The role of regulation in the improvement of business environmental performance: a case study of US fossil fuel-fired electric utilities

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Abstract

In order to improve the public policy of environmental management, it is of prime importance to assess the influence that regulation can have on business environmental performance. In our research, performance is quantified through use of benchmarking indicators, that incorporate all relevant information on the environmental impacts of companies, as well as their use of inputs and production of outputs. The methodology is illustrated by the analysis of a small data set of 39 U.S. fossil fuel-fired electric utilities, for which data were available over three different years (1987, 1991, 1994). Whereas no significant changes occurred in environmental performance between 1987 and 1991, this is not the case between 1991 and 1994. The main factor that allows to explain the significant improvement observed is the change in regulation (i.e., Clean Air Act amendments). Additionally, while the utilities generally show a high level of efficiency in the use of fuels (mainly due to their cost), this is not (yet) the case as regards the polluting behaviour. The main explanatory factor might be the lack of internalisation of external costs, i.e. the lack of (regulatory) incentive to be efficient in environmental terms.

1 Introduction

Due to international competition and the imperatives of commercial success, most private business companies behave efficiently as regards the use of inputs and effectively with respect to the production of
outputs. Those firms that are either inefficient in inputs and/or ineffective in outputs would in most situations be eliminated by the laws of free market. However, efficiency and/or effectiveness are not (yet) absolutely required when one considers factors that are not purely economic. Such is the case, e.g., for environmental dimensions, due to the fact that regulatory and economic incentives, or ethical pressures, are not yet powerful enough, although recent research tends to indicate that market more and more values firms that show a positive behaviour with respect to the environment.6,11

Incentives for environmental efficiency can take various forms. From a neoclassical economic viewpoint, definite efficiency would be attained when environmental costs will be fully internalised. However, we are still far from that stage, mainly because the information about environmental costs is very fragmentary. Presently, incentives are being progressively implemented in various ways. Political decision-makers have at their disposal either environmental regulations, or economic instruments. The latter include taxes, subsidies, as well as tradeable permits. From the business standpoint, environmental internalisation is possible, at least in theory, through various environmental assessment tools such as life cycle assessment, eco-audit and environmental accounting, within the scope of an environmental management system. The main problem is the current lack of knowledge about the way in which such regulations, instruments and managerial techniques influence the behaviour of companies with respect to the environment, although significant steps have been made in that direction. This issue appears even more complex when one realises that there are various additional factors, internal or external, that are likely to affect the environmental performance of firms. The external factors mainly include the influence of stakeholders (among whom the public decision-makers who set up regulations), while internal factors are mainly concerned with the actions the company can take as regards, e.g., investments and technology.

In a previous paper we showed how indicators could be used to assess the influence of internal factors on business environmental performance. Based on a study of fossil fuel-fired electric utilities, the factors that appeared most significant in this regard (and for which data were available) were identified, in decreasing order, as: the investments toward air pollution control in previous year of operation, the total investments for environmental protection in previous year, the initial year of operation, the fuel mix, the number of units, the operation and maintenance expenses per kWh, and the expenditures for environmental protection during the same year. In this paper our goal is to investigate the influence of external factors such as regulation and economic incentives, using the same environmental performance indicators and based on the same case study of U.S.
fossil fuel-fired electric utilities. In addition, in this situation, with respect to the previous study, to properly describe the intervention of regulation, we will have to exploit data collected at different periods of time, to allow for the assessment of performance progress (or regress) induced by regulatory changes.

2 External influences on environmental performance: the U.S. Clean Air Act

Various studies attempted to clarify the influence of stakeholders on business environmental performance. Some inquiries analysed the perceived relative importance of stakeholders among a particular group of firms\textsuperscript{7,16,18}. Generally, their results showed a great pressure from legislation and weak influence from financial stakeholders. In other words, presently, the regulatory pressure is the key factor explaining business environmental behaviour. Companies react to that legislative constraint by establishing a strategy of actions to which they devote resources (money, time, man-power, natural resources, raw materials and machinery).

Our research will take the electricity production sector in the USA as a case study. Several environmental legislative texts regulate the sector. The main pollution of the fossil-fueled steam-electric plants is atmospheric. The first version of the Clean Air Act was introduced in 1963. In 1970, the Congress passed some amendments. As required by the Act, the Environmental Protection Agency established uniform primary national ambient air quality standard (NAAQS) for six major pollutants: particulate matter, carbon monoxide, sulfur dioxide (SO\textsubscript{2}), nitrogen oxides (NO\textsubscript{x}), ozone, and lead. Each State then submitted a State Implementation Plan (SIP) that outlined how existing pollution sources would be regulated so that the NAAQS would be achieved by July 1975. At that time, coal-fired power plants were the source of more than 50\% of the nation’s SO\textsubscript{2} emissions and as a result were one of the first pollution sources to be regulated. Now, as then, the state plans vary greatly in both the stringency of the regulations and the method of regulation. Besides these NAAQS and the SIPs, new or modified sources face unique national emission standards: the New Source Performance Standards of 1971 (NSPS). The NSPS set specific limits to SO\textsubscript{2} and NO\textsubscript{x} emissions of coal-fired utility boilers built after August 17, 1971.

In 1977, the CAA was again amended. The compliance dates of the NAAQS were postponed and the standards were restricted. All regions not complying with the NAAQS were declared “non attainment regions” as opposed to the other, “attainment regions”. The non attainment regions were subject to more stringent control. New
sources were allowed within their borders only if equipped with the best technology insuring a minimum emission rate. A permit system was implemented for these new sources located in a non attainment region. For attainment regions, increments and ceilings were fixed under the Prevention of Significant Deterioration of Air Quality title, in order to avoid any worsening of the air quality. Following the amendments of 1977, the EPA also implemented the Revised New Source Performance Standards in 1979, setting slightly modified goals as regards SO₂ emissions, and a minor revision of the categories considered in NOₓ standards.

The last amendment of the Clean Air Act occurred in 1990. Its main feature was the introduction of an innovative marketable emission allowance program for SO₂ taking place in two phases. Phase 1 began in 1995, with specific restrictions for the most important 110 electric utilities. Phase 2, beginning in 2000, will lead to a reduction of the total annually allowed emissions, and will also establish restrictions on smaller coal or gas fueled production units. The objective concerning electricity generators is a 10-million-ton reduction in SO₂ emissions and a 2-million-ton reduction in NOₓ emissions with respect to 1980 levels.

3 Methods

In previous papers we reviewed several literature surveys about indicators of environmental performance and sustainable development at the firm level⁴,¹³,¹⁴,¹⁵. We need not reproduce them once more here, and simply give a short explanation on the design and function of the indicators we used in this research.

Indicators based on productive efficiency start from the principle of best observed behaviour. Initially designed to compare similar production units by their (technico-economic) efficiency in producing outputs using appropriate levels of inputs, they were recently extended to incorporate the efficiency in the release of undesirable outputs (i.e., pollutants). Thus we have three broad categories of factors: inputs, desirable outputs, and undesirable outputs. The latter behave in some respect as inputs, in the sense that one should minimize their quantity if one wishes to improve efficiency.

In previous research we used and tested several versions of environmental performance indicators based on productive efficiency. In this paper the focus is to relate performance with potential explanatory factors; therefore, based on the experience gained in previous research (especially Gallez & Tyteca⁹), we will use only one indicator, termed "undesirable output - oriented"
(abbreviated as UO). The central idea is that, while accounting for all available information on inputs and (un-)desirable outputs, the quantification of efficiency will concentrate specifically on the possible improvements in terms of undesirable outputs. Thus, the indicator will yield a value 1 for those producing units that perform efficiently with respect to pollutants, in the present (observed) state of technology, while the indicator value will be less than 1 for those units performing inefficiently, i.e., those for which improvements are still possible, compared to other existing, similar production units. A last point worth mentioning is that in the scope of productive efficiency, the weight factors used to aggregate the impacts are self-defined by the method, which is often considered an advantage but may entail significant objections as discussed, e.g., by Callens & Tyteca.

Because we wish to compare the performance of production units while accounting for the time period, a specific procedure had to be adopted as to the way in which the performance evolution over time should be described. Methods exist in the framework of productive efficiency, that allow to quantify the changes in technical and economic productivity, based on Malmquist indexes. In this paper we exploited the same method already used by Ball et al. and ourselves; i.e., one unique production frontier is generated, incorporating all data from several successive years and for all producing units; although simplified, this method allows to identify whether improvements over time have taken place or not.

Additionally, we also made use of an alternative environmental performance indicator, where the weights are arbitrarily fixed. This was inspired by Jaggi & Freedman and extensively used in previous research as mentioned in our aforementioned references. Their philosophy is quite comparable to productive efficiency methods, in the sense that for a given set of analogous units devoted to a given type of production, and characterised by a few variables reflecting inputs and (un-)desirable outputs, reference is made to the units that perform best. The essential difference is that here, the variables are compared one by one to their best possible value among the observed set, instead of being taken together; afterwards, the individual scores are summed using an arbitrary weight of 1. Dividing the value obtained by the number of variables will yield a standardised indicator whose value will be less than or equal to 1. Details about the method and formulations can be found elsewhere.

With respect to previous research, and because we wanted to compare specific pollution efficiency with input (i.e., fuel) efficiency, we also used so-called "sub-indicators", strictly concentrating on one given aspect (i.e., pollution or fuels), without accounting for the information on the other variables, but with the same meaning as before (i.e., less than or equal to 1 means inefficient or efficient,
respectively). Because these (very simple) indicators were not used before, we briefly describe here how they work. Assuming we have one quantity, poll, designating the pollution, or undesirable output, the "pollution indicator" of production unit indexed \( k \) can be defined in a first step as

\[
I(\text{poll})_k = \frac{\text{poll}_k}{\text{output produced}_k} \quad k = 1, \ldots, K
\]

and this for the whole set of \( K \) units whose efficiency has to be quantified. In a second step, we identify the unit that performs best and quantify the pollution performance relatively to that reference unit:

\[
(\text{pollution index})_k = \frac{\min_i \{I(\text{poll})_i\}}{I(\text{poll})_k}
\]

which obviously takes the value 1 only for the best unit and values less than 1 for other units. Similarly, a fuel index can be successively defined as

\[
I(\text{fuel})_k = \frac{\text{fuel}_k}{\text{output produced}_k} \quad k = 1, \ldots, K
\]

\[
(\text{fuel index})_k = \frac{\min_i \{I(\text{fuel})_i\}}{I(\text{fuel})_k}
\]

The initial idea of Jaggi-Freedman indicators is easily retraced from these equations: they are simply defined as arithmetic means of quantities analogous to those appearing in Equations (2) and (4).

4 Case study

In this research we used the same study case as in previous research on indicators\(^8,9,14,15\), with some additional data. The data used previously and the context of electricity production in the USA, based on fossil fuel consumption, was described in the references listed above. Essentially, the data exploited so far included annual values of inputs used (three fuels: coal, oil, and gas; labour; capital in the form of installed capacity), output produced (electricity in kWh), and undesirable outputs (atmospheric pollutants: sulfur dioxide, nitrogen oxides, and carbon dioxide), for year 1991. In one of the aforementioned studies data available for the same plants in 1987
were also exploited, while information on internal explanatory factors was used by Gallez & Tyteca.

For the present research we collected additional data that was available in 1996, i.e., data on the aforementioned production variables and explanatory factors, up to year 1994. This allowed us to build a pannel of 39 electric utilities for which all data were available for years 1987, 1991, and 1994. This would enable us to study temporal trends in the environmental performance and to study the influence of the potential external explanatory factors listed in Section 2, i.e., regulation in the form of amendments to the Clean Air Act, and (the absence of) economic incentives.

Table 1. - Descriptive statistics of the variables used (n = 117).

<table>
<thead>
<tr>
<th></th>
<th>Yr.</th>
<th>Mean</th>
<th>Std.dev.</th>
<th>Min.</th>
<th>Max.</th>
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<tr>
<td>Output</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Electricity generation (MkWh)</td>
<td>87</td>
<td>11740.</td>
<td>3303.4</td>
<td>7008.4</td>
<td>21504.</td>
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<td>91</td>
<td>12115.</td>
<td>3268.3</td>
<td>8166.8</td>
<td>21883.</td>
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<tr>
<td></td>
<td>94</td>
<td>10737.</td>
<td>4731.4</td>
<td>606.9</td>
<td>21443.</td>
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<tr>
<td>Inputs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregated fuels (tons oil equivalent)</td>
<td>87</td>
<td>2852.7</td>
<td>886.28</td>
<td>1532.</td>
<td>5409.</td>
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<td></td>
<td>91</td>
<td>2991.6</td>
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<td></td>
<td>94</td>
<td>2663.4</td>
<td>1294.3</td>
<td>141.</td>
<td>6213.</td>
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<td>Labour (number of employees)</td>
<td>87</td>
<td>455.33</td>
<td>219.13</td>
<td>133.</td>
<td>1112.</td>
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<td></td>
<td>91</td>
<td>446.82</td>
<td>212.40</td>
<td>132.</td>
<td>1050.</td>
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<td></td>
<td>94</td>
<td>369.08</td>
<td>159.61</td>
<td>57.</td>
<td>686.</td>
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<td>Installed capacity (MW)</td>
<td>87</td>
<td>2200.4</td>
<td>605.06</td>
<td>1305.5</td>
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<td></td>
<td>91</td>
<td>2199.7</td>
<td>609.52</td>
<td>1304.0</td>
<td>3953.0</td>
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<td></td>
<td>94</td>
<td>1949.7</td>
<td>834.08</td>
<td>158.0</td>
<td>3952.8</td>
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<tr>
<td>Wastes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Aggregated air pollution (10^3 $)</td>
<td>87</td>
<td>233180.</td>
<td>98818.</td>
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<td>94</td>
<td>213874.</td>
<td>82565.</td>
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As in previous research, the input fuels were merged into one unique input fuel, using energetic equivalents, while the pollutants (SO₂, NOₓ, CO₂) were merged into one synthetic pollution variable, using cost equivalents supposed to reflect harmful effects. Table 1 gives a few descriptive statistics for all variables used in our data set. As to the explanatory variables, no additional information is required herein: we do not need any specific values of, e.g., standards applied, or taxes per unit pollutant, since the influence of regulatory and economic instruments will be tested by investigating the evolution of
performance over time, and through comparison of the efficiency in input use with that observed in pollution removal.

5 Results and analysis

In the following, we will refer to the indicators as JF and UO for Jaggi & Freedman and undesirable output - oriented productive efficiency, respectively. The results obtained with the "global" indicators reveal that performance is best in 1994 for 21 plants with JF and 22 plants with UO (the plants often coincide but not systematically), i.e., for more than half of the total number of plants. This is sometimes accompanied by a decrease in performance between 1987 and 1991 (in seven cases over 21 with JF, nine cases over 22 with UO). Figs. 1 and 2 illustrate how performance evolved between the three years (only for the UO results). It can be seen that between 1987 and 1991 the changes are only minor (most points are concentrated along the diagonal), while between 1991 and 1994, there is much more spreading: a few plants significantly dropped, but most plants have improved their performance and depart somewhat more from the diagonal (in the upper-left direction) than between 1987 and 1991.

Although statistical tests applied do not allow to detect any significant trend, due to the counterbalancing effect of a few (very) bad plants, regulation, expressed in terms of the successive amendments to the Clean Air Act, seemed to play a visible role in the improvement of environmental performance. Between 1987 and 1991 nothing special happened; the most significant amendments to the CAA (over the period reported here) began in 1990 and already produced a clear improvement in the performance of most plants. An explanation, then, should be sought for the (few) plants that significantly decreased their performance between 1991 and 1994. As indicated in Section 2, the 1990 amendments to the CAA introduced a system of tradeable permits, besides strengthened standards. Thus there may be two kinds of explanations to the observed decrease in performance: the first is that some of the utilities already bought additional permits that would allow them to pollute more; this, however, is not a good solution in the long term, and these plants might well face a situation that we will propose as our second explanation, i.e., due to harsh competition and reinforced standards, the least performing plants are close to leaving the market and their bad performance is a first signal towards this evolution. Indeed, Table 1 indicates a trend in that direction: as can be seen, while the input and output quantities do not vary much between 1987 and 1991, a significant change took place between 1991 and 1994, with several plants seriously reducing their input use and output production.
The second explanatory factor we wished to investigate was about the economic incentives towards better environmental performance. Figs. 3 and 4, based on the simplified sub-indicators derived from Jaggi & Freedman as described in Section 3, provide us with some useful information in this regard. The figures illustrate a very dramatic trend, in the sense that, on the one hand, the economic
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(price) incentives seem to play a powerful effect as far as the fuels are concerned. Indeed, the spreading observed with respect to the best performer is rather moderate (the average lies between 82 and 83 percent of the best performer; see Fig. 3). On the other hand (Fig. 4), the spreading is much more pronounced for the pollution performance, the average lying between 50 and 51.5 percent of the best performer.

Thus, we have not yet reached a situation where incentives, either economic or other (ethical, stakeholders ...) are powerful enough to justify additional efforts towards improved environmental performance. The reason is that, clearly, the external costs electric utilities impose on society and the environment are not yet (sufficiently, if at all) internalized. Perhaps this will happen with the progressive adaptations electric companies will have to implement to meet the requirements and amendments of the Clean Air Act. However, we are still far from the point where the price of electricity incorporates all environmental externalities.

6 Conclusions

This paper illustrated the potential use of environmental performance indicators in the assessment of the efficiency of regulatory and/or economic incentives in meeting environmental quality goals. Based on the very limited amount of information that was available in our case study of US fossil fuel-fired electric utilities, two kinds of behaviour seemingly prevailed as an answer to strengthening environmental regulation. Most utilities turned out to be adequately prepared to the new amendments to the US Clean Air Act passed in 1990 and accordingly increased their environmental performance. A few other plants were apparently not prepared: their environmental performance dramatically dropped while input use and output production were reduced; these plants are likely to close down in the near future.

Parallelly, we also illustrated that we are still far from the situation where economic incentives are sufficient to adequately translate complete internalisation of external costs. For the utilities that were part of our data set, the price incentives in the purchase of fuels appeared to be much more effective in terms of rational use of energy, than the (economic and/or ethical) incentives towards better environmental behaviour. Indeed, the observed spreading of pollution efficiencies was much larger, and their average values considerably lower, than was the case with fuel efficiencies.

Thus the effectiveness of environmental regulation in phasing out the worst performers, and favouring those well equipped with appropriate technology, which provides them with sufficient capacity
to increase their environmental efficiency, was substantiated by our empirical findings. However, our results are still very limited, because of both the limited scale of the example and the impossibility to take profit of adequate, robust statistical procedures. Further research should obviously concentrate on the collection of additional, adequate data, that would describe in deeper detail both the technological options and the implementation of the Clean Air Act requirements and amendments. Our research should not be seen as more than a methodological exercise, showing the potentialities of indicators as an aid to public deciders towards the elaboration and implementation of appropriate environmental regulations and incentives.

7 Acknowledgements

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8 References

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SECTION 2

Life Cycle Assessment (LCA)