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Does Environmental Regulation Stimulate Innovative Responses? Evidence from U.S Manufacturing*

Abstract

A wide spread concern can be witnessed among businessmen, policy makers and academics about the role of environmental regulations on innovative responses. In this study, we examine whether these regulations enhance or hinder R&D expenditure using the data for eight major U.S industries for the period 1982 to 1992. We find no strong evidence to support the view that environmental regulations proxied by abatements costs have any significant impact on the pollution abatement technology. (**JEL codes**: K29, L6, O31, Q28)

1. Introduction

A key issue in the field of trade and the environment is the interaction between environmental regulations and innovations. Whether environmental regulation enhances or suppresses innovation is highly debated. However, environmental regulation has been blamed for at least some of the alleged decline in innovation of US firms. One major view is that environmental regulation constrains strategic choices and limits innovations, thereby disadvantaging environmentally regulated firms (Sanchez (1997). An opposing view is that environmental regulation enhances competitiveness by encouraging efficiency gains through innovation. Firms that develop technological expertise in response to environmental regulations hold an advantage over their competitors, who are obligated to purchase and learn to use the new technology (Porter, 1991; Porter and Linde, 1995).

This paper examines whether environmental regulation in the US has any significant impact on R&D on pollution abatement technology in the manufacturing sector. This issue is important given that the United States is the largest producer and consumer of environmental goods and services accounting for about 40% of the $200 billion world

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market[1]. The US seems to have a growing comparative advantage in environmental protection equipment as evidenced by the growing US trade surplus in this area, which has increased from $565 million in 1989 to $1.1 billion in 1991. According to the sources of the U.S Department of Commerce, there are 7000 to 10000 U.S companies involved in the environmental technology industry. In these circumstances, it is interesting to examine whether environmental regulations stimulate or hinder innovative responses in the U.S industries.

The studies examining the link between environmental regulations and innovations are limited. Previous literature has focused mainly on the impact of various pollution control instruments such as emission subsidies, pollution permits and taxes (e.g. Marin, 1991; Malueg, 1989; Millman and Prince , 1989; Magat, 1978; Downing and White, 1986). No comprehensive attempt has been made so far to examine the link between R&D expenditure on abatement technology and environmental abatement costs empirically. In order to reconcile the two opposing views (i.e. whether environmental regulations hinders or stimulates innovations), a proper empirical investigation on the link between the two is urgently needed. We make an attempt to do this in the present paper.

The paper is organized as follows. Section 2 outlines the theoretical aspects relating to the two opposing hypotheses. Section 3 explains the empirical model and data. Results and conclusions are presented in the final section.

2. **Theoretical Framework**

The literature has attributed innovation to an astounding variety of determinants at different levels (i.e. firm, industry and sectoral level). At the industry level the most traditional determinants of innovation are market structure and market/firm size. Schumpeter (1942) propounded these ideas in his seminal work on monopolistic practices, in which he claimed that large scale enterprise is the most powerful engine of

[1] OECD, Environment Industry: Situation, Prospects, and Government Policies, Paris, 1992.

economic progress and long run expansion of total output. Schumpeter's theory inspired two hypotheses that have been extensively tested empirically: (1) innovation increases more than proportionately with firm size; and (2) innovation increases with market concentration (Cohen and Levin, 1989). It is claimed by some that profits accumulated through the exercise of monopoly power are a key source of funds to support costly and risky innovation. However, the predictions of economic theory on this point are ambiguous. Proponents of this thesis argue that large firms can innovate more effectively because obtaining finance for risky projects is easier[2], the average fixed cost of R&D falls as output rises, and complementarities exists between R&D and other non-manufacturing activities. Opponents to this view claim that large enterprise managers, under less competitive pressure, may become less productive, and cross-inefficiency could arise due to a lack of managerial control and bureaucratic inertia (Geroski, 1990). Furthermore, as firms grow large the incentives for individual scientists become weaker as their ability to capture the benefits from their efforts decreases (Cohen and Levin, 1989). Because the predictions of economic theory on this point are ambiguous, the matter can only be resolved empirically. However, extensive empirical testing of the firm size hypothesis has revealed equally ambiguous results[3].

The market concentration hypothesis has also been extensively tested empirically. For example, Scherer (1967) found an 'inverted U' relationship between market concentration and innovation as a proportion of sales with innovation measured by the ratio of technical employees to total employees. He found that the technical employment ratio reached a maximum at a concentration ratio of between 50 and 55 percent, depending on the industry. Scherer also discovered that the effect of market concentration on innovation is dependent on interindustry differences in technological opportunity i.e. the potential for innovation. Later studies have shown that when technological opportunity and appropriability or two digit industry effects are taken account of market concentration ceases to have a significant coefficient and explains less of the variation in R&D intensity than the former variables (Cohen and Levin. 1989). Furthermore Geroski(1990) found

[2] Because size is positively correlated with the availability and stability of internally generated funds.

that when controlling for technological opportunity, increased concentration had an overall negative effect on innovation.

Having looked at the traditional hypotheses on the determinants of R&D activity, we next turn to examine the link between innovations and environmental regulations. It is reasonable to assume that increased environmental regulation in an industry will increase the associated pollution abatement expenditures, because tighter standards will compel firms to invest in additional equipment and/or extra workers in order to reduce pollution levels. As the burden of abatement rises, as measured by the ratio of abatement expenditures to sales, we expect the incentives for firms to invent either cleaner technology or more efficient abatement technology to increase. Figure 1 below illustrates this point[4].

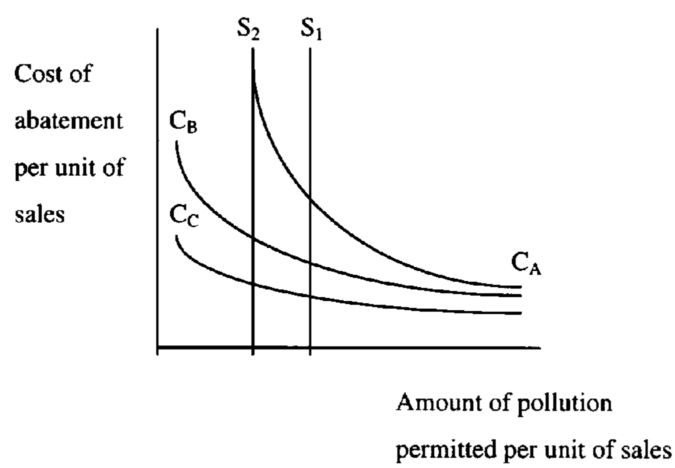

Figure 1: The R&D decision with a regulated standard

S_i (i = 1,2...n) represents the standard in period i. It can be seen that as the standard becomes stricter (e.g. moving from S_1 to S_2), in which case less pollution is permitted, the cost of abatement per unit of sales increases. This is likely to occur because of technological constraints. When technology is constrained, the marginal cost of reducing pollution increases as abatement laws become stricter. The line C_A represents the

[3] See Scherer (1984) and Cohen and Levin (1989) for reviews of this literature..

[4] David Haugh's assistance in constructing this figure is gratefully acknowledged.

abatement costs of an arbitrary firm given present technology. The firm can reduce abatement costs in two major ways. Firstly, it can embark upon a R&D project to increase the efficiency of the abatement process thereby shifting the firms cost curve down to C_B. Secondly, the firm can invest in another project to reduce the output of emissions from the production process, shifting the firms cost curve further down to C_C. The former reduces the firm's costs by reducing the cost of abating the emitted pollution, while the latter reduces the firm's costs by reducing the amount of pollution that must be abated. From the diagram it can be seen that as the amount of pollution permitted falls, the cost savings to the firm from either R&D project increase.

The above discussion shows a positive relationship between environmental compliance costs and environmental abatement technology. However, this contradicts with an influential argument which postulates a negative link between the two. According to this view, environmental regulations undermine innovations and restricts firms in pursuing cutting-edge technology (e.g. Breyer, 1982; Caincross, 1992)[5]. It has been shown that high compliance costs associated with environmental regulations use the resources that would otherwise would be invested in innovations. It should be noted, however, that this relationship can be affected by the nature of regulations. So called 'poor' regulations of 'command and control' type can act as a barrier to technological change while 'good' regulations acting as market incentives can encourage such investments. The poor regulations constrain the choices of technology and depend on end-of-pipe and clean-up measures (Porter, 1991).

3. The Empirical Model and the Data

In order to test the hypotheses formulated above, we specify the following model:

[5] See Sanchez (1997) and Jaffe et.al (1995) for reviews of this literature.

$EI_{it} = \alpha \pm \beta_1 Size_{it} \pm \beta_2 CR_{it} + \beta_3 PAE_{it} + u_i$,   i = industry, t = time

where,

EI = environmental innovations (computed as R&D/value of shipments),

R&D = Research and development on pollution abatement technology in the ith industry,

Size = The average sales of the 4 largest firms,

CR= 4-firm concentration ratio for industry i,

PAE = Pollution abatement expenditure in industry i, computed as a share of value of shipments.

In terms of the theoretical propositions presented above, coefficients of Size and CR can have either *plus* or *minus* sign while PAE (share of pollution abatement expenditure in sales) is expected to have a *plus* sign.

What is missing from the above equation is organisational and individual-level factors within the firm that might affect the relationship between environmental regulations and innovations. The organisational variables which can influence R&D expenditure are the centralisation of information analysis, R&D intensity and integration, and firm size (Sanchez, 1997). With the exception of 'Size' to represent the firm size, due to paucity of data at firm level, we were not able to include variables relating to other aspects of organisational and individual-level behaviour. However, this is not a major limitation of our study as it is conducted at the industry level rather than at firm level.

The equation is estimated on a set of pooled cross sectional data at 2-digit level industries of Standard Industrial Classification (SIC) for the period of 1982 to 1992. The industries used for investigation are food and tobacco products, paper and allied products, chemicals and allied products, petroleum and coal products, primary metals, fabricated metal products, machinery, and electrical equipment. The choice of industries and the level their aggregation is guided mainly by the availability of data as explained below.

The data for research and development on pollution abatement technology (R&D) is obtained from various issues of *Research and Development in Industry: 1993, National Science Foundation*. This data is the most detailed available in the U.S but unfortunately it is reported at a high level of aggregation, i. e. 2 or 3 digit SIC level, which limits the number of industries in the sample, and is the major constraint on empirical testing. The average value of shipments of the four largest firms is used to represent the size of the firm. The data for value of shipments is available from the Bureau of the Census, and is reported yearly in the *Annual Survey of Manufactures* which is a comprehensive survey of US industry at the 4 digit SIC level which includes data on individual firm sales. However, to match the series of industry size at 4-digit level, data are not available for industry concentration for all the years under consideration. The data on concentration ratios in manufacturing are available only for 3 years 1982, 1987 and 1992 for the period of 1980 to 1992. Finally, pollution abatement expenditure data is available at the 4 digit SIC level from *Pollution Abatement Costs and Expenditures, Bureau of the Census, US Department of Commerce*.

Because of the paucity of data, we had to estimate the above equation on 2 samples. For the large sample, data are available at least at 2-digit level of SIC (8 industries) for RD/VOS, Size and PAE/VOS for all ten years under consideration, resulting in 80 observations. The small sample has 24 observations because the data on concentration ratios are available only for 3 years.

4. Results and Conclusions

A simple pooled time series regression involving all 8 industries for the period 1982-1992 revealed a positive and significant slope coefficient, i.e an increase in pollution abatement costs as a percentage of sales leads to an increase in spending on pollution abatement technology as a percentage of sales. However, this regression assumes that the intercept and slope coefficients are the same across industries over the years. To take account of this possibility, R&D expenditure on pollution abatement technology is regressed on pollution abatement expenditure and industry size using slope and intercept dummies. The regression results are reported in Table 1. The equation estimated on small sample with all explanatory variables did not pass the model tests (e.g. F test), therefore we focus on the results obtained from the large sample.

Table 1: Determinants of pollution abatement expenditure in environmental technology

Explanatory variables	Small Sample (24 obs.)	Large Sample (80 obs.)
Constant	0.0041 (.103)	10.9671 (.001)***
Size	-0.0000 (.251)	-0.0001 (.013)***
PAE	-0.0322 (.262)	-0.2077 (.085)*
CR	-0.0000 (.179)	-
R^2	0.6179	0.5341
Test statistics		
F test	1.48 (.260)	3.89 (.000)***
Akaike Info. Crt	157.862	4.653
D-W test	2.859	2.038

Notes:
Probability values (P-value) are given in brackets with statistical significance denoted by: *** 1% , ** 5% and * 10%.

The coefficient of Size has a negative sign and is statistically significant at 1 per cent level implying that large enterprise size is acting as a barrier to innovations, probably resulting from low productivity and cross-inefficiency which could arise due to a lack of managerial control and bureaucratic inertia. The coefficient of PAE has a negative sign. However, the coefficient is statistically significant only just at 10 per cent level indicating that high pollution abatement costs do not have significant influence on innovations. This finding is consistent with the data on R&D expenditure on environmental technology and pollution abatement costs (not reported here). We plotted the data on research and development expenditure on pollution abatement technology and pollution abatement expenditure as a share of sales for all industries. R&D expenditure on pollution abatement technology (R&D) does not show any significant change over the years while total environmental compliance costs (PAE) show an increasing trend. However, R&D and PAE do not show any significant relationship. The correlation coefficient between these two variables is 0.253. In order to examine the link between these two variables properly, we estimate the model specified above.

These results have important policy implications on the nature of the environmental regulations in the United States. The results support the claim that the first generation of Environmental Protection Agency (EPA) regulations was of a 'command and control' type which heavily depend on tough administrative and legal legislation to control polluting behaviour of firms (Sanchez, 1997). These poor regulations constrain the choice of technologies and depend on end-of-pipe and clean-up measures. The second generation of EPA legislation is claimed to be of good type and could be expected to stimulate R&D on environmental technology in the near future.

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