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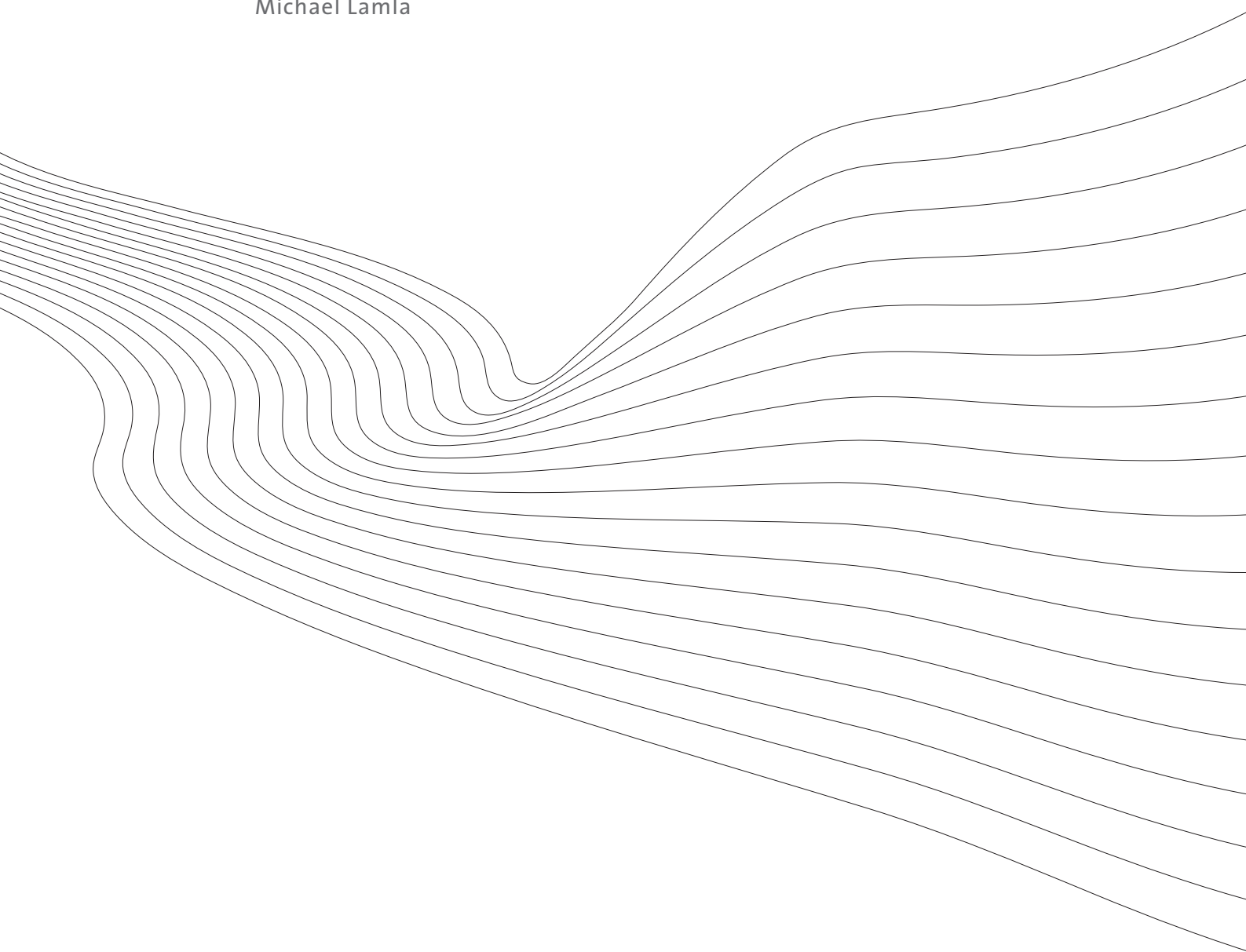
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# KOF Working Papers

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A Robustness Analysis

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# Long-Run Determinants of Pollution: A Robustness Analysis\*

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## Abstract

This paper examines how robust economic, political, and demographic variables are related to water and air pollution. Employing Bayesian Averaging of Classical Estimates (BACE) for a cross section of up to 74 countries, 33 variables and 3 proxies for air and water pollution over a period from 1980 to 1995 we confirm the Environmental Kuznets Curve hypothesis, highlight the relevance of efficient production technologies and underline the role of political and demographic variables.

*JEL classification* C52, O13, Q53

*Keywords:* pollution; sensitivity analysis; BACE

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# 1 Introduction

Previous studies have proposed an enormous range of variables as significant determinants of pollution. Recently, the focus of attention has shifted from mainly economic to political and demographic determinants. However, as most studies do not satisfactorily control for different measures of pollution, different samples, or, even more importantly, different sets of conditioning variables, it remains questionable whether the suggested explanatory variables are *robustly* linked to the level of environmental quality.

[Gassebner et al. \(2006b\)](#) recently survey this issue in a panel context and apply Extreme Bounds Analysis to solve the problem. With this setup they make a clear contribution and are able to crystallize out which variables have a significant impact on pollution levels.

We address this issue by employing an state-of-the-art estimation technique based on [Sala-i-Martin et al. \(2004\)](#). This technique reveals variables robustly related to a dependent variable by applying tools of Bayesian econometrics on classical estimating procedures (BACE). In addition to employing superior econometric techniques, we utilize a broader set of variables as any previous study. The data set comprises 74 respectively 47 countries, 33 variables and 3 proxies for air and water pollution. We calculate long term averages over 15 years. This makes our study invulnerable to short term effects (like business cycles, one-time effects, etc.). Furthermore, focusing on a cross section of countries allows us to incorporate variables which show little or no time series variation (e.g. political variables).

We provide evidence in favor of the environmental Kuznets curve irrespective of the pollution proxy in use. After a certain threshold of per capita income a further rise in output reduces environmental degradation. Furthermore, we find that efficient production technologies affect the level of environmental degradation significantly. The less energy is used to generate one dollar of output the higher is the environmental quality. These variables are relevant with respect to robustness (in terms of the conditioning set), but also concerning their overall effect as measured by the impact of a one standard deviation shock. Above from that, a specific set of variables affects the proxies for environmental degradation. Notably, air pollution proxies show strong similarities in their set of long-run determinants. We can conclude that variables not directly related to production do matter for the level of environmental quality. Accentuated should be the role of inequality, the degree of urbanization, the political leaning of the chief executive and the political system.

The paper is organized as follows. In [Section 2](#) we introduce potential determinants of pollution

proposed in the previous literature. Section 3 describes the method of estimation. Section 4 presents the results, while Section 5 concludes.

## 2 Literature and Variables Selection

The upcoming section discusses and motivates the variables incorporated in the previous literature. Overall, we gathered 33 variables and 3 different proxies of pollution. All variables are averages over 15 years, from 1980-95, for a set of 74 respectively 47 countries.<sup>1</sup> The necessity for a balanced sample, which is required for BACE, and data availability forces us concentrate on the range 1980-95 and 47 countries. In this period data availability is best. Out of the set of 33 variables, 23 variables were incorporated in the Panel Data study by Gassebner et al. (2006b) pursuing Extreme Bounds Analysis.

To allow for generality we employ proxies for water and air pollution. As our measure of water pollution we take *BOD* from the World Development Indicators CD-ROM (2003) as published by the World Bank (WDI 2003). The European Environment Agency notes that “*BOD* is a measure of how much dissolved oxygen is being consumed as microbes break down organic matter. A high demand, therefore, can indicate that levels of dissolved oxygen are falling, with potentially dangerous implications for the river’s biodiversity.”<sup>2</sup> The data on water pollution seems the most accurately measured pollution data, since sampling techniques are common in all countries.

Concerning air pollution, our main variable of interest is the level of carbon dioxide ( $CO_2$ ) emissions. Despite that these data are based upon calculations and not measured directly it is accepted to proxy the level of sufficiently precise.

Finally, we use sulfur dioxide  $SO_2$  as another proxy for air pollution. We employ the recently updated data prepared by Stern (2005). To construct the data set Stern has combined various sources and applied different econometric methods. This data gives a decent overview of the evolution of sulfur emissions. Nevertheless, in comparison to the preceding proxies, it seems to be interpreted more carefully when applying our estimation setup.<sup>3</sup> We use per capita and logged values of our pollution proxies.

The remainder of this section comprises the 33 variables and addresses briefly their underlying hypotheses. For matters of reading convenience we group the variables into three not mutually

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<sup>1</sup>BOD is the reason for this reduced sample. However, our results are not affected by enlarging the sample for CO2 and SO2.

<sup>2</sup>[http://themes.eea.eu.int/Specific\\_media/water/indicators/bod/index\\_html](http://themes.eea.eu.int/Specific_media/water/indicators/bod/index_html)

<sup>3</sup>Especially since some data-points are calculated via econometric means.

exclusive categories: economic, political and demographic.

## 2.1 Economic Variables

A commonly expressed view is that greater economic activity should lead to more pollution. However, this relationship is just partly true. The most prominent theory that questions this linear relationship is the *Environmental Kuznets Curve* hypothesis. The *Environmental Kuznets Curve* proposes an inverted U-shaped relationship between economic activity and pollution. From a theoretical point of view, the *Environmental Kuznets Curve* (EKC) is the most accredited hypothesis.<sup>4</sup>

A substantial body of theoretical models exists that leads to such an inverted U-shaped relationship.<sup>5</sup> Although there are many models in favor of the EKC they have been criticized to produce the desired outcome by imposing a specific set of ex-ante assumptions.<sup>6</sup> Since it is beyond the scope of the paper to discuss the various setups, we sketch the ideas of [Grossman and Krueger \(1995\)](#), [Antle and Heidebrink \(1995\)](#) and [Torras and Boyce \(1998\)](#).

Grossman and Krueger discern a scale, a composition and a technology effect. The scale effect describes the economic degradation driven by a ceteris paribus expansion in economic activity. When economic activity is increasing, more resources are used for production, more residuals are generated and thus more contamination occurs. The composition effect describes the change in the structure (e.g. the transformation from an industrial to service dominated economy) of the economy due to growth. Finally, the technology effect specifies the substitution of dirty and inefficient technology by more sophisticated and “cleaner” methods.

Other studies propose that the income elasticity of environmental demand is changing, see for instance, [Antle and Heidebrink \(1995\)](#). This argument is driven by the normal good character of environmental quality. As income grows, people realize a higher standard of living and hence care more about environmental protection. This changing attitude has in turn an impact on policy decision making.

Moreover, [Torras and Boyce \(1998\)](#) employ market mechanisms as explanatory factors. Low costs for natural resources today lead to heavy exploitation. Given a finite amount and an effective

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<sup>4</sup>[Kuznets \(1955\)](#) presumes such a inverted U-shaped relationship between income inequality and per capita income.

<sup>5</sup>For instance [Lopez \(1994\)](#) and [Selden and Song \(1994\)](#) assume infinitely lived agents, exogenous technological change and that pollution is generated by production and not by consumption. Furthermore, [John and Pecchenino \(1994\)](#), [John et al. \(1995\)](#), and [McConnell \(1997\)](#) develop models based on overlapping generations. Recent modelling setups involve total factor productivity (see [Chimeli and Braden \(2005\)](#)) and second-best fiscal policy frameworks (see [Cassou and Hamilton \(2004\)](#)).

<sup>6</sup>See for instance [Stern \(2004\)](#).

pricing of natural resources this in turn leads to rising prices. Higher prices increase the pressure to switch to less resource intensive technologies. This finally leads to a hump-shaped relationship between pollution and income.

Turning to the empirical evidence, [Shafik \(1994\)](#), [Selden and Song \(1994\)](#) and [Grossman and Krueger \(1995\)](#) report estimations that support the EKC.<sup>7</sup> Nevertheless, results presented by e.g. [Arrow et al. \(1995\)](#) point out that this finding is not necessarily robust.<sup>8</sup> We use the level and squared transformations of (the log of) real GDP per capita ( $LGDP$ ,  $LGDP^2$ ) to test the EKC theory.

Another highly debated topic with respect to environmental degradation is the relationship between emissions and trade. According to, e.g., [Cole \(2004\)](#) trade may reduce pollution emissions due to greater competitive pressure or “greater access to ‘greener’ production technologies” (p.79). For that reason we introduce the variable  $TRADE$ , representing trade intensity, in our analysis. This variable is defined as the ratio of imports plus exports over GDP.<sup>9</sup>

International capital transactions might also affect national pollution levels. [Antweiler et al. \(2001\)](#) incorporates inward foreign direct investment as percentage of GDP ( $FDIGDP$ ) in his analysis. As a final proxy for openness we employ the KOF Index of Globalization (GLOBAL) (see [Dreher \(2006\)](#)). This index incorporates economic as well as political and sociological aspects of globalization.

Real GDP growth ( $GDPGR$ ) is included to control for economic performance. This measure is originally proposed by [Carlsson and Lundström \(2003\)](#). The relationship is not predetermined. Since countries with on average high growth rates may “overheat” and hence exploit resources too much. On the other hand high growth countries may be the first where the consumption patterns change in favor of the environment.

[Neumayer \(2003\)](#) points out that the manufacturing sector is usually regarded as more polluting as the service sector. Thus, considering the industry share of an economy might help explain the level of pollution.<sup>10</sup> Hence, we employ a variable measuring the industry share concerning output ( $INDSHGDP$ ) as well as a variable denoting the share of people working in the industry sector

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<sup>7</sup>For a detailed survey of theoretical and empirical studies dealing with the EKC, we refer to [Dinda \(2004\)](#).

<sup>8</sup>Some authors propose an inverted N-shaped or even an N-shaped relationship. See for instance [Holtz-Eakin and Selden \(1995\)](#), [Cole et al. \(1997\)](#) or [Moomaw and Unruh \(1997\)](#).

<sup>9</sup>Often the effect of trade is also dis-aggregated into three components: a scale effect, a technique effect, and a composition effect. The scale effect refers to the fact that trade enlarges the sales markets which presumably increases production which in turn increases pollution. The technique effect relates to the trade induced changes of the production technology. The composition effect stems from changes in production of an economy caused by specialization. Due to the different nature of these individual effects, the overall impact of trade on the environment is ambiguous. For greater detail, see [Grossman and Krueger \(1991\)](#), [Antweiler et al. \(2001\)](#), [Cole and Elliott \(2003\)](#) and [Cole \(2004\)](#).

<sup>10</sup>See also [Torrás and Boyce \(1998\)](#), [Carlsson and Lundström \(2003\)](#) and [Cole and Neumayer \(2004\)](#).



(*INDSHEMP*) in our analysis. Although it might seem that these two variables quantify the same relationship this need not necessarily be the case. From a theoretical stance *INDSHGDP* measures the relative importance of the industry sector in an economy. By controlling for other characteristics *INDSHEMP* can be interpreted as the composition of the industry sector, i.e. labor or capital intensive.<sup>11</sup> On the other hand, *INDSHEMP* might also represent the pressure from industrial workers for lower environmental regulation. Since environmental regulation may lead to lay-offs, especially bourn by industrial workers, they have incentives to use their political power to prevent a rise in the environmental regulation.<sup>12</sup> Both theoretical reasonings for including those two variables are reinforced when calculating the correlation between both variables. A correlation coefficient of 0.37 (see Table A-5) does not imply a strong linkage between both measures.

Besides the degree of industrialization, the composition of a country’s energy sector might play an important role. To judge upon this hypothesis we include the share of electricity production from oil sources in total electricity production (*OILENERGY*), slightly adapting Neumayer (2003). A high share should negatively affect the quality of air pollution. The effect on water pollution is not that straightforward.

When considering the attributes of the underlying industry a proxy of efficiency is of vital importance. Following Neumayer (2003) we also utilize *ENERGYGDP* which stands for the amount of commercial energy used to produce one dollar of output. Accounting for other characteristics of an economy, this intends to proxy for the level of efficiency in the production process.<sup>13</sup> The more efficient an economy produces its goods and services, the less it should suffer from environmental degradation. In the case of *ENERGYGDP* this means: The higher *ENERGYGDP* the less efficient is the production process in the economy produces and thus the more waste it creates.

As a final economic structure variable, we take (the log of) the use of fertilizer (*LFERT*). Cole and Elliott (2003) proposes that higher fertilizer consumption might increase the level of water pollution. However, higher fertilizer use may also proxy the general attitude towards pollution in an economy. Moreover, fertilizer plants are classical “dirty” sector industries. A economy relying on fertilizer is likely to have a lower amount of clean capacities. In addition, recent ecological studies like Neff et al. (2002) highlight the effect of fertilizer on the assimilation capacities of carbon dioxides of firm ground. Hence, we also use it as an explanatory variable for our proxies for air pollution.

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<sup>11</sup>Especially due to underling technological changes in the production process these two variables do not have to move simultaneously.

<sup>12</sup>See also Damania et al. (2003).

<sup>13</sup>Note, that through implementing demographic, economic and political factors we should be able to achieve this conditioning in an sufficient way.

## 2.2 Political Variables

As emphasized in the introduction, recent studies discuss the role political variables play with respect to the environmental quality. Their performance in the sensitivity analysis are of especial interest to us. Hence, we discuss an extensive set of political variables.

Carlsson and Lundström (2003) introduce the index of economic freedom (*ECFREE*) and the Political Freedom Index (*POLFREE*) in this line of literature.<sup>14</sup> They claim that economic freedom leads to a more efficient allocation of resources and therefore to a lower level of emission.<sup>15</sup> A higher level of political freedom *POLFREE* allows people to express their preferences for higher environmental standards better. Other politically motivated variables included in our analysis are: a dummy variable measuring whether the party of the chief executive has a left-wing orientation (*EXECL*), the number of years the chief executive has been in office (*YRSOFFC*), a dictatorship dummy (*DICT*), an index measuring the economic organization (*ECORG*), a socialist dummy (*SOCIALIST*), an index capturing the level of corruption (*CORRUPT*) and a dummy for a presidential or parliamentary system (*SYSTEM*). The first is adapted from Neumayer (2003) and Neumayer (2004) who argue that left wing governments have strong settled traditional political objectives, generally driven by blue-collar workers' interests. However, they propound that a higher degree of sympathy towards environmental protection by left-wing governments is possible, too. For instance especially the poor and the working class suffer from environmental degradation. The second variable in this order is suggested by Klick (2002), who argues that the longer a government stays in power the less willing it is to enhance pollution controls. He presumes that staying in power has diminishing returns in time. Hence the incentive to stay in power for another day is higher at the first day in power than the day after and so on. This argument follows closely the ideas of Olson's institutional sclerosis.

Furthermore, Klick claims, contrary to the common view, that a dictator might have strong incentives to take care of the environment to verify his leading position. Because a dictator has a limited number of instruments at hand to remain in power, he might find it more optimal to invest in environmental protection rather than, e.g., schooling.<sup>16</sup> Contrary to that view Congleton (1992) contends that autocratic countries should have lower environmental standards. As he believes

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<sup>14</sup>We retrieve the indicators for economic and political freedom from, respectively Gwartney et al. (2003) and Freedom House (1999). *POLFREE* is computed out of the equally weighted sum of the two Freedom House Indices, i.e. civil liberties and political rights.

<sup>15</sup>In more detail, Carlsson and Lundström (2003) further decompose the economic freedom index and surveyed the elements separately. As most of the sub-components are highly correlated and the remainder catches the size of the government sector, we decided not to decompose the index.

<sup>16</sup>The variable *DICT* is calculated out of the Executive Indices of Electoral Competitiveness (EIEC) included in the Database of Political Institutions as collected and described by Beck et al. (1999).

autocratic rulers have a shorter time horizon. Since he holds a greater share of national income, he has also to bear the costs of higher environmental protection. Consequently, the dictator's incentives to invest in environmental protection should be lower.

Following Congleton (1992) we also employ the variable representing the degree of capitalism (*ECORG*) and a socialist dummy (*SOCIALIST*) representing countries which were under socialist rule for a relevant time period. More efficient market institutions imply larger wealth share. Due to higher welfare both consumption as well as expenditure on environmental protections increase. On the other hand greater income may increase environmental regulation costs.

Many authors like Persson et al. (2000) or Bueno de Mesquita et al. (2003) argue that a parliamentary or presidential system affects pollution. However, it is not clear if the public good, the environment, is underprovided or not. Persson, Roland and Tabellini (2000) state that the presidential system leads to an inefficient low provision of environmental protection. On the other hand Bueno de Mesquita et al. (2003) put forward that in a presidential system the size of coalitions might be different which may lead to a very high provision of public goods.<sup>17</sup> To analyze this issue we employ the variable *SYSTEM*.

Welsch (2004) puts forward that corruption in the government provides inefficiently low levels of a public good, e.g. environmental quality, because of the opportunities of rent seeking. Hence, we introduce the variable *CORRUPT*.

### 2.3 Demographic Variables

Finally, we introduce variables that capture further specific attributes of a country that are relevant for environmental issues.

In line with Congleton we, too, introduce *AREA* to proxy for resources. Assuming that resources are equally distributed a greater surface implies a greater probability of finding valuable resources. More resources denote higher wealth. This in turn increases the incentives to invest in environmental protection. However, increased environmental protection harms those people which own most of the producing facilities. To check for the influence of the size of the economy many authors introduce a population measure in their models. Following, e.g. Borghesi (2000) and Klick (2002), we include (the log of) population density (*LPOPDENS*) as well as population growth (*POPGR*). Population has been often conjectured to have a negative effect on the environment. It is emphasized that population as well as population growth exert unsustainable exploitation of

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<sup>17</sup>See also Bernauer and Koubi (2004) for a panel study on those political variables.

the environment. As a second demographic variable, we use the share of urban population in total population (*URBAN*). [Cole and Neumayer \(2004\)](#) argue that a higher share of urban population implies a higher density of means of production which decreases environmental quality. On the other hand [Cole et al. \(2004\)](#) contend that greater exposure to industrial pollution might have a positive effect either. If a higher amount of citizens face high pollution the propensity to vote in favor of higher standards of environmental protection increases which in turn reduces pollution.

[Torras and Boyce \(1998\)](#) argue that the distance to the coastline might be relevant, in particular, for water pollution. There is certainly a free-rider problem due to its public good character to keep domestic water clean. However, there exists a (low) threshold where poor water quality becomes unbearable by the population and countermeasures will be installed. Therefore, we introduce the variable *LANDLOCKED*.<sup>18</sup> To account for geographic, but also for temperature effects we include also *ABSLATIT* denoting position (absolute latitude) of a country. [Antweiler et al. \(2001\)](#) use temperature. Temperature is an issue because sulfur is a side product in industrial production as well as heating with fossil fuels. Since countries with higher latitude have a higher degree of industrialization but also need more burning of fossil fuels for heating we expect a positive sign.

A very important aspect and a source of lively discussion is the effect of inequality on pollution. A common view is presented by [Torras and Boyce \(1998\)](#) who state that inequality leads to environmental degradation. They argue that high income inhabitants (asset owners) have an interest in high production. As actions enhancing environmental quality will most likely affect their productive abilities they have incentives to behave opportunistic. Having greater economic but also political “power” this country would have to face a lower degree of environmental protection than the median voter would prefer.<sup>19</sup> However, there is no consensus about the direction of this relationship. Introducing a white-collar sector into the model specification alters the implications dramatically. For instance [McAusland \(2003\)](#) argues that both directions are possible depending on the type of the asset ownership and the openness of a country. Pollution may decrease with inequality if inequality stems from ownership of clean capacity and the terms of trade do not react. A very similar result is reported by [Gassebner et al. \(2006a\)](#). They show theoretically and empirically that the declining economic significance of the industrial sector, associated with falling industrial incomes and a lower political weight, leads policy-makers to increase environmen-

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<sup>18</sup>Landlocked is actually a very imperfect proxy. If a country is landlocked but has many lakes or rivers it might care as much for the level of water pollution than a country that has a long coastline.

<sup>19</sup>In their paper they comment on the political influence of a secretary and a CEO. They state that it is unlikely that the secretary has more political power.

tal regulations. Hence, we introduce the variable *INEQUAL*. It is taken from the University of Texas Inequality Project (UTIP (2001)) and is based on the United Nations International Development Organisation’s (UNIDO) database of payments. The inequality measure is derived from the between-groups component of the Theil’s T statistic.<sup>20</sup>

Pollution might also be related to the level of education in a country. [Torras and Boyce \(1998\)](#) as well as [Klick \(2002\)](#) include measures of education as control variables in their respective setup. However, one could also directly argue in the spirit of [Lipset \(1959\)](#), who states that education is at least a necessary condition for democracy. Hence, higher education may be a prerequisite for a higher demand of a clean environment.<sup>21</sup> Therefore, we include primary education (*PRIMEDU*) in our analysis.

Finally, we include a bunch of dummy variables to control for region specific effects. Hence, we employ an European dummy (*EUROPE*), an East Asian dummy (*EAST*), a Sub Saharan dummy (*SAFRICA*), a Latin American dummy (*LAAM*) and finally a dummy for oil-producing countries (*OIL*).

The variables in use – including expected sign and data source – are summarized in [Table A-1](#). Descriptive statistics are presented in [Table A-2](#).

### 3 Methodology

In a context where a representative body of empirical research exists and one theory does not rule out the applicability of another theory, model uncertainty is predominant.<sup>22</sup> In cross-country regressions with a small ratio of the number of countries compared to the variables of interest, asymptotic theory to rule out variables that are not related to the dependent variable does not apply. Hence, researchers face the challenge to find a way to discover the *true* set of explanatory variables.

This challenge has already been taken by various studies. A prominent methodology, as introduced by [Leamer \(1983\)](#) and [Levine and Renelt \(1992\)](#), has become the so-called Extreme Bounds Analysis (EBA). The basic idea is to run many regression continuously permutating explanatory variables and to test how the variable in the center of attention “behaves” (e.g., how often it is significant). The critical point is then to apply effective decision rules to check if a variable passes

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<sup>20</sup>For details see <http://utip.gov.utexas.edu/>.

<sup>21</sup>Especially in the growth literature education gained much attention.

<sup>22</sup>All methods discussed in this section only deal with uncertainties with respect to the inclusion of specific variables. The goodness of the structural form of the estimation equation is not addressed.

the test and by doing that being able to extract the true set of variables. In case of the EBA several rules have been imposed, evaluated and augmented.<sup>23</sup>

However, despite its prominence, this method has its critics. One problem the EBA has is that the output of every regression is treated equally. Hence, coefficients of a regression with a bad fit are handled the same way as coefficient stemming from a regression with a very good fit. Moreover, it restricts researchers to a specific model size which has to be set a priori.

BACE has the advantages of EBA but avoids some of its drawbacks.<sup>24</sup> BACE combines “Bayesian Model Averaging” with classical estimation techniques. For a survey on Bayesian Model Averaging see also [Hoeting et al. \(1999\)](#). Bayes’ rule describes a probability update due to additional information. Conditional on the estimation results, ex-ante beliefs about the true model or the significance of a variable are updated. This is done employing a certain goodness of fit statistic related to the Schwarz criterion. If a model is supported by the data the posterior model probability – calculated applying this goodness of fit statistic – will be higher than the ex-ante or prior probability of the model.<sup>25</sup>

Being able to infer whether data supports a specification turns out to be one major advantage of the BACE procedure. It is now possible that estimates of the conditional mean from a superior model are weighted more in the summary statistics in contrast to estimates from a inferior setup. Another argument in favor of this method is that except for the supra-parameter  $\bar{k}$  no additional structure is imposed from the researcher. This parameter  $\bar{k}$  represents the belief concerning the average model size.<sup>26</sup> Models of all sizes are considered and almost all permutations of variables are tested.<sup>27</sup>

In the upcoming paragraph we will give a short description and interpretation about the technique and the output statistics that will be presented in the results section.

Following a Bayesian approach the researcher has to judge about the *Prior Inclusion Probability*

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<sup>23</sup>[Leamer \(1983\)](#) and [Levine and Renelt \(1992\)](#) proposed the following: The extreme bounds test for variable  $F$  says that if the lower extreme bound for  $\beta$  – i.e. the lowest value for  $\beta$  minus two standard deviations – is negative, while the upper extreme bound for  $\beta$  – i.e. the highest value for  $\beta$  plus two standard deviations – is positive, the variable  $F$  is not robustly related to  $Y$ .

As contended by [Temple \(2000\)](#), it is rare in empirical research that we can say with certainty that some model dominates all other combination of models in all dimensions.

[Sala-i-Martin \(1997\)](#) rightly argues that the test applied in the extreme bounds analysis is too strong for any variable to really pass it. If the distribution of the parameter of interest has some positive and some negative support, then one is bound to find one regression for which the estimated coefficient changes sign if enough regressions are run.

<sup>24</sup>As in the EBA, many models are tested, results of regression analyzed and decision rules created to give the researcher methods at hand to judge upon whether a variable is robustly related or not.

<sup>25</sup>Given the data, respectively the information in the data, the model is *more* likely to be the true one.

<sup>26</sup>It is intuitively plausible that a researcher has a belief concerning a reasonable model size and should express this guess.

<sup>27</sup>Concerning the sampling algorithm we follow [Sala-i-Martin et al. \(2004\)](#).

of each variable. The *Prior Inclusion Probability* is denoted by  $P(\beta_i \neq 0) = \frac{\bar{k}}{K}$  where  $K$  represents the overall number of variables and  $\bar{k}$  signifies the prior mean model size. A fully specified Bayesian approach requires to define prior distributions for all parameters for every model. Allowing for all permutations of  $K$  regressors ( $2^K$  possibilities) makes this idea infeasible and highly subjective. Hence, it is assumed that the likelihood of every variable belonging into the true model is the same and thus the same prior inclusion probability is attributed to each.<sup>28</sup> In that consequence models with the same amount of parameters get the same prior model probability. This probability decreases with increasing distance to the prior mean model size  $\bar{k}$ . The prior model probabilities are computed via

$$P(M_j) = \left(\frac{\bar{k}}{K}\right)^{k_j} \left(1 - \frac{\bar{k}}{K}\right)^{K-k_j},$$

where  $k_j$  represent the amount of parameters of the model  $M_j$ . Since the prior inclusion probability is settled the derivation of the *Posterior Inclusion Probability* has to be tackled. *Posterior Inclusion Probability* is the sum of the posterior model probabilities for all models including that variable and is calculated via:

$$P(\beta_i \neq 0|y) = \sum_{j=1}^{2^K} P(M_j|y).^{29} \quad (1)$$

$P(M_j|y)$  is the posterior model probability, the probability distribution of model  $M_j$  given the data  $y$ . It is calculated as the proportional likelihood function corrected for the degrees of freedom

$$P(M_j|y) = \frac{P(M_j)T^{k_j/2}SSE_j^{-T/2}}{\sum_{i=1}^{2^K} P(M_i)T^{k_i/2}SSE_i^{-T/2}}, \quad (2)$$

where  $T$  is the sample size and  $SSE$  is the sum of squared errors.<sup>30</sup> The latter part of equation 2 is closely related to the Schwarz (1978) criterion. The posterior inclusion probability is a measure that relates the average goodness of fit of a model including that specific variable relative to the average goodness of fit of models without that variable. It therefore catches the contribution of that specific variable to the goodness of fit of a regression model. If the Posterior Inclusion Probability of the variable is higher than the Prior Inclusion Probability the variable is supported

<sup>28</sup>One could interpret this as in a consequence of having nearly no reliable information being conservative in his prejudgment.

<sup>29</sup>Note: If there are  $K$  variables one has  $2^K$  possible ways to combine them.

<sup>30</sup>This is the adjusted form of  $P(M_j|y) = \frac{P(M_j)P(y|M_j)}{\sum_{i=1}^{2^K} P(M_i)P(y|M_i)}$ .

by the data and is interpreted as being related to the dependent variable.<sup>31</sup>

Besides information about the relevance of a variable it is of equal importance to survey the magnitude of impact. For this purpose the OLS parameter estimates are weighted by the posterior model probability and summarized in the *Posterior Mean unconditional on inclusion* which is given by

$$E(\beta_i|y) = \sum_{j=1}^{2^K} P(M_j|y)\hat{\beta}_i,$$

where  $\hat{\beta}_i = E(\beta_i|y, M_j)$  is the ordinary least square (OLS) estimate. The classical estimates of the OLS regressions are weighted by the posterior model probabilities. The Posterior Variance unconditional on inclusion is derived by [Leamer \(1978\)](#) and calculated by

$$Var(\beta_i|y) = E[Var(\beta_i|y, M_j)|y] + Var[E(\beta_i|y, M_j)|y].$$

The variance of  $\beta_i$  is hence the sum of the variance within the model *and* the variance between the models. *Posterior Mean conditional on inclusion* and the *Posterior Variance conditional on inclusion* are given by the unconditional value over the posterior probability. Since the unconditional mean is a weighted average over *all* regression it includes models where the variable does not appear and has a coefficient of zero. To account for that we divide both measures by the posterior inclusion probability.<sup>32</sup>

To narrow the set of robust determinants additional statistics are employed. *Sign Certainty Probability* is the probability that the estimated coefficient is on the same side of zero as its mean conditional on inclusion. It is given by

$$P((sgn(\beta_i) = sgnE(\beta_i|y)|y, \beta_i \neq 0)).^{33}$$

This sign certainty probability is analogous to the area under the normal cumulative density function,  $CDF(0)$  in the EBA. The posterior density is equal to the classical sampling distribution. Hence a variable which is significant at a 5% level in every regression conditional on inclusion should have a sign certainty probability of 97.5 % given the two sided nature of this test. Finally, we report the share of significant coefficient estimates in classical terms, e.g. where the t-statistic is  $\gtrsim 1.96$ . To allow for inference about the magnitude of an impact of a variable we calculate the

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<sup>31</sup> $P(\beta_i \neq 0|y) > P(\beta_i \neq 0)$ .

<sup>32</sup>The Posterior Standard Error is the square root of the Posterior Variance.

<sup>33</sup>Where *sgn* denotes the signum function.



*Impact Rank.* Variables are ranked by the magnitude of the value calculated by multiplying the effect of one standard deviation shock with the estimated coefficient. A variable is supported by the data if the posterior probability of inclusion is higher than the ex-ante probability. Moreover, [Sala-i-Martin et al. \(2004\)](#) characterize “TOP” variables which have a posterior distribution of greater than 0.95 and should be almost surely incorporated in a final model.

## 4 Results

To allow comparison with other literature in which, in models with a similar number of observations, on average around 7 explanatory variables, are included, we opt to present results for this model size. This leads – given that we have a total of 33 variables – to a prior inclusion probability ( $P(\beta_i \neq 0)$ ) of  $7/33 \approx 0.21$ .<sup>34</sup> Results are presented in Tables 3, 1, and 2. Overall, the following picture emerges: Starting off with the “TOP” variables for every pollution proxy we can confirm the EKC hypothesis. Both, the log of per capita GDP and its square (LGDPPC, LGDPPCSQ) are significant. Hence, beyond a certain threshold of income, which varies for different indicators, economic growth leads to environmental improvement. Furthermore, the variable measuring efficient manufacturing technology (ENERGYGDP) is significant and shows a negative coefficient for both air pollution proxies. The less energy is used to produce one unit of GDP, the more efficient is the production process and the less waste is generated. Both results imply that a technology shock improves environmental quality in general. On the one hand this is clearly good news. After a certain threshold of output, the environment seems to benefit. On the other hand it should be noted that reaching this turning point it is not a self-fulfilling prophecy. Only if this level of output implies a production base with a certain technology level and a certain composition of the economy these results will emerge.

Concerning water pollution, inequality is negatively related. As discussed above, the theoretical and empirical literature is inconclusive about the overall effect. However, this result corresponds with the findings of [Gassebner et al. \(2006b\)](#). This effect may be due to the nowadays observable composition of the industrial sector. An expanding white-collar sector with high-skilled, high-income workers and a shrinking blue-collar sector associated with mostly low-skilled, low-income workers leads to greater inequality in income/wage but also implies higher environmental quality due to greater demand driven by white-collar workers. Since their jobs are based on “clean”

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<sup>34</sup>We also run versions beginning from 5 up to 15 variables. However, our results change marginally if at all. For Sulfur Dioxide and BOD we get posterior model sizes of very close to 7. For carbon dioxide the posterior model size is for the greater sample 9, for the smaller sample 7.

technologies aiming for a higher level of environmental stringency has no negative effect on the probability being employed while for blue-collar workers it certainly has.

Besides that, the remaining set of variables which is supported by the data (having a posterior probability greater than their prior probability), varies with the matching pollution measure. Overall, this list contains further variables not directly related to the production process. Moreover, it becomes clear that not only different determinants affect air and water pollution but the same determinants might have opposite effects.

With respect to carbon dioxide we find that population growth (POPGR), the industry share (INDSHGDP), the Latin America dummy (LATIN), the share of urbanization (URBREL), the oil producing dummy (OIL), the socialist dummy (SOCIALIST), the political system dummy (SYSTEM) and finally the share of energy derived from fossil fuels affect the level of carbon dioxide. Higher population growth leads to greater exploitation and to rising carbon dioxide levels. In line with Congleton (1992) we show that the endowment with resources matters. The more resources a country has at its disposal the greater the probability it takes the opportunity to exploit them. Furthermore, the share of energy derived from burning fossil fuels increases the concentration of carbon dioxide. The more a economy relies to burn fossil fuels the more carbon dioxide is depleted. This is exactly in line with our prior expectations. Moreover, big agglomerations tend to produce more air pollution. Besides that we can observe that variables not directly related to production do matter. For instance our results show that a parliamentary system seems to provide less environmental quality in terms of air quality than a presidential system. This result does not imply that a parliamentary system does not provide enough environmental quality. It may even be that the presidential system could provide too much (an inefficient high level) of this public good.

Concerning sulfur dioxide our results show that a country's geographic position (ABSLATIT), inequality (INEQUAL), the level of urbanization (URBREL), the Latin America dummy (LAAM), the political leaning of the incumbent (EXECL) and the share of energy derived from burning of fossil fuels affect the level of air pollution. Comparing the set of determinants for our air pollution proxies we can observe that those sets are quite similar. However, some variables stand out. In this respect, the left wing orientation of the chief executive seems to matter for sulfur dioxide. This result confirms our first judgement upon this variable. Since there is a long traditional tie between left wing parties and mainly industrial workers, measures that will reduce sulfur dioxide emission might increase the probability of unemployment for those groups will be blocked.

Turning to our proxy for water pollution we can observe that the share of oil in the energy production (*OILENERGY*), the level of globalization (*GLOBAL*), economic freedom (*ECFREE*), the position of a country (*ABSLATIT*), the economic organization (*ECORG*), the level of fertilizer matter (*LFERT*) and how energy-efficient the industry sector is operating.

*OILENERGY*, which denotes the share of oil in the energy production, has a positive effect on water pollution. This is to some extent surprising since, as shown for air pollution, more energy production from fossil fuels is typically considered to increase air pollution. However, this general statement is not valid in case of water pollution. Contrary it may proxy a certain type of industrialization which is obviously still polluting, but may overcome certain negative effects on water pollution. An economy strongly relying on oil for water pollution has to especially take care for their water quality since oil leaks can seriously contaminate large water reservoirs. Additionally, it has reached a certain level of industrialization. Another variable that affects water pollution is the exposure to globalization, which seems to improve the level of water pollution. As reasoned earlier, effective allocation and technology transfer might lead to this result. In addition, the location of a country matters. High industrialized countries are located further away from the equator. Besides that, economic freedom affects water pollution positively. Furthermore, and similar to the case of carbon dioxide, economic organization contributes to a lower level of water pollution. Moreover, fertilizer use is a determinant. This is in line with our a priori expectations. Fertilizers in the form of nitrates and phosphates flow into rivers from agricultural and urban runoff and then stimulate the overgrowth of plants and algae. This in turn leads to a reduction of oxygen in the water and harms other water-living animals and plants. Finally, and analogously to the air pollution proxies the way energy is used to produce output is relevant for water pollution.

Since we distilled a set of relevant variables it remains of interest to qualify our results. We would like to address this issue via a twofold approach. First, we compare how the set of robust variables delivered by BACE alters when we apply the EBA. Second, we check how the identified variables behave when implemented in a “final” model specification using outlier stable regression methods.

The results for the EBA are presented in Table A-3. Although both types of sensitivity analysis are not directly comparable it seems reasonable to validate how robust the set of identified variables is conditional on the method applied.<sup>35</sup> We include the variables identified as “TOP” determinants in the basic model. We presume that those variables should remain significantly related under

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<sup>35</sup>One issue for instance is that the EBA only considers models of up to three additional variables while BACE considers various model sizes.

the EBA as well. The remaining variables are analyzed separately. Our findings reinforce the outcomes of BACE for the air pollution proxies. In case of water pollution LGDPPCSQ clearly fails to meet the EBA criterion of 0.95 unweighted CDF(0).<sup>36</sup> Turning to the variables, which are supported by the data but do not belong to the elite group we find that not all meet the EBA criterion. Only for sulfur dioxide almost the complete set of variables is identified by the EBA as being robustly related, too. In case of carbon dioxide AREA and POPGR and for water pollution OILENERGY and LFERT find support from the EBA.<sup>37</sup>

Table A-4 presents the results of the final model specifications. We decided to run ordinary least squares (OLS) with robust standard-errors and two outlier robust methods. The first, denoted by ‘LAD’, is Least Absolute Deviations. This method minimizes the absolute distance between the fitted line and the observations. The second, represented by ‘LTS’, is Least Trimmed Squares.<sup>38</sup> Focussing on the signs and the significance, the results remain very stable. *LGDPPCSQ* becomes insignificant using robust estimation techniques in the case of water pollution. Despite that the LTS clearly identifies outlying observations, the general conclusions remain unchanged. Note that the estimated beta values are very similar to the average beta values delivered by the sensitivity analysis.

As a final remark we would like to address a caveat of this study. The utilization of this estimation technique comes at a cost: the need for a balanced sample reduces the cross section to 74 respectively 47 countries. Although we believe that the estimation technique is superior we have also to admit that the balanced sample restriction might bias the outcomes.<sup>39</sup> However, this is certainly still enough to draw sensible conclusion.

Overall, we can conclude that production specific variables are robustly related to both water and air pollution. We affirm the EKC hypothesis and emphasize the relevance of efficient production technologies. Moreover, we are able to conclude that other variables not closely related to production like inequality, political freedom, capitalism, resources, the political system and population growth do matter. For the latter variable set, however, a general statement for all proxies of environmental degradation is not possible. Finally, one variable has been proved to be significantly

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<sup>36</sup>In BACE it is theoretically possible that a variable on average improves the fit of a specific model without being significant at conventional levels.

<sup>37</sup>Although the remaining set of variables does not meet this specific criterion those variables still have some support by the data in the EBA as well.

<sup>38</sup>This method randomly draws sub-samples of observations. Coefficients are estimated and the sum of residuals is calculated. The regression with the minimum sum of residuals is identified. In turn this enables the researchers to identify outliers and remove them from the regression. A final regression without the outliers is calculated and displayed. For details see also [Rousseeuw and Leroy \(1987\)](#). We also used methods of imputation to correct for the unbalanced data set. However, the output stemming from this alternative do not alter our results.

<sup>39</sup>The bias argument only holds true if the values that lead to a unbalanced data are missing at random (see [Little and Rubin \(2002\)](#)). Under a selection bias using a balanced version would lead to unbiased results.

related to all three measures of pollution but with different implications. While the amount of fossil fuel used for generating energy improves the level of water pollution it clearly worsens the quality of air pollution. While this is a very interesting and robust result the investigation of the forces behind it are left for future research.

## 5 Conclusion

In this paper we analyze which variables are robustly interlinked with pollution. For this purpose we implement Bayesian averaging of classical estimates. Using a data set for 74 respectively 47 countries, 33 explanatory variables, 3 pollution proxies over a horizon of 15 years we are able to confirm the Environmental Kuznets Curve hypothesis and underline the importance of energy-efficient manufacturing technologies for all pollution proxies. Both results complement earlier studies, but for a broader set of conditioning variables. Consulting the overall magnitude of the effect, this set of variables seems to be of vital importance since they have the highest impact considering a one standard deviation shock. Hence, from a policy perspective, enhancing energy efficient production technologies has priority. However, while this conclusion is drawn easily from a researcher perspective, fostering efficient and clean technologies is one of the most difficult tasks in the political process to be fulfilled.

Concerning the remaining set of variables a general statement for all pollution proxies is not applicable. Nevertheless, we can highlight the relevance of variables not closely related to production like inequality, political freedom, capitalism, resources and population growth.

Those results remain remarkably robust when applying outlier resistant estimation methods as well as further means of sensitivity analysis.

Hence, this study ultimately shows that, in the long run, variables not directly related to production do matter. For the latter set of variables, however, a general statement for all proxies of environmental degradation is not possible.

Table 1: Results  $CO_2$ 

Variable	Posterior Inclusion Probability	Posterior Mean Conditional on Inclusion	Posterior StdErr Conditional on Inclusion	Sign Certainty Probability	Fraction of Regressions with t-stat>2	Impact Rank
LGDP	1.00	4.1945	0.658	1.00	1.00	2
LGDP	1.00	-0.4856	0.090	1.00	1.00	3
ENERGYGDP	1.00	0.3280	0.090	1.00	0.99	4
OILENERGY	0.91	0.0001	0.000	1.00	0.98	32
SYSTEM	0.86	0.1405	0.042	1.00	0.94	12
SOCIALIST	0.83	0.2607	0.087	1.00	0.99	5
OIL	0.66	0.2460	0.088	0.99	0.87	6
URBREL	0.52	0.0052	0.002	0.99	0.71	28
LAAM	0.47	-0.1654	0.070	0.99	0.64	10
INDSHGDP	0.39	-0.0105	0.005	0.99	0.52	24
POPGR	0.26	6.4910	3.254	0.97	0.41	1
ECORG	0.12	0.0320	0.021	0.93	0.05	18
EUROPE	0.11	-0.1456	0.099	0.93	0.08	8
INDSHEMP	0.10	0.0057	0.004	0.92	0.14	26
LPOPDENS	0.09	0.0618	0.048	0.90	0.07	14
PRIMEDU	0.09	-0.0026	0.002	0.91	0.06	30
INEQUAL	0.09	0.0082	0.007	0.89	0.08	23
SAFRICA	0.09	-0.1412	0.116	0.88	0.07	7
DICT	0.08	0.1221	0.111	0.86	0.12	9
EAST	0.06	-0.0483	0.110	0.68	0.02	13
ABSLATIT	0.06	0.0023	0.003	0.81	0.06	29
LANDLOCK	0.06	-0.0887	0.085	0.85	0.01	11
AREA	0.06	0.0000	0.000	0.70	0.14	33
GLOBAL	0.05	0.0506	0.054	0.82	0.04	15
YRSOFFC	0.05	0.0022	0.005	0.70	0.00	27
POLFREE	0.05	0.0014	0.034	0.53	0.05	25
GDPGR	0.05	0.0080	0.016	0.70	0.03	22
ECFREE	0.04	0.0222	0.047	0.68	0.06	16
FDINET	0.04	0.0090	0.021	0.66	0.04	20
TRADE	0.04	0.0003	0.001	0.65	0.01	31
CORRUPT	0.04	-0.0043	0.038	0.54	0.04	21
LFERT	0.04	0.0176	0.052	0.63	0.02	17
EXECL	0.03	-0.0093	0.063	0.56	0.00	19

Table 2: Results  $SO_2$ 

Variable	Posterior Inclusion Probability	Posterior Mean Con- ditional on Inclusion	Posterior StdErr Conditonal on Inclusion	Sign Certainty Probabil- ity	Fraction of Regres- sions with t-stat>2	Impact Rank
LGDP	1.00	5.289	0.911	1.00	0.98	2
LGDP	1.00	-0.658	0.127	1.00	0.96	3
ENERGYGDP	1.00	0.620	0.114	1.00	0.98	4
ABSLATIT	0.70	0.012	0.005	1.00	0.81	26
INEQUAL	0.68	0.031	0.011	1.00	0.71	23
URBREL	0.51	0.009	0.004	0.99	0.81	28
LAAM	0.45	-0.297	0.119	0.99	0.59	5
EXECL	0.41	0.239	0.098	0.99	0.58	9
OILENERGY	0.36	0.000	0.000	0.98	0.54	32
TRADE	0.21	0.002	0.001	0.96	0.23	30
FDINET	0.12	0.057	0.042	0.90	0.22	16
LANDLOCK	0.11	0.204	0.132	0.93	0.06	8
INDSHGDP	0.09	0.010	0.008	0.90	0.03	25
EAST	0.09	-0.202	0.171	0.87	0.07	6
AREA	0.07	0.000	0.000	0.85	0.07	33
SOCIALIST	0.07	0.192	0.168	0.87	0.12	7
OIL	0.06	-0.133	0.143	0.82	0.00	11
SAFRICA	0.05	0.120	0.163	0.78	0.08	10
LPOPDENS	0.05	-0.064	0.072	0.81	0.03	14
ECORG	0.05	-0.031	0.035	0.81	0.03	22
INDSHEMP	0.05	-0.006	0.007	0.81	0.02	27
POLFREE	0.05	0.030	0.043	0.75	0.06	21
YRSOFFC	0.05	0.001	0.008	0.57	0.00	29
DICT	0.05	-0.025	0.191	0.56	0.00	13
ECFREE	0.04	0.023	0.077	0.61	0.03	19
GDPGR	0.04	-0.011	0.024	0.68	0.00	24
SYSTEM	0.04	0.031	0.069	0.67	0.01	18
POPGR	0.04	-2.451	6.223	0.65	0.01	1
CORRUPT	0.04	0.029	0.059	0.69	0.02	20
EUROPE	0.04	0.078	0.171	0.68	0.01	12
LFERT	0.04	0.025	0.088	0.61	0.01	17
GLOBAL	0.04	0.045	0.090	0.69	0.02	15
PRIMEDU	0.04	0.000	0.003	0.55	0.00	31

Table 3: Results *BOD*

Variable	Posterior Inclusion Probability	Posterior Mean Conditional on Inclusion	Posterior StdErr Conditional on Inclusion	Sign Certainty Probability	Fraction of Regressions with t-stat>2	Impact Rank
LGDP	0.97	0.762	0.534	0.93	0.18	2
LGDP	0.97	-0.054	0.080	0.74	0.04	11
INEQUAL	0.97	-0.022	0.005	1.00	0.99	21
OILENERGY	0.92	-0.003	0.001	1.00	0.93	29
GLOBAL	0.84	-0.220	0.066	1.00	0.79	3
ECFREE	0.80	0.189	0.065	1.00	0.75	6
ABSLATIT	0.60	0.004	0.002	0.98	0.51	28
ECORG	0.53	-0.052	0.022	0.98	0.43	17
LFERT	0.21	0.102	0.052	0.98	0.51	9
ENERGYGDP	0.20	0.157	0.081	0.97	0.40	5
YRSOFFC	0.11	0.006	0.004	0.93	0.09	25
POPGR	0.09	-6.749	4.214	0.95	0.29	1
TRADE	0.09	0.001	0.001	0.94	0.28	32
SOCIALIST	0.09	0.113	0.118	0.84	0.16	4
SYSTEM	0.08	0.042	0.034	0.89	0.22	16
EXECL	0.07	-0.087	0.072	0.89	0.04	8
PRIMEDU	0.07	0.000	0.002	0.60	0.04	31
CORRUPT	0.06	0.067	0.059	0.86	0.29	12
FDINET	0.05	-0.001	0.020	0.52	0.09	24
AREA	0.04	0.000	0.000	0.58	0.02	33
LAAM	0.04	-0.066	0.078	0.81	0.05	10
LPOPDENS	0.04	-0.007	0.058	0.51	0.02	19
SAFRICA	0.03	0.016	0.109	0.59	0.01	15
INDSHGDP	0.03	-0.004	0.006	0.74	0.07	26
URBREL	0.03	0.000	0.002	0.52	0.13	30
DICT	0.03	0.031	0.116	0.64	0.07	14
INDSHEMP	0.03	0.005	0.005	0.80	0.14	23
OIL	0.03	0.066	0.100	0.75	0.01	7
POLFREE	0.03	-0.012	0.031	0.63	0.08	20
GDPGR	0.03	0.002	0.004	0.71	0.04	27
EAST	0.03	0.001	0.092	0.51	0.03	22
LANDLOCK	0.02	-0.043	0.088	0.69	0.00	13
EUROPE	0.02	-0.014	0.081	0.57	0.05	18



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# APPENDIX

Table A-1: List of variables and their sources

Variable	Sign	Description	Source
LCO <sub>2</sub> PC		Log of CO <sub>2</sub> Emissions in metric tons per capita	WDI (2003)
LBODPC		Log of BOD in gramms per day per capita	WDI (2003)
LSO <sub>2</sub> PC		Log of SO <sub>2</sub> Emissions in metric tons per capita	Stern (2005)
ABSLATIT	+	Absolute latitude	Barro (1999)
AREA	?	Land Area	WDI (2003)
CORRUPT	+	Corruption in government	Knack (1999)
DICT	?	Dummy variable for dictatorship (executive index of electoral competitiveness < 3)	Beck et al. (1999)
EAST	?	Dummy variable East Asian Country	
ECFREE	-	Fraser Economic Freedom Index	Gwartney et al. (2003)
ECORG	?	Degree of capitalism Index	Hall and Jones (1999)
ENERGYGDP	+	Commercial energy use times 1,000,000 (kt of oil equivalent)/GDP	WDI (2003)
EUROPE	?	Dummy variable European Country	
EXECL	?	Dummy variable for the party of the chief executive being left-wing	Beck et al. (1999)
FDINET	?	Net inflows of foreign direct investment (% of GDP)	WDI (2003)
GDPGR	?	GDP growth rate	WDI (2003)
GLOBAL	?	KOF Index of Globalization	Dreher (2006)
INDSHEMP	+	Employment in industry (% of total employment)	WDI (2003)
INDSHGDP	+	Manufacturing value added (% of GDP)	WDI (2003)
INEQUAL	+	Industrial pay-inequality measure	UTIP (2001)
LAAM	?	Dummy variable Latin America Country	
LANDLOCKED	?	Dummy variable Landlocked Country	
LFERT	+	Log of fertilizer use in 100g per ha of arable land	WDI (2003)
LGDP	?	Log of real GDP per capita (in constant 1995 US \$)	WDI (2003)
LGDP <sup>2</sup>	?	Squared log of real GDP per capita	WDI (2003)
LPOPDENS	+	Log of population per hectare	WDI (2003)
OIL	?	Dummy variable Oil producing country	
OILENERGY	+	Electricity production from oil sources (% of total)	WDI (2003)
POLFREE	-	Equally weighted sum of the Freedom House Indices	FHI (1999)
POPGR	-	Population Growth	WDI (2003)
PRIMEDU	-	Gross primary school enrollment (in %)	WDI (2003)
SAFRICA	?	Dummy variable Sub Sahara Africa Country	
SOCIALIST	+	Dummy for countries under Socialist rule for considerable time	Gallup et al. (2001).
SYSTEM	?	Parliamentary (2), Assembly-elected President (1), Presidential (0)	Beck et al. (1999)
TRADE	?	Trade intensity ((import + export)/GDP)	WDI (2003)
URBREL	?	Urban population (% of total)	WDI (2003)
YRSOFFC	+	Number of years chief executive in office	Beck et al. (1999)

Note: Sign refers to the expected sign. See main text for further explanation.

Table A-2: Descriptive Statistics

No	Variable	Mean	Maximum	Minimum	Std. Dev.
	LBODPC	0.79	1.48	0.12	0.34
	LCO <sub>2</sub> PC	0.56	1.28	-0.61	0.50
	LSO <sub>2</sub> PC	-1.91	-0.54	-3.01	0.50
1	ABSLATIT	31.69	63.89	0.51	17.90
2	AREA	1.18E+08	9.33E+08	32000.00	2.44E+08
3	CORRUPT	3.97	6.00	1.51	1.37
4	DICT	0.14	1.00	0.00	0.30
5	EAST	0.15	1.00	0.00	0.36
6	ECFREE	5.95	8.14	3.74	0.93
7	ECORG	3.51	5.00	0.00	1.25
8	ENERGYGDP	0.47	2.21	0.09	0.42
9	EUROPE	0.40	1.00	0.00	0.50
10	EXECL	0.34	1.00	0.00	0.37
11	FDINET	1.36	10.13	0.01	1.61
12	GDPGR	3.50	19.01	-20.62	5.71
13	GLOBAL	2.88	5.00	1.39	1.09
14	INDSHEMP	27.25	48.73	6.85	7.22
15	INDSHGDP	19.74	35.31	8.35	5.43
16	INEQUAL	40.33	52.92	28.69	6.34
17	LAAM	0.19	1.00	0.00	0.40
18	LANDLOCK	0.06	1.00	0.00	0.25
19	LFERT	3.11	4.57	1.59	0.55
20	LGDPPC	3.68	4.55	2.47	0.64
21	LGDPPCSQ	13.92	20.71	6.09	4.55
22	LPOPDENS	-0.23	1.68	-1.67	0.65
23	OIL	0.06	1.00	0.00	0.25
24	OILENERGY	25.73	97.88	0.06	27.63
25	POLFREE	2.79	6.49	1.00	1.66
26	POPGR	0.01	0.04	0.00	0.01
27	PRIMEDU	101.52	126.32	57.96	12.32
28	SAFRICA	0.06	1.00	0.00	0.25
29	SOCIALIST	0.06	1.00	0.00	0.25
30	SYSTEM	1.16	2.00	0.00	0.89
31	TRADE	66.95	337.90	17.43	50.33
32	URBREL	63.59	100.00	21.47	20.91
33	YRSOFFC	6.65	34.50	1.25	6.70

Table A-3: Results Extreme Bounds Analysis

$LCO_2PC$	$LSO_2PC$			$LBODDPC$			% Sign.	Unwght. CDF(0)	Std. Error	Unwght. $\beta$	Unwght. CDF(0)	Unwght. $\beta$	Std. Error
	% Sign.	Unwght. CDF(0)	Unwght. $\beta$	% Sign.	Unwght. CDF(0)	Unwght. $\beta$							
LGDPCC	100.00	1.00	4.628	0.622	0.622	0.622	100.00	1.00	6.806	1.154	0.94	0.898	0.538
LGDPCCSQ	100.00	1.00	-0.502	0.085	0.085	0.085	100.00	1.00	-0.827	0.157	0.85	-0.085	0.077
ENERGYGDP	100.00	1.00	0.765	0.094	0.094	0.094	100.00	1.00	0.847	0.174	1.00	-0.021	0.006
AREA	96.99	0.99	0.026	0.010	0.010	0.010	90.03	0.99	0.009	0.003	0.99	-0.002	0.001
POPGR	34.25	0.96	6.046	3.173	3.173	3.173	46.66	0.96	-0.259	0.129	0.99	0.117	0.049
SAFRICA	3.94	0.92	-0.151	0.100	0.100	0.100	17.71	0.95	-0.014	0.008	0.97	0.182	0.088
OILENERGY	3.75	0.90	0.001	0.001	0.001	0.001	32.78	0.95	0.083	0.045	0.97	0.067	0.035
YRSOFFC	7.69	0.89	0.006	0.004	0.004	0.004	16.54	0.94	-0.006	0.004	0.94	-5.567	3.187
ECORG	10.43	0.86	-0.030	0.025	0.025	0.025	9.70	0.94	0.032	0.020	0.89	0.051	0.039
PRIMEDU	2.31	0.86	-0.002	0.002	0.002	0.002	9.26	0.92	0.006	0.004	0.87	-0.082	0.068
FDINET	0.03	0.81	0.015	0.017	0.017	0.017	6.25	0.91	0.245	0.166	0.84	0.002	0.002
ECFREE	1.20	0.80	0.039	0.043	0.043	0.043	1.90	0.86	-0.087	0.072	0.79	0.004	0.004
INEQUAL	1.44	0.79	0.006	0.006	0.006	0.006	1.77	0.86	-0.077	0.067	0.74	0.001	0.002
LAAM	0.00	0.79	-0.061	0.072	0.072	0.072	2.25	0.83	-0.105	0.100	0.74	0.029	0.041
INDSHGDP	0.57	0.79	-0.004	0.005	0.005	0.005	7.85	0.81	0.012	0.011	0.74	0.083	0.123
EUROPE	0.00	0.76	-0.062	0.083	0.083	0.083	2.63	0.81	-0.129	0.133	0.70	0.056	0.102
SOCIALIST	0.24	0.75	0.096	0.130	0.130	0.130	1.33	0.79	0.221	0.240	0.69	-0.003	0.006
OIL	0.00	0.72	0.063	0.103	0.103	0.103	0.24	0.77	-0.007	0.009	0.68	-0.001	0.002
DICT	1.36	0.70	-0.057	0.091	0.091	0.091	0.60	0.74	0.005	0.008	0.68	-0.012	0.025
SYSTEM	0.00	0.69	0.020	0.037	0.037	0.037	0.00	0.68	-0.004	0.009	0.65	0.000	0.001
INDSHEMP	0.00	0.67	-0.002	0.005	0.005	0.005	0.00	0.67	-0.023	0.046	0.64	-0.010	0.023
LPOPDENS	1.39	0.66	0.018	0.039	0.039	0.039	0.52	0.66	0.073	0.153	0.63	-0.032	0.093
POLFREE	0.00	0.65	0.010	0.025	0.025	0.025	0.11	0.66	0.001	0.002	0.63	-0.014	0.038
LANDLOCK	0.00	0.61	0.027	0.097	0.097	0.097	0.14	0.65	-0.014	0.032	0.62	-0.028	0.083
LFERT	0.00	0.60	-0.015	0.054	0.054	0.054	0.00	0.64	0.067	0.180	0.61	0.005	0.017
URBREL	0.00	0.60	0.001	0.002	0.002	0.002	0.14	0.58	0.000	0.001	0.61	0.001	0.004
TRADE	0.00	0.57	0.000	0.001	0.001	0.001	0.00	0.57	1.284	6.119	0.60	-0.001	0.004
ABSLATIT	0.00	0.56	0.000	0.002	0.002	0.002	0.00	0.55	0.027	0.191	0.59	0.018	0.071
EXECL	0.00	0.55	0.010	0.069	0.069	0.069	0.08	0.55	0.013	0.080	0.59	-0.003	0.010
EAST	0.00	0.54	0.008	0.073	0.073	0.073	0.00	0.54	0.007	0.068	0.59	-0.018	0.070
CORRUPT	0.00	0.53	-0.002	0.037	0.037	0.037	0.00	0.53	0.010	0.129	0.54	-0.013	0.099
GDPGR	0.00	0.52	0.000	0.004	0.004	0.004	0.00	0.51	0.001	0.191	0.51	-0.002	0.098

Note: ‘%Sign.’ refers to the percentage of regressions in which the respective variable is significant at a 5% significance level. ‘CDF(0)’ Rank represents the ranking according to the CDF(0) criterion.



Table A-4: Final Models

	<i>LSO<sub>2</sub>PC</i>				<i>LBODPC</i>				
<i>LGDP</i>	4.186 *** (0.430)	3.818 *** (1.634)	4.187 *** (0.460)	5.179 *** (0.716)	5.193 *** (0.781)	4.399 *** (0.717)	1.061 *** (0.360)	0.961 ** (0.468)	0.741 * (0.389)
<i>LGDP</i>	-0.5 *** (0.061)	-0.41 * (0.226)	-0.485 *** (0.064)	-0.663 *** (0.097)	-0.674 *** (0.107)	-0.559 *** (0.099)	-0.091 * (0.050)	-0.08 (0.069)	-0.061 (0.059)
<i>ENERGY</i>	0.266 *** (0.072)	0.14 (0.202)	0.486 *** (0.093)	0.564 *** (0.089)	0.506 *** (0.095)	0.499 *** (0.083)	-0.02 (0.003)	-0.025 *** (0.004)	-0.031 *** (0.007)
<i>OIL</i>	0 *** (0.000)	0 (0.000)	0 *** (0.000)	0.012 *** (0.003)	0.014 *** (0.003)	0.014 *** (0.003)	-0.003 (0.000)	-0.002 *** (0.001)	-0.002 *** (0.001)
<i>SYSTEM</i>	0.164 *** (0.033)	0.066 (0.112)	0.116 *** (0.035)	0.036 *** (0.009)	0.029 *** (0.008)	0.033 *** (0.007)	-0.228 *** (0.037)	-0.257 *** (0.053)	-0.255 *** (0.045)
<i>SOCIALIST</i>	0.256 *** (0.064)	1.504 *** (0.234)	0.137 * (0.078)	0.009 *** (0.003)	0.008 *** (0.003)	0.006 *** (0.003)	0.202 *** (0.036)	0.236 *** (0.051)	0.237 *** (0.044)
<i>OIL</i>	0.187 *** (0.063)	-1.507 *** (0.248)	0.133 * (0.073)	-0.221 *** (0.089)	-0.172 * (0.103)	-0.088 (0.091)	0.004 (0.001)	0.004 *** (0.002)	0.005 *** (0.002)
<i>URBREL</i>	0.006 *** (0.002)	-0.001 (0.006)	0.005 *** (0.002)	0.265 *** (0.095)	0.188 ** (0.089)	0.21 *** (0.079)	-0.035 ** (0.015)	-0.044 ** (0.021)	-0.028 (0.024)
<i>LAAM</i>	-0.122 *** (0.050)	-0.074 (0.177)	-0.135 *** (0.050)	0 *** (0.000)	0 *** (0.000)	0 *** (0.000)	0.045 (0.034)	0.014 (0.041)	0.061 * (0.037)
<i>INDSHGDP</i>	-0.008 ** (0.004)	-0.012 (0.013)	-0.007 * (0.004)	0.002 *** (0.001)	0.002 *** (0.001)	0.003 *** (0.001)	0.13 * (0.067)	0.121 * (0.068)	0.172 ** (0.077)
<i>POPGR</i>	4.313 ** (1.978)	0.751 (8.772)	3.319 (2.517)	-14.614 *** (1.449)	-14.259 *** (1.453)	-13.061 *** (1.289)	Constant (0.660)	-1.324 *** (0.877)	-0.788 (0.771)
Constant	-8.531 *** (0.750)	-7.712 *** (2.864)	-8.722 *** (0.809)	0.943 (0.809)	0.798 (0.798)	0.847 (0.847)	0.927 (0.927)	0.927 (0.927)	0.96 (0.96)
R-Squ.	74	74	71	74	74	69	47	47	41
				R-Squ.	R-Squ.	R-Squ.	R-Squ.	R-Squ.	
				Obs.	Obs.	Obs.	Obs.	Obs.	

Note: Significance levels: \*\*\*significant at 0.01, \*\*significant at 0.05, \*significant at 0.10, standard errors in parenthesis

