Determinants of Environmental and Economic Performance of Firms: An Empirical Analysis of the European Paper Industry*

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Abstract

This paper examines the relationship between the environmental and economic performance of firms in the European paper manufacturing industry. Based on panel data, it first investigates the relationship separately, with the analysis based on four hypotheses formulated with regard to country influence, process influence and firm size influence on environmental and economic performance. Hypotheses are tested using pooled regression and a panel regression framework with random firm and temporal effects. The main results of this analysis based on separated regressions are that (i) only for a direct comparison between the UK and Germany, country effects are found to be consistent with the hypotheses, i.e. German firms have better environmental, but worse economic performance than UK firms, (ii) there is a significant sub-sector effect on environmental performance only, (iii) effectively no significant firm size effect can be detected. Subsequent to analysing the relationship separately, the paper estimates the determinants of the relationship between environmental and economic performance using three simultaneous equations systems. It was found that for the system with return on sales as economic performance variable, and an environmental performance index as environmental performance variable, a significant and positive regression coefficient was estimated for the asset-turnover ratio, as well as significant and negative coefficients for the dummy variables representing the industrial and mixed sub-sector. For the system with return on capital employed and the environmental index, significant and positive coefficients were found for the latter, both linear and squared. This last finding fits better with "traditionalist" reasoning about the relationship between environmental and economic performance, which predicts the relationship to be uniformly negative.

Key words: Economic performance; Environmental performance; Paper industry; Simultaneous equations system; Three-error-components model

JEL classification: C23; C30; L73; Q25

1 Introduction

The relationship between environmental and economic performance (i.e. short-term profitability and longer-term competitiveness) of firms is an important issue for environmental policy making. In the current discussion about this relationship, it is often argued that there is a conflict between competitiveness of firms and their environmental performance (Walley and Whitehead, 1994). For example, at the level of a specific industry, the share of environmental costs in total manufacturing costs might be considerably higher than average (Luken et al., 1996). Particularly, this might be the case for industries upstream in the production chain (such as primary resource extraction or primary manufacturing), which have been shown to give rise to environmental impacts disproportionate to the value added associated with their production activities (Clift, 1998). It has therefore often been argued that firms in such industries with higher environmental compliance costs face a competitive disadvantage. Given that in the past, firms have focused on end-of-pipe technologies as the major approach towards pollution control and environmental performance improvements in general, in the "traditionalist" view, environmental investments were often seen as an extra cost (Cohen et al., 1995).

Only recently, the notion emerged that improved environmental performance is a potential source for competitive advantage as it can lead to more efficient processes, improvements in productivity, lower costs of compliance and new market opportunities (Porter, 1991, Porter and van der Linde, 1995, and Schmidheiny, 1992), although this often refers to other aspects of environmental performance than those addressed and measured traditionally (Wehrmeyer and Tyteca, 1998). Two major reasons to underpin this argument exist. Firstly, companies facing higher costs for polluting activities have an incentive to research new technologies and production approaches that can ultimately reduce the costs of compliance. But innovations also result in lower production costs, e.g. lower input costs due to enhanced resource productivity (Porter and Esty, 1998). Secondly, companies can gain "first mover advantages" from selling their new solutions and innovations to other firms (Porter and Esty, 1998). In a dynamic, longer-term perspective, the ability to innovate and to develop new technologies and production approaches is likely a more important determinant of competitiveness than traditional factors of competitive advantage, e.g. low-cost production, or generally comparative cost advantages of a country (Porter and van der Linde, 1995). This position can be termed the "revisionist" view.

So far, the relationships between environmental and economic performance and its determinants have rarely been analysed in practice, partly due to data constraints, partly due to a far-from-well-developed theoretical framework. This paper attempts to discuss a number of important determinants for the above relationship in order to develop hypotheses on their expected influence. These determinants are initially though to be the country location of a firm, the industrial sub-sector it operates in, and the firm size. For example, country-level regulation and innovation initiatives are considered to have an influence on the relationship between environmental and economic performance. Also, technological progress in industrial sectors and sub-sectors is considered an important determinant that simultaneously influences the environmental and economic performance of a firm, as is the firm's size. This obviously raises the question whether the theoretical propositions made with regard to key determinants of the relationship between environmental and economic performance can be supported by empirical evidence.

This paper therefore empirically analyses the influence of the aforementioned determinants on the environmental and economic performance of firms in the European Union in a defined industrial sector. For this purpose, data has been collected from corporate environmental reports and emission inventories for the paper manufacturing industry in the Netherlands, Italy, Germany and the UK during the EU-funded project "Measuring Environmental Performance of Industry (MEPI)".[1] In parallel, financial

[1]The project has been funded under the 4th Framework Programme (Environment and Climate) of DGXII of the European Commission. Further information on MEPI can be found at http://www.environmental-performance.org. MEPI was coordinated by the Science Policy Research Unit – SPRU, University of Sussex, UK. The research has also been conducted by the Centre Entreprise-Société-Environnement – CEE, Université Catholique de Louvain, Belgium; the Institute for Environmental Studies, Vrije Univesiteit Amsterdam, Netherlands, the Department of Economics and Production, Politecnico di

information for the same set of firms, for which environmental performance data has been collected, has been extracted from financial databases in a comparable format for an number of accounting-based financial indicators. Based on this data set for a well-defined industrial sector (the paper manufacturing industry), the paper analyses what factors determine to which degree the environmental and economic performance of firms, as well as the relationship between the latter two. Results of this research will inform environmental policy making in more detail about the factors which should best be influenced in order to achieve a high effectiveness and efficiency of policy measures. At the same time results also provide an indication about the potential homogeneity or heterogeneity of determinants. This latter point seems to be specifically relevant for environmental policy, since it can provide an indication about the degree to which policy measures need to be differentiated depending on the country, sub-sector or firm population under consideration.

Our empirical analysis involves an estimation procedure based on: (i) a three-error-components panel data model for estimating separately the determinants of economic performance and environmental performance; (ii) a simultaneous equations system to account for the structural relationship characterizing the joint determination of economic performance and environmental performance. The main results emerging from separated regressions are that (i) only for a direct comparison between the UK and Germany, country effects are found to be consistent with the hypotheses, i.e. German firms have better environmental, but worse economic performance than UK firms, (ii) there is a significant sub-sector effect on environmental performance only, (iii) effectively no significant firm size effect can be detected. Subsequent to analysing the relationship separately, the paper uses three simultaneous equations systems. It was found that for the system with return on sales as economic performance variable, and an environmental performance index as environmental performance variable, a significant and positive regression coefficient was estimated for the asset-turnover ratio, as well as significant

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and negative coefficients for the dummy variables representing the industrial and mixed sub-sector. For the system with return on capital employed and the environmental index, significant and positive coefficients were found for the latter, both linear and squared.

The paper is organised as follows: literature overview and theoretical concepts motivating our own empirical approach are discussed in Section 2; the data collection methodology and sample description are presented in Section 3; the econometric models used are described in Section 4; estimation results are reported in Section 5. Section 6 concludes the study.

2 Overview and theoretical concepts

Based on these two contrasting positions described in the previous section, two specifications of the phenomenological relationship between the two concepts of environmental performance (measured e.g. in terms of resource consumption and emission levels) and economic performance (measured e.g. in terms of stock market performance or financial ratios) can be proposed. A first possible specification would be that the relationship between the two is uniformly negative. This reflects the "traditionalist" view presented above and is theoretically rooted in standard microeconomic theory, since pollution abatement measures in this theory are predicted to increase production costs and are assumed to have increasing marginal costs (e.g. pollution abatement and environmental performance improvements are assumed to have decreasing marginal benefits and increasing marginal costs). This situation is depicted in Figure 1a below , where high environmental performance (e.g., low normalised emissions and inputs) correspond to low economic performance (i.e. low normalised profitability or market performance) and vice versa.[2] Generally, economic performance would be required, under the circumstances of Figure 1a, to be monotonously decreasing with increasing environmental performance, i.e. the first derivative (of economic perfor-

[2]In the figures, environmental performance can be either an aggregate index of emissions and inputs, or an environmental rating and economic performance can be an individual financial ratio (return on sales or assets, value added per employee) or an aggregate index of financial or economic performance of a firm.

mance differentiated to environmental performance) is always negative. In addition to that, the second derivative is required to be negative, representing an increasing negative marginal impact of increasing environmental performance on economic performance.

Figure 1 about here

However, the relationship between environmental and economic performance of firms does not have to be unidirectional, but can be changing from positive to negative or vice versa. A second possible specification for the relationship would therefore be an inversely U-shaped curve across the environmental performance spectrum. Such a specification would also be theoretically supported by standard microeconomic theory, but would also be taking into account the innovation aspects brought forward in the "revisionist" perspective. Based on this the relationship between environmental and economic performance can be represented through a bell-shaped (i.e. inversely U-shaped) curve. It is upward-sloping for firms with environmental performance below the optimum (which is the point where economic performance is maximised). This means that the benefits reaped from increased environmental performance increase continuously for low levels of environmental performance. This curve holds up to a certain point around or slightly above average environmental performance.[3] Beyond this point, the relationship is likely represented by a downward sloping curve (which in a first approximation is considered to be fairly linear). Taken together, the shape of the relationship over the whole spectrum of environmental performance encountered would be an inversely U-shaped curve with an optimum point (i.e. a level of environmental performance, where the benefits for economic performance net the costs for achieving this level are maximised over the whole spectrum). Schaltegger and Figge (2000) have expanded on this, pointing out that the discussed relationship in general is neither positive, nor negative. They consider the relation to follow a gener-

[3] It is an interesting question, where exactly the optimum (i.e. economically efficient) level of environmental performance lies, since this would shed considerable light on the degree to which "pollution prevention pays". However, this is beyond the scope of this exposition of possible specifications.

alised bell-shaped/inversely U-shaped curve with a monotonously decreasing first derivative and a negative second derivative (i.e. an increasing negative marginal impact on economic performance from increasing environmental performance). The part of the curve which lies to the left of its maximum (i.e. the optimum level of environmental performance which corresponds to maximum economic performance) is characterised by a positive first derivative and a negative second derivative. The part of the curve which lies to the right of its maximum is characterised by a negative first derivative and a negative second derivative. This specification of the relationship (a synthesis of the "traditionalist" and "revisionist" views) is depicted in Figure 1b.[4]

These considerations allow to conclude that economic theories (particularly standard microeconomic theory and the theoretical reasoning behind the Porter hypothesis) propose the generalised relationship between environmental and economic performance to be a inversely U-shaped (i.e. concave) relationship, as depicted in Figure 1b. Following the argument above by Schaltegger and Synnestvedt (1999) a generalised bell-shaped/inversely U-shaped curve would represent the "best" possible case for the relationship between environmental and economic performance, since it allows for the existence of win-win situations with profitable (in the short-term) environmental performance improvement activities. On the other hand, a monotonously falling curve would represent the "traditionalist" view. This would correspond to a situation where at the phenomenological level environmental performance improvements can only increase costs and reduce profits. Under such conditions, the optimal level of environmental performance would be that prescribed by environmental regulations, i.e. compliance.

However, the interaction of environmental and economic performance (being represented at a very aggregated level by the phenomenological relationship between the two concepts as discussed so far) is in a causality perspective (i.e. regarding the causes of the relationship) most likely indirect, through factors influencing either environmental or economic performance, or both and should thus be perceived as the outcome of a complex process

[4] The environmental performance and the economic performance axis are defined as in Footnote 2.

of interaction and influence. In this process, the influence factors have a causal relationship to environmental and/or economic performance. Prior to generating hypotheses with regard to individual factors, the interaction between environmental and economic performance needs to be discussed in more detail. In order to do so, a more general model linking 1) influence factors, 2) environmental performance, and 3) economic performance needs to be developed. Therefore, in Figure 2, a model is shown for the interaction between influence factors, environmental performance and economic performance. In this model, the "phenomenological" relationship is related to the influence of moderating factors discussed above. The "phenomenological" relationship between environmental and economic performance is represented at the top level of the model. This is, what is observable (e.g. by way of a scatterplot of individual environmental performance indicators against financial indicators).

The model in Figure 2 shows the factors considered most important which cause a certain level of environmental and economic performance. In the most general form it should be assumed that each of these factors have a simultaneous influence on environmental and economic performance. However, it may well be possible that each factor can be considered to have a predominant influence on either environmental or economic performance, since the key factors influencing most directly and strongly environmental performance are possibly relatively distinct to these that influence economic performance.

Figure 2 about here

Next to the different influences (in terms of directness and strength) the factors at the bottom of Figure 2 have on environmental and economic performance, there are two more noteworthy aspects. Firstly, the influencing factors also interact amongst each other. For example, firm size can have an influence on corporate environmental strategies/management: it is often argued that small firms are laggards who have a relatively reactive stance towards environmental management (Bradford, 2000). As well country location (via environmental regulation) can have an influence on the processes operated: for example in Germany, the Kraft pulping process is indirectly prohibited through very stringent emission limits for pulp manufacturers, whereas in other countries, limits are not as strict and thus operation of the Kraft process is possible (Ganzleben, 1998, p. 24). If the influences and interaction between any two influencing factors are very direct and/or very strong, this needs to be taken into account. They can only be neglected, if the interaction between any two factors are very weak and very indirect compared with the influences each moderating factor has on environmental and/or economic performance.

Secondly, a number of additional factors need to be considered which have an influence exclusively on economic performance. Amongst these are investors and their expectations of return, changing market conditions with regard to demand, supply and prices, the cyclic nature and/or the average capital intensity of the industries under consideration. Given these potential influences mainly on economic performance, the model described above might have to be expanded as depicted in Figure 3.

Figure 3 about here

As can be seen in the model in Figure 3, the additional factors which mainly have an influence on economic performance can potentially also influence the set of influencing factors introduced in Figure 2 (which are considered to influence environmental and economic performance), hence, this interaction needs to be taken into account as well.

Based on the two models developed above, several hypotheses can be derived with regard to the most important influence factors influencing the relationship (environmental management, industry structure, processes operated, firm size and influence of regulation). In the following, the relevant influencing factors considered relevant in the first model (Figure 2) shall therefore be discussed in more detail in order to justify their theoretical relevance, particularly that they are likely to be the most important factors influencing environmental performance. In the following, hypotheses are therefore formulated regarding the influence of these factors on environmental and economic performance, respectively. This will concern the following factors necessary to explain (at least part of) the full variance encountered in the data set with regard to the relationship between environmental and economic performance: (i) country location (which proxies for level and efficiency of regulation in an industry), (ii) processes operated (which are proxied at least partly by individual firm effects), and (iii) firm size.[5]

The influence of the industry market structure/sector membership cannot be assessed with the data set at hand, since this only comprises of firms in the paper manufacturing sector in the EU. The additional factors in Figure 3 will also not be considered, since they are either industry- or country-related. In the former case they are assumed to be constant in their influence (since only the paper manufacturing sector is considered). In the latter case, they are captured in the country dummy variables included in the regressions.

- Country location

Country-level influences on the relationship between environmental and economic performance have so far often been excluded from the analysis, partly due to the dominance of US-based studies (focusing on only one country). To better understand the relationship between environmental and economic performance, a Europe-based study therefore seems necessary and timely. Country location proxies jointly for a number of influences. This can e.g. be the level of stringency of environmental regulations, the type of instruments used to implement these (e.g. economic instruments, or command-and-control legislation) which has an influence on the efficiency of environmental regulation in different countries, or the level of general business taxes in the country. The joint influence of these factors is captured in the country location. It is very well possible that the relationship between environmental and economic performance at the firm level is affected by differing country influences, if firms are not all located within one country. In such a case, country influence needs to be examined closely prior to drawing

[5] The influence of environmental management systems was not included in the analyses reported here, since there is evidence for the data set used, that it is not a good measure, since firms have no significantly different environmental performance, regardless of whether they have a certified Environmental Management System (EMS) or not (Wagner et al., 2001). In addition to that, for 1995, none of the firms in the data set had a certified EMS. Also, it is theoretically possible that firms without a certified EMS carry out the same environmental management activities as those which are certified. Nevertheless, information on EMS has been included in Table 2 below.

conclusions for a complete set of firms from different countries.

The most important factor in the context of this research is likely the regulatory regime in a country in general and for specific industries, i.e. the strictness of an approach to environmental legislation and regulation.[6]

If it is accepted that country influences on the relationship between environmental and economic performance result from the fact that in different countries the stringency of, as well as the approach to (and thus the efficiency of) environmental (and to a lesser degree other) regulation may differ, then under the assumption that firms are compliance-oriented (and not over-compliant) it can be expected that the level of environmental performance (i.e. the emission levels) of a firm is (linear) proportional to the stringency of environmental regulation (which can be measured as, e.g., the average level of emission standards in a country).[7] The reason for this relationship between stringency of regulation and environmental performance is that initially it only pays for firms to pursue emission reductions until they meet the emission standards for their industry, since only such reductions yield an economic benefit for firms in terms of minimizing their compliance costs by avoiding fines. In a compliance-oriented situation, the environmental performance of a firm (measured in terms of its emissions) can be considered as a "revealed regulatory stringency" (as opposed to a "stated regulatory stringency" as expressed by emissions standards). A situation of over-compliance is unlikely, since over-compliance would only be rational for firms if it can be achieved through cost-effective pollution abatement measures. Most cost-effective measures have however amortisation periods of more than 2 years so that annualised returns can usually not compete with other investment

[6] A third important aspect is the degree of certainty, in a country, regarding the future development of environmental regulation. This aspect is however very difficult to capture and is therefore excluded in this paper.

[7] The same situation applies equally to sectoral differences in regulation. For example, Henriques and Sadorsky (1996) argue that costs of regulation differ across industries, and that "firms in more regulated industries are more likely to embed environmental issues into their management strategies since the costs associated with non-compliance tend to be significantly higher" (p. 385). Nevertheless, differences with regard to regulation seem to be much more pronounced between countries, since within one country usually one specific regulatory body and process produces environmental regulation for various industries.

options. In addition to that, over-compliance needs a firm's careful consideration since it could signal to regulators a scope for tighter environmental regulations without significantly affecting companies' profitability and competitiveness. Therefore over-compliance can be expected to be the exception, rather than the norm. Nevertheless, the effect of distortions from over-compliance (resulting, for example from firms' anticipation of future tightening of regulations) needs to be taken into account and assessed prior to assuming the above relationship between stringency and performance.

Next to the strictness/stringency of environmental regulation, it is also necessary to consider the efficiency of regulation depending on the instruments used. From the point of economic theory it is usually argued that the use of economic instruments is more efficient than a command-and-control approach. For example, some countries have generally a very strong legal stance in their environmental regulation, whereas others lean more towards economic instruments, such as taxes or subsidies, and yet others tend to prefer voluntary or negotiated agreements. Germany, the UK and the Netherlands would be respective examples. However, it is at times difficult to distinguish such regimes clearly, since governments usually apply a mix of economic, legal and voluntary or negotiation-based instruments simultaneously. However, it has also to be taken into account, to what degree regulations are designed and implemented efficiently and are enforced properly.[8]

In Germany and the UK, the extent of corporate environmental protection has increased significantly over the last decade. The socio-political, regulatory and economic climates of the two countries show clearly differences, which has meant that companies in each country have developed management approaches and corporate environmental strategies that are specific to their national circumstance, with likely different influences on the environmental and economic performance of firms. For instance, Gordon (1994) acknowledges that, whilst awareness of broader political and social aspects

[8] This is a particularly important issue, since properly designed environmental regulation in the Porter hypothesis is expected to produce organisational and technical innovations which lead to production efficiency gains that can result in competitive advantages compared to less stringent regulation (Porter and van der Linde, 1995).

in environmental policy is greater in Britain, the level of analysis and the efficiency of environmental policy making is often greater in Germany. Peattie and Ringer (1994) report strong enthusiasm for environmental management amongst British companies, and suggest that in organisational terms, they are not significantly lagging behind, but may increasingly do so due to weak environmental legislation. James et al. (1997) find that for specific socio-political dimensions, such as stringency of regulation, the character of existing competitive strategies within firms, or the level and quality of public concern for environmental issues, have led to distinct environmental management types in both countries, with likely different influences on environmental and economic performance, and, ipso facto, the relationship of the latter two.

Compared to Germany and the UK, in the Netherlands, two key trends in Dutch policy influenced the situation with regards to European Eco-Management and Auditing Scheme (EMAS). This is firstly the strong stance for deregulation (also concerning environmental regulation) in the early as well as the rising level of political and public environmental awareness in the late 1980s (Wätzold et al., 2001). Within the Dutch National Environmental Policy Plan in particular, this implied two specific new strategies. Firstly, this was the introduction of Environmental Management Systems (EMS) within industry target groups, and secondly, the negotiation of agreements (so-called covenants) in which the target groups' contributions to the achievement of various environmental policy goals (e.g., greenhouse gas emission reductions) were defined (Wätzold et al., 2001).[9]

Based on WEF et al. (2001), the stringency of regulation and the orientation of regulation towards flexible instruments (as a proxy for the efficiency of environmental regulation) of the four countries (Germany, Italy, the Netherlands and the United Kingdom) studied in this paper can be classified as in Table 1.

Table 1 about here

[9] Regulatory relief was granted equally to EMS verified under EMAS or certified under ISO 14001.

As stated above, with regard to level (i.e. strictness of regulation), efficiency (determined by the approach to regulation) and future development of environmental regulation, it can therefore be expected that the level of environmental performance will be higher in countries and sectors with (i) a higher stringency of environmental regulation (i.e. more stringent emission standards), and (ii) a more efficient approach to regulation. In particular, the reason for (ii) is that despite the limitations of the mechanisms proposed by the Porter hypothesis, it is likely that incentive-based regulations using economic instruments or voluntary reduce private and social abatement costs as compared to command-and-control type regulation. Incentive-based regulations maintain incentives for firms in an industry to reduce emissions, provide cost-effective allocation of resources and abatement technologies and therefore at least reduce the negative impact of environmental regulation on firm profitability and competitiveness. Therefore, the following two hypotheses are proposed:

Hypothesis H1: In countries with more stringent regulation, firms are expected to have significantly better environmental performance, as well as significantly worse economic performance, than in countries with less stringent environmental regulation.

Hypothesis H2: In countries, where regulations are more oriented towards economic instruments, environmental, as well as economic performance are expected to be more positive than in countries where regulation is more oriented towards command-and-control type regulation. As a result of this, the relationship between environmental and economic performance is expected to be more positive.

- Processes operated

Generally, the processes operated at a site are more a classification criterion, rather than a influencing factor to be hypothesised about, since only firms and sites with fairly comparable processes per se can be compared with regard to the relationship between environmental and economic performance. Processes operated are therefore operationalised in this research by means of a broad classification scheme, in which newsprint, magazine-grade and graphics fine paper are represented by one category "cultural papers", and packaging corrugated and other boards by another category, "industrial papers". Also "mixed" and "other" categories were defined, resulting in a classification based on four (broad) sub-sectors . One important reason for introducing a "mixed" sub-sector is the fact that the actual unit determining the product is not the site, but the individual paper machine. Since one site usually runs more than one paper machine, it is often the case that two different products are produced at that site. A sub-sector category "mixed" accounts for this. Sub-sector dummy variables were introduced as control variables since it is assumed that the economic performance of a firm strongly depends on the sub-sector it operates in, and that also environmental performance may be influenced by sub-sector membership. Given this, significant sub-sector effects can be detected by including a sub-sector dummy. Therefore, the following hypothesis shall be tested:

Hypothesis H3: The environmental and economic performance of firms in one industrial sector is expected to vary significantly across its sub-sectors, i.e. there are significant differences in economic performance, environmental performance, and, ipso facto, the relationship between environmental and economic performance is expected to differ significantly across the different sub-sectors.

- Firm size

It is often argued that firm size has an influence on corporate environmental performance, as well as on its relationship with economic performance. One reason for this is that firm size can be used to reflect firm visibility, and, since larger firms tend to be more susceptible to public scrutiny, they are more likely to be industry leaders with regard to environmental performance (Henriques and Sadorsky, 1996). In addition to that, smaller and medium-sized firms are considered to be in many ways laggards who have a relatively reactive stance towards environmental management (Bradford, 2000).[10] Small and medium-sized firms (SMEs) are often found to be unaware of their legal duties regarding waste disposal and frequently do not consider their operations having a significant environmental impact. In ad-

[10] Usually, small firms are defined as those with less than 50 employees, whilst medium-sized companies are considered to be those in the range of 50-250 employees (EIM, 1997, p. 329). Such a definition however needs to account for potential distortions from transitory growth and size class changes of firms (Wagner, 1995).

dition to that they tend to be unfamiliar with environmental management systems and standards and respond strongest to regulation as a stimulus for environmental improvement (Bradford, 2000, and Meffert and Kirchgeorg, 1998).

This experience from a research project looking at Environmental Awareness in SMEs in five EU countries (Germany, Sweden, the Netherlands, Italy and the UK) is also supported by a Swedish survey which found in 1998 that small firms with less than 50 employees in Sweden had no significant ambition to become environmental leaders although attitude changes were noted in medium-sized companies above 50 employees, mainly triggered by the introduction of EMS, customer requirements and organizational change (Heidenmark and Backman, 1999). Consistent with this empirical experience it is found that competitiveness is the highest priority for SMEs, whilst avoidance of legal problems (under which environmental performance can be subsumed to a large degree due to the fact that SMEs were found to be mainly compliance- and regulation driven) are ranked very low (Bradford, 2000).

Implied by the above considerations is that, so far, SMEs themselves mainly perceive the relationship between environmental and economic performance to be negative or at least non-existence, since competitiveness (as a basis for good economic performance) is not considered to be linked to legal problems (such as breaches of environmental standards) or is thought to be conflicting with the avoidance of legal problems.

Economic theory provides mainly four reasons for differences in firm size and thus of different levels of market concentration (You, 1995, and Moschandreas, 1994). These are:

– the existence of U-shaped or L-shaped long-term average cost curves, i.e. a minimum efficient scale of production (MES) exists (the production theory justification);

– the existence of transaction costs, resulting in a substitution of allocation mechanisms, i.e. firms as organizational structures instead of markets (the transaction cost theory-based justification);

– the existence of heterogeneous (monopolistic, incomplete) competition, i.e. markets with many sellers and differentiated products (justification based on demand conditions in the market) which postulates niche markets for small firms; and

– the stochastic explanation often modeled as a Gibrat process following the law of proportionate effect (justification based on the notion that changes in concentration are the net effect of a large number of uncertain influences).

Basically these economic approaches to explain differences in firm size allow the conclusion that small firms exist where this is not a competitive disadvantage, e.g. where MES or transaction costs are low, or where the market structure allows the existence of niche markets. As far as the relationship between environmental and economic performance is considered, this would imply that from the point of economic theory, no direct explanation is provided as to why the relationship should be less positive for smaller firms than for larger firms (although, as explained above, precisely this is the self-perception of SMEs).[11]

Nevertheless (and possibly explaining empirical findings) it is possible that for SMEs a less positive relationship exists if there are economies of scale in environmental management systems and activities. This is well possible, since environmental management is likely to have a high level of fixed (i.e. output- and therefore size-independent) costs. In conclusion, the following hypothesis is proposed:

Hypothesis H4: Smaller firms are expected to have significantly lower average levels of environmental performance as well as higher cross-section variances in environmental and economic performance than larger firms (Schmalensee, 1989, p. 986). As a result of this, firm size should have a significant positive effect at least on environmental performance. Consequently, the relationship between environmental and economic performance should be stronger (i.e. more) positive for larger firms, whereas for smaller firms it is likely weaker or even negative since they often cannot achieve economies of scale in environmental management.

[11]However, Schmalensee (1989) states that it is a stylised fact that firm size tends to be negatively related to intertemporal and cross-section variability of profit rates, albeit also qualifying this to some degree.

3 Data

Panel data was collected on a set of 33 paper firms in four EU countries (Germany, Italy, the Netherlands and the United Kingdom) over the period from 1995 to 1997. The sample covers a considerable proportion of production capacity in each country, on average 20% in 1996 and 22% in 1997 (this is a reasonable response rate for surveys in general). Only in Italy, coverage is below average. Coverage is best in the Netherlands with approximately 50%. In the UK and in Germany it is around the average.

ISO-certified and EMAS-verified firms were distributed across countries as described in Table 2. In 1995, data on 33 firms was available, of which none was ISO-certified or EMAS-verified in 1995. In 1996, data for 34 firms was available (of which 1 was excluded due to missing observations in 1995), whereas in 1997, data on 37 firms was available (of which 4 were excluded due to missing observations in 1995 and 1996). Since data was also collected for single-site firms, it is possible that a firm is certified to ISO as well as verified under EMAS. Therefore numbers of ISO and EMAS do not always add to the total of EMS certifications. Given that not for all firms in all years data on all variables was available, the number of firms included in testing the above hypotheses was smaller than the total number of firms reported in Table 2.

Table 2 about here

Collection of most of the environmental performance data used in this paper (as well as the data country location, sub-sector, firm size and on EMS certification) took place in the framework of the project Measuring Environmental Performance of Industry (MEPI). However, additional environmental performance data was collected by the authors, based on the method used in the MEPI project (see Berkhout et al., 2001a,b) and incorporated in the MEPI database.

3.1 Data collection method for environmental performance data

The main data sources in MEPI for collection of environmental performance data were corporate environmental reports (all countries except Italy), EMAS statements (especially Germany and Austria), public pollution inventories (especially the Netherlands and the UK), and company surveys (especially Italy). The variety of data sources proved to be problematic in so far that the sources partly focus on different levels of activity. EMAS statements and pollution inventories for example focus on the site level, whereas corporate environmental reports usually report data aggregated across a number of sites. Nevertheless, this is not problematic, since single-site and multi-site firms can easily be integrated in one research design, as long as system boundaries for environmental and economic performance match, at least approximately. Generally, the data collection strategy under the MEPI project attempted to gather as much information as possible from public sources, whilst at the same time filling data gaps by direct contact with companies. Specific national approaches had to be developed, due to the fact that data availability and data sources varied between countries (Berkhout et al., 2001a).

The larger proportion of environmental performance data for the paper sector was collected within the MEPI project according to a defined data collection protocol. However, further data was collected to expand the data set in terms of the number of firms and the amount of data available on individual firms after the data collection process within the MEPI project was finished. This additional data collection also followed the data collection protocol used in MEPI (see Berkhout et al., 2001b, for details). Therefore, all data used in this study was collected following one unified and defined approach, based on the data collection protocol developed for the MEPI project. Prior to discussing in detail the structure and contents of the data collection protocol, the following section reports in more detail on the data sources and data collection strategies used in different countries.

3.2 Data sources and data collection strategies in different countries

Data collection aimed to gather information on a core set of variables which allows the construction of technically sound and useful environmental performance indicators for the paper manufacturing industry. The initial set of variables included five categories of data: resource input (e.g. water consumption), emissions (e.g. sulphur emissions), environmental management information (e.g. whether or not a firm has a certified EMS), production output (e.g. paper production) and business data (e.g. number of employees). A full list of the initial variables for which data was sought can be found in Berkhout et al. (2001b). Despite serious efforts, it was not possible to collect sufficient environmental data on all the initial variables, given the variability found with regard to the data categories. For example, emissions data is found in most sources, whereas resource inputs are not covered by the pollution inventories in the UK and the Netherlands, but are included in most corporate environmental reports and EMAS statements.

Given that data availability and data sources varied between countries, specific national approaches had to be developed (for details see Berkhout et al., 2001b, Appendix 3). In Germany data collection focused on environmental statements published under the EMAS regulations. It was attempted to gather data from all EMAS registered firms (as of 1998) in the paper manufacturing sector. With few exceptions, data has been collected from the EMAS statements and has been included in the MEPI data base. Because the collection and input of the EMAS registered companies' data involved a major effort, no other data sources (other CERs, surveys, databases etc.) were used.

In Italy, due to the lack of public environmental information, data was mainly collected through direct contact with firms since corporate environmental reporting was (in 1998/1999) less common than in other European countries. Even where reports existed they did often not disclose quantitative information consistent with the MEPI data collection protocol requirements. Also, in the paper manufacturing sector, neither public authorities, nor trade associations held databases on corporate environmental data or, did not disclose data to stakeholders.

The Dutch emissions register ER-I was the main data source for data collection in the Netherlands. However, the ER-I data only refers to air and water emissions. Additional data was therefore collected from negotiated agreements between business and government on environmental policies (so-called covenants). For data collection on energy consumption, physical production output and other information, mainly corporate reports and case studies were used as sources. Data for the paper manufacturing industry is nearly complete.

Generally, main data sources for the UK were corporate environmental reports, questionnaires and the public Pollution Inventory (former Chemical Release Inventory). In addition to that, two private consultancy companies provided additional data. Data in the paper manufacturing sector, however, was mainly collected from corporate environmental reports of sites and their parent firms, and in direct contact of MEPI researchers with firms' environmental managers.

Even though the sources of the collected data are diverse, it needs to be kept in mind that the data collection strategy in the MEPI project aimed to gather as much information as possible from public sources, whilst simultaneously filling crucial data gaps by direct contact with firms (Berkhout et al., 2001a).

Subsequent to data gathering, the environmental data collected was matched with financial data and data on economic performance. Financial data and data on economic performance was collected from the Amadeus database maintained by Bureau van Dijk. Matching of records in the two databases was carried out based on the name and address of firms/sites, as well as the number of employees for each year (as far as employee figures were available for both, environmental and financial data). Given that not for all firms, environmental and economic/financial data were available simultaneously, the initial number of firms for which environmental performance data was collected was reduced to the number of firms as described in Table 2 above.

3.3 Data comparability and data quality

From the outset, gathering corporate environmental data was seen as the main challenge of data collection in the MEPI project. It emerged, however, that even once data have been collected, ensuring data comparability and data quality were equally difficult since this required that data are expressed in the same units of measurement. Frequently, however, data was far from being standardized. Coal input to production, e.g., was reported in tonnes, Gigajoules, Gigawatt hours and tonnes of oil equivalent and waste was measured in tonnes, cubic metres and litres. In order to facilitate the conversion of measurement units and to minimise errors, a data conversion template was therefore developed in the MEPI project. This template facilitated automatic conversion between currencies, as well as weight, length and energy measurement units (for details see Berkhout et al., 2001b, Appendix 3). It also converted coal, gas and oil inputs from weight to energy units, using standard conversion factors for each country.[12]

A second problem encountered was that environmental and financial data did not always refer to the same period. Most environmental data refers to the calendar year. However, most business and financial data and a large part of environmental data stemming from corporate environmental reports refer to financial years (in the UK the financial year is April to March, whereas e.g. in Germany it is January to December). In the context of this paper, it was not possible to correct this mismatch. Data (on environmental, as well as economic performance) was attributed to the calendar year it best matched (e.g., if the financial year was April 1995 to March 1996, then the data was recorded as 1995 data). This seemed acceptable, since a three-month shift of financial against calendar year was the maximum mismatch.

The majority of environmental data in the MEPI database has not been object of rigorous verification procedures. Only EMAS data is systematically and formally verified. However, there are no such requirements for voluntary corporate reporting and even the quality of pollution inventories varies, for example, the UK Pollution Inventory has long been criticised for having

[12] Factors were extracted from Houghton et al. (1995), as cited in IPCC Greenhouse Gas Inventory Reference Manual.

insufficient quality checks. Environmental data gathered through questionnaires is entirely unverified. However, since the large majority of data in the paper manufacturing sector was collected from environmental reports prepared in the context of verified environmental management systems (either based on EMAS or ISO 14001) data quality can generally be expected to be good. The former is the case in the UK and Germany, where corporate environmental reports and EMAS statements were the main data sources. For example, one German firm with several sites/business units in the data set stated that their data is based on site data from validated environmental statements under EMAS where validation included an assessment of the quality and reliability of quantitative data through external environmental auditors. The same applies generally for the UK where data mainly stems from validated corporate environmental reports. Only in exceptional cases, members of firms' environmental department were contacted for additional data not available in the reports.

For the Netherlands, data has been taken mainly from the Dutch national emissions register ER-I and negotiated agreements between the paper industry and the Dutch government. Generally this data is considered to be highly reliable (Berkhout et al., 2001b). The only exception in respect to data quality is Italy, where data was usually directly supplied by company representatives, and thus can only be audited indirectly with regard to quality. As stated at the beginning of this section, in order to address the above and other related problems of data comparability and data quality, a data collection protocol was defined for the MEPI project. This protocol, which was the basis for all data collection activities within the MEPI project, as well as for the collection of additional environmental performance data in the pulp and paper manufacturing industry. No data quality issues exist with regard to the financial and economic performance data collected. The next sub-section describes in detail the environmental and financial variables used in the empirical analysis.

3.4 Description of individual variables

The variables used to operationalise the concept of environmental performance are SO_2 emissions, NO_x emissions, COD emissions, total energy input, and water input, all per tonne of paper produced. Olsthoorn et al. (2001) support the use of these indicators in the paper sector. Not for all variables used to operationalise environmental performance, data was sufficiently available to achieve meaningful regression results. Therefore, total energy input and total water input were subsequently excluded from the regressions. Theoretically, the use of value added instead of physical production output (i.e. tonnes of paper produced) as denominator is better justified, since in the case of value added the system boundaries match more precisely those of the emissions. Physical production output was used nevertheless, since the price of paper on the world markets dropped significantly between 1995 and 1996. It was assumed that this would influence more strongly value added than physical production output. In order to avoid distortions because of this, the latter was used as denominator.

In addition to the three individual environmental performance indicators (all normalised/standardized for production output), an index of these was also calculated, using the method initially developed by Jaggi and Freedman (1992) in the adaption used by Tyteca et al. (2001). The indicators used to calculate the index score were SO_2, NO_x and COD. Description on these indicators is given in Table 3.[13] The higher the value of this index is, the higher environmental performance is presented.

Table 3 about here

In order to calculate the environmental index variable (hereafter referred to as INDEX), data on a set of analogous units focused on a specific type of production (e.g., firms in the paper manufacturing sector), and characterised by a variables reflecting inputs, desirable outputs, and undesirable outputs (emissions) needs to be available (Tyteca, 1999, and Berkhout et al., 2001).

[13]To calculate this index, all pollutant emissions need to be measured in the same measuring unit (kilo tonnes per tonne). However, in estimations the measuring units of SO_2 and COD are rescaled to tonnes per tonne.

The principle for calculating INDEX is to make reference to the units that perform best among the given set, i.e., those that, in the context of this paper, release the least of emissions, for given levels of output production (i.e. have the lowest specific emissions per unit of production output, i.e. per tonne of paper). It is in the following assumed that INDEX will be calculated for k different individual environmental performance indicators (i.e. the emissions SO_2, NO_x and COD) – k thus designates the total number of individual variables/indicators taken into consideration to evaluate the performance.

Let therefore the emission of the pollutant k, $k = 1, ..., K$, for the production unit (in our case a specific firm) i be denoted as:[14]

$$V_{k,i} = \frac{\text{Absolute emissions for pollutant } \mathsf{k} \text{ of firm } \mathsf{i}}{\text{Unit of production output}}. \tag{1}$$

This variable can be calculated for each of n the firms considered. Based on this, in the next step, the minimum value for this variable is identified, over the whole set of firms:

$$V_{k,\min} = \min_i \{V_{k,i} \mid i = 1, ..., n\}. \tag{2}$$

Subsequently, for each firm, a new variable $C_{k,i}$ is defined according to the following equation:

$$C_{k,i} = \frac{V_{k,\min}}{V_{k,i}} \leq 1. \tag{3}$$

The value taken by this ratio will be 1 only for the unit(s) performing best for the variable considered; for all other units, it will be strictly less than 1, but larger than 0. It can be interpreted as the contribution (hence the variable name C_k) of variable $V_{k,i}$ to INDEX (or global performance indicator) for firm i. When calculating (3), a problem arises, if the minimum emission in the data is equal to zero, since then the ratio calculated in (3) will be equal to zero for all cases in the data set. In such a case, we followed Berkhout et al. (2001a, p. 141) in using as minimum value an arbitrary, strictly positive, value which was smaller than the smallest emission value different from zero in the data. At the same time, those cases with zero emissions on the variable in question were assigned the value of 1.

[14] In the case of the research reported here, data on specific emissions was readily available and did not need to be calculated separately.

Prior to calculating the variable INDEX_i for each firm, however, it is necessary to adjust the contribution C_k for inhomogeneities in the individual variables. Otherwise, some variables may be given a much higher weight than others. The reason for this is that the contribution C_k calculated for one variable may be sometimes on average several orders of magnitude higher or lower than that for another variable (Berkhout et al., 2001a,b). In such a case, when summing up the contributions into INDEX, only the variables with the highest average order of magnitude will influence the value of the latter. In order to adjust for this (essentially differences in the skewedness of distributions), an adjustment factor is calculated according to the following formula:

$$Ad_k = \frac{\max_{l=1,\ldots,K}\{\text{median}\,(C_l)\}}{\text{median}\,(C_k)} \tag{4}$$

For the calculation of the index, the $C_{k,i}$ for each firm i is then multiplied with corresponding Ad_k. Finally, the variable INDEX_i is calculated for each firm, according to the following formula (5). As can be seen from (5), when summing up the adjusted contributions of each individual environmental performance variable, these will be implicitly assigned an arbitrary weight of one. In the formula, the sum of the adjusted contributions is divided by the number of variables, resulting in an index which takes values smaller or equal to one (Berkhout et al., 2001a,b):

$$\text{INDEX}_i = \frac{1}{K}\frac{\sum_{k=1}^{K} C_{k,i}Ad_k}{\frac{1}{K}\sum_{k=1}^{K} Ad_k} \tag{5}$$

Tyteca et al. (2001) emphasize that with this index calculated according to the method suggested by Jaggi and Freedman's (1992), the variables are treated independently of each other, rather than being all considered simultaneously in a multi-dimensional space. Since the likelihood of a specific firm being the best on all individual indicators/variables is very small, INDEX therefore usually takes values strictly less than one. In the estimations, log(INDEX) was used to achieve less skewed distribution. Indeed, Figure 4 shows the kernel density estimate of INDEX with high frequencies for extreme values whereas Figure 5 displays a less heterogenous distribution of log(INDEX).[15]

[15] Gaussian kernel with optimal bandwidth criterion were used to estimate the density

Figures 4 and 5 about here

The variables used to operationalise the concept of economic performance are return on equity (ROE), return on capital employed (ROCE) and return on sales (ROS). They are briefly described in the following.

Return on equity (ROE, also called return on shareholders' funds) is defined as the ratio of profit before taxation (but after interest and preference dividends) to ordinary shareholders' funds (Pendlebury and Groves, 1999). Ordinary shareholders' funds consist of average ordinary share capital, reserves and retained profit for the period. Return on equity shows the profitability of the company in terms of the capital provided by ordinary shareholders (which are the owners of the company). It thus focuses on the efficiency of the firm in earning profits on behalf of its ordinary shareholders, by relating profits to the total amount of shareholders' funds employed by the firm. In doing this, return on equity is the most comprehensive measure of the performance of a company and its management for a period since it takes into account all aspects of trading and financing, from the viewpoint of the ordinary shareholder (Pendlebury and Groves, 1999, and Reid and Myddelton, 1995). As a consequence of this, ROE can be affected by a firm's capital structure (i.e. its gearing), which is not the case with the next ratio discussed.

The rate of return on capital employed (ROCE) measures the profitability of the capital employed. It is defined as the ratio between gross trading profit (net of depreciation) and the capital employed (Morris and Hay, 1991). However, this is only one possible definition, since no general agreement exists on how capital employed should be calculated, or on how profit should be defined (Lumby, 1991). More recent definitions fairly consistently define ROCE as the ratio between earnings before interest, taxation and exceptional items (EBIT) to the (average) net assets (i.e. total assets less current liabilities) for the period (Pendlebury and Groves, 1999, and Reid and Myddelton, 1995). This is also the definition adopted in this paper. Generally, ROCE measures the efficiency, with which capital is employed in producing

(Silverman, 1986). Note again that log(INDEX) is always negative. Positive values of log(INDEX) displayed on the abscissa are purely due to graphical rescaling.

income. It indicates the performance achieved regardless of the method of financing (i.e. the firm's capital structure), since it uses total capital employed (i.e. net total assets) before financing charges (i.e. interest), rather than only the part of total capital that relates to shareholders' interests (Pendlebury and Groves, 1999, and Reid and Myddelton, 1995).

Return on sales (ROS) can be based on net profit before interest and gross profit. The first yields the net profit percentage (also called net profit margin). It is defined as the net profit before interest and tax divided by sales revenue and measures the percentage of sales revenue generated as profit for all providers of long-term capital after deduction of cost of goods sold and other operating costs. For the purpose of this research, return on sales is defined as the ratio of profit (loss) before tax to total sales (i.e. operating revenue), in accordance with the literature (Reid and Myddelton, 1995). This ratio indicates to what degree a firm was successful in achieving the maximum sales possible whilst simultaneously keeping costs minimal (Pendlebury and Groves, 1999).

Next to the dependent variables described above used to measure the concepts of environmental and economic performance respectively, country dummy variables for the four countries in which data was collected for paper manufacturing firms, as well as a variable measuring the size of firms (in thousands of employees) were included as independent variables in the regressions. In addition to that, a number of control variables were included in the regressions with economic performance as dependent variable. These are briefly described in the following.

The asset-turnover ratio (i.e. the ratio of total assets to operating revenue) can be considered to measure the capital intensity of a firm's operations. Russo and Fouts (1997) suggest to include this ratio as a control variable when carrying out regressions with ROA (return on assets), ROCE, ROE and ROS as dependent variable. A low ratio would indicate a firm with below-average capital intensity which Schaltegger and Figge (1998) argue can also be considered beneficial in terms of value-oriented environmental management.

The solvency ratio addresses a firm's longer-term solvency (and thus its capital structure) and is concerned with its ability to meet its longer-term financial commitments (Arnold et al., 1985).[16] Defined as the ratio between shareholder funds and total assets, it is a measure for capital structure and investment/financial risk (Pendlebury and Groves 1999, pp. 262–263). This means that the inverse of the solvency ratio is a possible measure for financial leverage which Hart and Ahuja (1996) suggest to control for when assessing influences on economic performance. Therefore, we include the inverse of the solvency ratio (after deducting one) as a control variable in the regressions with ROE, ROS and ROCE as dependent variables. This is because the inverse of the solvency ratio minus one equals the gearing ratio which is usually used to control for financial leverage.

Value added per employee is an efficiency/effectiveness ratio and measures the labour productivity of a firm (Pendlebury and Groves, 1999). Value added here is defined as the sum of taxation, profit/loss for the period, cost of employees, depreciation and interest paid. Value added per employee was found to correlate highly with the asset-turnover ratio. To avoid multicollinearity it was therefore not used as control variable in the regressions.

The current ratio (i.e. the ratio between current assets and current liabilities, also called working capital ratio), as one of the liquidity/stability ratios, measures the resources available to meet short-term creditors (Pendlebury and Groves 1999, p. 201, and Myers and Brealey, 1988). This is of interest, because a weak liquidity position in the present implies increased challenges for a company to achieve its long-term objectives, including the generation of future cash flows. The current ratio, by computing the ratio between current assets and liabilities indicates a company's ability to meet its short-term cash obligations out of its current assets without having to raise finance through borrowing, issuing more share or the sale of fixed assets.[17] Acceptable values for the current ratio range between 0.5:1 to 2.5:1 (Arnold et al., 1985). A higher current ratio is consistent with a lower asset-turnover ratio (as a measure of capital intensity), i.e. firms with a lower asset-turnover

[16] Longer-term solvency is related to the composition of a firm's capital structure. The higher the proportion of a firm's finance that consists of loan capital, the higher are its interest payments. The increased risk of the firm failing to meet these affects in turn estimates of its future performance (Arnold et al., 1985).

[17] Raising additional finance in either one of these ways can adversely affect a company's ability to generate future net cash flows.

ratio have proportionally less fixed assets and correspondingly more current assets and vice versa. This means, however, that multi-collinearity between the current ratio and the asset-turnover ratio exists, and because of this, the current ratio was not included as a control variable in the analysis.

The four hypotheses formulated above were tested for the described data set of paper manufacturing firms using a pooled regression, a panel regression framework with random firm and temporal effects and a simultaneous equations system. It has to be noted that for the economic, as well as environmental performance variables, data is usually not available for all firms in the data set. Therefore, the set of firms differs slightly from one regression to another.

Descriptive statistics and a summary of the definition of variables are given in Appendix 1. For the economic performance variables, we find the mean for ROCE decreasing from 1995 to 1997, whereas the means for ROE and ROS are oscillating. Consistently with this, the minima and maxima for ROCE are changing most, year-on-year. Nevertheless, descriptive statistics for the economic performance variables vary much less over time than do those for environmental performance variables. Here, we find that the mean for COD increases from 1995 to 1997 a factor of 5. The mean of SO_2 oscillates in a similar way as found for economic performance, however the mean of NO_x increases from 1996 to 1997 by more than one order of magnitude. This is mainly due to a very high maximum value for NO_x in 1997. Mean, standard deviation, maximum and minimum of the aggregated variable INDEX (derived as described in the previous section) varies little across the three years. Of the control variables, firm size varies little across the years, whereas the inverse of the solvency ratio minus one (SR_1) and the asset-turnover ratio vary more in their descriptive statistics across 1995 to 1997. The dummy variables for country membership and sub-sector membership only vary very little across years, as would be expected of these rather structural factors. For both, the economic, as well as environmental performance variables, data was usually not available for all firms in the data set. Therefore, the set of firms differs slightly from one regression to another.

4 Econometric specifications

Our analysis of the empirical relationship of the determinants of environmental and economic performance of firms involves an estimation procedure based on panel data models and simultaneous equations system. In a first stage, we consider separately environmental performance and economic performance, that is, the indicators of environmental performance or those related to economic performance of firms are used as response (endogenous) variables. In a second stage we account for the endogeneity between these two concepts and estimate the structural relationships describing the variation of endogenous variables.

4.1 Separated equations

We consider a three-error-components panel data model. The specification has the following structure (Baltagi, 1995):

$$y_{it} = \alpha + \mathbf{x}_{it}\boldsymbol{\beta} + \mathbf{z}_i\gamma + u_{it}, \tag{6}$$

and

$$u_{it} = \mu_i + \lambda_t + \varepsilon_{it}, \quad i = 1, \cdots, N; t = 1, \cdots, T. \tag{7}$$

In the above specification, y_{it} denotes observation on the dependent variable for a firm i at period t, that is either the environmental performance of a given firm or its economic performance, $\mathbf{x}_{it}$ represents the set of time-variant regressors and $\mathbf{z}_i$ the time-invariant explanatory variables; u_{it} is composed of: (i) a disturbance μ_i (firm effect) that reflects left-out variables which are time-persistent in the sense that for each firm i, they remain roughly the same over time and capture unobservable firm heterogeneity; (ii) a period-specific component λ_t (year effect), traducing omitted variables which affect all individuals in period t, and finally, (iii) the idiosyncratic error ε_{it}. We assume that μ_i, λ_t and ε_{it} are mutually independent and independent of the regressors with constant variances σ^2_μ, σ^2_λ and σ^2_ε respectively.

On the assumption that $\mathbf{u} \equiv [u_{11}, u_{12}, ..., u_{NT}]' \sim N(0, \boldsymbol{\Omega})$, the specification above is known to be a random effects model and can be estimated by maximum likelihood procedure proposed by Amemiya (1971). Such a joint likelihood function of observations y_{it} conditional on the values of the independent variables $\mathbf{x}_{it}$ and $\mathbf{z}_i$ is relatively complex. It requires spectral decompositions of the covariance as well as the concentration of the likelihood function with respect to some parameters and Generalized Least Squares (GLS) implementation. So, we report the various steps of the estimation procedure in Appendix 2.

4.2 Simultaneous equations

In the above specification, we consider estimating separately parameters affecting environmental performance and economic performance of firms. As discussed in Section 2, as far as the channel relationships are concerned, the empirical analysis of mutual influences between environmental performance and economic performance can be entirely specified through the estimation of a structural relationship in a simultaneous equations system.

Our model contains G theoretical relationships ($g = 1, ..., G$) for endogeneity and K exogenous variables. Contrary to the separated estimations, the data is pooled to consist in NT observations. That is to say, we do not use the panel structure of the sample. The two reasons motivating such a consideration are: on the one hand, due to small data set, if we have to account for the panel structure, we might estimate much more parameters and, on the other hand, as shown in Figures 4 and 5 above, the distribution of variable log(INDEX) is less heterogeneous than the distribution of INDEX.

The full system of equations is

$$\underset{GNT\times 1}{\begin{bmatrix} \mathbf{y}_1 \\ \mathbf{y}_2 \\ \vdots \\ \mathbf{y}_G \end{bmatrix}} = \underset{GNT\times\sum_{g=1}^{G}(M_g+K_g)}{\begin{bmatrix} \mathbf{W}_1 & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \mathbf{W}_2 & \cdots & \mathbf{0} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{0} & \mathbf{0} & \cdots & \mathbf{W}_G \end{bmatrix}} \underset{\sum_{g=1}^{G}(M_g+K_g)\times 1}{\begin{bmatrix} \boldsymbol{\delta}_1 \\ \boldsymbol{\delta}_2 \\ \vdots \\ \boldsymbol{\delta}_G \end{bmatrix}} + \underset{GNT\times 1}{\begin{bmatrix} \boldsymbol{\epsilon}_1 \\ \boldsymbol{\epsilon}_2 \\ \vdots \\ \boldsymbol{\epsilon}_G \end{bmatrix}} \tag{8}$$

with $\boldsymbol{\epsilon} \equiv [\boldsymbol{\epsilon}_1, ..., \boldsymbol{\epsilon}_G]'$ such that $\boldsymbol{\Omega} \equiv E(\boldsymbol{\epsilon}\boldsymbol{\epsilon}') = \boldsymbol{\Sigma} \otimes \mathbf{I}_{NT}$ and elements of the matrix $\boldsymbol{\Sigma}$ are $\left(\sigma^2_{g,h}\right)_{g,h=1,...,G}$. The structure of $\boldsymbol{\Sigma}$ allows for correlation between the disturbances of these equations. The elements of the $NT \times (M_g + K_g)$ matrix $\mathbf{W}_g$ represent both the M_g endogenous variables and K_g

exogenous variables included in the right-hand side of the equations. The system can be estimated by tree-stage least squares as described in Greene (2000).

An important issue following from the estimation of simultaneous equations systems is the restrictions that can be placed on the structural form in order to identify parameters. Such restrictions are known to be the so-called "order condition". We set the discussion about the identification of our system in the next section, when presenting estimation results.

5 Estimation results

In this section, we use all the materials sketched above to evaluate empirically the determinants of the relationship between the economic performance and the environmental performance at firm level.[18] In addition to the variables presented in Table A1, we add the square of some of them in order to account for non-linearities. This is the case for firm size, economic performance indicators and environmental performance indicators. In the sequel, we present firstly the results for the separated regressions and then, we present estimates based on simultaneous equations system.

5.1 Separated equations

The results for pooled model and three-error-components model for economic performance indicators (ROCE, ROE and ROS) are reported in Tables 4 and 5, respectively. Results attached the same specifications for pollutant emissions (NO_x, SO_2 and COD) are presented in Tables 6 and 7, respectively. Estimation results for the environmental index are presented in Table 8.

Tables 4 and 5 about here
Tables 6-8 about here

For the three-error components models, we also present a Breusch and Pagan's (1980) test for the existence of random effects. This gives a Lagrange-

[18] Estimation procedures in GAUSS and STATA are available from the authors upon request.

multiplier statistic which has a χ^2 distribution. Three test statistics are computed corresponding to the following three null hypotheses: $H_0^1 : \sigma_\mu^2 = 0$ (non existence of random firm effect, $\chi^2_{(1)}$), $H_0^2 : \sigma_\lambda^2 = 0$ (non existence of random year effect, $\chi^2_{(1)}$) and $H_0^3 : \sigma_\mu^2 = \sigma_\lambda^2 = 0$ (non existence of both random firm and random year effects, $\chi^2_{(2)}$). The last test statistic is the sum of the first two. As reported in Tables 5, 7 and 8, we find that the random firm effect and then the joint random firm and random year effects specifications cannot be rejected in most cases (null hypotheses rejected at 5% or 10% level). However, there is no evidence of a random year effect model in all cases.

Concerning economic performance of firms, results indicate that the linear term of firm size has a significant and positive effect on ROE only for the pooled regression. Firm size has no significant effect on the other economic performance variables in both econometric specifications (pooled and random effects). Both, the inverse of the solvency ratio minus one (SR_1), as well as the asset-turnover ratio (i.e. the inverse of the turnover-to-asset ratio) have a significant effect on ROCE (10% level) and on ROS (5% level) in the pooled model. In the random effects model, SR_1 has a significant effect at the 5% level on ROS and ROE, but not on ROCE, whereas the asset-turnover ratio is significant only for ROCE at the 10% level. The inverse of the solvency minus one and the asset-turnover ratio have opposite signs for ROCE and ROS in both models. In other words, the inverse of the solvency ratio minus one (the asset-turnover ratio) is positive (negative) for ROCE, but negative (positive) for ROS, whereas they are always negative for ROE. The non-significance of SR_1 (as a proxy measure for leverage) in the case of ROCE for the random effects model is more in-line with theoretical reasoning, than the result of the pooled model, since theoretically ROCE in the way it is calculated is already controlled for capital structure.

Concerning sub-sector dummy variables (with the cultural sub-sector being used as the reference group), no significant effect was found, neither in the pooled model, nor in the random effects model. Regarding country dummy variables (with Germany being used as the reference group), the United Kingdom, Italy and the Netherlands were found to be significant and positive in the pooled regressions for some economic performance variables.

However, for Italy and the Netherlands, as well as for the United Kingdom in the case of ROS and ROE, the significant effects in the pooled model become insignificant in the random effects model. Only the positive effect of the United Kingdom (compared to Germany) dummy on ROCE remains significant at the 5% level, whichever econometric specification is applied.

Concerning environmental performance of firms, firm size is found to have no significant effect on any individual environmental performance variable (NO_x, SO_2 and COD) as well as the environmental index based on these individual variables, regardless of the econometric specification. SO_2 emissions were found to be negatively and significantly sensitive to firm membership in the mixed sub-sector, -6.824 at the 10% level in the pooled regression and -6.912 at the 5% level in the random effects model. Also, a positive and significant mixed and industrial sub-sector influence was found for COD emissions (in both econometric specifications) as well as a negative and significant influence on the environmental index (for the pooled regression model only).

Regarding country dummy variables (Gemany being considered as the reference country), country location of firms in the Netherlands was found to have a positive and significant influence on SO_2 and COD emissions. Country location of firms in the United Kingdom and Italy was found to have a significant positive (the United Kingdom) and negative (Italy) effect, respectively, on COD emissions. The influence is significant at the 10% and 5% level for the random effects and pooled regression model, respectively. For the environmental index, the United Kingdom and Italy were also found to have a negative (the United Kingdom) and positive (Italy) influence which is significant at the 5% level.

5.2 Simultaneous equations

Earlier, we have pointed out that identification issue is crucial when estimating simultaneous equations system. Before presenting the results, we now discuss this question. In order to achieve identification of each equation in the simultaneous system we have to look for the order condition which requires that the number of exogenous variables excluded from this equation must be at least as large as the number of endogenous variables included (see, e.g., Greene, 2000, Chapter 16).

Using the same notations as in Section 4, our system consist in $G = 2$ equations, the first one is for economic performance indicators (ROCE, ROS or ROE) and the second one is for the environmental index (the log of INDEX). Then we have to estimate three independent systems in total. In each system, we have four endogenous variables: two linear terms and their squares. The exogenous variables in each system are: firm size, the inverse of the solvency ratio minus one (SR_1), the asset-turnover ratio, country dummies, and sub-sector dummies. To meet the identification order condition we have to exclude some exogenous variables from each equation of the system. As in the separated regressions, we exclude SR_1 and the asset-turnover ratio from the environmental equation. Moreover, we decided to exclude the sub-sector dummies from the environmental equation while the country dummies are excluded from the economic equation. We also include from the environmental (economic) equation the linear and the square term of economic performance indicator (environmental index). Therefore, for the economic equation, there are two included endogenous variables against three excluded exogenous variables. For the environmental equation, there are two included endogenous variables against five excluded exogenous variables. Hence, the above identification condition is met.

The inclusion and the exclusion of country and sub-sector dummies in the system are motivated by preliminary estimations based on a system where sub-sector dummies are used as regressors in the environmental equation and where country dummies are excluded. In these preliminary estimations, we included country dummies in the economic equation (with sub-sector dummies being excluded). Other variables are used as described before. As above, there are also three independent systems to be estimated. This preliminary estimations provided us with no significant effects at 5% level for almost all parameters in all systems, excepted for the industrial sub-sector dummy in the environmental equation for the system given by ROS and log(INDEX).

We use the environmental index in each system in place of environmental performance indicators (NO_x, SO_2, and COD) separately. Indeed, this index seems to be a better global measure of environmental performance than each environmental indicator taken separately. Another important justification of the use of this index is that if we used separately NO_x, SO_2, and COD in the equations systems, we can only estimate a partial relationship between economic performance and environmental performance. For example, the system given by COD and ROCE does not take into account the interaction between NO_x, SO_2 and ROCE. However, these indicators could interact simultaneously with economic performance. Therefore, we propose to model such interaction in a simultaneous equations system for economic performance and the environmental index. The estimation results for the retained equation system are reported in Tables 9–11.

Tables 9–11 about here

Let us consider firstly the economic equations (ROCE, ROE, and ROS). We observe that the environmental index (both its linear and square terms) has a positive and significant (at 10% and 5% level, respectively) effect on ROCE but has no effect on the other economic performance indicators. In Figure 6, we plot the estimated relationship between ROCE and log(INDEX). The graph displays a U-shape curve. However, the increasing part of the curve is not robust due to few observations. Then only the decreasing part might be considered. This decreasing part shows a relation with a negative first derivative and a positive second derivative. This finding seems more consistent with "traditionalist" reasoning about the relationship between environmental and economic performance, which predicts the relationship to be uniformly negative (see Section 2, Figure 1). This result shows evidence of a trade-off between return on capital employed and environmental performance. Implications of this result will be discussed later.

Figure 6 about here

Firm size has no significant influence on our three economic performance variables. SR_1 in the ROCE equation is positive and significant at 5% level. This is however inconsistent with theory, since ROCE is theoretically already controlled for gearing. It is insignificant in other economic equations.

For the asset-turnover ratio, we obtain a negative and significant impact at 10% level on ROCE, and a positive and significant impact at 5% level on ROS while no relationship is found for ROE.

Concerning sub-sector dummies in the economic equations (remember that country dummies are excluded from this equation for identification purpose), industrial and mixed sub-sector have a significant effect at 10% and 5%, respectively, on ROS. This effect is negative. Then firms in these two sub-sectors have less return on sales than firms in the cultural sub-sectors (reference), all other things being equal.

Now we discuss the results following from the environmental equation. There is no evidence of significant relationship between economic performance variable and the log of the environmental index. The same conclusion applies to firm size. About country dummies (sub-sector dummies are excluded from the environmental equation), United Kingdom located firms have negative and significant effect on log(INDEX) in the system with ROCE (10% level) and in the system with ROS (5% level). Italy located firms influence positively and significantly at 5% level log(INDEX) in the system with ROS. As a result, from an environmental point of view, we can conclude that United Kingdom and Italy located firms perform respectively less and more than Germany ones. This may indicate a selection bias towards better-performing firms in Italy (likely as a result of self-selection).

In Tables 9–11, we also report the F-statistics to test the significancy of each equation in each system. The environmental equation is significant at 5% level in all systems, excepted for the system defined by ROCE and log(INDEX) which is significant at 10% level. The economic equation is significant only for ROS.

6 Conclusions and Recommendations

As noticed in Section 3, the data sample covers a low proportion of Italian firms. We also know that the environmental regulation is less stringent in Italy than in other countries (notably Germany). So the better environmental performance of Italian firms (in both separated and simultaneous regressions) is an unexpected result and we think that it should be treated carefully.

The hypothesis H1 seems to be confirmed, since, relative to Germany, other country dummies have a positive and significant effect on economic performance in the pooled regressions. This can be interpreted in a way that a strong country effect for economic performance exists, which can be interpreted as higher costs of environmental regulation since economic performance is relatively lower in Germany than in the other three countries. However, it has to be noted that most country effects become insignificant in the random effects model (except for the UK), thus indicating that any reduction of competitiveness through stringent environmental regulation has to be considered carefully with regard to other (random) influences on the economic performance of firms.

With regard to environmental performance, H1 seems to be confirmed in that there are some significant positive country effects for COD, SO_2 and the environmental index (i.e. significant and positive coefficients for the Netherlands and the United Kingdom). This can be interpreted as a better environmental performance of firms in Germany, relative to the other countries. Consistent with this is also the reversal of the coefficient signs in the case of the environmental index for the UK(since for the index, high values represent good performance, whereas the inverse is the case for the individual environmental performance variables). However, the country influences found for Italy for the index and for COD are inconsistent with H1. Therefore, (i) the influence of stringent environmental regulation on the environmental performance of firms seems to be sensitive to the specific measure for environmental performance and (ii) in the case of Italy, the selection of firms may have been biased towards the better environmental performers.

The Hypothesis H2 seems to be confirmed only to some degree, since the analysis found positive and significant coefficients for the United Kingdom and the Netherlands in the case of all economic performance variables in the pooled regression. Given that the Netherlands and the UK are rated highest with regard to the use of flexible (i.e. economic) instruments in Table 1 this result is as expected. However, it has again to be noted that (i) most effects become insignificant in the random effects model and that (ii) in the pooled regressions also Italy has a significant country effect on ROE, which is counter to the ranking in Table 1. Therefore, economic instruments seem to have a less negative/more positive influence on economic performance, but again, random effects seem to have some influence. In addition to this, there is of course some interdependence between hypotheses H1 and H2. In summary, the relationship between environmental and economic performance as predicted in H1 and H2 only holds in direct comparisons of Germany and the UK for ROCE, COD and the environmental index (based on the random effect model).

Hypothesis H3 is confirmed in the case of the environmental performance variables. The findings regarding sub-sector influences on environmental performance variables are consistent with the strong sub-sector effect found by Berkhout et al. (2001b). However, the fact that some of the sub-sector influences become insignificant in the random effects model indicates that do not account for unobservable firm heterogeneity in the pooled regression might have artificially increased significance levels for sub-sector influence in some cases. Regarding the economic performance variables, no significant sub-sector effect could be found.

Regarding hypothesis H4 it was found that there is almost no significant effect of firm size on either economic or environmental performance, the only exception being a positive and significant effect of the linear term for firm size on ROE in the case of pooled regression, which however becomes insignificant for the random effects model. This confirms H4 with regards to economic performance (where no significant effect was expected), but also indicates that there seems to be no substantial difference in environmental performance between smaller and larger firms. This means that the often perceived differences between SMEs and large firms are likely smaller than stated in the literature and that (given that the insignificance of firm size on economic performance was confirmed) the a priori assumption that smaller firms tend to have a less positive relationship between environmental and economic performance has to be considered carefully. At least the data analysed here does not provide an indication that smaller firms cannot achieve as easily economies of scale in environmental management as larger ones. Differences of cross-sectional variances were only analysed qualitatively based on scatterplots for 95-97 averages.[19] Scatterplots indicate decreasing variance with increasing firm size for ROS, ROCE, COD, NO_x and SO_2. This might indicate a higher variation in the relationship between environmental and economic performance for smaller firms.

What the separated regressions did not take into account is the possible endogeneity of the relationship between environmental and economic performance. The mutual influences between environmental and economic performance were therefore addressed by means of three simultaneous equations systems. For these, it was found that the results -for the system with ROCE as economic performance variable, only- were more consistent with the "traditionalist" view, than with the "revisionist" perspective on the relationship between environmental and economic performance. However results are not very clear-cut, in that similar results could not be found for the systems with ROS and ROE as economic performance variables, respectively.

The important question is of course at this point, what these findings imply for the relationship between environmental and economic performance. There seem to be two main conclusions. Firstly, there seems to be considerable influence of noise in the data. Environmental and economic performance can be influenced by many more factors than those included in the theoretical framework. Although it was attempted to keep the influence of these other factors constant, we have no definite benchmark indicating to which degree this was achieved. Given that the signal of environmental performance as an influence on economic performance is small, it would be desirable to utilize, in a next research step, more direct measures capturing the relationship between environmental and economic performance. One way to achieve this could e.g. be the separation of some "green profit" component from the overall economic performance of a firm. Secondly, even though some of the findings for the simultaneous equation systems fit better with "traditionalist" reasoning about the relationship between environmental and economic performance, which predicts the relationship to be uniformly negative, both theoretical models presented in the beginning of the paper are not well-supported by the results. This element of inconclusiveness in the

[19]Scatterplots are available from the authors on request.

results will likely be reduced if a more direct measure of that part of a firm's overall profitability which is the result of its environmental performance (or improvements thereof) can be devised and applied.

7 Appendix

7.1 Appendix 1: Variable definition and descriptive statistics

Table A1: Definition of variables.

	Variable	Description	Type[a]
Economic performance	ROCE	Return on capital employed	cont.
	ROE	Return on equity	cont.
	ROS	Return on sales	cont.
Environmental performance	COD	Emissions of chemical oxygen demand (tonnes per tonne, t/t)	cont.
	SO_2	Emissions of sulphur dioxide (t/t)	cont.
	NO_x	Emissions of nitrogen oxides (kilo t/t)	cont.
	Log(INDEX)	Log of the environmental index (dimensionless)	cont.
Control variables	Firm size	Number of employees (thousand)	int.
	SR_1	Inverse of solvency ratio minus one (%)	cont.
	Asset-turnover ratio	Inverse of the turnover-to-asset ratio (Great Britain Pounds GBP/GBP)	cont.
Country	United Kingdom	United Kingdom located firm	dum.
	Italy	Italy located firm	dum.
	Netherlands	Netherlands located firm	dum.
	Germany	Germany located firm	dum.
Sub-sector	Cultural	Newsprint, magazine-grade, and graphics fine paper (reference)	dum.
	Industrial	Packaging corrugated and other boards	dum.
	Mixed	Cultural and industrial paper production	dum.
	Other	Other paper production	dum.

[a] cont., int., and dum. mean respectively continuous type, integer type (treated in the estimations as continuous) and dummy type variables.

Table A2: Descriptive statistics for year 1995

Variable	Mean	Std.Dev.	Min	Max.	#obs.
ROCE	0.155	0.217	-0.1254	1.043	32
ROE	0.1278	0.2088	-0.2713	0.7032	33
ROS	0.0422	0.0664	-0.0711	0.2321	33
COD	7.9413	8.5049	0.2902	27.2964	28
SO_2	3.3497	9.559	0	49.1401	28
NO_x	0.0020	0.0047	0	0.0256	30
INDEX	0.1449	0.3383	0.0008	0.9886	22
Log(INDEX)	-4.3993	2.19	-7.138	-0.0115	22
Firm size	0.6873	0.6907	0.119	3.548	33
SR_1	2.7423	2.1846	0.2174	11.0048	33
Asset-turnover ratio	1.0285	0.919	0.4366	5.6249	33
United Kingdom	0.2571	0.4435	0	1	35
Italy	0.2	0.4058	0	1	35
Netherlands	0.2571	0.4435	0	1	35
Germany	0.2857	0.4583	0	1	35
Industrial	0.1714	0.3824	0	1	35
Cultural	0.4571	0.5054	0	1	35
Mixed	0.2571	0.4434	0	1	35
Other	0.1143	0.3228	0	1	35

Table A3: Descriptive statistics for year 1996

Variable	Mean	Std.Dev.	Min	Max.	#obs.
ROCE	0.113	0.1552	-0.3641	0.5582	31
ROE	0.1326	0.2364	-0.514	0.7951	32
ROS	0.0502	0.0807	-0.1264	0.254	32
COD	9.9113	15.7274	0.3301	80.057	28
SO_2	3.4133	10.105	0	51.9481	28
NO_x	0.002	0.0056	0	0.3070	29
INDEX	0.139	0.3318	0.0007	0.9883	23
Log(INDEX)	-4.5607	2.2535	-7.3214	-0.0118	23
Firm size	0.6913	0.7564	0.132	4.019	33
SR_1	2.3952	1.4604	0.3203	5.1162	32
Asset-turnover ratio	1.1476	0.7207	0.4187	3.5352	32
United Kingdom	0.2647	0.4478	0	1	34
Italy	0.2059	0.4104	0	1	34
Netherlands	0.2353	0.4306	0	1	34
Germany	0.2941	0.4625	0	1	34
Industrial	0.1765	0.387	0	1	34
Cultural	0.4412	0.504	0	1	34
Mixed	0.2647	0.4478	0	1	34
Other	0.1176	0.3270	0	1	34

Table A4: Descriptive statistics for year 1997

Variable	Mean	Std.Dev.	Min	Max.	#obs.
ROCE	0.0982	0.0872	-0.1146	0.346	29
ROE	0.0776	0.2334	-0.8601	0.5338	32
ROS	0.0213	0.1213	-0.5316	0.1902	33
COD	41.3956	187.1874	0.4293	1082.353	33
SO_2	2.4419	8.9888	0	49.6278	31
NO_x	1.1192	4.8961	0	26.4546	33
INDEX	0.1189	0.3028	0.0007	0.9879	28
Log(INDEX)	-4.4283	2.0578	-7.26	-0.0121	28
Firm size	0.6273	0.6827	0.11	3.697	36
SR_1	2.2948	1.5828	0.2425	5.8823	33
Asset-turnover ratio	1.0452	0.5665	0.3792	2.9673	32
United Kingdom	0.2432	0.435	0	1	37
Italy	0.2432	0.435	0	1	37
Netherlands	0.2432	0.435	0	1	37
Germany	0.2703	0.4502	0	1	37
Industrial	0.1892	0.3971	0	1	37
Cultural	0.4324	0.5022	0	1	37
Mixed	0.2432	0.435	0	1	37
Other	0.1351	0.3466	0	1	37

Appendix 2: Maximum likelihood estimation of the separated equations

To simplify notation, we denote $\bar{\mathbf{x}} = [\mathbf{x}, \mathbf{z}]$, and $\bar{\boldsymbol{\beta}} = [\boldsymbol{\beta}', \boldsymbol{\gamma}']'$ the proper stacked format of time-varying as well as time-invariant regressors and related vector of parameters, where the intercept term is excluded by tacking deviations from the overall sample mean. Then, on the assumption that $\mathbf{u} \sim N(0, \boldsymbol{\Omega})$, with

$$\boldsymbol{\Omega} = E(\mathbf{u}\mathbf{u}') = \sigma^2_\mu(\mathbf{I}_N \otimes \mathbf{J}_T) + \sigma^2_\lambda(\mathbf{J}_N \otimes \mathbf{I}_T) + \sigma^2_\varepsilon \mathbf{I}_{NT}, \tag{9}$$

the joint log likelihood of the observations $\mathbf{y}$, conditional on the values of $\mathbf{x}$ can be expressed as

$$\begin{aligned} L(\mathbf{y}|\mathbf{x},\bar{\boldsymbol{\beta}},\sigma^2,\rho,\omega) &= -\frac{NT}{2}\left(\ln 2\pi + \ln\sigma^2\right) - \frac{1}{2\sigma^2}(\mathbf{y}^*-\bar{\mathbf{x}}^*\bar{\boldsymbol{\beta}})'(\mathbf{y}^*-\bar{\mathbf{x}}^*\bar{\boldsymbol{\beta}}) \\ & -\frac{1}{2}\ln\left[\det\left(\xi_1\mathbf{B}_N + \xi_2\mathbf{B}_T + \xi_3\mathbf{W}\right)\right], \end{aligned} \tag{10}$$

where $\xi_1 = (1-\rho-\omega-T\rho)$, $\xi_2 = (1-\rho-\omega-N\omega)$, $\xi_3 = (1-\rho-\omega)$; and $\sigma^2 = \sigma_\mu^2+\sigma_\lambda^2+\sigma_\varepsilon^2$, $\rho = \sigma_\mu^2/\sigma^2$, $\omega = \sigma_\lambda^2/\sigma^2$, $\xi_3 = \sigma_\varepsilon^2/\sigma^2$. The matrix notations are completed as $\mathbf{B}_N = (\mathbf{I}_N - \frac{\mathbf{J}_N}{N}) \otimes (\frac{\mathbf{J}_N}{T})$, $\mathbf{B}_T = \frac{\mathbf{J}_N}{N} \otimes (\mathbf{I}_T - \frac{\mathbf{J}_T}{T})$, $\mathbf{W} = (\mathbf{I}_N - \frac{\mathbf{J}_N}{N}) \otimes (\mathbf{I}_T - \frac{\mathbf{J}_T}{T})$, $\mathbf{y}^* = (\boldsymbol{\Omega}^*)^{-1/2}\mathbf{y}$ and $\bar{\mathbf{x}}^* = (\boldsymbol{\Omega}^*)^{-1/2}\bar{\mathbf{x}}$, where $(\boldsymbol{\Omega}^*)^{-1/2}$ is the squared root matrix which yields the proper spectral decomposition representation of $\boldsymbol{\Omega}$ (Wansbeek and Kapteyn, 1982, 1983).

The log likelihood function can be concentrated in terms of the parameters ρ and ω by fixing these and maximizing out $\bar{\boldsymbol{\beta}}$ and σ^2. The GLS estimate that maximizes $\bar{\boldsymbol{\beta}}$ is given by

$$RSS(\rho,\omega) = \min_{\bar{\boldsymbol{\beta}}\in\boldsymbol{\Theta}} (\mathbf{y}^*-\bar{\mathbf{x}}^*\bar{\boldsymbol{\beta}})'(\mathbf{y}^*-\bar{\mathbf{x}}^*\bar{\boldsymbol{\beta}})$$

and the value of σ^2 which maximizes the log likelihood conditional on ρ and ω is

$$\hat{\sigma}^2 = \frac{RSS(\rho,\omega)}{NT}.$$

As a result, the concentrated log-likelihood function is a function only in arguments ρ and ω and can be maximised with respect those parameters by grid search or steepest ascent methods. For details on this computation, see Nerlove (1999).

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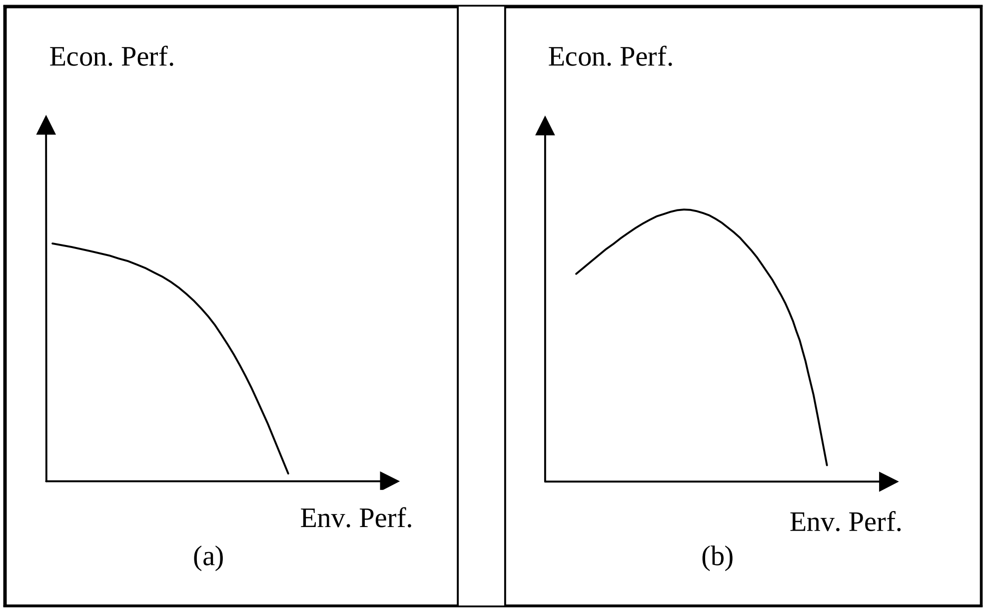

Figure 1: (a) the “traditionalist” view; (b) the “revisionist” view.

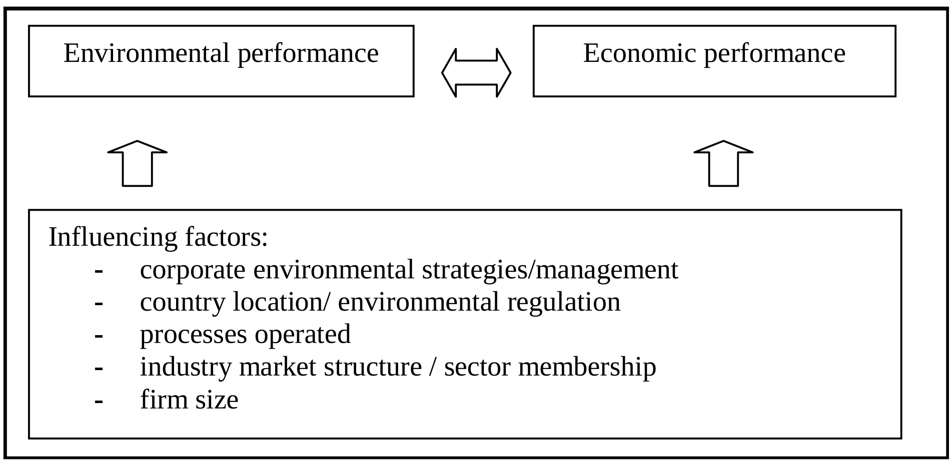

Figure 2: Initial model for the interaction of environmental and economic performance.

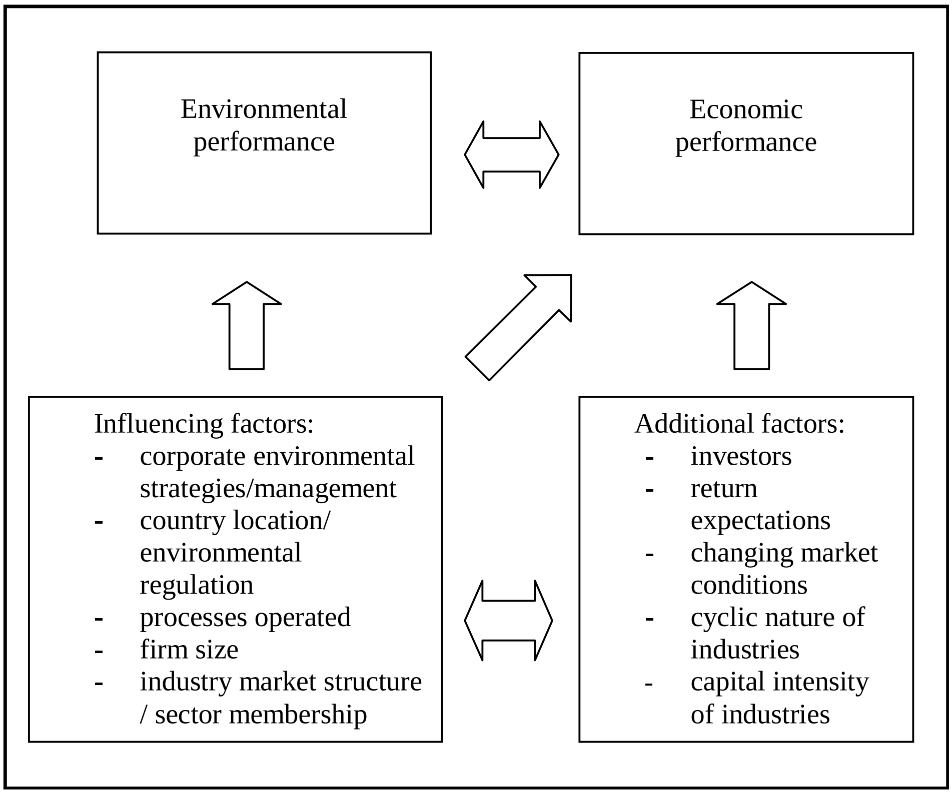

Figure 3: Expanded model for the interaction of environmental and economic performance.

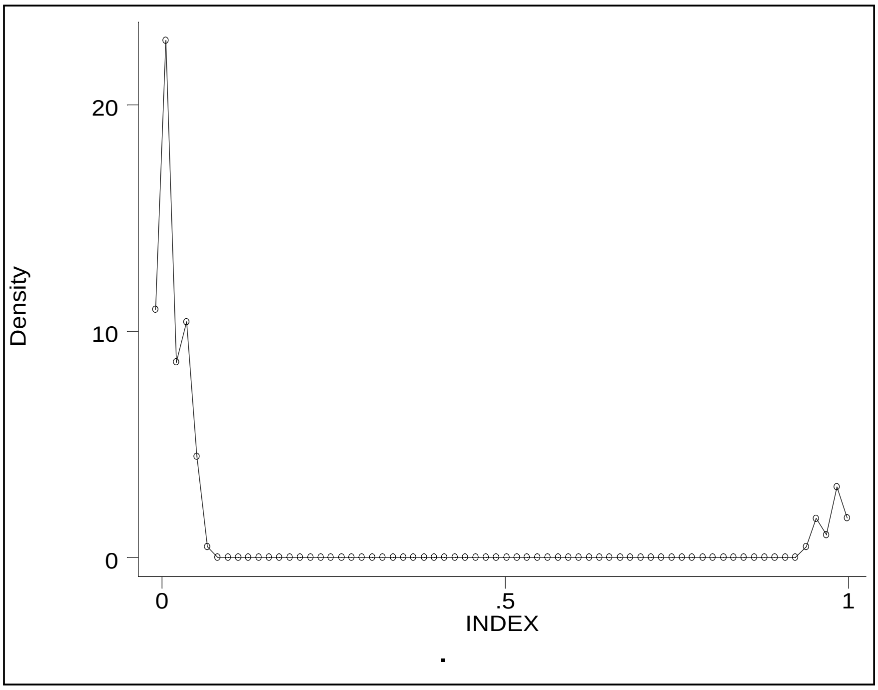

Figure 4: Kernel density estimate of INDEX for the pooled data. High frequencies for extreme values are observed.

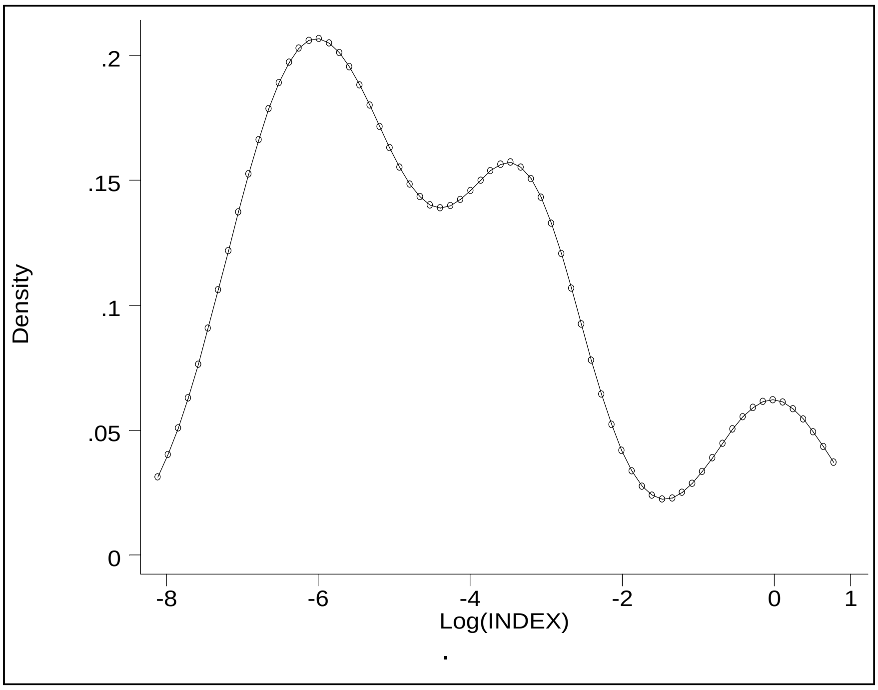

Figure 5: Kernel density estimate of log(INDEX) for the pooled data. Tri-modal distribution underlying the environmental index. Positive values of log(INDEX) displayed on the abscissa are due to graphical rescaling.

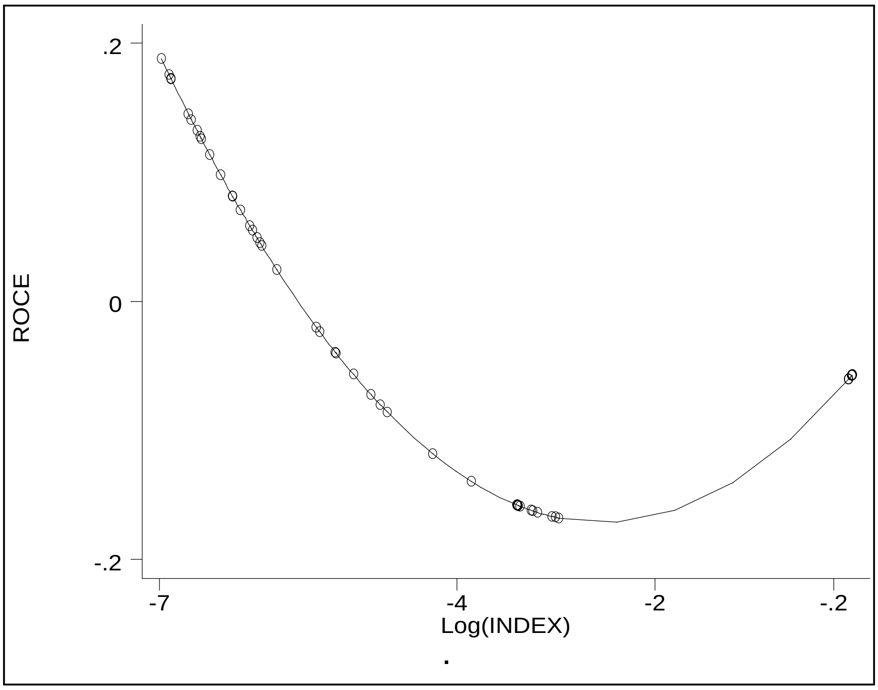

Figure 6: The relationship between ROCE and log(INDEX) obtained from the estimation of the simultaneous equations system.

Table 1: Stringency of regulation and orientation towards economic instruments in four countries

Country	Germany	Italy	Netherlands	UK
Stringency of regulation	1.82	0.25	1.53	0.99
(rank, 1 = highest) [a]	(1)	(4)	(2)	(3)
Use of flexible instruments				
(rank, 1= highest) [b]	(3)	(4)	(1)	(2)
Transparency of regulation	4.1	2.8	4.4	4.5
(rank, 1= highest) [c]	(3)	(4)	(2)	(1)
Innovation through regulation	0.7	-0.50	1.34	1.18
(rank, 1= highest) [d]	(3)	(4)	(1)	(2)
Regulatory and management	1.34	0.08	0.75	1.54
indicator [e]	(2)	(4)	(3)	(1)
Regulatory regime	1.205	0.035	1.623	1.087
index [f]	(2)	(4)	(1)	(3)

[a] Data of the measure “Stringency and consistency of environmental regulation, in 2000” in WEF et al. (2001). [b] Ranking is based on authors assessment of how much a country applies voluntary or economic instruments. [c] Data of the measure “Transparency and stability of environmental regulation, in 1999” in WEF et al. (2000). [d] Data based on measure “Degree to which environmental regulation promotes innovation, measured in 2000” in WEF et al. (2001). [e] Data based on “Regulation and management indicator” in WEF et al. (2001) which comprises of the measure “Stringency and consistency of environmental regulation, in 2000” in WEF et al. (2001) as one component. [f] Data of the index is based on Esty and Porter (2001). The index assesses stringency of standards, subsidies, regulatory enforcement, regulatory structure, information and environmental institutions.

Table 2: Data distribution and EMS certification across countries (out of total of firms in data set)

Year		Germany	Italy	Netherlands	UK	Total
1995	Total	10	7	9	9	35
	ISO 14001	1/10	0/7	1/8	0/9	2/34
1996	EMAS	3/10	0/7	0/8	1/9	4/34
	Total EMS	3/10	0/7	1/8	1/9	5/34
	ISO 14001	5/10	1/9	4/9	6/9	16/37
1997	EMAS	6/10	0/9	1/9	1/9	8/37
	Total EMS	7/10	1/9	4/9	6/9	18/37

Table 3: Environmental performance indicators used (all per tonne of paper produced)

Indicators name	Definition (MEPI, 2000)	Relevance (MEPI, 2000)	Unit	Relevance data sources
NO_x emissions (non-product outputs to air of nitrogen oxides) per production output	Emissions of NO_x comprising both, NO and NO_2, measured as NO_2	Acidification, local air pollution	Kilo tonnes per tonne of paper per annum	Environmental reports verified under EMAS or ISO, pollution inventories, surveys
SO_2 emissions (non-product outputs to air of sulphur dioxide) per production output	Emissions of sulphur dioxide from production processes	Acidification, local air pollution	Tonnes per tonne of paper per annum	As above
COD emissions (non-product outputs to water (before treatment) of chemical oxygen demand, COD) per production output	Annual chemically determined demand of oxygen from waste water contaminants discharged	COD of waste water (before treatment) measures the potential to cause waterway pollution from de-oxygenation	Tonnes per tonne of paper per annum	As above

Table 4: Separated estimation results for pooled (deviations from overall means) data for **economic performance**

Dependent variable	ROCE [a]		ROS [b]		ROE [c]	
Independent variable	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err.
Firm size	0.0688	0.0843	0.0531	0.037	**0.3078**	0.1295
Square of firm size	-0.008	0.0197	-0.0066	0.0087	-0.045	0.0303
SR_1 [d]	0.0226	0.0133	**-0.0166**	0.0052	-0.01	0.0182
Asset-turnover ratio	-0.0418	0.0226	**0.035**	0.001	-0.0176	0.0349
Other sub-sector	-0.0364	0.0818	0.0041	0.0271	0.0018	0.0949
Industrial sub-sector	0.0062	0.0526	0.0033	0.0202	-0.0227	0.0706
Mixed sub-sector	-0.0026	0.0389	-0.0246	0.0176	-0.0164	0.0617
United Kingdom	**0.1979**	0.0524	0.0432	0.0232	**0.2002**	0.081
Italy	0.1117	0.0729	0.0267	0.0325	**0.2542**	0.1137
Netherlands	0.1003	0.0577	**0.0634**	0.0256	**0.2427**	0.0894
#obs.	69		78		78	

[a] Return on capital employed; [b] return on sales; [c] return on equity; [d] inverse of solvency ratio minus one. Bold and italic figures mean significancy at 5% and 10% level respectively.

Table 5: Random effects separated estimation results for **economic performance**

Dependent variable	ROCE [a]		ROS [b]		ROE [c]	
Independent variable	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err.
Firm size	0.0706	0.1031	0.0383	0.0513	0.2725	0.1882
Square of firm size	-0.0069	0.0241	-0.0025	0.012	-0.0304	0.0442
SR_1 [d]	0.012	0.017	**-0.024**	0.0064	**-0.0888**	0.0275
Asset-turnover ratio	-0.0468	0.0257	0.0104	0.0115	-0.0588	0.0383
Other sub-sector	-0.0487	0.104	-0.0131	0.0447	-0.0864	0.1711
Industrial sub-sector	0.0256	0.0667	0.004	0.0315	0.0717	0.12
Mixed sub-sector	-0.0014	0.0494	-0.0292	0.0291	-0.0101	0.111
United Kingdom	**0.1985**	0.0653	0.0542	0.0358	0.1838	0.1354
Italy	0.1214	0.0911	0.0443	0.0497	0.3007	0.1869
Netherlands	0.0941	0.0725	0.0566	0.0396	0.1396	0.1515
Full log-likelihood	12.66		86.5		-12.34	
#obs.	69		78		78	
Breusch-Pagan test [e]						
– firm effect	0.2251		**9.605**		**5.374**	
– year effect	0.3389		0.4545		0.4158	
– firm & year effects	0.564		**10.06**		5.789	

[a] Return on capital employed; [b] return on sales; [c] return on equity; [d] inverse of solvency ratio minus one; [e] Breusch and Pagan's (1980) test is a Lagrange-multiplier test. Bold and italic figures mean significancy at 5% and 10% level respectively.

Table 6: Separated estimation results for pooled (deviations from overall means) data for **environmental performance**

Dependent variable	NO_x [a]		SO_2 [b]		COD [c]	
Independent variable	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err.
Firm size	-1.584	1.613	6.576	5.659	-1.962	2.293
Square of firm size	0.3827	0.3974	-1.81	1.377	0.6122	0.7321
Other sub-sector	-0.3416	1.094	-3.849	3.764	0.5147	2.217
Industrial sub-sector	1.283	0.8628	-4.418	3.154	**6.187**	1.799
Mixed sub-sector	0.4239	0.9571	-6.824	3.449	**11.93**	1.761
United Kingdom	0.8729	0.9628	3.593	3.386	**5.726**	1.991
Italy	-0.9709	1.22	3.094	5.28	**-5.229**	2.033
Netherlands	-0.7865	0.9927	**9.552**	3.45	**5.706**	2.037
#obs.	81		72		78	

[a] Emissions of nitrogen oxides per production output, [b] emissions of sulphur dioxide per production output, [c] emissions of chemical oxygen demand per production output. Bold and italic figures mean significancy at 5% and 10% level respectively.

Table 7: Random effects separated estimation results for **environmental performance**

Dependent variable	NO_x [a]		SO_2 [b]		COD [c]	
Independent variable	Coef.	Std.Err.	Coef.	Std.Err.	Coef.	Std.Err.
Firm size	-1.384	1.889	5.542	5.388	-2.184	3.166
Square of firm size	0.3403	0.4651	-1.557	1.308	0.5637	0.7725
Other sub-sector	-0.3016	1.312	-4.023	3.811	0.3158	3.689
Industrial sub-sector	1.31	1.034	-4.543	3.197	**6.047**	2.955
Mixed sub-sector	0.439	1.147	**-6.912**	3.501	**11.83**	2.918
United Kingdom	0.9256	1.153	3.385	3.412	5.415	3.148
Italy	-0.8898	1.449	2.645	5.29	-5.483	3.249
Netherlands	-0.7206	1.185	**9.283**	3.463	5.421	3.239
Full log-likelihood	-239.6		-252.2		-231.1	
#obs.	81		72		78	
Breusch-Pagan test[d]						
– firm effect	1.05		**67.76**		**60.97**	
– year effect	0.14		1.429		1.146	
– firm & year effects	1.19		**69.19**		**62.12**	

[a] Emissions of nitrogen oxides per production output; [b] emissions of sulphur dioxide per production output; [c] emissions of chemical oxygen demand per production output; [d] Breusch and Pagan's (1980) test is a Lagrange-multiplier test. Bold and italic figures mean significancy at 5% and 10% level respectively.

Table 8: Separated estimation results for the **environmental index** (log(INDEX))

	Pooled regression		Random effect regression	
Independent variable	Coef.	Std.Err.	Coef.	Std.Err.
Firm size	-0.9117	1.084	-0.4559	0.8553
Square of firm size	0.0711	0.242	0.0168	0.1927
Other sub-sector	0.1239	0.9149	0.2184	1.413
Industrial sub-sector	-0.8873	0.514	-0.758	0.769
Mixed sub-sector	**-1.245**	0.5714	-1.132	0.8762
United Kingdom	**-2.832**	0.6869	**-2.505**	0.8859
Italy	**3.658**	0.9681	**4.082**	1.21
Netherlands	-0.2405	0.7002	0.0804	0.9028
Full log-likelihood	–		-79.56	
#obs.	57		57	
Breusch-Pagan test[a]				
– firm effect	–		**48.25**	
– year effect	–		1.403	
– firm & year effects	–		**49.66**	

[a] Breusch and Pagan's (1980) test is a Lagrange-multiplier test. Dependent variable: log(INDEX). Bold and italic figures mean significancy at 5% and 10% level respectively.

Table 9: Estimation results for simultaneous equations system for ROCE and log(INDEX)

Equation	ROCE [a]		Log(INDEX) [b]	
Variable	Coef.	Std. Err.	Coef.	Std. Err.
Log(INDEX)	0.0914	0.0545	–	–
Square of log(INDEX)	**0.0181**	0.0084	–	–
ROCE	–	–	51.6494	38.2312
Square of ROCE	–	–	-54.2385	41.4976
Firm size	-0.1423	0.1138	-6.3224	4.9631
Square of firm size	0.0296	0.0269	0.9328	0.923
SR_1 [c]	**0.0564**	0.0241	–	–
Asset-turnover ratio	-0.0694	0.0416	–	–
Other sub-sector [d]	–	–	–	–
Industrial sub-sector	-0.0817	0.1028	–	–
Mixed sub-sector	-0.0895	0.0701	–	–
United Kingdom	–	–	-7.2846	3.9781
Italy	–	–	-3.0111	5.2966
Netherlands	–	–	-3.1919	2.7302
Intercept	0.0523	0.1082	-0.7123	3.2005
#obs.	51		51	
F-stat.	1.234		1.7731	

[a] Return on capital employed; [b] log of environmental index (INDEX), computed as described in Section 3; [c] inverse of solvency ratio minus one; [d] there are no observations in this sub-sector. Endogenous variables: ROCE, log(INDEX), square of ROCE, square of log(INDEX); exogenous variables: firm size, square of firm size, SR_1, asset-turnover ratio, other sub-sector, industrial sub-sector, mixed sub-sector, United Kingdom, Italy, Netherlands. Bold and italic figures mean significancy at 5% and 10% level respectively.

Table 10: Estimation results for simultaneous equations system for ROE and log(INDEX)

Equation	ROE [a]		Log(INDEX) [b]	
Variable	Coef.	Std. Err.	Coef.	Std. Err.
Log(INDEX)	0.0243	0.0649	–	–
Square of log(INDEX)	0.0037	0.0093	–	–
ROE	–	–	15.67	14.4732
Square of ROE	–	–	4.0698	6.9357
Firm size	0.083	0.1273	-3.4321	7.5529
Square of firm size	-0.0094	0.0320	0.4101	1.3669
SR_1 [c]	0.0203	0.0237	–	–
Asset-turnover ratio	-0.0201	0.0364	–	–
Other sub-sector	0.04	0.1271	–	–
Industrial sub-sector	-0.1577	0.1029	–	–
Mixed sub-sector	-0.1054	0.0708	–	–
United Kingdom	–	–	-3.7089	4.1119
Italy	–	–	2.2596	5.9312
Netherlands	–	–	-0.5373	4.246
Intercept	0.0506	0.1169	-2.9146	5.8569
#obs.	57		57	
F-stat.	1.2063		**5.6446**	

[a] Return on equity; [b] log of environmental index (INDEX) computed as described in Section 3; [c] inverse of solvency ratio minus one. Endogenous variables: ROCE, log(INDEX), square of ROCE, square of log(INDEX); exogenous variables: firm size, square of firm size, SR_1, asset-turnover ratio, other sub-sector, industrial sub-sector, mixed sub-sector, United Kingdom, Italy, Netherlands. Bold figures mean significancy at 5%.

Table 11: Estimation results for simultaneous equations system for ROS and log(INDEX)

Equation	ROS [a]		Log(INDEX) [b]	
Variable	Coef.	Std. Err.	Coef.	Std. Err.
Log(INDEX)	-0.0089	0.0175	–	–
Square of log(INDEX)	-0.0006	0.0025	–	–
ROS	–	–	13.1204	10.005
Square of ROS	–	–	-81.5832	51.6915
Firm size	0.0069	0.0347	-0.7053	1.5067
Square of firm size	-0.0017	0.0084	0.0296	0.314
SR_1 [c]	-0.00002	0.007	–	–
Asset-turnover ratio	**0.0329**	0.0131	–	–
Other sub-sector	0.0633	0.04	–	–
Industrial sub-sector	-0.0586	0.0333	–	–
Mixed sub-sector	**-0.0681**	0.0228	–	–
United Kingdom	–	–	**-2.1825**	0.9803
Italy	–	–	**3.8307**	1.224
Netherlands	–	–	0.0173	0.9937
Intercept	-0.0067	0.0359	**-3.5637**	1.3018
#obs.	57		57	
F-stat.	**4.068**		**11.1917**	

[a] Return on sales; [b] log of environmental index (INDEX), computed as described in Section 3; [c] inverse of solvency ratio minus one;. Endogenous variables: ROCE, log(INDEX), square of ROCE, square of log(INDEX); exogenous variables: firm size, square of firm size, SR_1, asset-turnover ratio, other sub-sector, industrial sub-sector, mixed sub-sector, United Kingdom, Italy, Netherlands. Bold and italic figures mean significancy at 5% and 10% level respectively.