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The Factors Behind CO2 Emission Reduction in Transition Economies

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Summary

The Central and Eastern European countries significantly reduced their carbon dioxide (CO_2) emissions between 1995 and 2003. Was this emission reduction just the fortuitous result of the major economic transformation undergone by countries in the transition? Or is it rather a result of more stringent environmental policy? The objective of the article is to answer this question through a simultaneous equation model of the demand (emissions) and supply (environmental stringency) of pollution. The supply equation takes into account the institutional quality of the country as well as consumer preferences for environmental quality. The results indicate that, all else equal, output growth would have increased industrial CO_2 emissions in the Central and Eastern European countries in our sample by 31% between 1995 and 2003, and the composition effect corresponded to an increase of 8.4% of emissions. Nevertheless, the technique effect, induced by more stringent environmental policy, reduced industrial CO_2 emissions by 58%, and allowed for a final beneficial result for the environment, i.e., -18% of industrial CO_2 emissions in 2003 compared to 1995. Finally, our study confirms the importance of institutional factors in the explanation and further prediction of pollution reduction in transition economies.

Keywords: Transition, CO_2 Emissions, Environmental Policy, Scale, Composition and Technique Effects

JEL Classification: C33, D72, P5, P27, Q53, Q58

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This revision covers a larger set of countries over a longer time period (1995-2003) compared to Zugravu, N., Millock, K. and G. Duchêne, "La dépollution dans les pays en transition est-elle volontaire? Le cas des émissions industrielles de carbone", Cahiers de la Maison des Sciences Economiques 2007.05, 2007.

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Introduction

The disintegration of the Soviet Empire and the changes that took place in Eastern and Central Europe by the end of the 1980s and the beginning of the 1990s revealed the extent of the disastrous environmental state of this part of the world. Although these countries differ significantly, the centralized planning of economic activity had generated common ecological problems: levels of industrial pollution that threaten human health; significant soil and water pollution (in particular in the old Soviet Union); a persistent negligence of nuclear safety and waste management issues, etc. The transition process towards a market economy and democracy could have contradictory effects on environmental quality in these countries. At first, the fall in industrial production directly reduced pollution levels, but the increased economic growth from the mid 1990s may lead to concerns about further deterioration of the state of the environment. The negative externality of pollution must in some way be internalized in economic decisions and the role of the State and of its environmental policy is crucial. In a democratic society, citizens and non-governmental associations have the possibility of expressing their preferences to government and polluting companies in order to reduce pollution and obtain more efficient application of existing regulations. But the Central and Eastern European transition countries have quite a short experience of democracy and are in the process of building new governmental administration.

A study of the empirical evidence shows that the transition to a market economy in the Eastern and Central European countries was beneficial for the environment, in particular for air and water quality. The emissions of the most important air and water pollutants declined quickly and drastically in the majority of these countries during the 1990s. Reductions from 30 to 70% of the emissions of pollutants such as sulphur dioxide, nitrogen oxides, suspended particles, BOD, solids and nitrogen were typical during the 1993-2000 period (Bluffstone, 2006).

Which were the determining factors behind these observed emission reductions? The key factors mentioned in the literature are:

- A massive fall in aggregate industrial output, the quasi-disappearance of the military-industrial complexes and redeployment of production towards the less polluting service sector;
- An increase in exports to Western Europe and the need for compliance with international standards;
- An expansion of the private sector and reduction of State participation in companies' property, that may have stimulated innovation and allowed an improvement of business management;
- An increase in foreign investments with their important technological externalities necessary for the modernization of production technologies and economic effectiveness;
- A better application of environmental policy;
- Intensification of public participation in decision-making and better functioning of the civil society, increased democratization.

Some of these factors may work both ways, which has caused some controversy as to their role: foreign direct investments (FDI) may concentrate in pollution-intensive sectors, for example. The interest in studying the case of transition countries is that they have undergone rapid and profound change in several of the determinants of pollution, such as economic growth, trade openness and environmental regulation.

Current research defines three variables or channels of influence that can determine the total economic impact of growth on the environment.

- The first is the *scale* of economic activity. For physical reasons, all things equal, more production means more pollution. But other things are not usually equal. An improvement of technology, for example, is likely to attenuate this relation.

- The second is the *structure / composition* of economic activity. Economic growth (and/or international trade) can move production from one sector to another (for example between the agricultural, manufacturing and service sectors). As the environmental damage per manufacturing unit varies according to the sector, the effect of growth or trade on the total pollution can change.

- The third is the production *techniques*. The same product can be manufactured by using a variety of rather different techniques, some "cleaner" than others. Depending on the use of more or less environmentally-friendly techniques, pollution per unit of GDP may decrease or increase.

The relation between GDP and environmental quality is not straightforward. It is seldom monotonous: sometimes the economic growth of a country is initially harmful for the environment and becomes beneficial later. The explanation lies in the three conflicting forces mentioned above. When GDP increases, the larger scale of production leads directly to more pollution and more environmental damage. At the same time, there is a tendency to favourable changes in the economic structure and production techniques. The question is whether the last two effects can compensate the first one. In section 2 we present some studies that have analyzed the empirical results related to this question (see also Dean [1992] and [2002], for a more detailed review of the literature). This aspect is important for transition countries since the strong economic growth during the last ten years may lead to increased pollution and maybe even a return to pre-1990 emission levels. Is it possible that the composition and technique effects will compensate the scale effect and stabilize emissions at acceptable levels for sustainable environmental quality?

The potential factors that contribute to environmental quality in transition countries may be grouped into two categories: the evolution of the economy (economic growth, changes in the economic and industrial structure) on the one hand, and changes in environmental regulation due to progress in democracy, on the other hand. The contribution of the article lies in the empirical estimation of these factors on industrial emissions of carbon dioxide (CO_2) in the Central and Eastern European transition countries. We estimate a simultaneous equation model of the demand and supply of pollution in order to distinguish the effects of economic factors versus the stringency of environmental regulation. The environmental policy is determined in its turn by consumer preferences for environmental quality and by institutional factors such as corruption and political instability.

For our specification of the *demand for pollution* we follow Antweiler, Copeland and Taylor [2001] but extend the basic model to include a more detailed composition effect. Antweiler, Copeland and Taylor [2001] consider one aggregate polluting sector, but in the case of transition countries, there was not only a change in the share of the manufacturing industry in the economy, but also important shifts within the manufacturing industry itself.

In order to account for the complex relationship between environmental quality and environmental policy, and possible endogeneity problems, we specifically need to model environmental policy formation. Given the prevalence of corruption and political instability in transition countries, we use the theoretical approach proposed by Fredriksson and Svensson [2003] to model the *supply of pollution*.

As for the empirical method, we use the two or three-stage least squares method, according to specification tests, in order to correct for any bias between variables in the same equation and between equations. We test the model over the period 1995-2003 on a sample of 60 heterogeneous countries from three different groups: Central and Eastern European transition economies, emerging economies, and industrialized economies. We compiled quite a rich dataset for this purpose, covering statistics on emissions, corruption, political instability, democratization, value added of different industrial sub-sectors, etc. We also use the dataset to develop a compact index of the stringency of environmental policy that enables us to compare environmental policy in the sample across countries and time.

Our empirical results show that industrial CO_2 emissions in the Central and Eastern European transition countries would have increased by 31% during 1995-2003 simply as a result of an economic scale effect. The composition effect, that represents a restructuring among the sub-sectors of the manufacturing industry, would have explained an 8.4% increase in pollution, whereas the technique effect had the largest marginal impact and corresponded to a 58% decrease in emissions.[2] In robustness tests, we also find a significant effect of trade openness: it increases industrial CO_2 emissions in transition countries, but this effect is reduced with increased capital accumulation. Finally, our analysis highlights the importance of institutional factors in explaining the emission reduction in transition countries, rather than factors related solely to economic restructuring as such (scale and composition effects).

The paper consists of six sections. In the first section we review the relevant literature and in the second section, we present some stylized facts on industrial CO_2 emissions. In the third section we develop a theoretical model that identifies the factors behind environmental quality in transition countries and enables us to specify the empirical relations. The econometric specification and a description of the data follow in the fourth section. The fifth section analyzes the empirical results and compares them with the results of other studies. The last section concludes.

1 Review of the literature

By now, several cross-country and time series studies have allowed researchers to generalize some results concerning the three conflicting effects of economic growth on the environment. For certain environmental quality measures, an inverted U-shaped relationship appears: in the case of low per capita income levels, pollution is generally low; above these levels, additional economic growth leads to an increasingly intense pollution until per capita income stabilizes on an intermediate level, above which any further economic growth results in an improvement of environmental quality; in the case of high per capita income, pollution is relatively limited. This empirical relationship is known under the name of the Environmental Kuznets Curve (EKC) following Grossman and Krueger's cross-country analyses [1993, 1995] on urban air pollution (sulphur dioxide emissions and smoke) and several measures of water pollution. Several studies later confirmed this kind of relationship (Selden and Song [1994], Hilton and Levinson [1998], Bradford, Schlieckert and Shore [2000], Bimonte [2001], Harbaugh, Levinson, and Wilson [2000]), although the existence of an EKC curve is sensitive to functional form and data updating, for example.

The idea behind the EKC is that economic growth is bad for the quality of air and water during the initial stages of industrialization, but later, once the country becomes rich enough to pay for the quality of its environment, growth contributes to the reduction of pollution. The dominant theoretical explanation is that the technology of production makes a certain level of pollution inevitable, but that the demand for environmental quality increases

[2] A summary of the results is presented in Table 4, page 24.

with income. A necessary condition for this demand to be satisfied is the existence of civil freedoms. Hence, in a country with a political regime of dictatorship, as the capacity of the population to express their opinions to put pressure on the government is very weak, a growth of the net per capita income does not necessarily result in a reduction of pollution, despite increased preferences for environmental quality. In a democratic society, by contrast, at high levels of per capita income, the public demand for environmental quality increases and leads to more stringent environmental regulation.[3]

Concerning the relation between trade openness and environmental quality, Eiras and Schaeffer [2001] show that the average index of sustainability[4] in open economies is at least 30% higher than the index in countries with a moderately open economy and almost double the level of the index in a closed economy. A casual inspection of data may lead to the conclusion that trade is good for the environment. Several studies have tried to isolate the independent effect of trade openness using a variety of methods on different samples (Lucas, Wheeler and Hettige [1992], Harbaugh, Levinson and Wilson [2000], Dean [2002], Copeland and Taylor [2001, 2004], Antweiler, Copeland and Taylor [2001], Frankel and Rose [2005]). Almost all find a rather positive relation between trade openness and environmental quality. Nevertheless, none of these studies considers the possible endogeneity of the relation between international trade and the environment: trade may be the result of environmental endowment, rather than the cause.

Studies in the field of environmental regulation often argue that the presence of corruption, political instability and absence of democracy induce socially sub-optimal effects of governmental policy. Empirical studies on the effects of political instability (Alesina and Perotti [1996], Alesina et al. [1996], Svensson [1998]), of corruption (Lopez and Mitra [2000], Fredriksson and Svensson [2003], Damania, Fredriksson and List [2003, 2004], Welsch [2003], Damania, Fredriksson and Mani [2004], Pelligrini and Gerlagh [2005]) and of the absence of democracy (Fredriksson et al. [2005] and Pelligrini and Gerlagh [2005]) confirm this hypothesis. Söderholm [2001] adds that the suggested policy already assumes the existence of an effectively operating institutional structure. Analyzing the Russian case, he identifies and discusses several reasons of why it may be difficult to implement an effective system of pollution taxes in an economy where the old legal and behavioural models are still present. He concludes that it is probably more suitable to consider the environmental problems in the transition economies not as market imperfections, but rather as a result of the institutional inertia in the economic and political systems. Pellegrini and Gerlagh [2005] find a very important negative and statistically significant impact of corruption on environmental policies, while democracy has a very limited positive impact. Consequently, the authors suggest that a reduction of the corruption level would induce higher growth rates and stricter environmental policies.

Among the studies that analyze the joint effects of several determinants of environmental policy, Fredriksson and Svensson [2003] were the first to analyze the common effects of political instability and corruption on policy creation. They found that political

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[3] Another possible explanation for the EKC is that it is formed naturally via the composition of production. In theory, the model could result from the usual phases of economic development: the transition from an agricultural economy to an industrial one and then from industry to services, the last tending to produce less pollution than industry (see Arrow et al. [1995]).

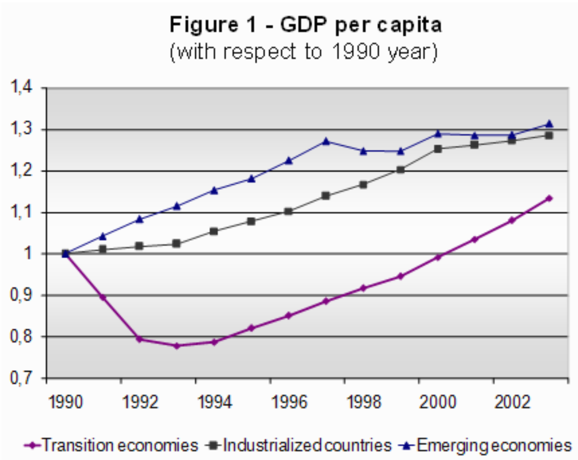
[4] The Yale Center for Environmental Law and Policy and the Center for International Earth Science Information Network, in collaboration with the World Economic Forum and the Joint Research Centre of the European Commission, publish annually a ranking of countries using a composite index – the Environmental Sustainability Index (ESI) or, since 2008, the Environmental Performance Index (EPI). The data is available on http://www.ciesin.columbia.edu/indicators/ESI.

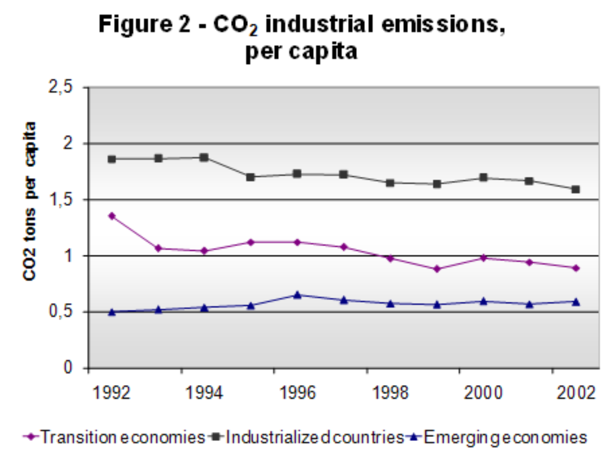
instability has a negative effect on the stringency of environmental regulation when the corruption level is low, but a positive effect when the degree of corruption is high. Corruption reduces the stringency of the policy, but this effect disappears with an increase of political instability. Cole, Elliott and Fredriksson [2006] interact the environmental effect of corruption with the one of foreign direct investments (FDI). They find that when the corruption level is very important (negligible), FDI induce less (more) stringent environmental policy. Damania, Fredriksson and List [2003] analyze the joint effect of trade openness and corruption on the stringency of environmental policy. According to their empirical results, trade openness increases the stringency of environmental policy, while corruption reduces it. The effects of the two variables are interdependent. Trade openness has a more important impact on environmental policy in countries with more corrupt governments. Moreover, a reduction of corruption has a greater effect on policy in a closed economy.

2 Some stylized facts

For reasons of data availability and compatibility, our database covers 60 countries over the period 1995-2003, including 14 transition economies, 19 emerging economies, and 27 industrialized economies (see the list of countries in the Appendix). Among the industrial air pollutants we chose carbon dioxide (CO_2) because of its international importance (the Kyoto Protocol) and because of the availability of annual emissions data from the International Energy Agency (IEA). CO_2 emissions originate primarily from three sources: residential heating, industry and transport. We chose to study industrial CO_2 emissions, which still constitute a large part of total CO_2 emissions in transition economies.

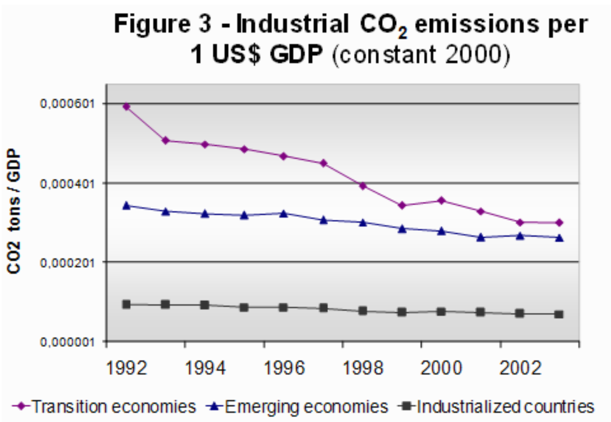
Transition economies have all gone through two phases of economic activity over the period of the sample: a deep transitional recession, followed by a period of economic recovery and rapid growth, that adds up to an increase in GDP per capita of 13% in 2003 compared to 1990 (Figure 1). The first period of transition, between 1990 and 1993, naturally led to a large reduction in CO_2 emissions. In the ten years that followed, industrial CO_2 emissions increased somewhat, then stabilized and even decreased in per capita levels (Figure 2). There is thus a tendency of progressive convergence towards the indicators of industrialized countries or emerging economies.

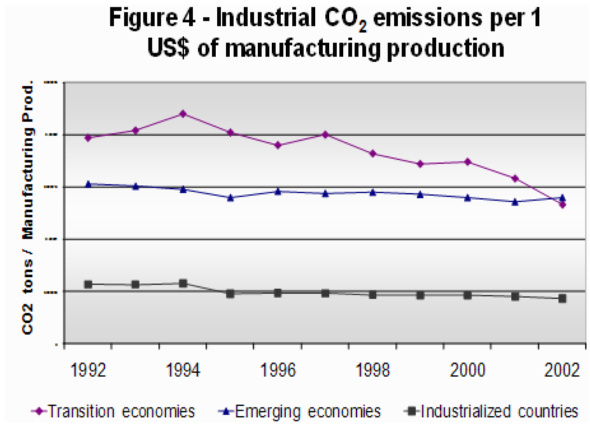




Sources: CO_2 emissions data – IEA; GDP per capita – World Bank

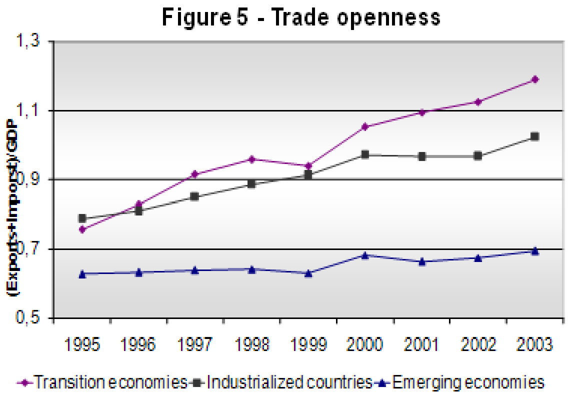
Still, industrial CO_2 emissions in terms of emissions per GDP or per USD of manufacturing production remain much higher than the levels in industrialized economies (Figures 3 and 4).

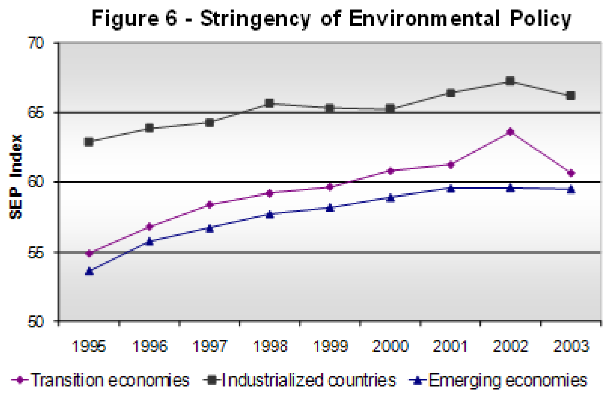




Sources: CO_2 emissions data– IEA; GDP – World Bank;
Manufacturing industry data – UNIDO

Is the positive evolution of CO_2 emissions per USD of GDP (or USD of manufacturing production) an indicator of increased production efficiency or is it rather the result of structural change in the economy? World Bank data shows a small decrease in the share of industry in GDP and some growth in the service sector (that represents 60% of GDP on average in 2000). Nevertheless, other factors may have played an important role: modernization of production technology due to a more stringent environmental policy or better corporate management, increased trade openness requiring compliance with international standards, or yet changes within the manufacturing sector itself. The UNIDO data on the manufacturing industry suggest that the development of some industrial sub-sectors (Food, Machinery and equipment, Wood products, Chemicals, and Iron & steel and basic metal products) seem to have contributed to a certain extent to the reduction in industrial CO_2 emissions. In parallel, Figure 5 shows a strong increase in trade openness. At the same time, being worse ranked than the other countries in terms of the stringency of environmental policy[5] at the beginning of the transition process, the countries in transition experienced an improvement in this index between 1995 and 2003 (Figure 6).





Sources: Trade openness data – World Bank;
Stringency of Environmental Policy Index – created by the authors.

These stylized facts suggest that it is relevant to study the relative weights of the different potential factors behind the reduction in industrial CO_2 emissions in transition countries. The following analysis is devoted to that task, first by constructing a theoretical model including the above mentioned factors, and then by testing it on available data to assess the individual impact of the causal factors.

[5] Index created by the authors (for details on its calculation see Section 4).

3 Theoretical Model

We model a small open economy composed of a non-polluting sector that produces a good Y, used as a numeraire, and n polluting (industrial) sectors that produce goods X_i, $i \in [1,n]$ with a constant returns to scale technology. By assuming that the representative consumer's utility is separable in consumption goods and disutility from aggregate pollution, the demand function for each good is $c_{X_i} = d_{X_i}(p_{X_i})$ with $d'_{X_i} < 0$. The consumer surplus can then be defined as:

$$S = \sum u_{X_i}\left[d_{X_i}(p_{X_i})\right] - \sum p_{X_i} d_{X_i}(p_{X_i}) \qquad (1)$$

where u_{X_i} (increasing and concave in c_{X_i}) are derived from the initial utility function $U = c_Y + \sum u_i(c_{X_i}) - \eta E$; c_Y and c_{X_i} are the consumption of the numeraire and of goods X_i; E is aggregate pollution and η measures the consumer's valuation of a unit of environmental damage (assumed constant here).

Let us now study the behaviour of a representative firm in sector *i*. Pollution is generated by the production of goods x_i. The firm has access to an abatement technology. Following Antweiler, Copeland et Taylor [2001], if a firm has a total production of x_i units and allocates x_{ai} units to reduce pollution, $h_i = x_{ai}/x_i$ represents the abatement effort of the representative firm in sector i. Due to different production technologies in the sectors i and thus different amounts of x_{ai} necessary to reduce polluting emissions by one unit, firms in different manufacturing sub-sectors, though subject to the same environmental regulation, will have different degrees of abatement. Pollution per manufacturing unit in sector i, which is the same for all the firms in the sector, can be written as a function of the abatement effort : $\theta_i = \theta_i(h_i)$, with $\theta_h < 0$ and $\theta_{hh} > 0$ corresponding to decreasing returns to scale in abatement.

We model the stringency of environmental policy by means of a unit emission tax on pollution, τ.[6] The profits of a firm equal its gross revenues less deduction of factor payments, pollution taxes and abatement costs. Using the definition of h_i, the profits of the representative firm in sector i (before the payment of any bribe) can be written

$$\pi_i = \left[\, p_i(1-h_i) - c_i - \tau\theta_i(h_i) \right] x_i \qquad (2)$$

where π_i denotes profits, c_i the marginal costs of production factors in sector *i*, assumed constant, and p_i the output price of the good of sector i.

Under the (simplifying) hypothesis of constant returns to scale, the production level is indeterminate. Since the objective here is to determine the effect of the stringency of the

[6] In reality, there are several fiscal and regulatory actions imposed on polluting production that generate a cost for the firm while not necessarily generating budget revenue for the government. We use an emission tax as a stylized means of capturing the stringency of environmental regulation in a simple manner.

environmental regulation on pollution, the level of abatement effort, h_i, is the key variable. The first-order condition for the abatement effort compares the marginal cost of reducing pollution with its marginal benefit (a reduction in the tax payment):

$$p_i = -\tau\theta_i'(h_i) \qquad (3)$$

which implies $h_i = h_i(\tau/p_i)$ with $h_\tau > 0$ and thus $\theta_i = \theta_i(\tau/p_i)$ with $\theta_\tau < 0$. (4)

To conclude, an increase in the emission tax leads to an increase in the abatement effort and a reduction in pollution per unit of production. Aggregate pollution E equals $\sum \theta_i(\tau/p_i)X_i$.

Government and pollution supply

The importance of institutional characteristics such as corruption and political instability in transition countries calls for modelling the creation of environmental policy following the approach proposed by Fredriksson and Svensson [2003] with the added features of a disaggregated polluting sector with constant returns to scale in each sub-sector, and the incorporation of consumer preferences for environmental quality.

The stringency of environmental policy is represented by the level of the emission tax on pollution. Total tax revenues equal:

$$T = \tau E = \tau \sum \theta_i(\tau/p_i)X_i \qquad (5)$$

Tax revenues are supposed to be redistributed to all individuals in an equal manner. Gross profits of polluting sector i, Π_i, is thus a function of environmental policy as modelled through the level of the emission tax τ, $\Pi_i(\tau)$. The polluting sectors i are assumed to be able to organize themselves into a lobby to negotiate a less stringent environmental policy (a lower emission tax) in return for a bribe to the incumbent government. The model is thus defined by a three-stage game between the incumbent government and the industrial lobby. First, the lobby offers the government a prospective bribe as a function of the tax level, denoted $B(\tau)$. The lobby takes into account political instability and the corruptibility of the incumbent government when making its bribe offer. In the second stage, the incumbent government decides on its optimal environmental policy, given the lobby's strategy. In the third stage, the environmental policy is implemented, given that the incumbent government stays in power. Once the emission tax has been announced, firms determine their production and abatement efforts.

The expected utility of the lobby (before any bribe payment) is given by:

$$W_L(\tau) = \left[1-\lambda(1-\delta)\right]\sum \Pi_i(\tau) + \lambda(1-\delta)\sum \Pi_i(\tau^p) \qquad (6)$$

where λ is the probability that the incumbent government will be thrown out of office; δ is the probability that the new government applies the same environmental policy as its predecessor; τ^p is the new, exogenous, tax level if the new government does not follow its predecessor's policy.

The incumbent government's objective function consists of a weighted average of the bribe and aggregate social welfare, denoted W_T:

$$G(\tau) \equiv B(\tau) + a(1-\lambda)W_T(\tau) \qquad (7)$$

The parameter a measures the exogenous weight accorded by government to social welfare relative to the bribe. A high value of the parameter a signifies a government that is less sensitive to corruption.

Following the Common Agency model by Bernheim and Whinston [1986], extended by Grossman and Helpman [1994] and by Dixit, Grossman and Helpman [1997], the political equilibrium maximizes the joint surplus of all parties. The equilibrium tax τ^* maximizes the sum of the lobby's utility and the government's objective function. In order to find the equilibrium tax τ^*, we thus have to solve

$$\frac{\partial W_L}{\partial \tau}\left(\tau^*\right) + a\left(1-\lambda\right)\frac{\partial W_T}{\partial \tau}\left(\tau^*\right) = 0 \ . \tag{8}$$

Social welfare is defined as the sum of total profits, consumer surplus, and tax revenues, less the disutility suffered from aggregate pollution:

$$W_T\left(\tau\right) = \sum \Pi_i\left(\tau\right) + S + \sum \tau\theta_i\left(\tau/p_i\right)X_i - \eta\sum\theta_i\left(\tau/p_i\right)X_i \tag{9}$$

We thus have, $$\frac{\partial W_L}{\partial \tau} = -\left[1-\lambda\left(1-\delta\right)\right]\sum\ \theta_i\left(\tau/p_i\right)X_i \tag{10}$$

and $$\frac{\partial W_T}{\partial \tau} = \left(\tau-\eta\right)\left[\sum X_i \frac{\partial\theta_i\left(\tau/p_i\right)}{\partial\tau}\right] \tag{11}$$

Substituting Equations (10) and (11) into (8), we obtain

$$-\left[1-\lambda\left(1-\delta\right)\right]\sum\ \theta_i\left(\tau^*/p_i\right)X_i + a\left(1-\lambda\right)\left(\tau^*-\eta\right)\left[\sum X_i\frac{\partial\theta_i\left(\tau^*/p_i\right)}{\partial\tau}\right] = 0 \tag{12}$$

In order to satisfy the equality, given that the first term is negative (see Equations (3) and (4)), the second term has to be positive. Thus, $\tau^* < \eta$, implying a sub-optimal emissions tax. By rearranging Equation (12), we obtain an implicit expression for the equilibrium environmental policy:

$$\tau^* = \frac{\left[1-\lambda\left(1-\delta\right)\right]\ \overbrace{\sum\theta_i\left(\tau^*/p_i\right)X_i}^{\text{The absolute level of emissions}}}{a\left(1-\lambda\right)\underbrace{\left[\sum X_i\frac{\partial\theta_i\left(\tau^*/p_i\right)}{\partial\tau}\right]}_{\substack{\text{The change in emissions following}\\ \text{a change in the tax level}}}} + \eta \tag{13}$$

For a socially optimal policy, the Pigovian tax applies and $\tau^* = \eta$. This is only possible in the absence of corruption and political instability. In order for the emission tax τ^* to approach η, the denominator has to be as large as possible. The higher the level of a (a government that is less sensitive to corruption), the smaller the level of political instability λ and the stronger the reaction by firms (by changing production techniques) following an increase in the emission tax, the closer the emission tax will be to the socially optimal level.

Pollution demand

Define Q – the value of total production in the economy (the scale of the economy); V_i - the value of production in sector i, $V_i = X_i p_i$; $\varphi = \sum V_i / Q$ - the weight of the aggregate polluting sector in the value of total production, and $\gamma_i = V_i / \sum V_i$ - the weight of each sub-sector i in the total value of the polluting sectors. We can then decompose pollution as:

$$E = \sum \theta_i X_i = \sum \theta_i \frac{V_i}{p_i} = Q\varphi \sum \gamma_i \theta_i / p_i \,. \tag{14}$$

Equation (14) shows that pollution depends on the scale of the economy, the share of the aggregate manufacturing industry in the economy, and on the relative weights of the different sub-sectors, characterized by different pollution intensities. In its differential form, Equation (14) becomes:

$$\hat{E} = \hat{Q} + \hat{\varphi} + \widehat{\left(\sum \gamma_i \theta_i / p_i \right)} \tag{15}$$

where « hats » represent percentage changes.

Given the hypothesis of constant returns to scale, standard profit maximization does not allow us to determine the firm's production. As we are in a partial equilibrium framework, we thus cannot determine the effect of the tax on the economic structure as such. The possible bias resulting from this simplification implies an under-estimation of the impact of environmental policy on pollution. We thus focus on the direct effect of the tax on pollution intensity. Recalling that $\theta_i = \theta_i\left(\tau / p_i\right)$, we have

$$\hat{\theta}_i = \varepsilon_{\theta_i, \tau/p_i} \left[\hat{\tau} - \hat{p}_i\right] \tag{16}$$

where $\varepsilon_{\theta_i, \tau/p_i}$ is the elasticity in emissions per unit of production (θ_i) with respect to a change in the real emission tax.

In order to focus on the variables of interest here, such as the value of total production Q, the share of the aggregate manufacturing industry φ, the relative shares of each sub-sector γ_i and the stringency of environmental policy, as represented by the level of the emission tax τ, we rewrite Equation (15):

$$\hat{E} = \hat{Q} + \hat{\varphi} + \frac{\sum \left(\hat{\gamma}_i + \varepsilon_{\theta_i, \tau/p_i} \hat{t} - (1 + \varepsilon_{\theta_i, \tau/p_i}) \hat{p}_i \right) \gamma_i \theta_i / p_i}{\sum \gamma_i \theta_i / p_i} \tag{17}$$

A change in aggregate emissions can thus be explained by a change in the scale of the economy, by a change in the aggregate share of the polluting manufacturing sector in the economy, by changes in the relative shares of each manufacturing sub-sector, and by a technique effect following a change in the stringency of the environmental policy, represented here by the real value of the emission tax.

We conclude the model by presenting the two equations of pollution supply and demand, for the specific case of industrial emissions that we study here:

$$\begin{cases} \tau = \tau\left(\underset{+}{E}, \underset{+}{a}, \underset{-}{\lambda}, \underset{+}{\eta}\right) & \text{Pollution supply} \\ E = E\left(\underset{+}{Q}, \underset{+}{\varphi}, \underset{?}{\gamma_i}, \underset{-}{\tau}, p_i\right) & \text{Pollution demand} \end{cases} \quad (18)$$

These two equations need to be estimated simultaneously in order to control for bias due to endogeneity, since pollution supply is influenced by current and past levels of pollution, whereas pollution demand is a function of the stringency of environmental policy. This is the subject of Section 4 and 5.

4 Econometric model and data

Econometric specification

Our theoretical model implies a system of two simultaneous equations and identifies the main determinants of the variables we seek to explain: the stringency of environmental policy and industrial air pollution.

After several preliminary tests with different functional forms and following the results obtained by the Jarque-Bera test for each one of those, we retain the log-log functional form, since, in our case, it ensures normally distributed residuals. This functional form also eliminates any problem with non-linearity in the relation between the dependent and the explanatory variables. The two econometric equations defined by Equation (13) and Equation (17) can then be presented as follows:

$$\begin{cases} \ln(\tau) = X'_{1,jt}\,\beta_1 + \varepsilon_{1,jt} \\ \ln(E_{jt}) = X'_{2,jt}\,\beta_2 + \varepsilon_{2,jt} \end{cases} \quad (19)$$

where j and t are respectively the country and year indices; E represents industrial CO_2 emissions and τ - the emission tax, that here is a modeling tool for the stringency of environmental policy and for the identification of the determining factors of environmental policy. Due to lack of available data on a comparable tax across countries, we construct our own index for the stringency of environmental policy (SEP) that represents an implicit level of an emission tax. This index is assumed to have the same impact on environmental quality as the stylized emission tax in the theoretical model. Actually, in many developing countries a high level of an emission tax does not imply a high stringency of actual policy since inspection and enforcement policies may be weak. In addition, using an index of the stringency of environmental policy enables us to include a larger sample of countries that do not use environmental taxes. β_1 and β_2 are vectors of elasticity coefficients to be estimated (since the variables in X_1' and X_2' are in natural logarithms); $\varepsilon_{1,jt}$ and $\varepsilon_{2,jt}$ are error terms, $\varepsilon \sim i.i.d.\ N(0,\sigma_{jt}^2)$.

The selected explanatory variables are: X_1'= {polluting emissions of the current year, polluting emissions of year t-1 (the variable $CO_{2\_var\ t-1}$)[7], net per capita income of the previous

[7] The theoretical model predicts that environmental policy depends simultaneously on current emissions and their variation with respect to a change in the stringency of environmental policy. After testing several regressions for years *t-1* up to *t-5*, we cannot determine a lag for which the effect is significant, but the effects of the other explanatory variables remain robust. Nevertheless we retain the variable $CO_{2\_var\ t-1}$ in order to control for the effects of all the variables suggested by the theoretical model.

year, political instability, and corruption} and X'_2 = {GDP in constant prices, the share of the manufacturing industry in the total economy, the relative shares of each industrial sub-sector, and the stringency of environmental policy}. Consumer preferences are not observable and proxied in our study by net per capita income. The higher is the net revenue, the higher is the willingness to pay for environmental quality. This variable is lagged by one year because of an inertia specific to policy creation and in order to avoid simultaneity problems (see the Wu-Hausman test in Table 1 in Section 5).

Data

In order to test the predictions of the theoretical model, we need data on industrial air emissions, evolution of the economic and industrial structure in the countries studied, the stringency of environmental policy, corruption, political instability, consumers' preferences for environmental quality (here represented by net per capita income), and other control variables. Here we describe the main variables, starting with the dependent variables (see the Appendix for definitions, sources and descriptive statistics of all the variables).

The IEA provides annual data on **CO_2 emissions** (variables **CO_2** and **$CO_{2\_var\ t-1}$**) for all countries in transition during the period 1990-2003, separating industrial emissions from the total emissions. This enables us to analyze industrial air pollution and to identify its determining factors.

The **stringency of environmental policy** (**SEP**) is the most difficult variable to measure since comparable data do not exist for all countries in the world and over time. Among the most used proxies one could quote: acceptable maximum lead contents in gasoline (data elaborated by Octel company in "Worldwide Gasoline Survey" and available only until 1995; see Hilton and Levinson [1998] for a detailed presentation of these data, used in a great number of studies: Damania, Fredriksson and List [2003] for example), number of environmental agreements signed by a country, etc. An interesting index used by Damania, Fredriksson and Mani (2004) is the one elaborated by the World Economic Forum, resulting from a questionnaire addressed to approximately 2000 businessmen of about sixty countries who evaluated the stringency of the environmental regulation in their country. We cannot use this index in our study, because it is available only beginning with the year 2001. In the literature on environmental policy creation one often encounters another index, created by Dasgupta et al. [1995] that evaluate the environmental policy in the agricultural sector of 31 countries for the year 1990, using a quantified analysis of reports prepared for the United Nations Conference on Environment and Development. This index was recomputed by Eliste and Fredriksson [2002] for 60 countries, using the same methodology as Dasgupta et al. [1995]. Here though, we wish to study the impact of environmental policy on industrial emissions. Moreover, we need a time series of data, whereas the index of Dasgupta et al. [1995] gives only a one year cross-country analysis. Another recently created index is the one of Cagatay and Mihci [2003], called Environmental Sensitivity Performance Index (ESPI), which is built on the basis of OECD's pressure, state and response indicators[8]. The advantage of this index is to take into account all environmental media (air pollution, water, waste, etc.) and to provide a general framework of the stringency of the environmental policy. However, since it is based on estimated variables rather than observed data, and based on the relative degree of pollution produced by certain industrial activities and the efforts of the economic agents to improve environmental quality, this index does not seem to take well into account the effort of government itself. By consequence, being an effect of pollution rather than its

[8] In this context, pressure indicators are used to determine the sources of various factors implying negative environmental changes, whereas state indicators are used to measure the environmental quality. The response indicators measure the efforts of certain economic agents to improve environmental quality and/or to protect the environment against various pollution sources.

determinant, the ESPI is not appropriate for our study, because of the impossibility to observe and analyze properly the factors of environmental policy creation. Thus we have no choice but to create our own index by using various proxies that evaluate directly or indirectly the stringency of environmental policy, resulting from government's effort and interest.

We calculate an index that classifies each country according to the stringency of its environmental policy. Our theoretical model suggests that the policy established by the government is the result of the joint welfare maximization of all actors in society: firms organized in lobbies in order to influence the government and actors in general which are represented by firms/people seeking to maximize their profits/utility according to their preferences. The government's decisions are influenced by the actions of these groups confronted themselves with the politicians' own interests. In this context, we created the SEP index that comprises at the same time variables of environmental policy and of industry's and the population's capacity to organize in lobbies (nongovernmental organizations, etc.) in order to put pressure on government's behavior towards a more environmentally-friendly direction. The more society demands environmental quality, the more one expects a stringent policy. We chose the following variables for the calculation of this index:

➢ Number of multilateral environmental agreements (**MEA**) signed by a country. As MEAs become increasingly strict and demanding, compliance with these agreements requires a more stringent domestic policy. Given pressure from the international organizations charged with observing compliance, one could assume that the fact of having signed an MEA would signal a government's willingness to harmonize its environmental policy with international standards in order to make it more effective.

➢ Existence of a regulation on air pollution (**ECOLEX** database of UNEP). We do not consider the absolute number of laws and regulations, because that could bias our results in favour of countries with many laws but that are not always applied or effective. For this reason, the variable takes value 1 if the country has air pollution regulations and 0 otherwise.

➢ Density of international nongovernmental organizations (**NGO**), represented by the number of NGO members by million inhabitants. NGOs play a considerable role in shaping and applying participative democracy. They take part in mechanisms or procedures instituted at national level in order to implement the Agenda 21 program, by using their particular capacities in the fields of education, poverty prevention, protection and improvement of the environment**.**

➢ Number of **ISO 14001** certified companies, weighted by GDP.

➢ Adhesion to the **Responsible Care**® Program, a unilateral voluntary initiative of the chemical industry within the framework of which the companies, represented by national associations, work together in order to improve their safety and environmental performances and to communicate with stakeholders about their products and manufacturing process. The program is currently applied as broadly as possible within the chemical and allied industries, and through all the supply chain.[9]

[9] In our analysis, this variable takes the value 2 for countries that adhere to the Responsible Care® Program, 1 for countries that do not adhere and that do not have or have only a modest chemical industry (<=5% of total industry, minimal value recorded by a country having adhered to the Program), 0 for countries that do not adhere and that have a more important chemical industry (>5% in the total industry), in order to account for different industrial structure across countries.

We calculate the SEP index for the period 1995-2003 based on these variables by using the Z-score technique[10] that yields a classification of countries according to the stringency of their environmental policy.

As for **corruption**, we use the opposite of the *Corruption Control* index developed by Kaufmann, Kraay and Mastruzzi [2005]. This index measures the extent to which governments fight corruption and it takes values ranging between -2.5 and +2.5, the maximum values signifying less corruption. The change of sign that we do thus yields an indicator that varies directly with the degree of corruption of the country. For **political instability (**the variable **Instab)**, we use the opposite of the *Political Stability* index by Kaufmann, Kraay and Mastruzzi [2005], similarly to the procedure for the previous variable. The *Political Stability* index measures the probability that the government in power is destabilized or replaced. To take into account **democracy** in the model, we introduce into a robustness test a dummy variable **FREE** that takes the value 1 if the country is characterized by important civil liberties and political rights. This variable is taken from the Freedom House database.

For data on **industrial structure** we have used UNIDO's INDSTAT4 (REV3) database and the value added of nine manufacturing sectors (on an ISIC three-digit level) and we have calculated their weights in total manufacturing production.

All other variables, such as GDP, net per capita income, and trade openness, are from the World Bank's *World Development Indicators 2005*.

Our database is an unbalanced panel[11] of 60 countries, limited to the 1995-2003 period for reasons of data availability. It contains 14 transition economies, 19 emerging economies and 27 industrialized economies (see the Appendix).

To conclude, Table 3 in the Appendix shows the correlations between the variables, that correspond overall with the predictions of the theoretical model.

5 Estimation results

The empirical results confirm the predictions of the theoretical model and they are robust with regard to alternative specifications taking into account additional variables that may influence the dependent variables and/or interact with the explanatory variables.

We start by analyzing the empirical results presented in Table 1. This table presents the estimation results using the method of two-stage least squares. We find a positive and significant effect on CO_2 emissions of GDP, the weight of the manufacturing industry in the total economy and the shares of the different sub-sectors, apart from the *Paper Products* sub-sector, that have the opposite effect. The shares of *Non-Metallic Mineral Products* and *Other Manufacturing Products* have no significant impact on CO_2 emissions (Model (1)). The scale effect appears to be more important in the transition economies and weaker in the

[10] In order to test the robustness of the SEP index we also calculated it using two alternative methods: factor analysis and principal component analysis. The indices calculated with these alternative methods are very strongly correlated with the index calculated by using the method of Z-score. The results of the regressions using the SEP index calculated with alternative methods are available from the authors upon request.

[11] The model has been tested for different samples of countries and the results are similar. The panel is unbalanced because of missing data in the INDSTAT4 database that do not seem to be linked to country characteristics that may be correlated with the variables in our model; for example, there are countries with a high degree of corruption that have no missing data, whereas there are missing data points for countries with a low level of corruption (mainly due to the choice of classification REV2 or REV3 by different countries and industries).

industrialized and emerging economies (Model (2)). That could be explained either by the different weights of strongly polluting sectors in the total production, or by differences in production techniques. The technique effect is represented by the responsiveness to a change in the stringency of environmental regulation (**SEP** index), that usually translates into a modernization of technology and an improvement of the production techniques. Like Antweiler, Copeland and Taylor [2001], we find, somewhat surprisingly, that this effect is always very important, significantly negative, and larger than both the scale and the composition effects. The particular contribution of our study is to test these three effects for different groups of countries, and we find that the stringency of the environmental policy has a more important marginal impact on pollution in the transition economies (the reference group) in our sample. The technique effect is more modest in the emerging economies (***Em*** in the table), and its marginal effect is the smallest in the industrialized economies (***Ind*** in the table).

As for the stringency of environmental policy, it is positively affected by consumer preferences for environmental quality, as represented by the net per capita income of the previous year. The impact of political instability and corruption are significantly negative (Model (1) in Table 1), as predicted by the theoretical model. Political instability and corruption have a very important negative effect on the stringency of environmental policy in the transition and emerging economies[12], but have a rather weak impact on the industrialized economies in our sample (Model (2)). Pelligrini and Gerlagh [2005] also found a significant and very important negative impact of corruption on environmental policy and conclude that institutional disorder prevents the economies in transition from obtaining effective compliance with their environmental policy, despite increasing incomes. The negative impact of corruption on the stringency of environmental policy that is found here confirms the results of other authors (Damania, Fredriksson and List [2003], Damania, Fredriksson and Mani [2004], Welsch [2003]).

Furthermore, and in line with the theoretical model, our results display the combined effect of corruption and political instability on the stringency of environmental policy. In a similar manner to Fredriksson and Svensson [2003], we find that corruption significantly reduces the stringency of the policy, but that this effect is reduced as the political instability increases. At the same time, political instability reduces the stringency of environmental policy, but for low corruption levels. This empirical result is the same for transition and emerging economies, but it is much weaker for industrialized economies. Finally, we do not find any significant impact of current and past levels of emissions (variables $\mathbf{CO_2}$ and $\mathbf{CO_{2\_var\ t-1}}$) on the stringency of environmental policy.

[12] The non-significant interaction term for this group of countries indicates that the effect is no different from the one of the reference group, i.e., transition economies.

Table 1 – Tests of the theoretical model

(reference group – transition economies)

Estimations by **2SLS**	(1)		(2)	
	ln(CO_2)	**ln(SEP)**	**ln(CO_2)**	**ln(SEP)**
ln(GDP)	**0,839*** *(0,029)*		**1,204*** *(0,068)*	
*Em*GDP*			***-0,217**** *(0,074)*	
*Ind*GDP*			***-0,297**** *(0,069)*	
ln(Manuf_%GDP)	**0,620*** *(0,15)*		**0,427*** *(0,13)*	
ln(Food_%Manuf)	**0,488*** *(0,098)*		**0,0215** *(0,089)*	
ln(Text_%Manuf)	**0,322*** *(0,050)*		**0,253*** *(0,047)*	
ln(Wood_%Manuf)	**0,147*** *(0,050)*		**0,126*** *(0,043)*	
ln(Paper_%Manuf)	**-0,232**** *(0,10)*		**-0,127** *(0,087)*	
ln(NonMetal_%Manuf)	**0,0265** *(0,047)*		**0,0232** *(0,039)*	
ln(Metal_%Manuf)	**0,396*** *(0,066)*		**0,271*** *(0,057)*	
ln(Chem_%Manuf)	**0,375*** *(0,094)*		**0,226*** *(0,087)*	
ln(Mach_%Manuf)	**0,500*** *(0,11)*		**0,144** *(0,10)*	
ln(Other_%Manuf)	**0,0616** *(0,055)*		**0,0438** *(0,046)*	
ln(SEP)	**-4,500*** *(0,22)*		**-6,489*** *(0,88)*	
*Em*SEP*			***5,579**** *(0,96)*	
*Ind*SEP*			***6,325**** *(0,99)*	
ln(CO_2)		**0,00152** *(0,0037)*		0,00107 *(0,0040)*
ln(CO_2_var$_{t-1}$)		**-0,0209** *(0,051)*		-0,0172 *(0,049)*
ln(Income$_{t-1}$)		**0,0605*** *(0,014)*		0,0623*** *(0,016)*
ln(Instab)		**-0,215*** *(0,065)*		-1,132** *(0,49)*
*Em*ln(Instab)*				*0,494* *(0,55)*
Ind ln(Instab)*				***1,017***** *(0,49)*
ln(Corruption)		**-0,0567**** *(0,027)*		-0,749*** *(0,26)*
*Em*ln(Corruption)*				*0,322* *(0,33)*
*Ind*ln(Corruption)*				***0,700**** *(0,26)*
ln(Corruption)*ln(Instab)		**0,127**** *(0,050)*		0,810** *(0,36)*
Em ln(Corruption)* ln(Instab)*				*-0,269* *(0,41)*
Ind ln(Corruption)* ln(Instab)*				***-0,772***** *(0,37)*
Em			**-14,62***	-0,531
Ind			**-16,51***	**-0,950***
Tr			**3,319**	
Constant		**3,765***		**4,627***
Observations	365	365	365	365
R^2	0,9960	0,2788	0,9975	0,3481

Legend: Standard errors in parentheses ; *** p<0,01 ** p<0,05 * p<0,1

Test statistics	(1)	(2)
Wald test, F (p-value)[a]:		
- CO_2	7349,59 (0,0000)	7237,85 (0,0000)
- SEP	23,15 (0,0000)	13,35 (0,0000)
Wu-Hausman test, F (p-value)[b]:		
- $Income_{t-1}$	0,80856 (0,3689)	0,81820 (0,3661)
Hausman (LM form), F (p-value)[c]:		
- CO_2	0,00 (1,0000)	0,00 (1,0000)
- SEP	0,00 (1,0000)	0,00 (1,0000)
Hausman specification test[d]:		
2SLS versus 3SLS, chi2 (p-value)	22,67 (0,0307)	139,88 (0,0000)

a- The Wald and Likelihood ratio tests give very similar conclusions : they test whether there exists an effect or not. In this case, the null hypothesis is that the coefficients of the explanatory variables equal zero. Given the calculated F statistics, we reject the null hypothesis.

b- This test indicates whether the variable $Income_{t-1}$ is exogenous. Since the p value exceeds 10%, we retain the null hypothesis, according to which the variable $Income_{t-1}$ is exogenous to the model.

c- The Hausman Test (in the Lagrange Multiplier form). We test whether the variables in *X* are endogenous (correlated with the error term). This test confirms that the explanatory variables, apart from the two that appear simultaneously in the two equations (CO_2 et SEP), are exogenous.

d- The Hausman specification test shows that the estimation of our model on the total sample of 60 countries is consistent using the method of two stage least squares, whereas the three stage least squares method is not.

We continue the empirical analysis with some robustness tests that are presented in Table 2. Model (3) is a replica of the base model (1) on the total sample, but with the added explanatory variable **FREE** (civil liberties representing democracy). In a similar manner to Fredriksson et al. [2005], we find that civil liberties and political rights have a significantly positive impact on the stringency of environmental policy. In the same way, this result confirms the conclusions of other authors, such as Pelligrini and Gerlagh [2005] who found a significant and positive marginal impact of democracy on the quality of environmental regulation.

Model (3) shows that when democracy is taken into account, the marginal effect of political instability (**Instab**) is no longer significant, whereas the coefficients of **Corruption** and $\mathbf{Income_{t-1}}$ increase somewhat. This change in the significance and size of the coefficients may be explained by the correlation between institutional variables and the level of income. In principle, a democratic society is necessary in order for consumers to have the possibility to express their preferences for environmental quality. Model (4) tests the impact of the variable **FREE** for different groups of countries. Among these three groups, only the industrialized economies in our sample have a significant positive effect of democracy on the stringency of environmental policy.

Concerning the equation of CO_2 emissions, since the three effects of growth also can be induced by trade, we test the robustness of our results by introducing a variable representing trade openness (the variable **OPEN** in Model (5)). By comparing models (3) and (5), we notice that the scale effect increases slightly. Some coefficients representing the relative share of different manufacturing sub-sectors change their size and significance. Only the coefficients of the industrial sub-sectors *Paper Products*, *Iron&Steel and Basic Metal Products*, and *Machinery and Equipment*, are more or less robust. Also, once trade openness is taken into account, the effect on industrial CO_2 emissions of the share of the manufacturing industry in the economy decreases. These changes can be explained by the correlation between trade openness and growth, countries' economic structure and their industrial specialization.

Table 2 – Robustness tests

Estimations by 2SLS	(3)		(4)		(5)		(6)	
	ln(CO_2)	ln(SEP)	ln(CO_2)	ln(SEP)	ln(CO_2)	ln(SEP)	ln(CO_2)	ln(SEP)
ln(GDP)	0,886***		0,873***		0,928***		1,010***	
	(0,030)		(0,029)		(0,038)		(0,039)	
ln(Manuf_%GDP)	0,509***		0,354**		0,388**		0,292*	
	(0,17)		(0,17)		(0,15)		(0,15)	
ln(Food_%Manuf)	0,413***		0,335***		0,241**		0,189**	
	(0,099)		(0,095)		(0,095)		(0,093)	
ln(Text_%Manuf)	0,315***		0,300***		0,193***		0,137***	
	(0,057)		(0,055)		(0,051)		(0,047)	
ln(Wood_%Manuf)	0,142**		0,144***		0,0259		0,0157	
	(0,056)		(0,054)		(0,054)		(0,046)	
ln(Paper_%Manuf)	-0,348***		-0,432***		-0,330***		-0,198**	
	(0,11)		(0,11)		(0,10)		(0,090)	
ln(NonMetal_%Manuf)	-0,0136		-0,0330		-0,0293		-0,0603*	
	(0,047)		(0,045)		(0,042)		(0,033)	
ln(Metal_%Manuf)	0,292***		0,279***		0,254***		0,314***	
	(0,079)		(0,077)		(0,068)		(0,058)	
ln(Chem_%Manuf)	0,299***		0,268***		0,0613		0,0351	
	(0,096)		(0,093)		(0,088)		(0,070)	
ln(Mach_%Manuf)	0,410***		0,383***		0,416***		0,159*	
	(0,12)		(0,12)		(0,10)		(0,096)	
ln(Other_%Manuf)	0,0839		0,0743		0,0933*		0,0288	
	(0,060)		(0,058)		(0,052)		(0,044)	
ln(SEP)	-4,415***		-4,065***		-4,203***		-2,354***	
	(0,24)		(0,22)		(0,27)		(0,54)	
ln(CO_2)		-0,00282		-0,00217		0,00363		0,00174
		(0,0036)		(0,0041)		(0,0045)		(0,0048)
ln(CO_2_var_{t-1})		0,00326		0,0132		-0,0162		-0,0284
		(0,053)		(0,051)		(0,055)		(0,053)
ln($Income_{t-1}$)		0,0764***		0,118***		0,0750***		0,117***
		(0,014)		(0,016)		(0,015)		(0,017)
ln(Instab)		-0,0362		-0,0470		-0,0372		-0,0652
		(0,071)		(0,069)		(0,071)		(0,069)
ln(Corruption)		-0,0781***		-0,114***		-0,0751***		-0,139***
		(0,028)		(0,029)		(0,028)		(0,030)
ln(Corruption)*ln(Instab)		0,114**		0,103**		0,0935*		0,141***
		(0,051)		(0,049)		(0,051)		(0,050)
FREE		0,0682***		0,0128		0,0461**		0,0587***
		(0,017)		(0,039)		(0,019)		(0,020)
*Em*FREE*				0,0572				
				(0,042)				
*Ind*FREE*				0,144***				
				(0,050)				
ln(OPEN)					-2,009***	-0,131*	3,188*	-0,0260
					(0,37)	(0,071)	(1,66)	(0,15)
Em ln(OPEN)*							-3,603***	-0,222
							(0,93)	(0,19)
Ind ln(OPEN)*							-4,587**	-0,232
							(2,25)	(0,29)
ln(OPEN)*ln(KL)					0,219***		-0,355*	
					(0,038)		(0,19)	
Em ln(OPEN)*ln(KL)*							0,0462***	
							(0,012)	
Ind ln(OPEN)*ln(KL)*							0,508**	
							(0,23)	
ln(OPEN)*ln($Income_{t-1}$)						0,0169**		0,0119
						(0,0075)		(0,017)
Em ln(OPEN) *ln($Income_{t-1}$)*								0,0192
								(0,021)
Ind ln(OPEN) *ln($Income_{t-1}$)*								0,0137
								(0,029)
Em				-0,00224			-8,434***	0,0345
Ind				-0,238***			-9,046***	-0,107***
Tr							-8,253***	
Constant		3,384***		3,068***		3,470***		3,210***
Observations	329	329	329	329	317	317	317	317
R^2	0,9962	0,3335	0,9964	0,3990	0,9972	0,3518	0,9984	0,4179

Legend: Standard errors in parentheses ; *** p<0,01 ** p<0,05 * p<0,1

Moreover, the technique effect, represented by the marginal impact of the stringency of environmental policy, is decreased. One may conclude that its effect is not always direct and represented by a technical response to policy stringency, but can be complemented by the effect of trade openness and the need for compliance with technical and international environmental standards.

Model (6) shows that the direct effect of trade openness is to reduce industrial CO_2 emissions of emerging and industrialized economies. In industrialized economies, this effect decreases as countries become more capital-abundant, whereas the negative effect of trade openness on emissions increases with capital accumulation for emerging economies. Opposite results are found for the countries in transition. Trade openness directly increases industrial CO_2 emissions of the transition economies in our sample, but the effect decreases with capital accumulation. One could explain this result by the specific development of the economies in transition, that were strongly and irrationally industrialized during the communist period. In fact, trade openness would have stimulated the production of sectors in which these countries had comparative advantages, i.e., rather polluting sectors. Based on Antweiler, Copeland and Taylor's [2001] analysis and our empirical results, we can conclude that trade openness increases pollution in the countries that export goods whose production is pollution intensive. If the direct effect of trade openness is to increase industrial CO_2 emissions of the economies in transition, then the indirect one that interacts with the accumulation of physical capital reduces this effect. Economic openness (trade, FDI) would have contributed to the replacement of old capital (strongly polluting installations and equipment) by more modern technologies.

Finally, trade openness has also a direct impact on the stringency of environmental policy. Model (5) on the total sample shows that trade openness reduces the stringency of environmental policy ("race to the bottom" phenomenon[13]), but that this effect is attenuated as the net per capita income increases, and society's willingness to pay for environmental quality increases. Model (6) does not enable us to distinguish separate effects of trade openness on the stringency of environmental policy for the different groups of countries, so future research that specifically analyses the impact of trade openness is needed.

We finish the empirical analysis by estimating the base model on the reduced sample of transition economies only (Table 3). Given the Hausman test statistic (18.58) we discuss the results estimated by three stage least squares that are consistent and efficient. Starting with the composition effect, the share of the manufacturing sector in the economy was not a significant determinant of industrial CO_2 emissions in the transition economies in our sample over the period 1995-2003. Since the manufacturing sector experienced a sharp drop in the first phase of transition (1990-1995), it could however have been the determining factor in explaining the fall in CO_2 emissions during those years.

As for the structure of the manufacturing industry itself, the marginal effects of changes in the shares of the *Paper Products* and *Chemical* sectors are not significant. The relative share of the *Wood Products* sector has reduced CO_2 emissions, though, whereas the marginal effect of changes in the relative shares of all the other sectors has increased CO_2 emissions.

[13] The "race to the bottom" assumption is used as an argument to fear that international trade and investment put pressure on the environmental standards of countries and thus damage the environment. For some, the expression "race to the bottom" suggests that the result will be a world of little or without environmental regulation. In general, the concern is that, insofar as countries are open to international trade and investment, environmental standards will be lower than those that would have prevailed otherwise.

Table 3 – Transition countries only

	2SLS		3SLS	
	$\ln(CO_2)$	ln(SEP)	$\ln(CO_2)$	ln(SEP)
ln(GDP)	**1,043*** *(0,078)*		**1,034*** *(0,061)*	
ln(Manuf_%GDP)	-0,183 *(0,32)*		0,162 *(0,24)*	
ln(Food_%Manuf)	**0,400*** *(0,23)*		**0,411**** *(0,18)*	
ln(Text_%Manuf)	0,124 *(0,10)*		**0,213***** *(0,078)*	
ln(Wood_%Manuf)	-0,189 *(0,12)*		**-0,168*** *(0,092)*	
ln(Paper_%Manuf)	0,0699 *(0,18)*		0,0344 *(0,14)*	
ln(NonMetal_%Manuf)	**0,543***** *(0,21)*		**0,396**** *(0,15)*	
ln(Metal_%Manuf)	0,222 *(0,18)*		**0,398***** *(0,14)*	
ln(Chem_%Manuf)	0,0546 *(0,13)*		0,141 *(0,094)*	
ln(Mach_%Manuf)	**1,204***** *(0,21)*		**0,912***** *(0,15)*	
ln(Other_%Manuf)	**0,437***** *(0,14)*		**0,303***** *(0,10)*	
ln(SEP)	**-5,455***** *(0,50)*		**-5,547***** *(0,41)*	
$\ln(CO_2)$		-0,000263 *(0,0084)*		0,00122 *(0,0078)*
$\ln(CO_2\_var_{t-1})$		0,00847 *(0,072)*		-0,0212 *(0,055)*
$\ln(Income_{t-1})$		**0,0945**** *(0,039)*		**0,114***** *(0,033)*
ln(Instab)		**-1,122**** *(0,46)*		**-1,248***** *(0,39)*
ln(Corruption)		**-0,723***** *(0,25)*		**-1,012***** *(0,21)*
ln(Corruption)*ln(Instab)		**0,833**** *(0,34)*		**1,063***** *(0,29)*
Constant		**4,175***** *(0,59)*		**4,323***** *(0,48)*
Observations	82	82	82	82
R^2	0,9976	0,5606	0,9973	0,5315
2SLS vs 3SLS (Hausman chi2 and p-value)	18,58 (0,0992)			

To conclude the test of the basic model on the sample of transition economies, we find empirical results similar to those of Antweiler, Copeland and Taylor [2001]: significant scale, composition and technique effects, the last being represented by a responsiveness to the stringency of environmental policy, and having the most important marginal impact. As to the total impact on CO_2 emissions, the scale and the composition effects have both increased industrial CO_2 emissions, whereas the technique effect has reduced them and actually compensated for the first two effects, bringing about an 18% reduction in industrial CO_2 emissions over the period 1995-2003. Table 4 shows the results for each effect. Using the change in GDP in transition countries between 1995 and 2003 (+30%), and of all the sub-sectors for which we found a statically significant effect in the three stage least squares regression on transition economies, and multiplying them by their marginal effects (the elasticity coefficients from Table 3), we estimate that the scale effect and the composition effect have increased CO_2 emissions by 31% and by 8.4% respectively. By multiplying the change in the SEP index (+10.5%) with the estimated marginal effect of an increase in the stringency of environmental policy, we find that the technique effect reduced industrial CO_2 emissions by 58%.

Table 4 – Estimation of the scale, composition and technique effects for transition economies, variation in CO_2 emissions in 2003 compared to 1995.

X	dCO_2/dX	P>z	Δ 2003 vs 1995, % X	Δ 2003 vs 1995, % CO_2	[C.I. of ΔCO_2, 95%]	
ln(GDP)	**1,0337**	**0,0000**	**30,04**	**31,05**	**27,46**	**34,65**
Ln(Manuf_%GDP)	*0,1619*	*0,5000*	*-11,38*	*-1,84*	*-7,19*	*3,51*
ln(Food_%Manuf)	**0,4108**	**0,0240**	**15,84**	**6,51**	**0,88**	**12,14**
ln(Text_%Manuf)	**0,2133**	**0,0060**	**36,71**	**7,83**	**2,20**	**13,46**
ln(Wood_%Manuf)	**-0,1683**	**0,0670**	**33,89**	**-5,7**	**-11,81**	**0,41**
ln(Paper_%Manuf)	*0,0344*	*0,8020*	*-0,99*	*-0,03*	*-0,30*	*0,23*
ln(NonMetal_%Manuf)	**0,3957**	**0,0110**	**34,22**	**13,54**	**3,16**	**23,92**
ln(Metal_%Manuf)	**0,3985**	**0,0040**	**-6,18**	**-2,46**	**-4,16**	**-0,77**
ln(Chem_%Manuf)	*0,1407*	*0,1330*	*-33,65*	*-4,73*	*-10,92*	*1,45*
ln(Mach_%Manuf)	**0,9121**	**0,0000**	**-20,35**	**-18,56**	**-24,74**	**-12,38**
ln(Other_%Manuf)	**0,3031**	**0,0040**	**24,06**	**7,29**	**2,35**	**12,24**
ln(SEP)	**-5,5469**	**0,0000**	**10,47**	**-58,1**	**-66,51**	**-49,64**

Note : The estimates of variables (X) in **bold** are significant at a 5% level, except ***Wood_%Manuf*** – at 6.7%.

Overall, the total reduction of 18% of industrial CO_2 emissions is considerable. Nevertheless, our analysis suggests that there is yet more potential for pollution reduction by means of a technique effect induced by increased stringency of environmental policy. In particular, our econometric analysis shows a significant impact of institutional quality on the stringency of environmental policy, and thus on pollution. If there were convergence in the indicators measuring corruption and political instability in transition economies towards the level of the same indicators for industrialized economies, further improvement of environmental quality could be achieved in the transition economies studied here. In 2003, the industrialized economies in our sample had an average score of 1.3 for corruption and of 1.98 for political instability. In the transition economies in our sample, the equivalent indicators were 3.01 and 2.66[14], respectively. Convergence towards the same level of the indicators for industrialized economies implies a reduction by 57% in the corruption indicator and by 26% in the indicator for political instability. This reduction in corruption alone would bring about an improvement of 57% of the SEP index, all else equal (in particular, an unchanged level of political instability). This would translate into a considerable reduction of industrial CO_2 emissions. If, all else equal, the level of political instability was reduced to the level of industrialized economies, there would be an increase of 32% in the SEP index. If the two indicators – corruption and political instability – converged simultanously towards the level of the industrialized economies in our sample, the stringency of environmental policy would increase further, yielding a considerable improvement in environmental quality of the transition economies.

[14] These values represent the inverse of the original Kaufmann indicators, with a transformation of negative values into positive values: a low value thus indicates a low level of corruption and a high value a higher level of corruption.

Conclusion

The objective of the article was to test if the environmental performance observed in the countries in transition between 1995 and 2003 was the result of the change in the economic and industrial structure or rather determined by an improvement in the stringency of environmental policy. We developed a theoretical model specifying the demand for pollution and the creation of the environmental policy (supply of pollution) at the same time and we tested this model on the determining factors of industrial CO_2 emissions in the countries in transition compared to the groups of emerging and industrialized economies. Our results confirm the existence of a scale effect, a disaggregated composition effect, and a technique effect, the last having had the largest marginal impact on industrial CO_2 emissions.

The scale effect is greater in the transition economies (compared to the industrialized economies where it had less of an effect). As for the composition effect, the share of the manufacturing sector in the economy was not a significant determinant of industrial CO_2 emissions in the countries in transition between 1995 and 2003. In terms of industrial structure, the composition effect has had a significant impact on industrial pollution in the economies in transition. We can conclude that the environmental performance in these countries can be explained partly by changes in their industrial structure: increases in the relative weights of more pollution-intensive sub-sectors and reduced shares of the less pollution-intensive sectors.

The technique effect is represented in our study by the reactivity of producers to a change in the stringency of environmental policy that usually occurs through a modernization of production technology. This effect is significantly negative and greater than both the scale and the composition effects. Nevertheless, when the effect of trade openness is taken into account, the marginal impact of the stringency of environmental policy decreases. One could conclude that the technique effect is due also to trade openness and the need for complying with international technical and environmental standards. At the same time, the direct effect of increased trade openness is to reduce industrial CO_2 emissions, but the impact decreases when an economy becomes more capital-intensive. This result is valid for the industrialized economies in our sample, and to a lesser extent for the emerging economies. In the case of the transition economies, the impact of trade openness is to increase industrial CO_2 emissions, but this effect is attenuated with capital accumulation. Their very industrialized economic structure and the comparative advantage in the (strongly polluting) production of capital-intensive goods at the beginning of the transition, could explain this result. It is only with the accumulation of more modern capital that these countries have been able to improve production technology and become more effective in terms of pollution abatement.

As for the stringency of environmental policy itself, it is determined by the institutional quality of the country and consumer preferences for environmental quality. The impact of political instability and corruption is negative, as predicted by the theoretical model; their effect on the stringency of environmental policy is very strong for the economies in transition, whereas it is weak for the industrialized countries in our sample. We also find an interdependent effect of corruption and political instability on the stringency of environmental policy. Finally, following tests of robustness, we note that the stringency of environmental policy is also determined by two other variables: democracy and trade openness. The first is strongly correlated with the institutional quality of the country and has a significant and positive impact on the stringency of the policy. As for trade openness, our results on the total sample indicate that trade openness reduced the stringency of the environmental policy, but that this effect was attenuated with higher net income per capita. These results confirm the "race to the bottom" hypothesis, the effect of which is mitigated once consumers become richer and more concerned with environmental quality.

To conclude, the environmental performance in terms of industrial CO_2 emissions of the countries in transition recorded between 1995 and 2003 can be explained by the following factors: a modernization of production technology induced mainly by increased stringency of the environmental policy (contributing to a 58% reduction in industrial CO_2 emissions), and that compensated the increase in emissions due to the scale effect (+31%) and the composition effect in terms of changes in the structure of the manufacturing industry in favour of more pollution-intensive sectors (+8.4%). The technique effect thus permitted an overall net reduction of 18% of industrial CO_2 emissions in 2003 compared to 1995. Finally, the analysis concluded that further emission reductions may be obtained in transition economies through convergence of the quality of institutional governance indicators, such as corruption control and political stability, towards those in industrialized economies.

References

Alesina A. et Perotti R. [1996], Income Distribution, Political Instability, and Investment, *European Economic Review* 40(6), 1203-1228.

Alesina A., Özler S., Roubini N. et Swagel P. **[1996]**, Political Instability and Economic Growth, *Journal of Economic Growth* 1(2), 189-211.

Antweiler W., Copeland B.R. et Taylor M.S. [2001], Is Free Trade Good for the Environment? *American Economic Review* 91(4), 877-908.

Arrow, K., Bolin B., Costanza R., Dasgupta P., Folke C., Holling C. S., Jansson B. O., Levin S., Mäler K. G., Perrings C. et Pimentel D. [1995], Economic Growth, Carrying Capacity, and the Environment, *Science* 268, 520-521, April 28.

Bernheim B. D. et Whinston M. D. [1986], Common Agency, *Econometrica* 54(4), 923-942.

Bimonte S. [2001], Model of Growth and Environmental Quality: A New Evidence of the Environmental Kuznets Curve, *Quaderni del Dipartimento di Economia Politica*, No. 321, Università degli Studi di Siena.

Bluffstone R. A. [2006], After a Dozen Years of Transition, Why are Dirty Industries in Central and Eastern Europe Generally Greener? PHASE 1, *A Report to the Swedish International Development Cooperation Agency and the University of Gothenburg*.

Bradford D., Schlieckert R. et Shore S. [2000], The Environmental Kuznets Curve: Exploring a Fresh Specification, *NBER Working Paper* No. 8001.

Cagatay S. et Mihci H. [2003], Industrial Pollution, Environmental Suffering and Policy Measures: An Index of Environmental Sensitivity Performance (IESP), *Journal of Environmental Assessment Policy and Management* 5(2), 205-245.

Cole M.A., Elliott R. et Fredriksson P.G. [2006], Endogenous Pollution Havens: Does FDI Influence Environmental Regulations? *Scandinavian Journal of Economics* 108(1), 157–178.

Copeland B.R. et Taylor M. S. [2001], International Trade and the Environment: A Framework for Analysis, *NBER Working Paper* No. 8540, Oct.

Copeland Brian R. et Taylor M.S. [2004], Trade, Growth and the Environment. *Journal of Economic Literature* 42(1), 7-71.

Damania R., Fredriksson P.G. et J. List. [2003], Trade Liberalization, Corruption, and Environmental Policy Formation: Theory and Evidence, *Journal of Environmental Economics and Management* 46(3), 490-512.

Damania R., Fredriksson P.G. et J. List. [2004], The Multiplier Effect of Globalization, *Economics Letters* 83(3), 285-92.

Damania R., Fredriksson P.G. et Mani M. [2004], The Persistence of Corruption and Regulatory Compliance Failures: Theory and Evidence, *Public Choice* 121(3-4), 363-390.

Dasgupta S., Mody A., Roy S. et Wheeler D. [1995], Environmental Regulation and Development: A Cross-Country Empirical Analysis, *Policy Research Working Paper* N° 1448, Washington: World Bank.

Dean J. [1992], Trade and the Environment: A Survey of the Literature, *in Patrick Low, ed.*, *International Trade and the Environment*, World Bank Discussion Paper No. 159.

Dean J. [2002], Does Trade Liberalization Harm the Environment? A New Test. *Canadian Journal of Economics*, 35(4), 819-842.

Dixit A., Grossman G. et Helpman E. [1997], Common Agency and Coordination: General Theory and Application to Government Policymaking, *Journal of Political Economy*, 105(4), 753-769.

Eiras A. et Schaefer B. [2001], Trade: The Best Way to Protect the Environment, *Backgrounder, The Heritage Foundation* no. 1480, September 27.

Eliste P. et Fredriksson P.G. [2002], Environmental Regulations, Transfers, and Trade: Theory and Evidence, *Journal of Environmental Economics and Management* 43 (2), 234–250.

Frankel J.A. et Rose A.K. [2005], Is Trade Good or Bad for the Environment? Sorting out the Causality, *Review of Economics and Statistics* 87(1), 85-91.

Fredriksson P.G. et Svensson J. [2003], Political Instability, Corruption and Policy Formation: The Case of Environmental Policy, *Journal of Public Economics* 87(7-8), 1383-1405.

Fredriksson P.G., Neumayer E., Damania R. et Gates S., [2005], Environmentalism, Democracy, and Pollution Control, *Journal of Environmental Economics and Management* 49(2), 343-65.

Grossman G.M. et Helpman E. [1994], Protection for Sale, *American Economic Review* 84(4), 833-50.

Grossman G.M. et Krueger A.B. [1993], Environmental Impacts of a North American Free Trade Agreement, *in P.M. Garber (Ed.), The Mexico-US Free Trade Agreement, Cambridge, MA: MIT Press*.

Grossman G.M. et Krueger A.B. [1995], Economic Growth and the Environment, *Quarterly Journal of Economics* 110(2), 353-377.

Harbaugh W., Levinson A. et Wilson D. [2000], Re-examining the Empirical Evidence for an Environmental Kuznets Curve, *NBER Working Paper* No. 7711.

Hilton F.G. H. et Levinson A. [1998], Factoring the Environmental Kuznets Curve: Evidence from Automotive Lead Emissions, *Journal of Environmental Economics and Management* 35, 126-141.

Kaufmann D., Kraay A. et Mastruzzi M. [2005], Governance Matters IV: Governance Indicators for 1996–2004, *World Bank Policy Research Working Paper 3630, June 2005.*

Lopez R. et Mitra S. [2000], Corruption, Pollution and the Kuznets Environment Curve. *Journal of Environmental Economics and Management* 40(2), 137-150.

Lucas R., Wheeler D. et Hettige H. [1992], Economic Development, Environmental Regulation, and the International Migration of Toxic Industrial Pollution, 1960-1988, *International Trade and the Environment, Ed. Patrick Low* (Washington DC: World Bank).

Olson, M . [1965], *The Logic of Collective Action*, Harvard University Press, Cambridge, MA.

Pelligrini L. et Gerlagh R. [2005], An Empirical Contribution to the Debate on Corruption, Democracy and Environmental Policy, *Working Paper 2005.8, Fondazione Eni Enrico Mattei*.

Selden T. et Song D. [1994], Environmental Quality and Development: Is There a Kuznets Curve for Air Pollution? *Journal of Environmental Economics and Environmental Management* 27, 147-162.

Söderholm P. [2001], Environmental Policy in Transition Economies: Will Pollution Charges Work?, *Journal of Environment and Development* 10(4), 365-390.

Svensson J. [1998], Investment, Property Rights and Political Instability: Theory and Evidence, *European Economic Review* 42, 1317-134.

Welsch H. [2003], Corruption, Growth and the Environment: A Cross-Country Analysis, *German Institute for Economic Research, Discussion Paper* 357, Berlin.

APPENDIX

List of countries in the sample

Economies in transition[15]: Albania**,** Bulgaria, Czech Republic, Estonia, Georgia, Hungary, Latvia, Lithuania, Moldova, Poland, Romania, Russian Federation, Slovenia, Slovak Republic.

Emerging economies[16]: Argentina, Brazil, Chile, China, Colombia, India, Indonesia, Jordan, Malaysia, Mexico, Morocco, Pakistan, Peru, Philippines, South Africa, South Korea, Thailand, Turkey, Venezuela.

Industrialized economies[17]: Australia, Austria, Belgium, Canada, Cyprus, Denmark, Finland, France, Germany, Greece, Hong Kong, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Malta, the Netherlands, Norway, Portugal, Singapore, Spain, Sweden, Switzerland, UK, USA.

[15] Previously planned economies that have embarked upon a transition process towards a market economy.

[16] We define emerging economies according to the Morgan Stanley Emerging Markets Index, 2006. They are countries for which the GDP per capita is lower than that of developed countries, but that go through rapid economic growth, and for which living standards converge towards those in developed countries, and that are characterized by a growing share of world commerce.

[17] According to the 1997 edition of World Economic Outlook (IMF), a certain number of newly industrialized countries in Asia (Hong Kong, Singapore), and Israel, are categorized in the group traditionally known as industrialized countries. These countries, as well as Cyprus and Malta, are among the top 30 countries in terms of standard of living (Economist Intelligence Unit's quality of life index, 2005).

Variable descriptions

Table 1 – Variable definitions and sources

Name	Definition	Source
CO_2	Industrial carbon dioxide emissions, in kT	International Energy Agency
GDP	GDP in constant 2000 US$	World Development Indicators 2005, World Bank
Manuf_%GDP	Share of the manufacturing sector's value added (VA) in the GDP	INDSTAT4 (REV3) database of the United Nations Industrial Development Organization (UNIDO)
Food_%Manuf	Share of the *Food* sub-sector's VA in the total manufacturing sector's VA	UNIDO INDSTAT4 (REV3) database
Text_%Manuf	Share of the *Textiles* sub-sector's VA in the total manufacturing sector's VA	UNIDO INDSTAT4 (REV3) database
Wood_%Manuf	Share of the *Wood* products sub-sector's VA in the total manufacturing sector's VA	UNIDO INDSTAT4 (REV3) database
Paper_%Manuf	Share of the *Paper products* sub-sector's VA in the total manufacturing sector's VA	UNIDO INDSTAT4 (REV3) database
NonMetal_%Manuf	Share of the *Non-Metallic mineral products* sub-sector's VA in the total manufacturing sector's VA	UNIDO INDSTAT4 (REV3) database
Metal_%Manuf	Share of the *Iron & steel and basic metal products* sub-sector's VA in the total manufacturing sector's VA	UNIDO INDSTAT4 (REV3) database
Chem_%Manuf	Share of the *Chemicals* sub-sector's VA in the total manufacturing sector's VA	UNIDO INDSTAT4 (REV3) database
Mach_%Manuf	Share of the *Machinery & equipment* sub-sector's VA in the total manufacturing sector's VA	UNIDO INDSTAT4 (REV3) database
Other_%Manuf	Share of the *Other manufacturing products* sub-sector's VA in the total manufacturing sector's VA	UNIDO INDSTAT4 (REV3) database
SEP	Stringency of Environmental Policy Index	Calculated by the authors
	MEA – number of signed multilateral environmental agreements	World Trade Organization
	ECOLEX – takes value 1 if the country has air pollution legislation and 0 otherwise.	United Nations Environment Program
	NGO – the number of members of international non-governmental organizations per million inhabitants	Center for the Study of Global Governance. 2004. *Global Civil Society 2004/5*
	ISO14001- the number of ISO 14001 certified firms weighted by GDP	ISO – International Organization for Standardization
	Responsible Care® membership (see explanations in section 4)	Responsible Care® The chemical industry's global voluntary initiative
$Income_{t-1}$	Net income per capita lagged by one year, international current dollars in PPP	World Development Indicators 2005, World Bank
OPEN	Trade openness. Calculated by the basic method used in international statistics : (Exports+Imports)/GDP	World Development Indicators 2005, World Bank
Instab	Index for political instability (see explanations in section 4)	Kaufmann et al. [2005]
Corruption	Index for corruption (see explanations in section 4)	Kaufmann et al. [2005]
FREE	A dummy variable taking the value 1 if the country is considered democratic and 0 otherwise. In fact, it takes value 1 if the average of the two variables of Freedom House : « Political Rights » and « Civil Liberties » lies between 1.0 and 2.5 (which indicates a high level of freedom).	Freedom House
OPEN*KL	Interaction term between trade openness and the Capital stock to Labour ratio. The capital stock is calculated by using the following formula: Creation of fixed $assets_t$ +0.95*Capital $stock_{t-1}$. Because of data availability, the fixed assets created in 1989 are taken as a basic capital stock.	World Development Indicators 2005, World Bank
OPEN *$Income_{t-1}$	Interaction term between trade openness and the net per capita income	World Development Indicators 2005, World Bank
Corruption*Instab	Interaction term between corruption and political instability	Kaufmann et al. [2005]
Tr, Em and Ind	Dummy variables for transition economies, emerging economies and industrialized economies, respectively	Constructed by the authors

Table 2 – Descriptive statistics

Variable	Obs.	Mean	Std. dev.	Min.	Max.
CO_2	533	63900,86	156913,6	15	1266205
GDP	540	4,75E+11	1,33E+12	1260000000	1,03E+13
Manuf_%GDP	456	19,75191	5,743874	4,548165	39,34211
Food_%Manuf	428	19,04128	9,856324	2,97583	64,52444
Text_%Manuf	428	7,749555	5,759608	0,1061753	36,48632
Wood_%Manuf	428	2,884719	2,780549	0,1630973	17,79805
Paper_%Manuf	428	9,479729	5,047287	1,942741	33,62775
NonMetal_%Manuf	428	5,590139	3,373295	0,0177442	19,53495
Metal_%Manuf	428	10,9699	4,998871	0,7675812	30,59557
Chem_%Manuf	540	18,04802	8,954029	2,10706	62,09823
Mach_%Manuf	428	23,47831	10,6087	2,075568	53,69643
Other_%Manuf	428	2,787934	1,738049	0,0606678	9,722948
OPEN	504	0,8409266	0,5443998	0,171077	3,255867
$Income_{t-1}$	540	15174,49	10513,65	1270,449	57846,66
Corruption	540	2,262923	1,065265	0,4170122	4,154919
Instab	540	2,502241	0,8626573	1,242691	4,947204
FREE	477	0,7148847	0,4519433	0	1
SEP	***540***	***61,52841***	***7,683734***	***37,75274***	***98,0698***
MEA	*540*	*15,13704*	*3,787946*	*0*	*23*
ECOLEX	*540*	*0,8981481*	*0,3027338*	*0*	*1*
NGO	*540*	*474,2888*	*1014,68*	*0*	*6353,3*
ISO14001/GDP(Mrd)	*540*	*58,48929*	*1334,457*	*0*	*31011,02*
Responsible Care®	*540*	*0,6666667*	*0,4718416*	*0*	*1*

Table 3 – Partial correlations (significance / p-values in *italic*)

	CO_2	GDP	Manuf_ %GDP	Food_% Manuf	Text_% Manuf	Wood_ %Manuf	Paper_% Manuf	NonMetal_ %Manuf	Metal_ %Manuf	Chem_ %Manuf	Mach_% Manuf	Other_% Manuf	SEP	OPEN	$Income_{t-1}$	Corruption	Instab	FREE
CO_2	1.0000																	
GDP	0.5773	1.0000																
	0.0000																	
Manuf_%GDP	0.3169	0.0266	1.0000															
	0.0000	*0.5715*																
Food_%Manuf	-0.1637	-0.1633	-0.2462	1.0000														
	0.0007	*0.0007*	*0.0000*															
Text_%Manuf	0.0111	-0.1769	-0.2590	0.1019	1.0000													
	0.8206	*0.0002*	*0.0000*	*0.0350*														
Wood_%Manuf	-0.1483	-0.1173	0.0370	0.1035	0.0220	1.0000												
	0.0023	*0.0151*	*0.4806*	*0.0323*	*0.6500*													
Paper_%Manuf	-0.1940	0.0339	-0.2085	-0.2882	-0.2688	0.1905	1.0000											
	0.0001	*0.4840*	*0.0001*	*0.0000*	*0.0000*	*0.0001*												
NonMetal_%Manuf	-0.0630	-0.1432	-0.1959	0.3259	0.3070	-0.0567	-0.2896	1.0000										
	0.1970	*0.0030*	*0.0002*	*0.0000*	*0.0000*	*0.2416*	*0.0000*											
Metal_%Manuf	0.0621	0.0874	-0.0239	-0.3397	-0.2673	0.0383	0.0358	-0.0142	1.0000									
	0.2032	*0.0708*	*0.6495*	*0.0000*	*0.0000*	*0.4290*	*0.4603*	*0.7690*										
Chem_%Manuf	0.0812	0.0243	0.0929	-0.1309	-0.1909	-0.4240	-0.3394	-0.1399	-0.1222	1.0000								
	0.0611	*0.5732*	*0.0473*	*0.0067*	*0.0001*	*0.0000*	*0.0000*	*0.0037*	*0.0114*									
Mach_%Manuf	0.2134	0.2447	0.4063	-0.6888	-0.3302	-0.1597	0.2013	-0.5182	0.0440	-0.1255	1.0000							
	0.0000	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0009*	*0.0000*	*0.0000*	*0.3638*	*0.0094*								
Other_%Manuf	-0.0822	0.0015	-0.0922	-0.1361	0.0648	0.2528	0.1798	-0.0057	0.1202	-0.4519	0.0881	1.0000						
	0.0920	*0.9750*	*0.0786*	*0.0048*	*0.1812*	*0.0000*	*0.0002*	*0.9070*	*0.0129*	*0.0000*	*0.0688*							
SEP	-0.1728	0.0478	0.0685	-0.2109	-0.2459	0.1660	0.3932	-0.1972	0.0953	-0.1504	0.1867	0.1926	1.0000					
	0.0001	*0.2670*	*0.1444*	*0.0000*	*0.0000*	*0.0006*	*0.0000*	*0.0000*	*0.0488*	*0.0005*	*0.0001*	*0.0001*						
OPEN	-0.2690	-0.2679	0.0352	-0.1682	0.1719	0.1112	0.1220	-0.0366	-0.1865	-0.0728	0.0921	0.1082	0.1798	1.0000				
	0.0000	*0.0000*	*0.4589*	*0.0007*	*0.0006*	*0.0263*	*0.0147*	*0.4654*	*0.0002*	*0.1024*	*0.0662*	*0.0307*	*0.0000*					
$Income_{t-1}$	-0.0120	0.3150	-0.1132	-0.4788	-0.3817	-0.0040	0.5660	-0.3941	0.2941	-0.0705	0.4049	0.2215	0.5335	0.2753	1.0000			
	0.7824	*0.0000*	*0.0156*	*0.0000*	*0.0000*	*0.9350*	*0.0000*	*0.0000*	*0.0000*	*0.1015*	*0.0000*	*0.0000*	*0.0000*	*0.0000*				
Corruption	0.0594	-0.2003	0.0154	0.4853	0.4461	-0.0488	-0.6730	0.3738	-0.1979	0.1158	-0.4427	-0.1520	-0.5497	-0.1953	-0.8633	1.0000		
	0.1710	*0.0000*	*0.7432*	*0.0000*	*0.0000*	*0.3135*	*0.0000*	*0.0000*	*0.0000*	*0.0070*	*0.0000*	*0.0016*	*0.0000*	*0.0000*	*0.0000*			
Instab	0.0629	-0.1319	-0.1275	0.3936	0.3546	-0.1981	-0.5474	0.2614	-0.1893	0.2341	-0.3688	-0.2681	-0.5593	-0.3191	-0.7253	0.8081	1.0000	
	0.1469	*0.0021*	*0.0064*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0001*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*		
FREE	-0.1097	0.1498	-0.0439	-0.2329	-0.2917	0.2036	0.3916	-0.3481	0.4181	-0.1313	0.1674	0.4008	0.4880	0.1293	0.5789	-0.5508	-0.6570	1.0000
	0.0173	*0.0010*	*0.3742*	*0.0000*	*0.0000*	*0.0001*	*0.0000*	*0.0000*	*0.0000*	*0.0041*	*0.0011*	*0.0000*	*0.0000*	*0.0060*	*0.0000*	*0.0000*	*0.0000*	

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