland	0.244***	0.0859**	-0.0677	0.314***	698
France	0.232***	0.0536***	-0.129***	0.474***	2 511
Germany	0.0838**	0.0625***	-0.116***	0.500***	1390
Italy	0.093	0.00391	-0.192**	0.485***	747
Korea	0.152*	0.045	-0.118*	0.859***	628
Luxembourg	0.434***	0.0349	-0.142	0.226*	207
Netherlands	0.0219	0.0902***	-0.044	0.409***	1 374
NZ	0.128**	0.0662***	-0.135***	0.682***	993
Norway	0.256***	0.0407	-0.0716	0.344***	672
Switzerland		0.113***	-0.091	0.295	394
UK	0.150***	0.0580***	-0.121***	0.550***	2 989

* significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level.
Source: OECD STI Outlook, 2008, p.245

Notes:
For Canada and Brazil the regressions are weighted to the population. Results are based on 2004 innovation surveys (CIS-4 for European countries), except for Austria which used CIS3 data and Australia where the innovation survey has 2005 as the reference year.
Belonging to a group; and having implemented process innovation are 0/1 dummies. Size is measured as log employment.
Industry dummies and inverse Mills ratio are included but not reported.
For Australia the group variable is imputed from responses to the question about whether the enterprise collaborated with other members of their group and is underreported as it omits enterprises that are part of an enterprise group but did not collaborate with other enterprises within the group on innovation projects.
For New Zealand information on innovation sales is codified as a categorical variable; to transform it to a continuous variable midpoints of each range are used and multiplied by total reported expenditure.