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Environmental Regulation and Productivity: New Findings on the Porter Hypothesis *

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Résumé / Abstract

Ce texte présente une analyse empirique de la relation entre l'ampleur de la réglementation environnementale et la productivité totale des facteurs en utilisant des données du secteur manufacturier québécois. Cet exercice nous permet de pousser l'analyse de l'hypothèse porterienne dans trois directions. Premièrement, l'introduction de variables réglementaires retardées nous permet de mieux capter l'aspect dynamique de l'hypothèse. Deuxièmement, nous postulons que l'hypothèse de Porter a plus de chance d'être valide dans les secteurs très polluants. Troisièmement, nous postulons qu'il sera de même dans les secteurs plus exposés à la concurrence extérieure. Nos résultats empiriques suggèrent que : 1) l'impact de la variable contemporaine de réglementation est négatif ; 2) le résultat contraire est observé pour les variables de réglementation retardées et 3) cet effet est plus fort dans les secteurs les plus exposés à la concurrence extérieure.

This paper provides an empirical analysis of the relationship between the stringency of environmental regulation and total factor productivity (TFP) growth in the Quebec manufacturing sector. This allows us to investigate more fully the Porter hypothesis in three directions. First, the dynamic aspect of the hypothesis is captured through the use of lagged regulation variables. Second, we argue that the hypothesis is more relevant for more polluting sectors. Third, we argue that the hypothesis is more relevant for sectors which are more exposed to international competition. Our empirical results suggest that: 1) the contemporaneous impact of environmental regulation on productivity is negative, 2) the opposite result is observed with lagged regulation variables and 3) this effect is stronger in a sub-group of industries which are more exposed to international competition.

Mots Clés : Hypothèse de Porter, réglementation environnementale, productivité

Keywords: Porter hypothesis, environmental regulation, productivity

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1. Introduction

In two well-known essays (Porter, 1991 ; Porter and van der Linde, 1995), Michael Porter has suggested that more severe environmental regulation may have a positive effect on firms' performance by stimulating innovations. He actually argues that « properly designed environmental regulation can trigger innovation that may partially or more than fully offset the costs of complying with them » (1995, p.98). This is basically due to the fact that pollution is a manifestation of economic waste, and involves unnecessary and incomplete utilization of resources, which suggests that pollution reduction may improve the way firms use resources. In this vein, he adds : « Reducing pollution is often coincident with improving the productivity with which resources are used » (1995, p.98).

Of course, the so-called « Porter hypothesis » is controversial. Environmentalists and policy makers tend to like such « win-win » solutions. However, its opponents (in particular, Palmer et al., 1995) have raised severe arguments against it. Among them, one can point out : 1) the empirical evidence supporting Porter's view is anecdotal and cannot be generalized ; 2) there are no « low-hanging fruits » : in standard neoclassical models, firms are perfectly rational and never fail to implement a profit maximizing strategy, they do not need the regulator to help them in doing so; and 3) rigorous studies that have investigated the relationship between environmental regulation and productivity (a proxy for performance) have found that it was negative (see Jaffe et al., 1996, for a review).

More systematic analysis of Porter's hypothesis is needed before policy makers can base intervention on it. We argue that existing empirical analyses related to the hypothesis can be extended in three directions. First, the Porter hypothesis is dynamic ; it thus involves that environmental regulation adopted today will affect firms' productivity and performance a few years down the road when the innovation process has been completed. Systematic studies of the relationship between regulation and productivity have only looked at the contemporaneous impact of regulation. Actually, Jaffe and Palmer (1997), who provide an empirical test related to the Porter hypothesis by examining the relationship between pollution control expenditures and measures of innovative activities, have taken steps in the direction we suggest. Indeed, they look at the impact of lagged compliance expenditures on innovation[1]. Second, Porter's arguments suggest that firms with a high load of polluting emissions will have more opportunities to identify and eliminate inefficiencies, so that the positive effect of regulation on performance should be more important for firms that are initially more polluting. Third, Porter's arguments suggest that firms in industries that are more exposed to competition from abroad are more likely to have an incentive to innovate to reduce costs than firms in less exposed sectors (Reinhardt, 2000).

This paper provides an empirical analysis of the total factor productivity (TFP) growth in the Quebec manufacturing sectors that allows us to investigate more fully the Porter hypothesis in the three directions we just mentioned; that is, we consider the impact of a lagged regulation

1. They find that the impact of compliance expenditures depends on the measure of innovation that they use.

variable on productivity and we investigate separately what is happening in the most polluting sectors and in those that are more exposed to competition. The rest of the paper is organized as follows. The next section presents our model and data. Section 3 discusses our empirical results which show that : 1) the contemporaneous impact of environmental regulation on productivity is negative, 2) the opposite result is observed with lagged regulation variables; and 3) this effect is stronger in a sub-group of industries which are more exposed to international competition. Section 4 provides some concluding remarks.

2. Empirical Model And Data

As in most of the literature, we measure total factor productivity growth by the Törnqvist index :

$$T\dot{F}P \quad = \quad \log\left(Y_{it} - \log Y_{it-1} \right) - \sum_{j} \left[\left(\alpha_{jit} + \alpha_{jit-1} \right) / 2 \times \left(\log X_{jit} - \log X_{jit-1} \right) \right] \tag{1}$$

The subscripts *i* and *t* refer to industries and time periods, and the j refers to inputs. The α's are the inputs'cost shares[2].

A host of factors account for observed variations in $T\dot{F}P$ (Denny et al., 1981, Gray, 1987, Dufour et al., 1998) : 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.

In the following analysis, we define an equation relating the rate of growth of TFP to an indicator of the importance of environmental regulation and to a series of control variables[3] :

$$\begin{aligned} T\dot{F}P = \alpha_0 + \alpha_1 \cdot ENVIRONMENT_{it} + \alpha_2\ ENVIRONMENT_{it-1} + \alpha_3\ ENVIRONMENT_{it-2} + \\ \alpha_4\ ENVIRONMENT_{it-3} + \alpha_5 OSH_{it} + \alpha_6 \cdot SCALE_{it} + \\ \alpha_7 \cdot CYCLE_{it} + \sum_i \mu_i + \sum_t \varphi_t + e_{it} \end{aligned} \tag{2}$$

where e_{it} is an error term.

As in previous papers, the stringency of environmental regulation is proxied by a variable, ENVIRONMENT_{it}, which 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*. As in most preceding studies, we include a contemporaneous measure, but also a one-year, a two-year and a three-year lag to

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2. 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. More details on the computation of the $T\dot{F}P$ are given in Dufour et al. (1998), and Dufour (1992).
3. Note that, given the nature of our dependent variable, all the independent variables (except of course the fixed effects) are expressed in first difference.

capture the dynamics of the Porter hypothesis[4]. This procedure to capture dynamic effects is suggested by Greene (1997). As in Jaffe and Palmer (1997), we also consider three moving average of the prior years (see the definition in Table 1). We thus expect the contemporaneous impact to be negative, but the converse result could be observed with the different lagged variables. Furthermore, as discussed in the introduction, we expect this pattern to be stronger in the most polluting industries and in the industries that are more exposed to external competition. Therefore, we will capture these effects with crossed-terms involving dummies to separate the sample between the more polluting (POLL) and the less polluting (LESS POLL)[5] sectors, as well as between the sectors which are more exposed to competition (COMP), and those which are less exposed (LESS COMP)[6].

As in Gray (1987) and Dufour et al. (1998), we also include a variable, OSH_{it}, capturing the stringency of the occupational safety and health regulation, one of the other important areas in which firms are regulated. However, Porter's argument is certainly less relevant in this field – it can hardly be argued that workplace accidents are a physical manifestation of economic waste ! Hence, we do not introduce lagged variables in this case. Our measure accounts for five different types of interventions in OSH : inspections, fines, applications of the right to refuse a dangerous task, application of the right to protective reassignment, and requirement for a prevention program[7].

$SCALE_{it}$, 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 this variable to take a positive sign if economies of scale lead to an increase in productivity growth[8].

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 fixed inputs) still has to be counted as an input. Therefore, the variable $CYCLE_{it}$, defined as the change in the capacity utilization index, is included on the right-hand-side of the equation. It is expected to take a positive sign.

Industry specific effects are captured by the use of industry dummy variables, μ_i. These capture, for instance, the absence of marginal cost pricing. The omitted fixed influences that vary across

4. Beyond a three-year lag, we would face a problem of degrees of freedom.
5. The sectors considered in our analysis are : Clothing, food and beverage, leather, machinery, textiles, electrical and electronic products, furnitures and fixture, wood, printing and publishing, metal fabricating, rubber and plastics, transportation equipment, petroleum and coal products, primary metals, non-metallic minerals, paper and allied products, and chemicals. The sectors were presented from the less polluting to the most polluting following a classification of Environment Canada (1994) based on the emissions of regulated pollutants. The most polluting sectors are the last ten sectors.
6. Our measure of exposure to outside competition is standard: (exports + imports / total shipments). Our most exposed sectors are: 1) Leather; 2) paper and allied products; 3) primary metals; 4) machinery; 5) transportation equipment; 6) electrical and electronic products and 7) chemicals.
7. Our measure is a summation of the five interventions. More details are provided in Lanoie (1992) and in Dufour et al. (1998).
8. One could argue that this variable is potentially endogenous. A Hausman test (using $SCALE_{it-1}$ as an instrument) did reject the hypothesis of exogeneity. We thus report results of estimations in which $SCALE_{it}$ has been instrumented.

time but not across industries, φ_t, will be captured by time dummies. In particular, the latter may capture technological progress.

For estimation purposes, pooled time-series and cross-section data are used. The data are annual and cover 17 sectors in the Quebec manufacturing industry for the period 1985-1994 inclusively. The mean and standard deviation of the variables are presented in Table 1. The data were available mostly from Statistic Canada, Environment Canada and from the Commission de la santé et de la sécurité du travail (the Quebec Board responsible for OSH).

3. Empirical Results

The estimations are performed using a generalized least-squares (GLS) procedure based on the cross-sectionally heteroskedastic and time-wise autoregressive model presented in Kmenta (1986, pp. 616-685). Table 1 presents three series of estimates, one without any subgroups of sectors, one including cross terms distinguishing the impact on sectors that are more or less polluting, and one including cross terms distinguishing the impact on sectors that are more or less exposed to competition. In each series, we present one specification including the ENVIRONMENT variable itself (and its lags) and another using moving averages.

In the first series of estimates without cross terms, the anticipated pattern of effects is observable: The coefficient of the contemporaneous ENVIRONMENT variable is negative and significant, as in the rest of the literature. As in Gray (1987), let us define the short-run contribution of independent variable “x” on the instantaneous rate of growth of productivity as the product of x's estimated coefficient and x's sample mean. This gives, for changes in environmental norms (our variable ENVIRONMENT), and for our first estimated equation, a value of -0.0007, which represents roughly 14 % of the (mean) observed decline in $T\dot{F}P$ (our dependent variable). Now, the long-run impact of a one-shot change in ENVIRONMENT can be approximated as the sum of the contemporaneous and lagged coefficients on ENVIRONMENT[9]. We observe that the variable ENVIRONMENT lagged one year is positive but not significant, while the variables lagged two and three years are positive and significant. Again, for our first estimating equation, the computed long-run impact of ENVIRONMENT can be approximated at 4.335 and the long-run contribution can be estimated at 0.001, which is positive, and which represents roughly 24 % of the observed change in $T\dot{F}P$. Hence, reinforcing environmental regulation at first reduces TFP growth, then over a four-year cycle, it leads to an increase in TFP growth – thus confirming Porter's conjecture.

9. See Greene (1997:512) for a discussion of short and long-run impact multipliers.

Table 1

Coefficient (standard errors)

Independant variable	Mean (Standard deviation)		Without Subgroups		Polluting / Less Polluting		Exposed to competition / Less exposed	
	Lags	*Moving Average*	*Lags*	*Moving Average* [a]	*Lags*	*Moving Average*	*Lags*	*Moving Average*
$Environnement_{i,t}$	0,250E-03 (0,333E-02)		-2,629*** (0,507)	-2.629*** (0.507)				
$Environnement_{i,t-1}$	0,331E-04 (0,253E-02)		0,412 (0,622)	-2.855*** (0.562)				
$Environnement_{i,t-2}$	0,645E-04 (0,258E-02)	0.488E-04 (0.129E-02)	3,267*** (0,647)	-0.378E-01 (1.211)				
$Environnement_{i,t-3}$	0,546E-04 (0,255E-02)	0.508E-04 (0.817E-03)	3,286*** (0,607)	9.859*** (1.788)				
$Environnement_{i,t}$*Poll	0,809E-05 (0,174E-03)				-22,597*** (7,712)	-22.597*** (7.491)		
$Environnement_{i,t}$*Less Poll	0,242E-03 (0,332E-02)				-2,548*** (0,492)	-2.548*** (0.4896)		
$Environnement_{i,t-1}$*Poll	-0,459E-05 (0,171E-03)				-32,681*** (8,473)	-46.396*** (10.079)		
$Environnement_{i,t-1}$*Less Poll	0,377E-04 (0,253E-02)				0,634 (0,585)	-2.740*** (0.533)		
$Environnement_{i,t-2}$*Poll	0,233E-05 (0,171E-03)	-0.112E-05 (0.119E-03)			13,715 (10,459)	49.527*** (20.962)		
$Environnement_{i,t-2}$*Less Poll	0,622E-04 (0,257E-02)	0.499E-04 (0.129E-02)			3,374*** (0,632)	0.287 (1.193)		
$Environnement_{i,t-3}$*Poll	0,101E-04 (0,192E-03)	0.262E-05 (0.978E-04)			-11,048 (13,017)	-33.144 (35.408)		
$Environnement_{i,t-3}$*Less Poll	0,445E-04 (0,254E-02)	0.481E-04 (0.809E-03)			3,231*** (0,625)	9.692*** (1.852)		
$Environnement_{i,t}$*Comp	0,249E-03 (0,332E-02)						-2,550*** (0,494)	-2.550*** (0.493)
$Environnement_{i,t}$*Less Comp	0,166E-05 -(0,194E-03)						-1,387 (10,153)	-1.387 (10.020)
$Environnement_{i,t-1}$*Comp	0,397E-04 (0,253E-02)						0,504 (0,607)	-2.736*** (0.551)
$Environnement_{i,t-1}$*Less Comp	-0,662E-05 (0,187E-03)						-9,321 (12,382)	-29.307 (19.879)
$Environnement_{i,t-2}$*Comp	0,58895E-04 (0,257E-02)	0.493E-04 (0.129E-02)					3,240*** (0,669)	0.9282E-01 (1.238)
$Environnement_{i,t-2}$*Less Poll	0,565E-05 (0,177E-03)	-0.482E-06 (0.131E-03)					19,987 (14,182)	51.849 (32.239)
$Environnement_{i,t-3}$*Comp	0,503E-04 (0,254E-02)	0.49638E-04 (0.808E-03)					3,194*** (0,626)	9.581*** (1.856)
$Environnement_{i,t-3}$*Less Comp	0,434E-05 (0,169E-03)	0.112E-05 (0.113E-03)					-5,938 (16,125)	-17.813 (42.210)
$OSH_{i,t}$	4,4104 (18,597)		-0,941E-04 (0,787E-04)	-0.941E-04 (0.788E-04)	-0,10E-04 (0,78E-04)	-0.100E-03 (0.785E-04)	-0,777E-04 (0,786E-04)	-0.777E-04 (0.795E-04)
$Cycle_{i,t}$	-0,10063 (4,2200)		0,607E-02*** (0,517E-03)	0.607E-02 *** (0.5186E-03)	0,619E-02*** (0,49E-03)	0.619E-02*** (0.4905E-03)	0,594E-02*** (0,529E-03)	0.5941E-02*** (0.529E-03)
$Scale_{i,t}$	25546 (0,343E+06)		0,164E-06*** (0,987E-08)	0.164E-06*** (0.988E-08)	0,168E-06*** (0,859E-08)	0.169E-06*** (0.861E-08)	0,166E-06*** (0,944E-08)	0.169E-06*** 0.947E-08
Constant			0,192E-01*** (0,527E-02)	0.192E-01*** (0.527E-02)	0,239E-01*** (0,604E-02)	0.239E-01*** (0.609E-02)	0,179E-01*** (0,598E-02)	0.179E-01*** (0.596E-02)
Industry dummies			Yes	Yes	Yes	Yes	Yes	Yes
Year dummies			Yes	Yes	Yes	Yes	Yes	Yes
R^2 adj			0.8503	0.8503	0.8524	0.8524	0.8462	0.8462
Nb. of observations	102	102	102	102	102	102	102	102

* sig. at 10%, ** sig. at 5%, *** sig. at 1%

[a] $MA\text{-}Environnement_{i,t-s} = [Environnement_{i,t-1} + Environnement_{i,t-2} + \ldots + Environnement_{i,t-s}]/s$

The results using the moving averages are similar and lead to identical short-run and long-run estimated contributions of ENVIRONMENT on $\dot{TFP}$. Three differences are worth mentioning : a) the variable lagged one year is now negative and significant; b) the two-year lagged variable is not different from zero; c) and the three-year lagged variable has a very strong and statistically positive impact. Hence, only the intertemporal patterns differ. Therefore, once again, the following pattern emerges: reinforcing environmental norms reduces $\dot{TFP}$ in the front year, but over a four-year window, it appears to stimulate it.

In the series of estimates where there are cross-terms involving subgroups of sectors that are more or less polluting, the pattern is present but less clear. In both series of estimates, the impact of the contemporaneous and the one year lag ENVIRONMENT variable is negative and significant for both subgroups[10]. However, the impact is much stronger in the subgroup of the more polluting sectors. The impact becomes positive in both series for both subgroups when the two year lag ENVIRONMENT variable is used. It is significant for the less polluting sectors in the first series and significant for the more polluting sectors in the second series (with moving averages). With the three year lag ENVIRONMENT variable, the impact is positive and significant for the less polluting sectors, while it becomes negative but not significant for the more polluting sector. The results observed with the moving averaged variables are similar. The short run (contemporaneous) contribution of ENVIRONMENT for pollution-intensive sectors is estimated at -0.005 (roughly one half of a percentage point of $\dot{TFP}$), and the long-run contribution at -0.013, which is substantial (it corresponds to three times the observed annual $\dot{TFP}$). For less polluting industries, the comparable contribution figures are -0.006 (short-term) and 0.001 (long-term). Therefore, the pattern observed previously of strong and negative short-term effects and more “positive” long term effects is replicated here, but **only** for the less polluting industries.

Turning to the series of estimates where we distinguish between sectors which are more or less exposed to competition, we find again the original pattern. In both series of estimates, the impact of the contemporaneous and the one-year lag ENVIRONMENT variable is negative and significant for the subgroup of sectors which are more exposed to competition, and negative but not significant in the other subgroup. The impact becomes positive in both series for both subgroups when the two year lag ENVIRONMENT variable is used. It is significant for the sectors that are more exposed to competition in the first series of estimate, but not in the second series (with moving averages). With the three-year lagged ENVIRONMENT variable, the impact is positive and significant for the sectors that are more exposed to competition (in both series), and not significant in the other subgroup. As an indication, the long-term contribution of ENVIRONMENT is estimated at 0.001 (or 24 % of average $\dot{TFP}$) for the exposed to competition sectors and at 0.0008 for the less exposed to competition sectors.

10. Note that, when we do not use moving averages, the impact of the one year lag ENVIRONMENT variable is not significant for the less polluting sectors.

Regarding the OSH measure, the impact is always small, negative and not significant. This contrasts with results presented in Dufour et al. (1998) and in Gray (1987), which showed a negative and significant effect. As for the SCALE and CYCLE coefficient, these are significant and correctly signed. The estimated contribution of SCALE is 0.004 and that of CYCLE is 0.0006. This suggests that economies of scale are important in explaining observed $T\dot{F}P$: changes in shipments have added half a percentage point yearly to $T\dot{F}P$. By comparison, the autonomous (technological change based) growth of TFP can be estimated at about 0.02 (the estimated intercept value).

4. Conclusion

In this paper, we have extended in three different directions the existing empirical analyses related to the Porter hypothesis which suggests that more severe environmental regulation may have a positive effect on firms' performance by stimulating innovation. First, using productivity as a proxy for performance, we allowed for the dynamic aspect of the Porter hypothesis to be tested by examining the impact of environmental regulation adopted in a given year on productivity a few years later when the innovation process has been completed. Second, Porter's arguments suggest that firms with a high load of polluting emissions will have more opportunities to identify and eliminate inefficiencies, so that the positive effect of regulation on performance could be more important in firms that are initially more polluting. We have tested this by distinguishing the impact of environmental regulation on productivity between sectors that are more polluting and sectors that are less polluting. Third, Porter's arguments suggest that firms in industries that are more exposed to competition from abroad are more likely to have an incentive to innovate to reduce costs than firms in less exposed sectors. This was also tested by examining the effect of regulation in two different subgroups of sectors, those that are more exposed to external competition and those that are less.

Our analysis showed that, when one allows dynamic effects to occur, the impact of environmental regulation on productivity could become less detrimental and even positive, confirming the Porter hypothesis. This pattern was seen clearly in our results when we used our whole sample. It seemed also that sectors which are more exposed to competition are more likely to behave in a fashion that confirms the hypothesis than sectors which are less exposed. When distinguishing between more and less polluting industries, and contrary to our conjecture, Porter's hypothesis is confirmed only for the second group of industries. More polluting industries see long-run declines in productivity after an increase in the stringency of environmental regulation.

It thus seems that the level of external competition in an industry is a key driving force inducing firms to turn environmental constraints into their advantage. It seems to be a more important factor than potential for efficiency gains from waste and emissions reduction. This could be another line of argument in the debate about the effect of free trade on environment protection (see for instance, Antweiler et al., 1998), indicating that free trade could be good for the environment.

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