CIRANO

Centre interuniversitaire de recherche en analyse des organisations

Série Scientifique

Scientific Series

Nº 95s-12

REGULATION AND PRODUCTIVITY IN THE QUEBEC MANUFACTURING SECTOR

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Montréal
Février 1995

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ISSN 1198-8177

Regulation and Productivity in the Quebec Manufacturing Sector*

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Abstract / Résumé

We investigate the impact of occupational safety and health (OSH) and environmental regulation on the rate of growth of total factor productivity (TFP) in the Quebec manufacturing sector during the 1985-88 period. Our results show that environmental regulation and OSH protective reassignments (a prevention policy with respect to OSH) have led to a reduction in productivity growth, while the presence of mandatory prevention programs and of fines for infractions to OSH rules have led to an increase in productivity growth. Interestingly, this is, to our knowledge, the first result showing that OSH regulation may have had a positive effect on productivity growth.

Nous évaluons l'impact qu'ont eu les réglementations en matière de santé et sécurité du travail et d'environnement sur la croissance de la productivité totale des facteurs (PTF) du secteur manufacturier québécois au cours des années 1985-88. Nos résultats montrent que la réglementation environnementale et les réaffectations préventives (une mesure de prévention des accidents de travail) ont réduit la croissance de la productivité, alors que les mesures de prévention obligatoires et l'importance des amendes imposées pour infraction aux normes du travail ont augmenté la productivité. Notre étude est la première, à notre connaissance, qui indique un effet potentiellement positif de la réglementation sur la croissance de la productivité.

Keywords: environmental regulation, safety and health regulation, productivity.

Mots clé : réglementation environnementale, réglementation de la santé et de la sécurité du travail, productivité.

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* The authors want to thank Pierre Lasserre, Peter Kennedy, Melvyn Fuss, three anonymous referees and workshop participants at the 1992 Meetings of the Canadian Study Group on the Economics of Natural Resources and the Environment held in Quebec for their helpful comments. Financial support from the Social Sciences and Humanities Research Council of Canada and the Fonds FCAR is gratefully acknowledged. The usual disclaimer applies.

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I. Introduction

The impact of regulation on productivity growth has been a subject of growing interest during the last decade for various reasons. First, some authors (e.g., Christainsen and Haveman, 1981) suggested that regulation might be (partly) responsible for the preoccupying productivity slowdown of the American economy in the 1970s.[1] Second, we need to know what is the effect of regulation on productivity in order to provide a complete cost-benefit analysis of regulation (examples of such an analysis include Mendeloff, 1988 and Viscusi, 1986).

Several studies have investigated the impact of regulation activities on productivity growth. Most of these studies are American and were published in the late 1970's or in the 1980's. These studies vary in a number of ways, including the definition of productivity that is used, the type of regulation (mostly environmental), the industries considered and the magnitude of their results.

In a pioneering study, Denison (1978) estimates that about 16 percent of the productivity slowdown in the U.S. non-residential business sector during the 1972-75 period was due to regulation from OSHA (Occupational Safety and Health Administration) and EPA (Environmental Protection Agency). Christainsen and Haveman (1981) find, using measures of the amount of total federal U.S. regulation, that regulation reduced the rate of growth of labor productivity in the U.S. manufacturing sector by 0.27 % per year during the 1958-77 period. Gollop and Roberts (1983) estimate that the American Clean Air Act reduced productivity growth by 0.59 % per year during the 1973-1979 period in the fossil fuelled electric utilities industry. Gray (1987) finds that about 30 % of the decline in productivity growth in the U.S. manufacturing sector during the 1970's may be attributed to OSHA and EPA regulation. As for Canada, Sims and Smith (1985) show that "pollution charges" did not affect significantly the productivity of four firms in the Canadian brewing industry. Moreover, Conrad and Morrison (1989), in a study of the manufacturing sectors of the U.S., Germany and Canada, find that pollution investment expenditures had virtually no effect on productivity growth in Canada during the 1967-80 period.

This paper contributes to the understanding of the impact of regulation on productivity growth in Canada, specifically in the Quebec manufacturing sector. To our knowledge, this is the first attempt to assess empirically the impact of OSH regulation on Canadian productivity. The analysis is based on Gray (1986, 1987), who posits a relation between the rate of growth of total factor productivity (TFP) and a variety of indicators measuring the intensity of the occupational safety and health and

[1] A similar slowdown was also observed in Canada (see Stuber, 1986).

environmental regulations. Apart from the data set, the present analysis differs from Gray's in four respects. First, while Gray argues that regulation has necessarily a negative impact on productivity growth, our theoretical discussion allows for positive impacts. Second, the set of variables we use to assess the impact of OSH regulation is more extensive than Gray's in order to capture the variety of means by which the Quebec OSH Board (the Commission de la Santé et Sécurité du Travail or CSST) deals with workplace safety problems. Indeed, this Board has been innovative with the adoption of different safety policies, some of them unique in North America, such as compulsory prevention programs, safety committees, the right to protective reassignments, and the right of refusal.[2] Third, two independent variables are included in the estimated equation to control for the impact of economies of scale and business cycle fluctuations on TFP growth. Fourth, in contrast with Gray (1986), we use the cross-sectionally heteroskedastic and time-wise autoregressive estimation procedure presented in Kmenta [1986, pp. 616-625] in order to prevent potential problems of serial correlation or heteroskedasticity.[3]

The rest of the paper is organized as follows. Section I discusses theoretically the expected impact of OSH and environmental regulation on TFP. It also presents the estimated equation and the data set (from 19 sectors of the Quebec manufacturing industry for the period 1985-88). The empirical results are presented in Section II. They show that environmental regulation has a negative impact on productivity growth, while certain measures adopted by the OSH authorities have a positive impact, which is a new result in this literature. Finally, Section III provides concluding remarks.

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[2] The right to refuse hazardous tasks allows a worker to refuse to carry out a certain task if he or she believes that this task is "abnormally" dangerous. The joint worksite safety committees usually assume the following responsibilities: obtaining and disseminating information on OSH, identifying the sources of hazard to workers and making recommendations on means of eliminating hazards to the employer. The equal representation of management and workers on a committee is compulsory. A prevention program must meet the approval of the OSH board and must address the training and supervision of workers, inspections, accident investigations, personal protective equipment as well as the maintenance and disclosure of records. In Quebec, prevention programs (as well as the safety committees which implement the programs) are imposed only on firms with more than 20 employees in the fifteen most risky industries. Protective reassignment gives a worker the right to be transferred to another job within the same firm if he or she can provide a medical certificate that attests the potential medical harm his or her job could cause. So far, this right can only be used by pregnant women. It is noteworthy that most of these safety policies are targeted, or have a larger incidence, in risky industries like mining, forestry or the chemical industry.

[3] In Gray (1987), serial correlation is less likely to be a problem since the dependent variable is the change in annual TFP growth: 1959-69 to 1973-78, while we adopt a similar estimation strategy with panel data as Gray (1986, chap. 7).

II. Theoretical Discussion, Specification of the TFP Equation and Data

As in most of the literature, we measure total factor productivity growth ($\dot{TFP}$) by the Törnqvist index:

$$(1) \qquad \dot{TFP}_{it} = (\log Y_{it} - \log Y_{it\ 1}) - \sum_j [(\alpha_{jit} + \alpha_{jit\ 1})/2$$
$$x\ (\log X_{jit} - \log X_{jit\ 1})]$$

The subscripts i and t refer to industries and time periods, and the j refer to inputs. The α's are the inputs' cost shares.

A host of factors account for observed variations in $\dot{TFP}$ (see Cowing and Stevenson, 1981; Denny *et al.*, 1981; and Ouellette and Lasserre, 1985): changes in the scale of production, technological shocks, fluctuations in the rate of use of quasi-fixed inputs, non-marginal cost pricing, and regulatory shocks, among other things.

The derivation of a precise relationship between these determinants of productivity and our measure of $\dot{TFP}$ would require a complete characterization of the technology of the Quebec manufacturing industry - which is beyond to scope of this paper. We use the theoretical results of productivity analysis to shed light on the relationship between productivity growth, our regulation variables and other control variables.

As shown in Gray (1987), the impact of OSH and environmental regulation on productivity growth is expected to be negative since regulation is likely to induce firms to invest in non-productive inputs. For instance, regulation can "impose constraints on the firm's choice of production processes, make it harder to take advantage of new innovations, cause firms to lower new investments by increasing uncertainty, etc." (p. 999). Therefore, compliance with regulation leads to an increase in the rate of growth of inputs with no counterpart on the output side or, in other words, since regulation introduces an extra constraint in the minimization problem of the firm, it necessarily leads to lower productivity. Of course, if the social benefits of regulation were fully taken into account as an additional output, the preceding conclusions would no longer be true.

Although this view is prevailing in the literature, one can imagine situations in which regulation may induce firms to adopt productivity-enhancing measures that they would not have adopted otherwise. Meyers and Nakamura (1980), Sonnen (1991) as well as Kennedy (1994) discuss the positive impact that environmental regulation may have on productivity growth. In particular, it is possible that regulation induces the firm to intensify its research and development activities, thus stimulating productivity growth. Imagine a model (see Kennedy, 1994, for a formal argument) where production costs depend negatively on the amount spent on research. In such a model, environmental regulation raises the cost of production and this strengthens the incentive to engage in cost-reducing research which, in turn, can offset the initial increase in cost due to regulation, or even lead to a reduction in total cost. This last outcome may happen, for instance, if the probability of a major technological breakthrough (e.g., the use of waste material as a new source of combustion) increases with the amount spent on research, or if there are spillovers between innovating firms through the diffusion of knowledge.[4]

The same line of reasoning can be followed with respect to OSH regulation, but probably to a lesser extent since occupational safety is conceivably less related to technology than pollution control. In a Canadian context, however, it is interesting to note that OSH regulation-induced innovation may be due to the "forced" participation of workers in the solution of safety problems. Indeed, Canadian OSH authorities have put much emphasis on this kind of participation through the adoption of the right of refusal or the compulsory creation of joint safety committees. This participation, which is somewhat imposed upon employers as a means to improve safety in the workplace[5], may lead to a better identification of the sources of danger and more appropriate suggestions as to how problems may be solved than those adopted by the firm otherwise[6]. Therefore, if this kind of regulation leads to a reduction of workplace accidents, it in turn induces a reduction of the costs incurred because of accidents. These costs include both direct costs (wage compensation and medical care), which are supported to some extent by the firm depending on the degree of experience

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[4] This line of reasoning, involving inter-firm externalities, may also explain why compliance to acid rain regulation, for instance, may lead to lengthened lives of structures that would otherwise be eroded by acid rain and thus, to lower costs and higher productivity for firms.

[5] See Viscusi, 1983, Carmichael, 1986 or Lanoie, 1991 for economic arguments showing that, left alone, firms would not provide an optimal amount of safety in the workplace, so that government intervention is justified to improve the level of safety.

[6] In other words, in the absence of regulation, information known to the workers and unknown to the employer is not used by the employer. Legislation giving workers the right of refusal, for instance, allows this information to be used. Here, legislation, instead of adding new constraints, releases to some extent a constraint that prevents the use of information.

rating[7], and indirect costs (halt of the production process, mechanical breakdown, training of a substitute worker, etc.). Certain authors (e.g., Brody *et al.*, 1990) have estimated that these indirect costs are at least as large as the direct costs.

Therefore, taking the preceding arguments into consideration, it is not clear whether or not environmental and/or OSH regulation has a negative impact on productivity growth. This remains an empirical issue.

Following our discussion, we define an equation relating the rate of growth of TFP to indicators of the importance of regulation:

$$(2) \qquad \dot{TFP}_{it} = \alpha_0 + \alpha_1 \cdot ENVIRONMENT_{it} + \sum_{k\,2}^{6} \alpha_k \cdot OSH_{it} + \sum_i \mu_i + \sum_t \Psi_t + \alpha_7 \cdot SCALE_{it} + \alpha_8 \cdot CYCLE_{it} + \alpha_9 \cdot ENERSHARE_{it} + e_{it}$$

$ENVIRONMENT_{it}$ and OSH_{it} are variables capturing the intensity of environmental and OSH regulation (to be defined in more details below); the term μ_i reflects omitted fixed effects pertaining to industry i, whereas Ψ_t reflects omitted fixed influences that vary across time, but not across industries; $SCALE_{it}$, $CYCLE_{it}$ and $ENERSHARE_{it}$ are control variables, and e_{it} is a random error term. Note that, given the nature of our dependent variable, all the independent variables (except, of course, the fixed effects) are expressed in first difference.

$\dot{TFP}_{it}$ is calculated (see equation (1)) as the difference between real output growth and real input growth. Output is measured by the value (in real terms) of industry shipments. Five inputs are considered: production workers, nonproduction workers, nonenergy materials, energy and capital. The latter is calculated as the cost of capital times the stock, and the different fiscal treatment of capital relatively to the other inputs is taken into account. The detailed definition of these variables, their means, standard deviation and statistical source, as well as those of the other variables in the analysis, are provided in Table 1 at the end of the text. More details on the computations of the TFP are provided in Dufour (1992).

Concerning the independent variables, $ENVIRONMENT_{it}$ is the change in the ratio of the value of investment in pollution-control equipment to the total cost in industry i at time t. Unfortunately, this data is only available since 1985 and we

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[7] In North America, firms are considered liable for workplace accidents and pay insurance premia to a Workers' Compensation Board which, in turn, pays compensation benefits to accident victims. Via an experience rating mechanism, these premia are partially adjusted to reflect the firm's own claim experience.

suspect that it underestimates the real expenditures devoted to pollution control. This is so because an investment in new production equipments that happen to reduce pollution is not necessarily reported as an investment in pollution control, and because our measure covers only capital expenditures and ignores labor and material costs. Our estimate of the impact of regulation on productivity growth will not diverge from the true impact if the numerator of ENVIRONMENT_{it} and the real expenditures on pollution control are highly (positively) correlated.

Since no data is available on the cost of compliance with occupational safety and health regulation, we capture the intensity of OSH regulation by a vector of safety-enforcing measures adopted by the Quebec board responsible for OSH (the CSST). As in Gray (1987), it is assumed that enforcement effort is likely to be positively correlated with compliance costs. In Quebec, five types of safety-enforcing measures can be documented: inspections (INSPECTIONS_{it}); penalties (fines) imposed for infractions or noncompliance with safety standards (INFRACTION_{it}); applications of the right to refuse a dangerous task (REFUSAL_{it}); applications of the right to protective reassignment (PROTECT_{it}), and requirement for a prevention program (PREVENT_{it})[8]. Protective reassignments and refusals are not safety-enforcing measures per se, but they can be interpreted as employees' actions resulting from government intervention. Note that Gray used only an inspection variable.

It is well-known that changes in the scale of production, the presence of quasi-fixed inputs, and non-marginal cost pricing influence the measurement of TFP growth (Denny *et al.*, 1981; Ouellette and Lasserre, 1985). Therefore, to assess the impact of regulation on productivity, we must control for these influences.

SCALE_{it}, defined as the change in the level of output, is included in the estimated equation to capture the effect of economies of scale on productivity. We expect the coefficient on SCALE_{it} to take a positive sign if economies of scale lead to an increase in productivity growth, while the converse would indicate that there are decreasing returns to scale. Since no variable could be found to control adequately for the absence of marginal cost pricing, the industry dummies may serve as proxies to capture this phenomenon.

It is also necessary to control for cyclical fluctuations in the presence of quasi-fixed inputs. For instance, a temporary plant closing will drastically reduce a firm's productivity level since no output is produced, while the capital stock (or other

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[8] Our measure here is the percentage of firms in the industry that have adopted a prevention program. This policy was adopted in 1984 and firms that were affected by the program had three years to comply with the rule. See footnote 2.

fixed inputs) still has to be counted as an input. Therefore, the variable $CYCLE_{it}$, defined as the change in the utilization capacity index, is included on the right-hand side of the equation. Its coefficient is expected to be positive since an increase in the capacity utilization rate should lead to an increase in productivity growth. One should note that the two preceding control variables are ignored by Gray (1987). Finally, as in Gray (1987), the change in the cost share of energy $ENERSHARE_{it}$ is included to check for the possibility that energy-intensive industries have experienced higher rates of growth in productivity following the reduction in oil prices in 1986 (Gray was expecting the opposite because of the oil price increases in the 1970's).

The omitted fixed effects pertaining to industry i, μ_i, will be captured by the use of industry dummy variables. The omitted fixed influences that vary across time but not across industries, Ψ_t, will be captured by the use of time dummies. In particular, the latters may capture technological progress. Note that our fixed-effects specification departs from Gray's (1986).

For estimation purposes, pooled time-series and cross-section data are used. Annual data cover the period 1985-88 inclusively (the data for 1984 are also used for the calculation of the TFP). The data cover 19 manufacturing industries (see the list in Table 1). Hence, since we are using explanatory variables in first differences, the sample contains 57 observations. All data can be found in publications by the CSST and Statistics Canada. Interestingly, TFP has increased on average by .3 % per year during the period under study, which is consistent with the results of Denny *et al.* (1992), which show that the decline in the productivity of the Canadian manufacturing sector observed in the 1970's has recently been reversed. Note the variance of TFP growth across industries (.086): our sample clearly contains industries characterized by rapid productivity growth and others by a sharp decline.

III. Empirical Results

The estimations are performed using a generalized least-squares (GLS) procedure based on the cross-sectionally and time-wise autoregressive model presented in Kmenta [1986, pp. 616-625]. Furthermore, as suggested by Gray (1987), a Hausman (1978) exogeneity test was performed to check if productivity growth might have had an influence on the level of regulation. It is indeed possible that less productive firms react by reducing their expenses to comply with regulation. In turn, the regulatory agency (namely, the CSST) may react by increasing its enforcement measures. Furthermore, one may also suspect that the SCALE variable be endogenous given that output growth enters directly in the calculation of TFP. We tested for the non-exogeneity of the regulation and control variables. The test did reject the exogeneity of the variables PROTECT, PREVENT, SCALE, CYCLE, and ENERSHARE, and these variables are instrumented in our final estimations[9].

Table 2 presents six different specifications of equation (2) with various groups of independent variables. Overall, the explanatory power of the different specifications seems satisfactory, and the results are relatively stable across specifications. Column (1) presents the full specification on which we will base the rest of our discussion.

The variable capturing the amount of resources devoted to pollution-control equipment, ENVIRONMENT, has a negative and significant coefficient. The contribution of the ENVIRONMENT variable to productivity growth is estimated at -0.001 at the sample means. This result is obtained by multiplying the regulation coefficient by the mean value of the regulation measure (taken in first difference). The magnitude of this effect is in general lower than that observed in American studies (see the Introduction), but comparable to that obtained in other investigations based on Canadian data (Smith and Sims, 1985; Conrad and Morrisson, 1989). This may be due to the fact that U.S. environmental regulation and its enforcement is in general considered more severe than its Canadian counterpart (for convincing arguments on this matter, see Marchant, 1990). And since our data covers a more recent period than the other studies, we may be capturing certain positive effects of environmental regulation on productivity as those described in our theoretical discussion. Gray (1987) also found the environmental regulation variable to affect negatively productivity growth. But the coefficient on his environmental variable is unstable and not statistically significant when other regressors are included.[10]

Three of the OSH regulation variables are statistically significant. One has a negative coefficient (PROTECT) and two, INFRACTION and PREVENT, a positive and significant coefficient. The sum of the implied contribution of the last two on productivity is 0.007 (at the sample means). This result suggests that these two measures have reduced the incidence of workplace accidents, leading to a reduction of direct and indirect costs related to accidents sufficient to have an enhancing effect on productivity growth. Interestingly, Lanoie (1992a) shows that the inspections,

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[9] The set of instruments includes the ratio of machinery to labor in the industry, the yearly average number of hours worked per week per worker, the percentage of female workers in the industry, the percentage of unionized workers in the industry and the average firm size in the industry. Each of these variables is related with a potentially endogenous variable, but not necessarily with TFP growth. For instance, the percentage of female workers is associated with the use of protective reassignments (PROTECT). These instruments were also used to perform the Hausman test. Complete results are available upon request.

[10] Furthermore, in Gray's (1986) panel data analysis, the coefficients of all the regulatory variables are not significant.

which give rise to detected infractions and fines, have reduced the frequency of accidents.[11] To our knowledge, this is the first result showing that OSH regulation may have a positive impact on productivity.

The coefficient on the rate of protective reassignment (PROTECT) is negative and significant. The implied contribution on productivity is -.019, which is substantial. For a comparison with Gray who had only one measure of OSH costs, it is useful to compute the net impact of OSH measures on productivity. This net effect is -0.012, which is larger than the average impact found in Gray, (-0.003). Two reasons may explain this result. First, it seems that the enforcement of safety policies is more intense in Quebec than in the United States, especially during the period under study (for instance, our rate of inspection is twice as large as that reported in Gray, 1987; see Lanoie, 1992b, for further discussion). Second, it may be the case that OSH measures are a proxy of the riskiness of an industry; i.e., safety enforcement is targeted to firms in riskier sectors. These firms have to pay higher payroll taxes (insurance premia) to the Workers' Compensation Board (WCB), which compensates their injured workers. These insurance premia are in general more expensive in Quebec than in United States since, in particular, Quebec's compensation regime is more generous than in most States of the United States (see Lanoie, 1994, for more details on this issue). In other words, our results may reflect the fact that OSH variables capture the effect of Quebec's WCB generosity on the cost of labor.[12]

The coefficients of the other OSH regulation variables are never significant. An F-test has shown that the OSH regulation variables are globally significant in the equation. Also note that the results pertaining to the significant OSH variables (PROTECT, INFRACTION, PREVENT) persist when these variables are included as the only OSH variables in the equation (see specification (6)).

Concerning the control variables, as expected, the SCALE variable has everywhere a positive and significant coefficient, which is relatively stable across specifications. The coefficient on SCALE suggests that the contribution of economies of scale to TFP growth was about 0.0006 per year, which is relatively small. Similarly, and as expected, the capacity utilization index variable (CYCLE) has always a positive and significant coefficient (except in specification 3). The implied contribution of this variable to TFP growth is 0.029. Finally, the variable related to the share of energy

[11] This result was obtained with a sample of data covering 28 industries for the period 1983-87.

[12] In particular, it is well recognized that protective reassignment is a measure that do not prevent many accidents, but that increases labor costs (see Lanoie, 1992a).

cost (ENERSHARE) has everywhere a positive coefficient, but not stable and not always significant.

IV. Conclusion

This paper has investigated the impact of OSH and environmental regulation on the rate of growth of productivity in the Quebec manufacturing sector during the period 1985-88. On one hand, the results showed that both environmental regulation and OSH protective reassignments have led to a reduction in productivity growth. Of course, before condemning these regulatory measures because of these results, one should perform a complete analysis to balance these costs with the benefits of these measures. On the other hand, the presence of mandatory prevention programs and of fines for infractions to OSH rules has led to an increase in productivity growth. Interestingly, this is, to our knowledge, the first result showing that OSH regulation may have had a positive effect on productivity growth. Such a result may induce employers to stop perceiving OSH regulation solely as a constraint: it is also a potential source of productivity and profitability.

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TABLE 1

DEFINITION, MEAN, STANDARD DEVIATION (SD) and SOURCE of all VARIABLES

Variables are at the industry level on a yearly basis

VARIABLES DEFINITION			MEAN	SD	STATISTICAL SOURCE
1. DEPENDENT VARIABLE					
TFP_{it}	:	rate of growth of total factor productivity (TFP)	0.0032	0.086	
Variables used for the calculation of TFP					
1.1 OUTPUT					
$SHIP_{it}$	:	value of shipments ('000 $ 1981)	2871800	2012500	STAT CAN, 31-203
1.2 INPUTS					
$MATR_{it}$	:	cost of material and supplies used ('000 $ 1981)	1788700	1438200	STAT CAN, 31-203
ENR_{it}	:	cost of fuel and electricity ('000 $ 1981)	82443	117020	STAT CAN, 31-203
$PRODR_{it}$	:	wages of the production and related workers ('000 $ 1981)	335680	201260	STAT CAN, 31-203
$NPRODR_{it}$	:	wages of the administrative, office and other non-manufacturing employees ('000 $ 1981)	162410	120350	STAT CAN, 31-203

VARIABLES		DEFINITION	MEAN	SD	STATISTICAL SOURCE
CAPITAL [13]					
$\mathbf{K}_{C,it}$	:	stock of capital-Construction ($ 1981)	816.68	836.28	STAT CAN, 1992
$\mathbf{I}_{C,it}$	:	investments-Construction ($ 1981)	20.39	50.81	Idem
$\mathbf{d}_{C,i}$	:	rate of depreciation of the capital stock-Construction	0.034	0.007	Idem
$\mathbf{u}_{C,t}$	:	taxation rate of corporations-Construction	0.426	0.008	Guide du contribuable canadien
$\mathbf{z}_{C,t}$	:	value of future tax savings from depreciation deductions-Construction	0.531	0.011	Idem
$\mathbf{k}_{C,t}$	:	tax credit for investment-Construction	0.055	0.016	Royer et Drew, Impôts et planification
$\sigma_{C,t}$	:	rate of capital allowance cost-Construction	0.100	0.000	Guide du contribuable canadien
$\mathbf{q}_{C,it}$	:	price index-Construction	128.65	6.34	STAT CAN, 13-211
$\mathbf{r}_{C,t}$	:	opportunity cost of capital-Construction	0.109	0.005	Revue de la Banque du Canada
$\mathbf{K}_{M,it}$	:	stock of capital-Machinery and equipment ($ 1981)	1066.7	1513.3	STAT CAN, 1992
$\mathbf{I}_{M,it}$	:	investments-Machinery and equipment ($ 1981)	66.38	133.78	Idem
$\mathbf{d}_{M,i}$	:	rate of depreciation of capital stock-Machinery and equipment	0.086	0.021	Idem

[13] The capital is divided into two categories: construction and machinery and equipment. The stock of capital is computed following: $K_{it} = I_{it} + (1-d_i)K_{i,t-1}$, while the cost of capital (C_{it}) is calculated according to the equation developed by Christensen and Jorgenson (1969): $C_{it} = \frac{(1 - U_t Z_t - K_t)}{(1 - U_t)} \left[q_{it} r_t + q_{it} d_i - (q_{it} - q_{it-1}) \right]$ where $Z_t = \sigma_{it} \left[\frac{1 + r_t}{r_t + \sigma_{it}} \right]$

VARIABLES		DEFINITION	MEAN	SD	STATISTICAL SOURCE
$u_{M,t}$	:	taxation rate of corporations-Machinery and equipment	0.426	0.008	Guide du contribuable canadien
$z_{M,t}$	:	value of future tax savings from depreciation deductions-Machinery and equipment	0.718	0.009	Idem
$k_{M,t}$	:	tax credit for investment-Machinery and equipment	0.055	0.016	Royer et Drew, Impôts et planification
$\sigma_{M,t}$	:	rate of capital allowance cost-Machinery and equipment	0.200	0.000	Guide du contribuable canadien
$q_{M,it}$	:	price index-Machinery and equipment	123.25	6.93	STAT CAN, 13-211
$r_{M,t}$	:	opportunity cost of capital-Machinery and equipment	0.109	0.005	Review of the Bank of Canada
2. INDEPENDENT VARIABLES					
2.1 REGULATION VARIABLES					
ENVIRONMENT$_{it}$	:	% in total costs of investments in pollution-control equipment	0.0008 (0.0001)[a]	0.0017 (0.001)	STAT CAN, unpublished report
INSPECTION$_{it}$	:	number of OSH inspections / 1000 full-time employees	10.688 (-1.631)	8.488 (4.363)	CSST annual reports
REFUSAL$_{it}$	:	number of interventions from CSST officials for refusals / 1000 employees	0.248 (0.035)	0.252 (0.347)	Idem
PROTECTIVE$_{it}$	:	number of protective reassignments / 1000 employees	4.504 (0.487)	6.094 (2.572)	Idem
INFRACTION$_{it}$	:	number of penalties imposed (infractions) / 1000 employees	0.577 (0.192)	1.477 (1.549)	Idem
PREVENT$_{it}$	:	% of firms that have adopted a prevention program	0.399 (0.041)	0.406 (0.224)	Idem

2.2 CONTROL VARIABLES			
CYCLE$_{it}$: capacity utilisation index	81.425 (0.993)	10.513 (7.422)	STAT CAN, 31-003
SCALE$_{it}$: output growth rate	0.0374 (0.0372)	0.1549 (0.1769)	STAT CAN, 31-203
ENERSHARE$_{it}$: share of energy costs in total costs	10.579 (0.621)	.749 (1.712)	STAT CAN, 31-203
2.3 DUMMY VARIABLES-industries ("miscellaneous mfg. industry" is default)			
The industries considered are: food and beverage, tobacco, rubber and plastics, leather, textiles, clothing, wood, furnitures and fixtures, paper and allied products, printing and publishing, primary metals, metal fabricating, machinery, transportation equipment, electrical products, non-metallic minerals, petroleum and coal products, chemicals.	0.225	0.051	
2.4 DUMMY VARIABLES -TIME			
1985 is default.	0.250	0.436	

a The number in parenthesis is the value for the variable in first-difference.

TABLE 2

The TFP Equation (N=59), Coefficients (t-stastistics) [1]

INDEPENDENT VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
ENVIRONMENT	-10.613 (-1.84)	___	-7.768** (-2.34)	-14.265** (-4.75)	-12.452** (-2.05)	-5.778 (-1.029)
INSPECTION	0.001 (0.41)	-0.001 (-0.24)	___	0.0003 (0.17)	0.0004 (0.22)	___
REFUSAL	0.019 (1.14)	0.017 (1.04)	___	0.025* (1.68)	0.019 (1.20)	___
PROTECTIVE	-0.040* (-1.91)	-0.046** (-2.16)	___	-0.043** (-3.01)	-0.044** (-2.23)	-0.031 (-1.43)
INFRACTION	0.009** (3.02)	0.009** (3.16)	___	0.009** (3.38)	0.006** (2.21)	0.005** (1.98)
PREVENT	0.154** (2.86)	0.163** (2.97)	___	0.151** (4.48)	0.119** (2.27)	0.148** (2.34)
SCALE	0.019** (2.94)	0.023** (3.54)	0.013** (2.57)	___	0.018** (3.28)	0.022** (3.21)
CYCLE	0.030** (2.73)	0.023** (2.17)	-0.008 (-1.19)	0.036** (5.47)	0.015 (1.37)	0.010 (0.80)
ENERSHARE	0.012 (1.19)	0.018* (1.85)	0.001 (0.11)	0.019** (2.46)	___	0.009 (0.93)
Intercept	0.029 (0.38)	0.043 (0.56)	-0.001 (-0.004)	0.025 (0.37)	0.050 (0.59)	0.026 (0.33)
R^2	0.72	0.73	0.67	0.77	0.56	0.54
Log L	134.14	131.80	138.54	150.38	129.71	128.26

1 Each specification includes 18 industry dummies and 2 time dummies. ** Statistically significant at the 5% level (two-tail test) * Statistically significant at the 10% level (two-tail test)