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NOTE DE RECHERCHE

Impact of Innovation Motivated by Environmental Concerns and Government Regulations on Firm Performance: A study of survey data

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Introduction

The conventional wisdom among economists is that environmental regulations impose significant costs, slow productivity growth, and thereby hinder the ability of firms to compete in international markets. According to OECD (1997a) compliance with environmental regulation reduced the damage to environment in OECD countries but it cost from 1 to 2% of their GNP.

According to an alternate view (Porter, 1991; Porter and Van der Linde, 1995) properly crafted environmental standards can trigger innovation offsets, allowing companies to improve their competitiveness and productivity. In their view, the potentially detrimental static effect of compliance with environmental regulations on the cost of production may be more than compensated by a positive dynamic effect due to new business opportunities and innovation motivated by environmental compliance. This will, accordingly to the authors, bring a double dividend, an improvement in environment and in profits.

The Statistics Canada Innovation Survey 1999 makes it possible to identify firms that innovated, among other reasons, in order to comply with government regulations and/or to reduce environmental damage. Associating these motives with the impact of innovation on a firm's performance, suggests whether the regulatory burden related to environmental protection in particular, is associated with inferior economic performance. The nature of the information available from the survey has, however, limitations which have to be taken into account in interpretation of whatever result will be found. As Jaffe and Palmer (1997) and Lanjouw and Mody (1995) studies, the present one can not provide evidence relative to the strong version of Porter-Van der Linde hypothesis. At best, it may show whether innovations introduced to alleviate environmental damage and in response to government regulations had a positive or a negative effect on the performance of their firm.

The study is organized in the following way. The next section provides a selective review of the empirical literature. It is followed by a descriptive statistical analysis of the Statistics Canada Innovation Survey 1999 data that characterize the sub-population of innovating firms that launched new or improved products or processes in order to respond to government regulation and/or to environmental concerns and those that experienced during their innovation process problems related to government regulations.

The third section presents a series of tests of the hypothesis that firms that introduced innovations to reduce environmental damage and/or to comply with government regulations are more likely than other innovating firms to report that innovations impaired their economic performance (e.g. reduced profitability, productivity and market shares). The fourth section presents a series of regression models estimating the probability that innovations introduced to reduce environmental damage and/or to comply with government regulations impaired economic performance of innovating firms.

The conclusion of the study suggests that innovating to reduce *environmental damage* does not appear to have a negative impact on the innovating firm. In contrast, productivity, profitability and market share of firms that introduced new and improved products and processes in response to *government regulations* are likely to be negatively affected. However, those firms that listed among their motives for innovation *both environmental concerns and regulatory compliance* reported mostly improved performance.

Survey of the literature

From a theoretical point of view of neoclassical economics it is difficult to demonstrate how an introduction or any tightening of environmental standards could set in motion innovation that in the end would increase the profits and competitiveness of profit maximizing polluting firms (Oates, Palmer and Portney, 1995). Only under rather special circumstances when regulators and polluting firms engage in strategic behavior, government may improve the international competitive position of domestic exporters

by imposing environmental standards (Barrett, Scott, 1994 and Simpson and Bradford, 1996). In another context, when less polluting technologies are also more productive, environmental regulation can enhance pollution–reducing innovation while at the same time increasing firm's profitability (Ambec and Barla, 2002).

Of course, tighter environmental standards increase demand of polluting firms for abatement equipment and lead to an increase in R&D activities and innovation within the abatement equipment industry. This may enhance international competitiveness of abatement equipment producing innovators. In a perfectly competitive world, however, the increased R&D investment of abatement equipment producers will reduce R&D activity in other more profitable fields.[1]

The empirical evidence from the United States supports the conventional view. A study of 445 manufacturing industries by Robinson (1995) suggests that regulation diverts economic resources and managerial attention away from innovations that are productivity enhancing. However, studies that attempted to measure the effect of environmental policies on international competitiveness, flow of trade and localization of industrial sites found that the effects were not important and statistically not significant (cf. review of the literature in Fukasaku, 2000).

Jaffe and Palmer (1997) established that environmental compliance increases R&D expenditures. They found, however, little evidence that those industries' inventive output, and by implication innovation, is related to compliance costs. In contrast, Lanjouw and Mody (1995) found a positive effect of environmental regulation on the share of patents for environmental technologies. According to Jaffe and Palmer, the two studies suggest that "…in the aggregate, the disincentives for R&D attributed to a command - and - control approach to environmental regulation may be overcome by the high returns that regulation creates for new pollution –control technology." However, the authors concede in the discussion of their findings, "...these results, do not indicate whether the increased R&D is merely an expensive diversion from firms' other, more profitable, R&D projects. Results reported in both studies provide evidence in support of the weak version of Porter-Van der Linde hypothesis that environmental regulation stimulates certain kinds of innovation. These studies certainly do not provide an evidence of the *strong* version of the hypothesis that regulation induces innovation whose benefits exceeds its costs (Jaffe and Palmer, 1997, p.611).

A survey of firms that introduced environmental innovations in five European countries suggest that environmental product and service innovations increase significantly the probability of creating jobs. In contrast, end-of-pipe ecological innovations increase the risk of destroying jobs (Rennings, Ziegler and Zwick, 2001).

There is to our knowledge little information on these aspects of technological change and innovation in Canada. Respondents to the Statistics Canada *Survey of Innovation and Advanced Technology in Manufacturing, 1993* indicated whether their most significant innovation improved their ability to respond to government regulatory requirements with respect to environmental or health and safety regulations. An analysis of the survey information led to the conclusion that environment and health regulation do not universally have a deleterious impact on the firm performance. Indeed, innovation that improves regulatory compliance is uniformly associated with improvements in the quality of product, working conditions, interaction with customers, and reduced lead times. Moreover, it usually improves both the profit margins and the market share of the firm (Baldwin and Hanel, 2003).

[1] Under familiar hypothesis of a competitive equilibrium, profit maximising firms allocate their resources (including R&D) to the most profitable activity. Should there exist unexploited profitable opportunities for environmental innovation, profit maximising firms would invest in pollution abatement technologies even without government regulation. Therefore, government regulation can only make things worse by diverting resources to environmental innovation from their optimum use in other sectors at a net cost to society.

A study based on the Statistics Canada survey of the use of a set of 22 biotechnologies used by mining and manufacturing firms by Arundel and Rose (1999) shows that a majority of firms reported cost saving from the adoption of environmental biotechnology to either control pollution or for use in their production process. A more direct test of the Porter hypothesis is the study by Lanoie, Patry and Lajeunesse (2001). The authors regressed the total factor productivity growth on the stringency of environmental regulation in the Quebec manufacturing industries. They found that after an initial negative effect, the longer term impact of environmental regulation on productivity is positive, particularly in sectors more exposed to international competition. However, after splitting manufacturing sector in more and less polluting subsets, the long-run impact is positive only for the less polluting subset.

Descripton of the data

Innovators were asked to rate on a scale from 1 (low importance) to 5 (high importance) how important were different reasons that led them to introduce new or improved products and processes (innovations). The list of twelve reasons[2] included two that are of direct interest to the present study. Almost three quarters of innovating firms (74.7%) reported 'reduction of environmental damage' and 71% mentioned 'dealing with or response to government regulation' among the relevant reasons that led them to introduce innovations. In addition there is information whether firms faced problems caused by «Government regulations affecting new and significantly improved products or processes». The frequencies of responses to these questions are tabulated in Table 1.

Many firms considered these reasons of relatively low importance.

Before using, as is the custom with interpretation of Likert scores, the two highest scores (4) and (5) as an indication that a firm innovated to reduce environment damage (Q9J) or in response to government regulation (Q9L), we examined the frequency distribution of responses to those two questions. They are somewhat different. To determine whether to use the two or the three highest scores as an indication that the respondents found the particular reason for innovation very important, we performed a regression analysis described in Appendix A1. The results of the regression analysis show that responses to question Q9J are conform to convention using the two highest scores «4» and «5» as an indication that the firm innovated to reduce environmental damage. In contrast, in the case of question Q9L, the results suggest that to identify firms that innovated in response to government regulations it is more appropriate to use response scores «3», «4» and «5». This convention will be followed throughout the report.[3]

Table 1. Reasons for Innovation and Problems Related to Government Regulations
(% of innovating firms)

		Importance					
Reasons for innovation	**Question**	**Relevant**	**% of innovating firms that found the question relevant considered the importance of these reasons :**				
			Low	Moderately low	Median	Moderately high	High
To reduce environmental damage	Q9J	74.7	24.8	19.5	22.5	17.2	16.0
To deal with or to respond to new gvmt. regulations	Q9L	71.0	31.3	20.6	23.0	13.1	12.1
Problems and obstacles faced by innovating firms		yes					
Innovating firms that faced problems and obstacles related to government regulations :	Q10N *	10.4	n.a.				

Source: Author's compilation from Statistics Canada, Survey of Innovation, 1999.
Note: *Information on problems faced by the innovating firms during the 1997-1999 period is limited to a yes or no response for the question Q10N.

Interpreting the survey responses to both questions in this manner, about one quarter of all innovators were motivated by environmental concerns and even more (34.2%) by government regulations. About

[2] For details see : Statistics Canada, Innovation in Canadian Manufacturing: National Estimates, Cat. No. 88F0006XIE01010.

[3] The tests of sensitivity of principal results to this interpretation are presented with the results.

19% of innovating firms reported both environmental concerns and regulatory compliance. On the other hand, 10.4% of innovating firms reported that Government regulations slowed down or caused problems in development of new or improved products and production processes (Table 1). The break down of these proportions according to the OECD classification in low, medium and high technology sectors shows that the highest incidence of innovating firms motivated by environment and/or regulatory compliance is found in industries belonging to medium technology sector (Table 2). The differences among sectors are relatively minor[4] with respect to innovation in response to government regulations; they are more notable for environmental innovations.

The industrial distribution of innovators that introduce new or improved products and production processes to reduce environment damage depends on the one hand on the role of a particular industry in inter-industry linkages and on the other hand on the environmental impact of its production. The solutions of environmental problems caused by «smoke-stack » industries can come from within the industry in form of improved or new production processes. They also come as product innovations introduced by suppliers of inputs, machinery and production equipment in up-stream industries.

Table 2. Percentage of Innovating Firms that Introduced an Innovation to Reduce Environmental Damage or in Response to Government Regulations and Proportion of Innovating Firms that Experienced Problems with Government Regulations, by Technology Sector
(% of firms in each category).

		Technology sector		
	All innovating firms	**Low**	**Medium**	**High**
Reason for innovation		% of innovating firms in each sector		
To reduce environ. damage*	24.6	23.3	26.2	14.7
Response to gvmt. regulations*	34.0	33.1	35.0	31.0
Problems with gvmt. regulations#	10.4	11.4	9.2	16.8
% of all innovating firms	100.0	42.1	54.2	3.7

Source: Author's compilation from Statistics Canada, Survey of Innovation, 1999.
Note: *Firms that scored 4 or 5 (high or very high importance) the statement " innovated to reduce environmental damage" (Question/ Q9J)" and/or scored 3, 4 or 5 the statement "innovated in response to government regulation" (Question /Q9L). The list included of 12 objectives for innovation, multiple choices were allowed.
#Information on problems faced by the innovating firms during the 1997-1999 period is limited to a yes or no response for the question Q10N.

The highest concentration of environmental innovations is found in chemical, petroleum and wood industries (sawmill & wood preservation and veneer and plywood) and primary metal industries, where they account for 43%, 42%, 34 to 37% and 34 % respectively (2nd column of Table 3). The proportion of innovations in response to government regulations is presented in the 2nd column of the table. The highest proportion of innovators responding to government regulations is found in petroleum, leather products, pharmaceutical and chemical industry (64%, 61%, 52% and 50% respectively).

There is an important overlap between innovations introduced to reduce environmental damage and those introduced in response to government regulations. Indeed, both objectives are often closely associated; the contingency coefficient between the two objectives varies from industry to industry (see the 3rd column in Table 3.). The contingency coefficient[5] for all manufacturing industries is 39%.

[4] The Ho of no relationship between the technology sector and the incidence of innovations introduced in response to government regulations is rejected at a statistically barely significant level (Chi-square = 5.7, p= 0.06).

[5] The contingency coefficient measures the association between two variables. The closer is the value of the coefficient to one, the closer is the association between the two variables.

Table 3. Percentage of Innovating Firms by Objective of Innovation

NAICS4	Industry	Contingency coefficient	Objectives of innovation: Reduce env. damage % of industry's innovators *	Objectives of innovation: Comply with gvmt. regulations % of industry's innovators*
311	Food	0.36(all.)	21.4	41.4
312	Beverage and tobacco	--	32.0	40.3
313	Textile mills	0.43 (all textile)	31.3	26.8
314	Textile product mills	--	17.3	18.6
315	Clothing manufacturing	na	19.3	33.5
316	Leather and allied products manufacturing	na	31.6	61.0
3211	Wood _sawmills and wood preservation	0.32 (all wood)	34.1	45.5
3212	Wood - veneer, plywood and eng. wood	--	37.3	20.9
3219	Wood - Other	--	16.3	30.9
322	Paper manufacturing	0.45	30.3	30.4
323	Printing	0.39	21.0	29.0
324	Petroleum and coal products manufacturing	0.08	41.7	63.9
325	Chemicals (excpt. Pharmaceuticals)	0.43	43.1	49.6
3254	Pharmaceuticals	0.29	12.5	52.2
326	Plastics and rubber products manufacturing	0.33	32.1	34.4
327	Non-metallic mineral products manufacturing	0.52	31.5	40.1
331	Primary metals manufacturing	0.47	33.1	38.2
332	Fabricated metals manufacturing	0.41	20.2	31.5
3331+2	Agro-Construction and mining machinery mfg.	--	31.5	32.6
333	Machinery (excpt. 3331 and 3332)	0.41 (all machinery)	17.0	27.6
334	Computer and peripheral eqpmt. manufacturing	0.52	7.0	16.7
3342+3	Communications and audio eqpmt. manuf.	na	7.4	33.1
3344	Semiconductor and other electronic eqpmt.	0.38	25.8	27.5
3345+6	Navigation, measuring, med. and contr. instrument mfg.	0.37	7.7	24.4
335	El. equipment, appliances and component mfg.	0.38	23.5	35.2
3361+2	Motor vehicles, bodies and parts manufacturing	0.39	31.1	45.0
3364	Aerospace products and parts manufacturing	0.41	22.4	25.5
65+6+9	Railroad rolling stock, ship and other transport eqpmt.	0.44	33.7	44.9
337	Furniture and related products manufacturing	0.39	20.7	26.9
339	Miscellaneous manufacturing	0.16	20.1	29.5
	Total manufacturing industries	**0.39**	**24.6**	**34.0**

Source: Author's compilation from Statistics Canada, Survey of Innovation, 1999.
Note: *Firms that scored 4 or 5 (high or very high importance) the statement " innovated to reduce environmental damage" (Question/ Q9J)" and/or scored 3, 4 or 5 the statement "innovated in response to government regulations (Q9L). The list included 12 objectives or reasons for innovation. Multiple choices were allowed.

Relationship between reasons to innovate, problems related to government regulations and the size of firm

The size of firm may influence the reasons to innovate in at least two ways. First, the impact of large firms on environment, public health and other aspects subject to government regulation is quantitatively more important than the impact of small firms. Larger firms may therefore be more likely exposed to government scrutiny than smaller ones and may react by innovating. Larger firms are also more likely to have the resources needed to address environmental problems. On the other hand, the increasing public awareness and concerns about environmental damage, health problems and other hazards associated with industrialization is a relatively new phenomenon and the innovative response to these concerns and

constrains may have led to creation of new firms which are at the initial stages of the life cycle and therefore still relatively small.

A more detailed analysis not presented here [6] shows that the largest firms are more likely than the medium size and small ones to introduce environmental innovations as well as innovations in response to government regulations. The positive association between the reason for innovation and the size of firm is statistically very significant and virtually identical for both questions. The substantial differences in economic structure and specialization of Canadian provinces are also reflected in interprovincial differences in the incidence of innovations responding to environmental concerns and to government regulations. However, the inter-regional differences in the incidence of both types of innovations that concern us here are relatively minor.[7]

The impact of innovations introduced to comply with government regulations and to reduce environmental damage on the performance of innovating firms

The respondents of the survey were asked to score their agreement[8] with a series of propositions on the impact of introduction of new and significantly improved products and manufacturing processes developed and introduced over the 1997-199 period. The list of innovation impacts included, among others

- increased productivity of your firm,
- increased profitability of your firm ,
- allowed your firm to maintain its profit margins,
- increased your firm's domestic market share and
- increased your firm's international market share
- Increased speed of supplying or delivering of firm's products
- Increased firm's ability to adapt flexibly to different client demands

The scores given to performance statements listed above are interpreted as follows. The score 3 reflects « neutrality », 4 « agree » and 5 « strong agree ». The sum of 4 and 5 is interpreted as an indication that the innovation had the impact in question.[9] To see the impact of innovations introduced to reduce environmental damage and to comply with government regulations on various indicators of firm's performance, the two sets of variables were cross-tabulated. The two-way classification enables to test the null hypothesis H_0 of no relationship between the objectives of innovation and their impact on the bottom line and other performance indicators. Presenting all these contingency tables here would be too fastidious, instead we summarize the results of tests of independence between the firms that pursued both environmental and regulatory objectives of innovation and the indicators of the firm's performance. The series of chi2 tests are presented in Table 4.

[6] Tabulations by firm size are presented in (Hanel, 2003) and are available on request. The hypothesis of independence between the reason to innovate and the size of the firm is rejected with a probability <0.0001, Contingency coefficient =0.07.

[7] The cross-tabulation of the incidence of environmentally motivated innovation by province-regions shows that even though the differences are statistically very significant ($p< 0.0001$), the relationship is not very strong (contingency coefficient = 0.06).

[8] The proposed scale ranges from 1 « strongly disagree » to 5 «strongly agree », 0 « not relevant ».

[9] There is another point regarding the interpretation of survey's results. For the minority of firms that introduced one innovation only, the relationship between the reasons for the innovation and its impact on the firm's performance provides a direct evidence of the impact of the particular innovation. The situation is less clear in the majority of cases where firms introduced more than one innovation. The indicators of firm's performance evaluate the impact of all innovations introduced during the three period 1997-1999. The same is true for the reasons or objectives of innovation. Thus for firms that introduced several innovations, a two-way classification of those two sets of variables can only illustrate and test the hypothesis that firms that introduced new or significantly improved products among other reasons in order to reduce environmental damage and/or to respond to government regulations, recorded/or not, certain positive impacts on their performance. From this evidence on the relationship between the sets of firm's innovation activities and impacts it is only possible to draw an indirect inference for the specific innovations themselves.

The rows in Table 4 present the proportion of innovators that did not and those that did introduce new and improved products and processes (innovations) to comply with government regulation and to reduce environmental damage. Each column shows the impacts associated with the particular group of innovators (those who did not and those who did innovate for the two reasons) and in the row below the impact on all innovators . For example, the figure in the first row and first column tells us that 46% of innovators who did not introduce innovations to reduce environmental damage agreed or strongly agreed with the statement that innovations they introduced over the 1997-1999 period increased the productivity of their firm. In contrast, 62% of firms that introduced innovations to reduce environmental damage and to comply with government regulations found that their productivity increased owing to innovations introduced over the same period etc. The Chi^2 statistics and the probability of obtaining as large or larger deviations from equal proportions computed for the two-way classification is presented for each category of impact. Thus, to continue the example, the test of the H_0 that there is no relationship between introduction of innovations motivated by regulatory compliance and environmental concerns on the one hand and the increase of productivity on the other hand is rejected at the 1% probability level (Chi^2=126.0).

The results presented in Table 4 show that firms that innovated among other reasons for these two objectives reported improved performance on all indicators. Thus for the manufacturing sector as a whole, the H_0 is rejected for all impact categories at the 1% significance level.

The strength of this relationship varies among technology sectors. As presented above, there are important inter-industry and inter-sectoral differences in the incidence of environmentally and regulation-motivated innovations. Economic conditions and performance of firms also varies from industry to industry. It is therefore to be expected that the relationship between the performance of innovating firms and orientation of their innovations toward environmental objectives may vary from sector to sector. The lower part of the Table 4 shows that for firms in the Low and Medium technology sectors the H_0 of no relationship can be rejected for all categories of impact at the 1% level. The positive association with performance indicators is more tenuous in the High technology sector, where it is not statistically significant for '*maintained profit margins*' and for '*increased domestic market share'*.

A series of contingency tables where the relationship between the joint environmental and regulatory objectives and firm's performance is tested for small (20 -49 employees), medium (50-249 employees) and large firms (more than 250 employees) show that the relationship remains statistically significant for all firm size categories.

The results of the statistical independence tests resumed in Table 4 suggest strongly that innovating to reduce damage to environment in compliance with government regulations is not harmful to innovating firm's performance. On the contrary, firms that were motivated by these two reasons reported improved performance significantly more often than other innovating firms.

A similar series of tests performed separately for innovations introduced to reduce environmental damage show a similar pattern, of a statistically significant positive strong association with all performance indicators. The tests for innovations introduced in compliance with government regulations displayed also mostly a statistically significant positive association but the relationship was not as strong as the one for environmentally motivated new products and processes.[10]

Since other characteristics of innovating firms and innovations not taken into consideration at this stage may yet influence the results of the analysis, a final verdict must await the results of a multivariate analysis in the last section of the report.

[10] Both sets of results are available on demand.

Table 4. Effects of Introducing Innovations in Response to both Environmental concerns and Government Regulations (% of innovating firms in the given category)

Innovated in response to gvt. regulations	Increased productivity	Increased profitability	Maintained profit. margin	Increased domestic mrkt.share	Increased intl. mrkt.share	Increased speed of delivery	Increased flexibility
All innovators *Chi² p*	*126.0a*	*105.53a*	*127.6a*	*77.7a*	*52.2a*	*104.7a*	*161.4a*
No	46.0	46.4	47.1	36.9	30.6	35.3	50.6
Yes	62.0	61.5	63.8	48.7	40.6	49.5	69.6
All	48.1	48.8	49.8	38.1	32.2	37.6	53.6
Technology Sectors							
Low tech. Chi² p	*99.2a*	*78.7a*	*100.4a*	*51.3a*	*59.4a*	*59.3a*	*49.8a*
No	43.7	42.8	43.5	34.2	27.3	33.9	50.3
Yes	66.6	63.1	66.5	51.4	44.1	52.7	66.5
All	47.2	45.9	47.0	36.7	29.3	36.2	52.7
Medium tech. *Chi² p*	*32.2a*	*31.4a*	*38.3a*	*30.5a*		*35.5a*	*116.6a*
No	46.6	48.7	49.3	37.2	Na	37.0	50.3
Yes	57.8	59.7	61.5	47.8		49.4	71.5
All	48.5	50.6	51.4	39.0		38.7	54.0
High tech. Chi² p	*14.2a*	*5.4b*	*2.1*	*0.28*	*14.4a*	*23.3a*	*4.1b*
No	Na	Na	Na	Na	Na	Na	Na
Yes	Na	Na	Na	Na	Na	Na	Na
All	Na	Na	Na	Na	Na	Na	Na
Size of firm							
20-49 empl. *Chi² p*	*20.0a*	*31.1*	*34.4a*	*17.6a*		*23.1a*	*34.3a*
No	41.6	42.7	40.7	32.2	Na	34.1	48.1
Yes	54.6	58.8	57.6	43.6	Na	47.5	65.1
All	43.4	44.8	42.9	33.8	Na	35.9	50.4
50-249 Chi² p	*61.4a*	*47.0a*	*61.5a*	*55.7a*		*40.2a*	*99.1a*
No	47.0	46.5	48.5	37.2	Na	36.9	51.5
Yes	62.7	60.1	64.2	51.8	Na	49.2	71.4
All	49.5	48.6	51.0	39.5	Na	38.8	54.6
250+ Chi² p	*39.5a*	*17.8a*	*20.2a*	*3.3a*		*44.1a*	*24.6a*
No	47.7	55.2	55.9	40.4	Na	30.5	52.4
Yes	69.4	69.6	71.1	46.6	Na	52.5	69.4
All	52.8	58.6	59.4	41.8	Na	35.6	56.4

Source: Author's compilation from Statistics Canada, Survey of Innovation, 1999.

Notes: The probability levels p associated with the chi² show the probability of obtaining as large or larger deviation from equal proportions: a < 1% ; 1%#b<5% ; 5%#c#10%.

The impact of innovations motivated by environmental concerns and government regulations on the performance of firms : multivariate logit regression models

The series of tests presented in the previous section have failed to show any evidence that introduction of innovations to reduce environmental damage or to comply with government regulations had a negative impact on the performance of innovating firms. The major shortcoming of those bivariate tests is that the relationships involved may be influenced by other industry, firm and innovation characteristics than those for which the contingency tables were controlled for. This section presents a series of multivariate regression models estimating the probability that innovations motivated by environmental concerns and regulatory compliance improve firms performance. The multiple regression framework controls for the effects of other industry, firm and innovation specific characteristics likely to influence firm's performance.

I first present the theoretical formulation of the model. Follows the specification of dependent and explanatory variables, estimation results and their interpretation.

A probabilistic model of innovation impact on firm's performance

Private firms innovate in the expectation that a new or improved product or process will increase their profits, productivity, market share etc. The expected post-innovation impact r_{ik}* of innovation activity[11] for the firm i is supposed to be a function of a set of firm specific and industry specific exogenous variables x_i. This may be formally written for k impact indicators as:

$$r_{ik}^* = b\, x_i + u_i \qquad (1)$$

Firms reported the observed impact of their innovation activity on various performance indicators IM_k. Even though the expected impact r_{ik}* is not directly observable, we know whether an innovating firm i reported a given impact IM_{ik} or not. The observable binary variable IM_{ik} takes a value of one when the firm reported the impact k and zero otherwise. Thus we can write

$$IM_{ik} = 1 \qquad \text{if } r_{ik}^* > 0 \qquad (2)$$

$$IM_{ik} = 0 \qquad \text{otherwise}$$

$$E(r_{ik}^* | x_i) \text{ gives us } Prob(IM_{ik}=1) = F_k(\mathbf{b_k}' \mathbf{x_i}) \qquad (3)$$

The functions F_k are the cumulative distributions of functions defining the probability of the outcome. The two most popular probability functions used for estimation of probability models are probit and logit distributions. The first is the cumulative distribution of the standard normal N[0,1] random variable, the second is the logistic distribution. Both give results that are for all practical purposes identical.[12]

Dependent Variables

Innovation impact variables

Respondents of the survey were asked to score their agreement[13] with a series of propositions on the impact of introduction of new and significantly improved products and manufacturing processes

[11] Introduction of an innovation involves various activities including often, but not always, R-D. Therefore the variable of interest here is the return on investment in innovation activity rather than the return on investment in R&D.

[12] See for instance Griffiths, Hill and Judge (1993, p. 752) who compare results of the two models for the same data and conclude that there is little difference between the two. Comparison of results of exploratory logit and probit regressions estimates with our data led to the same conclusion.

[13] The proposed scale ranges from 1 « strongly disagree » to 5 «strongly agree », 0 « not relevant ».

developed and introduced over the 1997-1999 period. The list of innovation impacts included among others:

- increased productivity of your firm,
- increased profitability of your firm ,
- allowed your firm to maintain its profit margins,
- increased your firm's domestic market share and
- increased your firm's international market share
- keep-up with competition.

The sum of scores 4 and 5 is interpreted as affirmative response and is coded IMPk=1, lower scores are coded IMPk=0.

Explanatory Variables

The impact of innovation on the innovating firm's performance depends to a large extent on characteristics, perceptions, strategies and activities of innovating firms. It is also likely to be influenced by technological opportunity, industry life cycle, competitive conditions and host of other industry specific variables. Therefore, the impact of innovation on a firm's performance is assumed to be a function of both firm-specific and industry-specific variables.

In addition to the two reasons for innovation of interest in this study, i.e. whether a firm innovated in compliance with environmental and/or regulatory requirements, firm-specific variables include the size of firm, perception of their management relative to firm's competitive environment and success factors (strategies) and firm activity variables—such as R&D, collaboration with other firms or public institutions and the use of intellectual property protection. Industry-specific variables include proxies for technological opportunity and industry and /or industry sector dummy variables.

Firm Characteristics

– *Size*

Return to R&D and innovation investment are an increasing function of firm's size. Due to easier access to financing, large firms can spread the fixed costs of innovation over a larger volume of sales and may benefit from economies of scope and complementary relations between R&D and other manufacturing activities. They could therefore be in a better position than small firms to take risks in introducing innovations in new fields such as environmental technologies could. On the other hand, as firms grow large, their R&D becomes less efficient. Levin and Reiss (1988b) reviewed the empirical evidence on the relationship between innovation and firm size and found it inconclusive. Economies of scale and scope may exist, but may be exhausted at the medium-size. Furthermore, many fields of environmental engineering are at the beginning of the life cycle characterized by small and medium size firms.[14] Thus the effect of the size of firm has to be determined empirically.

Size is measured by the total number of employees. Firms are classified as belonging to one of three size categories—20 to 49 employees, 50 to 249 employees and firms employing more than 250 employees. Based on this, three binary variables have been constructed to capture size effects.

[14] Keep in mind however, that what is considered here a large firm (a firm employing 250 persons or more) is barely a medium size firm in the U.S. context.

Firm's perceptions

– *Competitive Conditions*

In contrast to earlier studies which considered market structure of an industry as one of the major exogenous determinants of innovation, the theoretical research (Dasgupta P. and Stiglitz J. 1980) and empirical work by Levin (Richard C. Levin, Peter C. Reiss (1984,1988a) and (W. M. Cohen, Levinthal,1989) suggests that it is more likely to be an endogenous outcome of dynamic growth of innovating firms.

The concept we want to measure is the degree of competition faced by a firm. The firm's representatives were asked to score their agreement with several statements describing the degree of competition faced by the firm. The competition variables take a value of one when the responded agrees or strongly agrees with the statements identifying high degree of competition (variable COMPET)[15] as been important or very important.[16] Another proxy variable for the competitive challenge is identified as a *'threat of rapidly changing production or office technology'*, TECHCH. Firms in rapidly moving fields often face difficulties hiring and retaining qualified staff and workers. The variable STAFF takes value one when a firm indicates that this problem is important or very important and zero otherwise.

– *Competitive strategies-success factors*

In response to questions on success factors firm representatives revealed what they considered to be successful competitive strategies. Responses to questions related to firm's success were used to construct three variables. The first, NEWMT, captures responses that give a high score to the importance of new markets and new products for the success of the firm.[17] The next, EXPMT, identifies firms that draw their success from export markets. A more general strategy is associated with promotion of the firm or the product reputation. This variable REPUT identifies firms adopting a strategy that may be associated with the use of trademarks.

Firm Activities

– *Research and Development*

Even though firms not involved in R&D activities introduced 32 percent of innovations, R&D is the principal input for innovative activity, especially for introducing the more original products and processes. Firms that have established an effective R&D program are more likely to innovate for several reasons. First, R&D usually aims at creating and/or adapting new or improved products and processes. Second, firms that perform R&D are also more receptive to the technological advances made by others and capable to absorb and adapt spillovers to their advantage (Cohen and Levinthal, 1989). A binary variable RDACT takes a value one if the firm carries out R&D and zero otherwise.

The way firms organize their R&D activities - establishing a separate R&D unit and/or contracting R&D is likely to influence their innovation performance. The presence or absence of a particular organizational form is identified by a set of binary variables. When a firm conducts R&D in a separate division, the

[15] Agree or strongly agree with the statement:
Q1b= My clients can easily substitute my products (goods and services) for the products of my competitors.
Q1d= The arrival of new competitors is a constant threat.
Q1e=The arrival of competing products (goods and services) is a constant threat.
Q1i= My products (goods and services) quickly become obsolete

[16] We first tried to reduce the scores on eleven competitive environment related questions to a smaller number of factors by a principal component analysis. Since the results of this more complex approach are less transparent and statistically not better than the ones reported above, we abandoned the principal component approach.

[17] Respondents rated the importance of the Q2a = "Seeking new markets" and Q2c Developing niche or specialized markets".

variable RDSEP=1, otherwise, RDSEP=0. When a firm contracts out all or specific parts of R&D tasks; the variable RDCONTR equals one and zero otherwise.

Government support programs

Government programs in support of innovation and R&D activities subsidize their cost, either directly by grants or indirectly by tax credits. Other government assistance programs such as information and Internet services may also enhance private innovation activities. A series of binary variables identifies the cases when a firm uses a particular government assistance program by a value of one, otherwise the variable takes value zero. Unfortunately, the information on the use of government programs and services does not allow us to identify the specific incentives for introduction of innovations for environmental or regulatory compliance.

Industry Sector Effects

Technological opportunities differ across industries when the scientific environment provides more fertile ground for advances in some industries than others.[18] Progress in science reduces the cost of technological advance generated per unit of R&D expenditures and thus affects its economic impact. The classification of a firm in one of the three technology sectors (High, medium and low technology) provides an approximate proxy for technological opportunity.

Industry specific effects

Industries vary widely not only with respect to technological opportunity and their position in technology life cycle but also with respect to the degree of exposure to external competition, availability and cost of factors such as specialized manpower, natural resources etc. Thus relying on a simple three-technology typology (introduced above) may not capture those other industry specific conditions that may have a bearing on innovation and its effects. A set of industry dummy variables identifies the 24 major manufacturing industry groups.

Province-specific effects

Innovation is a social activity. As such it depends not only on incentives, motivations, resources and the thriving private sector but also on the institutional environment in which enterprises operate. Given the federal structure of the Canada, the complex relationships between the private sector and its institutional environment are shaped by federal and provincial policies and institutions. Many aspects of education, science, technology, industrial and fiscal policies are provincial responsibility and are likely to affect the performance of resident firms. For example, owing to provincial R&D tax credit programs the real cost of conducting R&D varies from one province to another (Warda,1997). Provinces also differ with respect to environmental and regulatory requirements and policies. To explore whether the province of residence of a firm affects the economic impact of innovations a set of dummy variables identifies the province of residence of the firm. Results of exploratory regressions showed that only three provinces: Ontario, Quebec and Alberta stood out. Firms from these three provinces are identified by three dummy variables. Provincial enterprises from other provinces than those three are the 'default' or reference cases.

Econometric issues

1. In order to be representative of the "provincial enterprise" which is the statistical unit selected by Statistics Canada for the Innovation Survey 1999, the regressions are appropriately weighted so as to be representative of the population of 'provincial enterprises', the sampling unit of the survey.

[18] The concept of technological opportunity goes back at least to (F. M. Scherer 1965)). J. Baldwin, P.Hanel and D. Sabourin, 2001) proxy technological opportunity of an industry by the percentage of R&D performers within an industry that have collaborative agreement with universities, colleges or external R&D institutions. The variable proved to be a statistically significant determinant of innovation.

2. All explanatory variables are binary, taking the value 1 or 0. In the case a variable classifies firms into several subcategories (e.g. firms are classified in one of several size categories) one of the dummy variables is left out and serves as the default category. The estimated regression coefficients (after an appropriate transformation) show the marginal effect of a given explanatory variable on the probability of the event with respect to the reference case given by the default category.

3. Due to the exploratory nature of this study, the regression equations presented in all tables usually exclude those explanatory variables which were statistically not significant in previous runs.

Since there are no theoretical or econometric reasons to prefer probit or logit models and logit regression results are easier to interpret, the probabilities are estimated by logit regressions

Table 5. Summary of Dependent and Explanatory Variables

I. DEPENDENT VARIABLES		Values
IMPACT OF INNOVATION		
IMPa	Innovations increased the productivity	Yes=1, No=0
IMPb	Innovations increased profitability	Yes=1, No=0
IMPc	Innovations increased speed of supply	Yes=1, No=0
IMPd	Innovations increased flexibility	Yes=1, No=0
IMPe	Innovations increased domestic market share	Yes=1, No=0
IMPf	Innovations increased intl. market share	Yes=1, No=0
IMPg	Innovations allowed to keep profit margin	Yes=1, No=0
IMPh	Innovations allowed to keep up with competition	Yes=1, No=0
II.EXPLANATORY VARIABLES		
1. REASONS FOR INNOVATION		
ENV	To reduce the environmental damage	Yes=1, No=0
REG	To respond to government regulations	Yes=1, No=0
ENV & REG	Both reasons listed above	Yes=1, No=0
2. FIRM CHARACTERISTICS		
Size	Employment Size	
SIZE-A	- 20 to 49 employees	Yes=1, No=0
SIZE-B	- 50 to 250 employees	Yes=1, No=0
SIZE-C	more than 250 employees	Yes=1, No=0
3. FIRM'S PERCEPTION OF COMPETITIVE CONDITIONS		
COMPET	High competition in the product market	Yes=1, No=0
TECHCH	Technology changes rapidly	Yes=1, No=0
STAFF	Difficulties hire and/or retain qualified staff	Yes=1, No=0
4. SUCCESS STRATEGIES		
NEWMT	Seeking new and/or developing special. markets	Yes=1, No=0
EXPMT	Developing export markets	Yes=1, No=0
REPUT	Promoting firm or product reputation	Yes=1, No=0
5. FIRM ACTIVITIES		
RDACT	Performs R&D activity	Yes=1, No=0
RDSEP	Performs R&D in a separate unit	Yes=1, No=0
RDCONTR	Contracts R&D out	Yes=1, No=0
COLLAB	Collaborates with other firms and institutions	Yes=1, No=0
6. GOVERNMENT SUPPORT		Yes=1, No=0
7. ACTIVITIES LINKED TO INTRODUCTION OF INNOVATIONS		
EQPT	Acquisition of eqpmt. and machinery	Yes=1, No=0
TOOL	Tooling up and production start up	Yes=1, No=0
TRAIN	Training linked to introduction of innovations	Yes=1, No=0
8. USE OF INTELLECTUAL PROPERTY RIGHTS		
PATENTS	Firm used patents	Yes=1, No=0
TRADEM	Firm used trademarks	Yes=1, No=0
COPYRIGHT	Firm used copyright	Yes=1, No=0
SECRET	Firm used trade secret	Yes=1, No=0
CONFIDENTIALITY	Firm used confidentiality agreement	Yes=1, No=0
9. INDUSTRY CHARACTERISTICS		
HIGH	Firm belongs to 'High' technology sector	Yes=1, No=0
MEDIUM	Firm belongs to 'Medium' technology sector	Yes=1, No=0
LOW	Firm belongs to 'Low' technology sector	Yes=1, No=0
10. PROVINCE		
ALTA	Firm located in Alberta	Yes=1, No=0
ONT	Firm located in Ontario	Yes=1, No=0
QC	Firm located in Quebec	Yes=1, No=0
11. PROBLEMS WITH GVT. REGULATIONS		Yes=1, No=0
12. TYPE AND ORIGINALITY OF INNOVATION		
INPDT	Product innovation	Yes=1, No=0
INPCS	Process innovation	Yes=1, No=0
W-1st	World-first innovation	Yes=1, No=0
C-!st	Canada-first innovation	Yes=1, No=0

Table 6. Logit Regressions of Innovation Impacts on Explanatory Variables

I. Dependent Vars.	IMPa Productivity	IMPb Profitability	IMPg Maintain profit marg.s	IMPe Larger dom. mrkt.share	IMPe Larger intl. mrkt.share	IMPc Faster delivery	IMPd Flexible response	IMPh Keep up with competition
II. EXPLANATORY VARIABLES								
INTERCEPT	-.997a	-1.110a	-0.910a	-1.490a	-2.524a	-1.600a	-1.025a	-0.387b
1. REASONS FOR INNOVATION								
ENV	0.373a	0.254a	0.403a	0.238a	0.198a	0.225a	0.222a	0.227a
REG	-0.113a	-0.050	-0.173a	-0.106c	-0.139b	0.145b	0.132b	-0.011
2. FIRM CHARACTERISTICS								
Size								
SIZE-A	0.077	0.149b	-0.104c	-0.136b	-0.153b	0.145b		
SIZE-B								
SIZE-C	-0.047	0.155b	0.078	-0.126c	-0.269	-0.269a	-0.229	
3. FIRM'S PERCEPTION OF COMPETITIVE CONDITIONS								
HCOMP	0.118c				-0.1305c	0.106d	0.312a	0.262a
TECHCH	0.316a	0.253a	0.074	0.231a		0.288a	0.327a	0.232a
STAFF	-0.127b	-0.248a	-0.129b	0.084d		0.113b		
4. SUCCESS STRATEGIES								
Newmt	0.364a	0.378a	0.396a	0.703a	0.387a	0.393a	0.499a	0.417a
Expmt	0.134b	0.117b	0.156a		1.331a	0.132b		
Reput								
5. FIRM ACTIVITIES								
COLLAB	0.088d	0.186a	0.208a	0.064	0.111c		0.180a	0.288a
RDACT					0.085			0.042
RDSEP					0.055		0.066	
RDCONTR								
6. GOVERNMENT SUPPORT	0.038	0.189a	0.238	0.085d	0.371a	-0.159a	0.126b	0.260a
7. INNOVATION								
W-1st	-0.297a		-0.240b		0.188c			-0.366a
C-1st			0.264a		0.283a	-0.275a		0.089
INPDT	-0.931a		-0.060	0.019	-0.102	-0.618a	0.044	-0.046
INPCS	0.339a			-0.270a	-0.229a	0.378a	-0.180b	-0.228a
8. ACTIVITIES LINKED TO INTRODUCTION OF INNOVATIONS								
EQPT	0.401a	0.156c	0.248a	0.008	0.223b	0.233a	0.079	0.091
TOOL	0.268a	0.240a	0.105	0.239a	0.130c	0.169b	0.008	0.155b
TRAIN	0.349a	0.199a	0.269a	0.249a	0.236a	0.474a	0.581a	0.281a
9. USE OF INTELLECTUAL PROPERTY RIGHTS								
PATENTS			0.089					0.159b
TRADEM		0.159a	0.138b	0.266a	0.175a	-0.123b	-0.206a	0.147b
COPYRIGHT				0.244a		0.139c	0.182b	
SECRET			0.119b		0.121c			0.089
CONFIDENTIALITY		0.076d	-0.130a		0.113c		0.076	
10. INDUSTRY CHARACTERISTICS								
HIGH				-0.268b	0.236c			
MEDIUM								
LOW	-0.055	-0.102b	-0.102c	-0.096c	-0.104	-0.058	-0.012	-0.108c
11. PROVINCE								
ALTA	0.185c	0.181c						
ONT	0.304a	0.252a		-0.095d		0.300a		0.211a
QC		0.176b		0.215a		0.141b	0.141b	0.360a
12. PROBLEMS WITH GVT.REGULATIONS	0.113	0.346a	-0.250a	-0.282a	-0.095	-0.075		
Likelihood ratio	721.8	322.0	344.8	367.9	1091.8	507.9	333.2	308.1
% CONCORDANT	66.4	60.8	61.3	62.7	72.2	65.1	61.8	63.3

Notes: Weighted regressions. Level of statistical significance of std. errors in parentheses : c= 10%, b= 5%, a= 1%. The likelihood ratio rejects the null hypothesis beta=0 with a probability P>chi2 smaller than 0.001 for all regressions.

Results

Note that the survey the questions were formulated so that the CEO, or the person delegated by him, could respond without the help of figures, statistics or recourse to specialists. The questions are often only imperfect indicators of the characteristic they purport to represent. Owing to unavailable quantitative information on several fundamental aspects of firm's activity, the information is often indirect and "soft". Thus the estimated equations are far from being well-specified functions of productivity, profitability, market share etc. Therefore, one should not expect from these data more than it can deliver. And, for the same reason, the results have to be interpreted with caution.

The outcome (the answer yes or no) of each of the selected performance indicators is regressed on the set of explanatory variables. Depending on the equation the estimated logit regressions classify correctly between 61% and 72% of observations (Table 6). Regression coefficients with the positive sign indicate that the variable increases the probability of a positive outcome; those with the negative sign reduce it. The results are convincing and robust as far as the main objective of the study is concerned.[19] The null hypothesis that innovations motivated by environmental concerns have harmful effects on the performance of the firm are consistently rejected. The regression coefficients of the dummy variable identifying firms that innovated to reduce environmental damage are always highly significant and positive (in the range from 0.2 to 0.4) i.e. increasing the probability of a positive impact by 5 to 10 percentage points. The regression results are in general in agreement with the contingency table tests. Firms that pursued reduction of environmental damage as one of their innovation objectives were more likely than other innovators to report that innovations improved their performance.

In contrast, the mostly negative regression coefficients of the REG variable, suggest that innovating in response to government regulation is decreasing the probability of obtaining productivity, profitability and market share gains. These negative associations are however generally smaller than those of the ENV variable and the estimates are not always statistically significant. The lower value (in absolute terms) of REG regression coefficients means that the deleterious effect of regulatory compliance on firm's economic performance is likely not to be very large. It reduces the probability of a positive outcome by less than 3 percentage points. The likely harmful effect of government regulations on performance of innovating firms is also corroborated by the mostly negative and statistically significant values of the regression coefficient of the "PROBLEMS WITH GVT. REGULATIONS " variable.

Before concluding that innovation in response to government regulation affects performance indicators negatively we tested the sensitivity of the regression results to the change in the definition of the variable REG.[20] Estimating regressions in Table 6 with variable REG defined conventionally (taking value one for the scores 5 and 4 and zero otherwise), the sign of the regression coefficient remains negative. It is however not any more significant in productivity and profitability equations and it changes to statistically significant positive sign for the domestic market share (IMPe). Thus, depending on the definition of the variable REG, the effect of government regulation on innovation and the subsequent impact of the latter variable on firm's performance ranges from inconclusive to negative. We should add here, that changing the definition of the REG variable does not affect significantly regression coefficients of the ENV and other variables in regressions on different performance indicators.

The next logical step in our analysis is to ask whether firms that reported among their innovation objectives both environmental and regulatory compliance (i.e. firms that indicated as highly relevant both questions (Q9J and Q9L) were likely to report positive impact of innovation on their performance

[19] For the sake of brevity the effect of other variables on the given performance indicator is not analysed here.

[20] Recall that we initially defined the variable REG as taking value one (innovation in response to government regulation is considered a relevant objective) when the respondents scored this objective 5, 4 and 3 rather than 5 and 4 as variable ENV (see the beginning of Section II and Appendix 1 for more details).

indicators. To test this weak version of Porter-Van der Linde hypothesis we specify a new dummy variable that takes the value one for firms that presumably innovated to comply with government environmental regulations and zero otherwise. [21]

The word 'presumably' is important here because even a firm with an affirmative response to both questions OB_9J=1 and OB_L=1 (hence OB_9JL=1) may innovate in response to other than environmental regulations, say passenger safety, and list among its various innovation objectives environmental concerns, e.g. reduce fuel consumption. Since the information on innovation objectives concerns overall innovation activity over the 1997-1999 period rather than a specific innovation, such cases contradicting our interpretative assumption can not be ruled out, especially for firms with many innovations.[22]

The results of logit regressions modeling the probability of various innovation impacts on firm's performance with exogenous variables including the new dummy variable OB_JL are presented in Table 7.[23] They show that firms that presumably innovate to comply with government environmental regulations are more likely to report productivity, profitability and market share improvements than other innovating firms. The same goes also for as increased flexibility and speed of response to consumers and capacity to keep up with competitors. These firms typically introduce Canada-first innovations and in the process acquire new machinery, equipment and other forms of new technology and engage in manpower training.

As the technological sector dummy variables indicate, firms reporting a positive impact of innovation activity on their performance belong typically to medium technology sector, those belonging to the high or to the low technology sectors are less likely to report improvements in their performance.[24]

[21] A new dummy variable OB_9JL takes value one when a firm scored both objectives (scores 4 or 5 for Q9J and scores 3, 4 or 5 for Q9L) and zero otherwise.

[22] This and several other questions in the Innovation Survey would have given less ambiguous information had they been focused on the most important innovation of the firm instead of asking about firm's overall innovation activity.

[23] The series of contingency table tests (cf. Table 4) was also replicated with the OB_9JL variable. The results reject even more persuasively the Ho of a negative impact of innovations introduced in environmental and regulatory compliance on various performance indicators are available on demand.

[24] Introduction of industry dummy variables (major manufacturing industry groups at the two digit level though statistically significant as a group did not change in a noticeable way the regression coefficients of those variables that were statistically significant in the previous specifications without dummy variables. Since their introduction affects almost exclusively only the intercept values for individual industries and does not change the tenet of our conclusions, the results are not reported here.

Table 7. Logit Regressions of Innovation Impacts on Explanatory Variables

I. DEPENDENT VARIABLES	IMPa Productivity	IMPb Profitability	IMPg Maintain profit margins	IMPe Larger domestic mrkt.share	IMPe Larger intl. mrkt.share	IMPc Faster delivery	IMPd Flexible response	IMPh Keep up with competition
II. EXPLANATORY VARIABLES								
INTERCEPT	-1.048a	-1.062a	-1.11a	-1.561a	-2.513a	-1.503a	-0.977a	-0.384b
1. REASONS FOR INNOVATION								
ENV &REG	0.338a	0.191a	0.254a	0.329a	0.147b	0.399a	0.459a	0.305a
2. FIRM CHARACTERISTICS								
Size								
SIZE-A	0.077	0.147b	-0.071	-0.131b	-0.134b	0.123b	0.057	0.010
SIZE-B	left out	left out	left out	left out	left out	left out	left out	left out
SIZE-C	-0.037	0.162b	0.061	-0.125c	-0.291a	-0.235a	-0.217a	-0.112
3. FIRM'S PERCEPTION OF COMPETITIVE CONDITIONS								
HCOMP	0.122c	-0.015	-0.008	0.038	-0.115d	0.103d	0.315a	0.267a
TECHCH	0.320a	0.261a	0.085d	0.233a	-0.002	0.297a	0.346a	0.234a
STAFF	-0.141b	-0.252a	-0.138b	0.074	-0.039	0.114b	-0.027	0.014
4. PROBLEMS WITH GVT.REGULATIONS	-0.163b	0.163b	0.102	0.318a	-0.267a	-0.264a	-0.104	-0.093
5. SUCCESS STRATEGIES								
NEWMT	0.371a	0.387a	0.413a	0.709a	0.389a	0.393a	0.504a	0.408a
EXPMT	0.141b	0.118b	0.157a	-0.045	1.315a	0.155a	-0.048	0.013
6. FIRM ACTIVITIES								
RDACT	-0.237a	-0.076	0.086	0.025	0.071	-0.156b	-0.058	0.026
RDSEP	-0.123c	-0.058	-0.058	-0.060	0.056	-0.000	0.093	0.088
COLLAB	0.097c	0.208b	0.187a	0.071	0.096d	0.029	0.193a	0.288a
7. GOVERNMENT SUPPORT	0.042	0.216a	0.235a	0.090c	0.376a	-0.106c	0.139b	0.266a
8. INNOVATION								
W-1st	-0.214b	-0.095	-0.255b	-0.119	0.189c	0.029	-0.022	-0.375a
C-!st	-0.089	0.084	0.259a	0.107d	0.269a	-0.242a	0.032	0.107
INPDT	-0.931a	-0.189b	-0.019	0.036	-0.086	-0.612a	0.041	-0.059
INPCS	0.330a	0.087	0.127c	-0.270a	-0.215b	0.325a	-0.177b	-0.227a
9. ACTIVITIES LINKED TO INTRODUCTION OF INNOVATIONS								
EQPT	0.408a	0.148c	0.244a	0.022	0.208b	0.231a	0.074	0.088
TOOL	0.287a	0.219a	0.067	0.212a	0.037	0.224a	0.009	0.192b
TRAIN	0.360a	0.205a	0.253a	0.244a	0.212b	0.498a	0.580a	0.295a
ENGN	-0.035	0.098d	0.146b	0.078	0.290a	-0.084	0.079	-0.095
10. Use of Intellectual Property Rights								
PATENTS	-0.081	0.020	0.082	-0.056	0.114c	-0.079	-0.197a	0.169b
TRADEM	0.037	0.178a	0.121b	0.341a	0.198a	-0.056	0.117b	0.142b
SECRET	-0.024	-0.031	0.087d	-0.072	-0.016	0.003	0.064	0.085
11. INDUSTRY CHARACTERISTICS								
HIGH	0.099	-0.013	0.032	-0.208d	0.287b	-0.175	-0.034	0.186
MEDIUM	left out	left out	left out	left out	left out	left out	left out	left out
LOW	-0.067	-0.109b	-0.067	-0.105b	-0.088d	-0.103c	-0.021	-0.093d
12. PROVINCE								
ALTA	0.242b	0.187c	0.142	0.087	-0.192d	0.113	-0.075	-0.001
ONT	0.366a	0.259a	0.110d	-0.056	-0.013	0.343a	-0.015	0.220a
QC	0.066	0.158b	0.048	0.209a	-0.115d	0.156b	0.094	0.362a
R^2	0.156	0.072	0.075	0.085	0.230	0.115	0.078	0.072
Likelihood ratio	717.6	319.1	329.79	376.0	1107.0	519.4	346.4	315.5
% CONCORDANT	66.3	60.6	61.4	62.8	72.4	64.9	61.9	63.4

Notes: Weighted regressions. Level of statistical significance of std. errors in parentheses : d=15%, c= 10%, b= 5% and a= 1%. The likelihood ratio rejects the null hypothesis beta=0 with a probability P>chi2 smaller than 0.001 for all regressions.

Summary and concluding remarks

Respondents to Statistics Canada Innovation Survey 1999 were asked to score the reasons why their firm had introduced new or improved products and processes. About one out of four innovators reported that reducing environmental damage was of high or very high importance and about one third scored similarly high compliance with government regulations. Less than one of five of innovating firms listed both environmental and regulatory concerns.

The Survey information on the impact of introduction of new or improved products and processes on the subsequent performance of innovating firms was used to determine whether firms that introduced environmentally and/or regulatory motivated innovations reported weaker economic performance. A series of contingency table- based statistical tests did not uncover any evidence that firms whose innovations are motivated by environmental concerns or by both environmental concerns and regulatory compliance suffered a negative impact on their productivity, profitability or other performance indicators. On the contrary, the overwhelming majority of tests suggest that these firms have a slight but statistically significant edge over other innovating firms.

These results derived from cross-classification of various reasons to innovate and the impact of innovation on firm's performance may, however, be misleading insofar as the tested relationships are more complex. Therefore in the next step we estimated a series of multivariate logit regressions that take into account the motivations for innovation along the host of other variables that may have a bearing on the performance impact of innovation. The regression results reject convincingly the hypothesis that innovating for both environmental concerns and in response to government regulations undermines firm's performance. They support an alternative view that innovating for these reasons (among others), may improve firm's performance.

How to relate this conclusion to Porter- van der Linde hypothesis that "properly designed environmental standards can trigger innovation that may partially or more than fully offset the cost of complying with them"? Owing to the design of the questionnaire and the formulation of questions, the results should not be interpreted as a test of the Porter –van der Linde hypothesis. In order to use the survey information certain interpretative assumptions, which may or may not be realistic, had to be made:

1). The self-reported, subjective, approximate, non-quantitative information on innovation's effect on firm's performance may be intentionally biased or overly optimistic.

2). Even if the objection (1) is rejected, the interpretation of the situation when a firm indicated to have innovated, among other reasons, in response to government regulations and for environmental concerns as if the firm innovated in response to *environmental regulations* may not always be incorrect.

3). More importantly, the advantage and the cost of innovation in response to environmental regulation are likely to affect different firms in different way. It may enhance the profitability and/or the market share of manufacturers producing pollution abatement equipment, machinery and inputs.[25] By the same token it may not be profitable for the downstream polluting firms that have to introduce the pollution abatement technology to conform to stricter environmental regulations. The questions in the Innovation Survey were not formulated with the intent to test the Porter hypothesis and their interpretation with respect to this problem remains ambiguous.

[25] As the example of introduction of more stringent clean air legislation in the U.S. shows, equipment producers responded to this new situation by research, invention, patenting and introduction on the market of improved or new pollution abatement equipment (Taylor, 2001).

4). Let us assume that the objection (3) could be rejected by factual evidence, i.e. it could be proved that the population of firms covered by the survey is balanced in the sense that producers of environmental technology are not over-represented and the-users are not under-represented. However, even then, the finding that innovation in compliance with environmental regulations is performance enhancing rather than performance impairing should not be construed as a support for Porter's double dividend hypothesis. Because even if it were profitable for the innovating firms that created and for those that use these technologies, the resources used to comply with regulatory constraints might have been more profitably used elsewhere in the economy. For instance, firms that introduced environmental innovations in response to government regulation might have been subsidized to do so by resources diverted from a more efficient allocation.[26]

Thus our results should not be interpreted as a test of the Porter-van der Linde double dividend hypothesis. However, the results do not reject weaker, nevertheless important conclusions.

Introducing new or improved products and processes to reduce *environmental damage* does not appear to impair innovating firm's performance.

- The subset of firms that listed among their motives for innovation *both environmental and regulatory compliance* found that innovation mostly improved their performance.

Since these results are based on interpretation of rather soft, qualitative data, they provide an evidence best described as circumstantial. They are, however, interesting enough to warrant the collection and analysis of more specific data on innovations introduced in compliance with environmental concerns and regulatory constraints.

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Appendix

Table A1 Innovation objectives and problems related to gvt. regulation (% firms weighted)

Q9J	Frequency	Cumulative Percent	Cumulative Frequency	Percent
0	1940.765	25.96	1940.765	25.96
1	1359.047	18.18	3299.812	44.14
2	1073.303	14.36	4373.115	58.49
3	1263.636	16.90	5636.751	75.39
4	968.3611	12.95	6605.112	88.34
5	871.4512	11.66	7476.564	100.00

Frequency Missing = 1033.00

Q9L	Frequency	Cumulative Percent	Cumulative Frequency	Percent
0	2213.59	29.61	2213.59	29.61
1	1646.16	22.02	3859.75	51.62
2	1095.32	14.65	4955.08	66.27
3	1192.01	15.94	6147.09	82.22
4	695.88	9.31	6842.97	91.53
5	633.58	8.47	7476.56	100.00

Frequency Missing = 1033.01

Q10N	Frequency	Cumulative Percent	Cumulative Frequency	Percent
14	748.15	100.00	748.15	100.00

Frequency Missing = 7761.42

All responses to question #9- reasons for innovation share the following problem: There is a response category :

0 = «not relevant», in addition to category «missing» response. How to interpret it, where to classify it? Does the «not relevant» have the same meaning for all questions? A related question concerns the interpretation of scores (1 to 5). Other studies based on Statistics Canada Innovation survey 1999 (e.g. Pierre Therrien ,2000 and Hanel, 2001) treated in the sum of scores 4+5 as = yes, 3 as neutral and the rest (1 and 2 lowest importance) as «no» for any given question. The frequency distribution of responses to both questions Q9J and Q9L by individual manufacturing industry groups shows, however, a somewhat different pattern. The regression of the proportion of respondents that indicated that the reason is «Relevant» on the sum of scores 4+5 = «High», 3=«Neutral» and 1+2= «Low» show that those relationships are not the same for the two questions:

Q9j-innovated to reduce environment damage:

			R^2 adj
RELEVANT= 62 + 0.4 HIGH		0.27	
	(14.9)a (3.3)a	(11.4)a	
RELEVANT= 70.9 + 0.21NEUTRAL		-0.018	
	(11.07)a (0.7) (0.5)		
RELEVANT= 96.6 - 0.46 LOW			0.44
	(21.4)a (-4.9)a	(16.3)a	

This means that industries that had a larger proportion of » RELEVANT» responses had a larger proportion of scores (4+5) than industries where the «RELEVANT» was low. The correlation was non-existent for the relationship between RELEVANT and NEUTRAL (score3) and negative for the relationship between RELEVANT and LOW. This is interpreted as an indication that, indeed, the mid-point (score «3») indicates an indifference level, i.e. «we do not care» kind of response, while only scores 4 and 5 show that the objective was important. Thus firms that selected in response to question Q9J scores «4» and 5 are deemed to have innovated in order to reduce the damage to environment.

2. Regressions of the proportion of respondents that indicated «RELEVANT» on the proportion that selected the score «3» for question Q9L *»Innovated to deal with or to respond to new gvt. regulations»* display a statistically significant positive correlation, suggesting that for this question, the score «3» is not neutral!

Question Q9l

			$R^2_{adj.}$
RELEVANT= 66.1 + 0.20 HIGH			0.09
	(15.1)a (2.1)b	(4.4)b	
RELEVANT= 63.8 + 0.34 NEUTRAL			0.12
	(18.9)a (2.32)b	(5.3)a	
RELEVANT= 81.8 - 0.20 LOW			0.18
	(16.1) (-2.8)	(7.9)a	

Note: Regressions estimated for 32 manufacturing industries.
The statistical significance levels are a=1%; b=5% and c=10%.

To test this hypothesis, the regressions were estimated for a modified interpretation of scores. The new the mid-point was modified to score «2», the new «HIGH» is the sum of scores 3+4+5, the new «LOW» is the score 1. The estimated regressions are:

Question Q9l

			$R^2_{adj.}$
RELEVANT= 62.1 + 0.20 High			0.183
	(18.1)a (2.8b) (5.2)b		
RELEVANT= 73.7 -0.11 NEUTRAL		0.07	
	(30.)a (-1.1)	(1.2)	
RELEVANT= 77.9 - 0.21 LOW			0.12
	(25.1)a (-2.3) (5.2)a		

Note: Regressions estimated for 32 manufacturing industries.
The statistical significance levels are a=1%. B=5% and c=10%.

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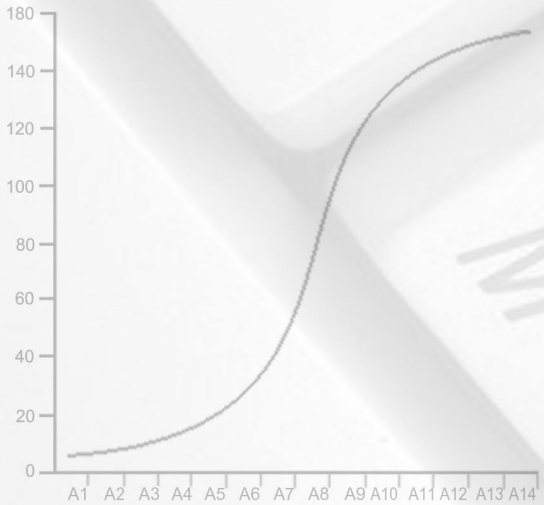

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