Long-run Determinants of Pollution: A Robustness Analysis*

Michael Lamla†

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Abstract

The 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 set of 47 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 importance of inequality and resources for environmental quality.

JEL classification C52, O13, Q53

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†Department of Management, Technology and Economics (MTEC), ETH Zurich (Swiss Federal Institute of Technology Zurich);EMail: lamla@mtec.ethz.ch

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 the 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 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).

The paper is organized as follows. In Section 2 we introduce potential determinants of pollution proposed in the previous literature. In 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.[1]

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 47 countries.[2] 23 of these variables were also incorporated in the Panel Data study pursuing Extreme Bounds Analysis by Gassebner et al. (2006b).

To allow for generality we employ measures 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). According to the European Environment Agency "*BOD* is a measure of how much dissolved oxygen is being consumed as microbes break down organic matter. A high demand, therefore,

[1]For an overview of the approaches taken and the variables introduced so far see also Gassebner et al. (2006b)

[2]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.

can indicate that levels of dissolved oxygen are falling, with potentially dangerous implications for the river's biodiversity."[3] The data on water pollution is probably the most accurately measured pollution data, since sampling techniques are well understood and common in all countries. Additionally, data on water pollution are more readily available than other emissions data because most industrial pollution control programs start by regulating emissions of organic water pollutants.[4]

Concerning air pollution, our main variable of interest is the level of carbon dioxide CO_2 emissions also reported in WDI (2003).[5] Despite that these data are based upon calculations and not measured directly it should be able to display the real pollution level in a sufficient way.

Finally, we also include sulfur dioxide SO_2 emissions as a pollutant in our setup. The latest and largest source for data on SO_2 is Stern (2005). To construct the data set Stern has combined various sources and used different methods. This data gives a decent overview of the evolution of sulfur emissions. Nevertheless, among the dependent variables it is the most problematic data when applying our estimation setup.[6]

The remainder of this section describes the 33 variables and their underlying hypotheses employed in our empirical analysis. For matters of reading convenience we group the variables into three not mutually exclusive categories: economic, political and demographic.

2.1 Economic Variables

A commonly expressed view is that greater economic activity should lead to a higher level of 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 a 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.[7]

A substantial body of theoretical models exists that leads to such an inverted U-shaped relationship.[8]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. See for instance Stern (2004). 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).

[3]http://themes.eea.eu.int/Specific_media/water/indicators/bod/index_html

[4]See also the section "Water Pollution" in World Development Indicators 2005.

[5]Unless mentioned otherwise, all data stem from the WDI (2003) database.

[6]Especially since some data-points are calculated via econometric means.

[7]Kuznets (1955) presumes such a inverted U-shaped relationship between income inequality and per capita income.

[8]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)).

Grossman and Krueger discriminate between a scale, a composition and a technology effect of growth on the environment. The scale effect describes the economic degradation due to simple ceteris paribus boost in economic activity. If economic activity is increasing, more resources are used for production and hence more dissipation occurs. The composition effect describes the change in the structure (transformation from industrial to service economy) of the economy due to growth. Finally, the technology effect specifies the substitution of obsolete, dirty and inefficient technology by more sophisticated and "cleaner" methods.

Other studies argue that the income elasticity of environmental demand is changing, see for instance, Antle and Heidebrink (1995). As income growths, people realize a higher standard of living and hence care more about environmental protection. This changing attitude has an impact on policy decision making.

Moreover, Torras and Boyce (1998) employ market mechanisms as explanatory factors. Early stage industries are characterized by heavy exploitation of natural resources. This in turn significantly reduces the available stock of resources. Conditioning on an effective market mechanism in pricing resources the consequence of this exploitation are rising prices. Higher prices increase the pressure to switch to less resource intensive technologies. Again this 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.[9] However, results presented by e.g. Arrow et al. (1995) point out that this finding is not necessarily robust.[10] We use the level and squared transformations of (the log of) real GDP per capita ($LGDPPC$, $LGDPPC^2$) to test the EKC theory.

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.[11]

In a similar vein, international capital transactions might also affect national pollution levels. Following Antweiler et al. (2001) we therefore include inward foreign direct investment as percentage of GDP ($FDIGDP$) in our 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.

[9]For a detailed survey of theoretical and empirical studies dealing with the EKC, we refer to Dinda (2004).

[10]Some authors propose an inverted N-shaped or even a N-shaped relationship. See for instance Holtz-Eakin and Selden (1995), Cole et al. (1997) or Moomaw and Unruh (1997).

[11]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).

Real GDP growth (*GDPGR*) is included to control for economic performance. It 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 recourses 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, given that the industry sector is usually regarded as more pollution intensive than the service sector, the industry share might help explain the level of pollution.[12] We introduce such an industrialization measure both in terms of output (*INDSHGDP*) as well as in terms of labor input (*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.[13] 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 beard by industrial workers, they have incentives to use their political power to prevent a rise in the environmental regulation.[14] 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-6) 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).[15]

Following Neumayer (2003) we also utilize *ENERGYGDP* which stands for the amount of commercial energy used to produce one dollar of output. Conditioning on the characteristics of an economy, this intends to proxy for the level of efficiency in the production process.[16] The more efficient an economy produces its goods and services, the less polluted it should be. In 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*) up in our list of potential explanatory variables. Cole and Elliott (2003) suggest that higher fertilizer consumption might increase the level of water pollution.

[12] See also Torras and Boyce (1998), Carlsson and Lundström (2003) and Cole and Neumayer (2004).

[13] Especially due to underling technological changes in the production process these two variables do not have to move in parallel. The following example clarifies the difference between both measures. Assume that a technological shock increases the productivity per worker. If the employment remains unaltered then *INDSHEMP* is unaffected. However, *INDSHGDP* raises in this case.

[14] See also Damania et al. (2003).

[15] Obviously oil is not the only energy source used in electricity production. However, data limitations force us to restrict our attention to oil.

[16] Note, that through implementing demographic, economic and political factors we should be able to achieve this conditioning in an sufficient way.

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.

2.2 Political Variables

As emphasized in the introduction, recent studies discuss the role political variables play with respect to the environmental quality. Carlsson and Lundström (2003) also introduce the index of economic freedom (*ECFREE*) and the Political Freedom Index (*POLFREE*) in this line of literature.[17] They claim that economic freedom leads to a more efficient allocation of resources and therefore to a lower level of emission.[18] The intuitive reasoning behind *POLFREE* is that people are able to express their preferences for higher environmental standards better in a more democratic political system. 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 respectively and parliamentarian system (*SYSTEM*). The first is adapted from Neumayer (2003) and Neumayer (2004) who suggests that despite the traditional political objectives, generally driven by blue-collar workers' interests, a higher degree of sympathy toward environmental protection by left-wing governments is possible.[19] The second is suggested by Klick (2002), who argues that the longer a government is 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.

Furthermore, Klick claims that a dictator might take care of the environment to verify his leading position. He holds forth that because a dictator has a limited number of instruments at hand to remain in power he has strong incentives to invest in environmental protection rather than, e.g., schooling.[20] Contrary to that view Congleton (1992) contends that autocratic countries should have lower environmental standards. As he believes autocratic rulers have a shorter time hori-

[17] 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.

[18] 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.

[19] Besides other arguments he puts forth that especially the poor and the working class suffer from environmental degradation.

[20] 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).

zon. Moreover, they hold a larger share of national income. Consequently, their incentives to invest in environmental protection are 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 parliamentarian 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.[21] To analyze this issue we employ the variable *SYSTEM*.

Welsch (2004) argues that a corrupt government provides inefficiently low levels of environmental quality. Hence, we introduce the variable *CORRUPT*.

2.3 Demographic Variables

In line with Congleton we, too, introduce *AREA* to proxy for recourses. 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.[22] 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 opt for including (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 explorations of the environment. As a second demographic variable, we use the share of urban population in total population (*URBAN*). Cole and Neumayer (2004) argue that means of transports, like cars, buses, etc., are more intensively used in urbanized areas as in rural parts of a country. Moreover, food and other consumer goods have to be transported into cities, which again should lead to higher pollution. Both examples suggest higher levels of pollution in an economy that is more urbanized. On the other hand Cole et al. (2004) argue that greater exposure to industrial pollution by a higher amount of citizen should increase environmental stringency and hence, should reduce pollution.

Torras and Boyce (1998) argue that the distance to the coastline might be related to, in particular, water pollution. On the one hand, the incentive to keep domestic

[21] See also Bernauer and Koubi (2004) for a panel study on those political variables.

[22] Congleton argues that there is a high correlation between area and resources. He assumes that resources are randomly distributed.

water clean with an ocean or sea with its public good character nearby might be limited. On the other hand, water pollution from other countries without coastal area will eventually have to pass through to these regions. Therefore, we introduce the variable *LANDLOCKED*.[23] To account for geographic, but also for temperature effects we include also *ABSLATIT* denoting position (absolute latitude) of a country. Antweiler et al. (2001) uses 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.

Torras and Boyce (1998) state that inequality leads to environmental degradation. High income inhabitants (asset owners) are likely to have greater economic but also political "power".[24] Due to their asset ownership they earn more relative to the cost they have to bear of increased economic activity and hence degradation. Since their vigilance to pursue environmental protection is somewhat muted, they favor actions which allow them to increase or hold their level of economic activity. As a result the social optimal level (median voter, etc.), of pollution is not reached. Nevertheless, this positive relationship between inequality and environmental degradation needs not necessarily hold true. Introducing a white-collar sector into the model specification, alters the implications dramatically. For instance McAusland (2003) argues that the entire effect depends on the type of the asset ownership. 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 developed 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, tends policy-makers to decrease environmental 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.[25]

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.[26] Therefore, we include primary education (*PRIMEDU*) in our analysis.

Finally, we include dummies to control for region specific effects. Hence, we

[23]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.

[24]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.

[25]For details see http://utip.gov.utexas.edu/.

[26]Especially in the growth literature education gained much attention.

employ an European dummy (*EUROPE*), an East Asian dummy (*EAST*), a Sub Saharan dummy (*SAFRICA*), a Latin American dummy (*LAAM*) and additionally 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.[27] 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 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 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.[28]

However, despite its recent prominence, this method has its critics. As one problem with the EBA, the output of every regression is treated equally. Hence, coefficients of a regression with a bad fit are handled the same as a regression with a very good fit. Moreover, it restricts the researches to a specific model size which has to be set a priori.

BACE has the advantages of EBA but avoids some of its drawbacks.[29] 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

[27] 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.

[28] 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 β – i.e. the lowest value for β minus two standard deviations – is negative, while the upper extreme bound for β – i.e. the highest value for β plus two standard deviations – is positive, the variable F is not robustly related to Y.

As argued 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.

[29] As in the EBA, many models are tested, results of regression analyzed and decision rules created to give the reader methods at hand to judge whether a variable is at the end robustly related.

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.[30]

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. The parameter $\bar{k}$ represents the belief concerning the average model size.[31] Models of all sizes are considered and almost all permutations of variables are tested.[32]

In the upcoming paragraph we 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* 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 set-up 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.[33]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:

$$P(\beta_i \neq 0|y) = \sum_{j=1}^{2^K} P(M_j|y).^{34} \tag{1}$$

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

[30]Given the data, respectively the information in the data, the model is *more* likely to be the true one.

[31]It is intuitively plausible that a researcher has a belief concerning a reasonable model size and should express this guess.

[32]Concerning the sampling algorithm we follow Sala-i-Martin et al. (2004).

[33]One could interpret this as in a consequence of having nearly no reliable information being conservative in his prejudgment.

[34]Note: If there are K variables one has 2^K possible ways to combine them.

rected for the degrees of freedom

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

where T is the sample size and SSE is the sum of squared errors.[35] The latter part of the 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 by the data and is interpreted as being related to the dependent variable.[36]

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 β_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 measure by the posterior inclusion probability.[37]

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

$$P\left((sgn(\beta_i) = sgnE(\beta_i|y)|y, \beta_i \neq 0)\right).^{38}$$

[35]This is the adjusted form of $P(M_j|y) = \frac{P(M_j)P(y|M_j)}{\sum_{i=1}^{2^K} P(M_i)P(y|M_i)}$.

[36]$P(\beta_i \neq 0|y) > P(\beta_i \neq 0)$.

[37]The Posterior Standard Error is the square root of the Posterior Variance.

[38]Where sgn denotes the signum function.

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 fraction of regression where the coefficient is significant in classical terms, e.g. where the t-statistic is $\gtrapprox 1.96$. To allow for inference about the magnitude of an impact of a variable we calculate the *Impact Rank*. Variables are rank ordered 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.

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 $7/33 \approx 0.21$.[39] 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. Finally, inequality seems to be negatively related with water pollution. As discussed above, theoretical and empirical literature is inconclusive about the overall effect. However, this result corresponds with the findings of Gassebner et al. (2006b). An expanding white-collar sector and a shrinking blue-collar sector leads to greater inequality in income/wage but also implies higher environmental quality due to greater demand driven by white-collar workers.

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 respective pollution measure. With respect to carbon dioxide we find that population growth (POPGR), land area (AREA), inequality (INEQUAL), the years the incumbent stays in office (YRSOFFC) and the level of capitalism (ECORG) affect the level of carbon dioxide. Higher population growth leads to greater exploitation

[39] We also run versions beginning from 5 up to 15 variables. However, our results change marginally if anything.

and to rising carbon dioxide levels. In line with Congleton (1992) we show that the endowment of resources matters. The more resources a country has at its disposal the greater the probability it takes the opportunity to exploit them. Moreover, inequality seems, which contrasts the results for water pollution, worsen air quality. The longer the incumbent stays in office the lower is air quality. This result might indicate that long lasting dominant power distribution within governments may lead to inefficient allocations. Finally, economic organization is relevant. A higher degree of capitalism reduces the level of CO_2. Hence, an efficient market mechanism does not only boost economic welfare but also forces people to act more efficiently and to produce less waste.

Concerning water pollution (BOD) *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 more production from fossil fuels is usually considered to increase pollution. However, this reasoning is not valid in case of water pollution. Moreover, the exposure to globalization seems to improve the level of water pollution. Effective allocation and technology transfer might lead to this result. In addition the location of a country matters. High industrialized countries are located at greater latitude. 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. Finally, fertilizer use is a determinant. This is in line with our a priori expectations. Fertilizers in the form of nitrates and phosphates flow into a river 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.

Concerning sulfur dioxide our results show that a country's geographic position affects the pollution sign positively. This is in line with our expectations. Since sulfur is a by-product of burning fossil fuels, a higher degree of latitude should increase the level of emission. Moreover, highly industrialized countries are also almost exclusively located there. As in the case of carbon dioxide, *AREA* has a negative impact on the level of pollution, too. The East Asian countries produce on average less sulfur dioxide. Interestingly, political freedom is significantly positively related to pollution. Hence, we may conclude that during the period under consideration, on average, the public accepted environmental degradation in exchange for a higher level of production. Another interesting result is the negative impact of GDP growth. A interpretation may be that countries that are on a high growth path can easier afford to implement higher standards of environmental protection. Finally, inequality reduces air quality.

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-4. 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.[40] We include the variables identified as "TOP" determinants in the basic model. We presume that those variables should remain significantly related under 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).[41] 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.[42]

Table A-5 presents the results of the final model specifications. We decided to run ordinary least squares (OLS) with robust standarderrors 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.[43] Focussing on the signs and the significance, the results remain very stable. Again *LGDPPCSQ* is insignificant in the case of water pollution and inequality becomes insignificant for air pollution. Despite that the LTS clearly identifies outlying observations the general conclusions remain unchanged. 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 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.[44]

Overall, we can conclude that production specific variables are robustly related to both water and air pollution. We reconfirm the EKC hypothesis and underline the importance of efficient production technologies. In addition, we highlight the moment of other variables not closely related to production like inequality, political freedom, capitalism, resources and population growth. For the latter variable set, however, a general statement for all proxies of environmental degradation is not possible.

[40] One issue for instance is that the EBA only considers models of up to three additional variables while BACE considers various model sizes.

[41] In BACE it is theoretically possible that a variable on average improves the fit of a specific model without being significant at conventional levels.

[42] 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.

[43] 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 researches 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).

[44] 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.

Table 1: Results CO_2

Variable	Posterior Inclusion Probability	Posterior Mean Conditional on Inclusion	Posterior StdErr Conditonal on Inclusion	Sign Certainty Probability	Fraction of Regressions with t-stat>2	Impact Rank
LGDPPC	1.00	4.4629	0.659	1.00	0.99	2
ENERGYGDP	1.00	0.6804	0.121	1.00	0.93	3
LGDPPCSQ	1.00	-0.4764	0.096	1.00	0.93	4
AREA	0.68	0.0000	0.000	0.99	0.78	33
POPGR	0.40	7.8702	3.519	0.98	0.47	1
ECORG	0.40	-0.0574	0.026	0.98	0.51	16
INEQUAL	0.25	0.0164	0.009	0.96	0.26	22
YRSOFFC	0.24	0.0121	0.007	0.97	0.14	24
DICT	0.19	-0.2794	0.161	0.94	0.08	5
SYSTEM	0.17	0.0564	0.037	0.93	0.10	14
OILENERGY	0.16	0.0013	0.001	0.90	0.09	30
LPOPDENS	0.12	0.0597	0.046	0.90	0.08	13
INDSHGDP	0.11	-0.0030	0.006	0.69	0.04	25
PRIMEDU	0.11	-0.0028	0.002	0.91	0.04	27
SAFRICA	0.10	-0.1379	0.102	0.91	0.05	7
GLOBAL	0.10	0.0739	0.056	0.90	0.17	10
SOCIALIST	0.08	0.1644	0.166	0.84	0.29	6
EXECL	0.07	-0.0098	0.071	0.57	0.01	17
ECFREE	0.06	0.0282	0.054	0.71	0.13	15
FDINET	0.06	0.0139	0.017	0.80	0.11	21
EUROPE	0.06	-0.0677	0.086	0.78	0.11	9
LAAM	0.05	-0.0506	0.074	0.75	0.04	12
POLFREE	0.05	0.0034	0.031	0.56	0.14	23
OIL	0.05	0.0743	0.103	0.76	0.07	8
ABSLATIT	0.05	0.0009	0.002	0.63	0.07	29
TRADE	0.05	0.0001	0.001	0.59	0.03	31
CORRUPT	0.05	0.0124	0.045	0.59	0.14	18
GDPGR	0.05	-0.0015	0.005	0.62	0.01	26
LANDLOCK	0.04	0.0441	0.093	0.68	0.00	11
LFERT	0.04	0.0058	0.057	0.55	0.06	20
EAST	0.04	-0.0069	0.077	0.53	0.01	19
INDSHEMP	0.04	-0.0012	0.005	0.61	0.26	28
URBREL	0.04	0.0000	0.002	0.50	0.24	32

Table 2: Results SO_2

Variable	Posterior Inclusion Probability	Posterior Mean Conditional on Inclusion	Posterior StdErr Conditonal on Inclusion	Sign Certainty Probability	Fraction of Regressions with t-stat>2	Impact Rank
LGDPPC	1.00	6.405	1.251	1.00	0.98	2
LGDPPCSQ	1.00	-0.782	0.175	1.00	0.97	4
ENERGYGDP	0.98	0.718	0.202	1.00	0.74	3
ABSLATIT	0.57	0.011	0.005	0.99	0.58	25
AREA	0.56	0.000	0.000	0.99	0.52	33
POLFREE	0.51	0.117	0.049	0.99	0.69	16
EAST	0.44	-0.349	0.147	0.98	0.50	6
GDPGR	0.34	-0.015	0.007	0.98	0.26	23
INEQUAL	0.32	0.027	0.013	0.97	0.31	21
TRADE	0.19	0.002	0.001	0.93	0.12	32
URBREL	0.16	0.006	0.004	0.94	0.48	28
FDINET	0.11	0.051	0.046	0.85	0.10	18
PRIMEDU	0.10	-0.005	0.004	0.87	0.04	29
SOCIALIST	0.09	0.233	0.349	0.74	0.24	5
SYSTEM	0.09	-0.074	0.079	0.82	0.03	15
DICT	0.08	0.113	0.211	0.71	0.02	7
INDSHGDP	0.08	-0.006	0.011	0.72	0.03	24
LFERT	0.07	-0.083	0.108	0.78	0.02	12
ECFREE	0.07	0.080	0.101	0.78	0.07	13
LPOPDENS	0.07	-0.044	0.084	0.69	0.02	17
POPGR	0.06	1.351	7.247	0.56	0.02	1
OILENERGY	0.06	0.001	0.002	0.77	0.02	31
GLOBAL	0.06	0.000	0.117	0.52	0.12	27
INDSHEMP	0.06	-0.006	0.009	0.75	0.18	26
LAAM	0.06	-0.072	0.173	0.66	0.06	8
SAFRICA	0.05	0.046	0.217	0.59	0.00	10
EXECL	0.05	0.075	0.139	0.70	0.00	9
YRSOFFC	0.05	0.001	0.010	0.57	0.01	30
ECORG	0.05	-0.006	0.049	0.55	0.05	22
EUROPE	0.05	0.039	0.202	0.57	0.06	14
OIL	0.04	-0.004	0.212	0.50	0.01	19
CORRUPT	0.04	-0.010	0.073	0.56	0.07	20
LANDLOCK	0.04	0.055	0.165	0.63	0.00	11

Table 3: Results *BOD*

Variable	Posterior Inclusion Probability	Posterior Mean Conditional on Inclusion	Posterior StdErr Conditonal on Inclusion	Sign Certainty Probability	Fraction of Regressions with t-stat>2	Impact Rank
LGDPPC	0.97	0.762	0.534	0.93	0.18	2
LGDPPCSQ	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	0.19	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

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 47 countries, 33 explanatory variables, 3 pollution proxies over a horizon of 15 years we are able to reconfirm the Environmental Kuznets Curve hypothesis for all pollution proxies and underline the importance of energy-efficient manufacturing technologies.

We also highlight the relevance of variables not closely related to production like inequality, political freedom, capitalism, resources and population growth. Hence, this studies 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.

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APPENDIX

Table A-1: List of variables and their sources

Variable	Sign	Description	Source
LCO_2PC		Log of CO_2 Emissions in metric tons per capita	WDI (2003)
LBODPC		Log of BOD in gramms per day per capita	WDI (2003)
LSO_2PC		Log of SO_2 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)
LGDPPC	?	Log of real GDP per capita (in constant 1995 US $)	WDI (2003)
$LGDPPC^2$	?	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_2PC	0.56	1.28	-0.61	0.50
	LSO_2PC	-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: Country List

Australia	Italy	Sri Lanka
Austria	Japan	Sweden
Bolivia	Jordan	Syrian Arab Republic
Canada	Kenya	Trinidad and Tobago
Chile	Korea, Rep.	Turkey
China	Kuwait	United Kingdom
Colombia	Malaysia	United States
Denmark	Malta	Uruguay
Ecuador	Mexico	Venezuela, RB
Egypt, Arab Rep.	Morocco	
Finland	Netherlands	
France	New Zealand	
Greece	Norway	
Honduras	Philippines	
Hungary	Portugal	
Iceland	Senegal	
India	Singapore	
Indonesia	South Africa	
Ireland	Spain	

Table A-4: Results Extreme Bounds Analysis

LCO_2PC	% Sign.	Unwght. CDF(0)	Unwght. β	Std. Error	LSO_2PC	% Sign.	Unwght. CDF(0)	Unwght. β	Std. Error	$LBODPC$	% Sign.	Unwght. CDF(0)	Unwght. β	Std. Error
LGDPPC	100.00	1.00	4.628	0.622	LGDPPC	100.00	1.00	6.806	1.154	LGDPPC	18.68	0.94	0.898	0.538
LGDPPCSQ	100.00	1.00	-0.502	0.085	LGDPPCSQ	100.00	1.00	-0.827	0.157	LGDPPCSQ	3.23	0.85	-0.085	0.077
ENERGYGDP	100.00	1.00	0.765	0.094	ENERGYGDP	100.00	1.00	0.847	0.174	INEQUAL	99.39	1.00	-0.021	0.006
AREA	96.99	0.99	0.026	0.010	ABSLATIT	90.03	0.99	0.009	0.003	OILENERGY	93.89	0.99	-0.002	0.001
POPGR	34.25	0.96	6.046	3.173	EAST	46.66	0.96	-0.259	0.129	LFERT	90.93	0.99	0.117	0.049
SAFRICA	3.94	0.92	-0.151	0.100	GDPGR	17.71	0.95	-0.014	0.008	ENERGYGDP	60.02	0.97	0.182	0.088
OILENERGY	3.75	0.90	0.001	0.001	POLFREE	32.78	0.95	0.083	0.045	SYSTEM	35.14	0.97	0.067	0.035
YRSOFFC	7.69	0.89	0.006	0.004	PRIMEDU	16.54	0.94	-0.006	0.004	POPGR	23.68	0.94	-5.567	3.187
ECORG	10.43	0.86	-0.030	0.025	AREA	9.70	0.94	0.032	0.020	CORRUPT	3.18	0.89	0.051	0.039
PRIMEDU	2.31	0.86	-0.002	0.002	URBREL	9.26	0.92	0.006	0.004	EXECL	2.61	0.87	-0.082	0.068
FDINET	0.03	0.81	0.015	0.017	DICT	6.25	0.91	0.245	0.166	PRIMEDU	0.03	0.84	0.002	0.002
ECFREE	1.20	0.80	0.039	0.043	LPOPDENS	1.90	0.86	-0.087	0.072	INDSHEMP	0.00	0.79	0.004	0.004
INEQUAL	1.44	0.79	0.006	0.006	SYSTEM	1.77	0.86	-0.077	0.067	ABSLATIT	0.00	0.74	0.001	0.002
LAAM	0.00	0.79	-0.061	0.072	LFERT	2.25	0.83	-0.105	0.100	ECFREE	0.05	0.74	0.029	0.041
INDSHGDP	0.57	0.79	-0.004	0.005	INEQUAL	7.85	0.81	0.012	0.011	SOCIALIST	0.00	0.74	0.083	0.123
EUROPE	0.00	0.76	-0.062	0.083	LAAM	2.63	0.81	-0.129	0.133	OIL	0.00	0.70	0.056	0.102
SOCIALIST	0.24	0.75	0.096	0.130	SOCIALIST	1.33	0.79	0.221	0.240	INDSHGDP	0.00	0.69	-0.003	0.006
OIL	0.00	0.72	0.063	0.103	INDSHGDP	0.24	0.77	-0.007	0.009	URBREL	0.00	0.68	-0.001	0.002
DICT	1.36	0.70	-0.057	0.091	YRSOFFC	0.60	0.74	0.005	0.008	ECORG	0.00	0.68	-0.012	0.025
SYSTEM	0.00	0.69	0.020	0.037	INDSHEMP	0.00	0.68	-0.004	0.009	TRADE	8.66	0.65	0.000	0.001
INDSHEMP	0.00	0.67	-0.002	0.005	ECORG	0.00	0.67	-0.023	0.046	POLFREE	0.38	0.64	-0.010	0.023
LPOPDENS	1.39	0.66	0.018	0.039	EUROPE	0.52	0.66	0.073	0.153	LANDLOCK	0.00	0.63	-0.032	0.093
POLFREE	0.00	0.65	0.010	0.025	OILENERGY	0.11	0.66	0.001	0.002	LPOPDENS	0.60	0.63	-0.014	0.038
LANDLOCK	0.00	0.61	0.027	0.097	FDINET	0.14	0.65	-0.014	0.032	EUROPE	0.00	0.62	-0.028	0.083
LFERT	0.00	0.60	-0.015	0.054	LANDLOCK	0.00	0.64	0.067	0.180	FDINET	0.00	0.61	0.005	0.017
URBREL	0.00	0.60	0.001	0.002	TRADE	0.14	0.58	0.000	0.001	GDPGR	0.00	0.61	0.001	0.004
TRADE	0.00	0.57	0.000	0.001	POPGR	0.00	0.57	1.284	6.119	YRSOFFC	0.00	0.60	-0.001	0.004
ABSLATIT	0.00	0.56	0.000	0.002	SAFRICA	0.00	0.55	0.027	0.191	EAST	0.00	0.59	0.018	0.071
EXECL	0.00	0.55	0.010	0.069	ECFREE	0.08	0.55	0.013	0.080	AREA	0.03	0.59	-0.003	0.010
EAST	0.00	0.54	0.008	0.073	CORRUPT	0.00	0.54	0.007	0.068	LAAM	0.00	0.59	-0.018	0.070
CORRUPT	0.00	0.53	-0.002	0.037	EXECL	0.00	0.53	0.010	0.129	SAFRICA	0.00	0.54	-0.013	0.099
GDPGR	0.00	0.52	0.000	0.004	OIL	0.00	0.51	0.001	0.191	DICT	0.00	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-5: Final Models

LCO_2PC				LSO_2PC				$LBODPC$			
	OLS	LAD	LTS		OLS	LAD	LTS		OLS	LAD	LTS
LGDPPC	3.979 ***	4.045 ***	4.562 ***	LGDPPC	6.220 ***	7.062 ***	6.694 ***	LGDPPC	0.562	0.725	1.050 ***
	(0.526)	(0.526)	(0.431)		(0.725)	(0.725)	(0.838)		(0.349)	(0.349)	(0.298)
ENERGYGDP	0.603 ***	0.587 ***	0.590 ***	LGDPPCSQ	-0.744 ***	-0.886 ***	-0.833 ***	LGDPPCSQ	-0.025	-0.053	-0.107 ***
	(0.107)	(0.107)	(0.067)		(0.107)	(0.107)	(0.120)		(0.052)	(0.052)	(0.045)
LGDPPCSQ	-0.394 ***	-0.403 ***	-0.465 ***	ENERGYGDP	0.585 ***	0.534 ***	0.630 ***	INEQUAL	-0.021 ***	-0.024 ***	-0.022 ***
	(0.072)	(0.072)	(0.062)		(0.097)	(0.097)	(0.136)		(0.003)	(0.003)	(0.003)
AREA	0.030 ***	0.028 ***	0.030 ***	ABSLATIT	0.008 *	0.010 *	0.013 ***	OILENERGY	-0.003 ***	-0.003 ***	-0.002 ***
	(0.007)	(0.007)	(0.007)		(0.004)	(0.004)	(0.003)		(0.001)	(0.001)	(0.000)
POPGR	6.862 ***	10.092 ***	7.322 ***	AREA	0.047 ***	0.051 ***	0.053 ***	GLOBAL	-0.251 ***	-0.223 ***	-0.201 ***
	(2.461)	(2.461)	(2.325)		(0.009)	(0.009)	(0.014)		(0.046)	(0.046)	(0.037)
ECORG	-0.067 ***	-0.051 ***	-0.089 ***	POLFREE	0.123 ***	0.112 ***	0.078 **	ECFREE	0.229 ***	0.224 ***	0.258 ***
	(0.027)	(0.027)	(0.020)		(0.034)	(0.034)	(0.036)		(0.037)	(0.037)	(0.033)
INEQUAL	0.007	0.002	0.010 *	EAST	-0.253 ***	-0.287 ***	-0.237 **	ABSLATIT	0.004 ***	0.004 ***	0.005 ***
	(0.004)	(0.004)	(0.005)		(0.095)	(0.095)	(0.108)		(0.002)	(0.002)	(0.001)
YRSOFFC	0.005 ***	0.005 ***	0.006 **	GDPGR	-0.012 ***	-0.023 ***	-0.015 ***	ECORG	-0.055 ***	-0.064 ***	-0.074 ***
	(0.002)	(0.002)	(0.002)		(0.005)	(0.005)	(0.006)		(0.014)	(0.014)	(0.014)
Constant	-9.081 ***	-9.088 ***	-10.280 ***	INEQUAL	0.013	0.010	0.019 **	Constant	-0.611	-0.686	-1.511 ***
	(0.937)	(0.937)	(0.759)		(0.009)	(0.009)	(0.009)		(0.595)	(0.595)	(0.528)
				Constant	-15.784 ***	-16.787 ***	-16.614 ***				
					(1.271)	(1.271)	(1.540)				
R-Squ.	0.945	0.945	0.968	R-Squ.	0.846	0.846	0.873 ***	R-Squ.	0.915	0.915	0.96
Obs.	47	47	44	Obs.	47	47	46	Obs.	47	47	42

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

Table A-6: Correlation Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1 LBODPC	1.00	0.75	0.57	0.69	0.03	0.83	-0.42	-0.04	0.66	0.32	-0.49	0.70	0.01	0.16	-0.15	0.56	0.31	-0.79	-0.30	0.02	0.63	0.85	0.86	-0.02	-0.15	-0.38	-0.65	-0.74	0.25	-0.29	-0.03	0.69	0.18	0.62	-0.31
2 LCO2PC	0.75	1.00	0.81	0.54	0.18	0.70	-0.28	-0.07	0.63	0.28	-0.41	0.56	-0.05	0.20	-0.24	0.57	0.14	-0.56	-0.20	-0.01	0.49	0.86	0.85	-0.01	0.05	-0.20	-0.52	-0.50	0.09	-0.31	-0.01	0.53	0.19	0.75	-0.18
3 LSO2PC	0.57	0.81	1.00	0.50	0.17	0.47	-0.04	-0.24	0.39	0.15	-0.29	0.39	-0.10	0.11	-0.31	0.49	0.05	-0.32	-0.10	0.02	0.27	0.63	0.61	-0.15	0.09	-0.13	-0.25	-0.36	-0.02	-0.19	0.08	0.24	0.16	0.68	-0.06
4 ABSLATIT	0.69	0.54	0.50	1.00	-0.01	0.69	-0.19	-0.32	0.32	0.20	-0.41	0.72	0.06	-0.31	-0.16	0.36	0.20	-0.68	-0.44	0.08	0.34	0.67	0.69	-0.17	-0.24	-0.36	-0.52	-0.66	-0.01	-0.25	0.08	0.53	-0.15	0.42	-0.16
5 AREA	0.03	0.18	0.17	-0.01	1.00	0.13	-0.11	0.10	0.20	0.01	0.33	0.13	0.24	-0.04	0.02	-0.18	0.11	-0.17	-0.10	-0.08	-0.19	-0.03	0.00	-0.33	-0.03	-0.24	-0.01	0.00	0.18	-0.06	0.22	-0.01	-0.28	-0.07	-0.14
6 CORRUPT	0.83	0.70	0.47	0.69	0.13	1.00	-0.43	-0.14	0.71	0.52	-0.43	0.76	0.14	0.11	-0.09	0.45	0.20	-0.80	-0.45	-0.02	0.51	0.82	0.83	-0.15	-0.30	-0.38	-0.63	-0.58	0.13	-0.04	-0.07	0.68	0.13	0.52	-0.30
7 DICT	-0.42	-0.28	-0.04	-0.19	-0.11	-0.43	1.00	0.02	-0.16	0.01	0.13	-0.37	-0.39	-0.17	-0.03	-0.15	-0.35	0.57	0.04	-0.01	-0.28	-0.30	-0.31	-0.10	0.46	0.35	0.49	0.38	-0.42	0.06	-0.12	-0.46	0.03	-0.11	0.68
8 EAST	-0.04	-0.07	-0.24	-0.32	0.10	-0.14	0.02	1.00	0.17	-0.08	0.16	-0.34	-0.22	0.34	0.16	-0.11	0.46	-0.05	-0.20	-0.11	0.33	-0.12	-0.11	0.41	0.14	0.35	0.34	0.13	0.18	-0.11	0.14	0.03	0.27	-0.15	0.13
9 ECFREE	0.66	0.63	0.39	0.32	0.20	0.71	-0.16	0.17	1.00	0.66	-0.54	0.59	-0.12	0.38	-0.15	0.25	0.17	-0.51	-0.29	-0.13	0.51	0.76	0.77	0.02	0.00	-0.11	-0.56	-0.41	0.08	-0.22	-0.40	0.52	0.35	0.58	-0.17
10 ECORG	0.32	0.28	0.15	0.20	0.01	0.52	0.01	-0.08	0.66	1.00	-0.49	0.47	-0.14	0.07	0.00	0.05	-0.16	-0.15	-0.11	-0.18	0.12	0.51	0.52	-0.31	-0.18	-0.11	-0.54	-0.09	-0.12	0.10	-0.60	0.30	0.07	0.36	-0.11
11 ENERGYGDP	-0.49	-0.41	-0.29	-0.41	0.33	-0.43	0.13	0.16	-0.54	-0.49	1.00	-0.50	0.12	-0.07	0.22	-0.44	-0.10	0.33	0.04	-0.04	-0.27	-0.72	-0.69	0.05	0.12	-0.03	0.63	0.46	0.01	0.29	0.56	-0.29	-0.15	-0.60	0.15
12 EUROPE	0.70	0.56	0.39	0.72	0.13	0.76	-0.37	-0.34	0.59	0.47	-0.50	1.00	0.22	-0.06	-0.16	0.28	0.10	-0.70	-0.40	-0.04	0.30	0.75	0.77	-0.16	-0.22	-0.34	-0.78	-0.69	0.16	-0.22	-0.22	0.65	-0.02	0.43	-0.33
13 EXECL	0.01	-0.05	-0.10	0.06	0.24	0.14	-0.39	-0.22	-0.12	-0.14	0.12	0.22	1.00	-0.10	-0.03	-0.12	0.05	-0.26	-0.04	0.28	-0.21	-0.03	-0.01	-0.03	-0.15	-0.13	-0.23	-0.31	0.13	0.01	0.17	0.16	-0.21	-0.21	-0.26
14 FDINET	0.16	0.20	0.11	-0.31	-0.04	0.11	-0.17	0.34	0.38	0.07	-0.07	-0.06	-0.10	1.00	0.24	0.15	0.19	-0.15	0.04	-0.01	0.36	0.10	0.08	0.36	-0.15	0.28	0.09	0.09	0.11	-0.15	0.00	0.25	0.77	0.26	0.12
15 GDPGR	-0.15	-0.24	-0.31	-0.16	0.02	-0.09	-0.03	0.16	-0.15	0.00	0.22	-0.16	-0.03	0.24	1.00	-0.04	0.15	0.01	0.02	-0.15	0.03	-0.29	-0.29	0.04	-0.41	0.17	0.27	0.32	0.29	0.01	0.14	0.01	0.16	-0.28	0.34
16 INDSHEMP	0.56	0.57	0.49	0.36	-0.18	0.45	-0.15	-0.11	0.25	0.05	-0.44	0.28	-0.12	0.15	-0.04	1.00	0.37	-0.40	-0.08	0.23	0.31	0.58	0.55	0.14	-0.17	-0.16	-0.26	-0.43	0.27	-0.08	-0.01	0.32	0.20	0.46	-0.08
17 INDSHGDP	0.31	0.14	0.05	0.20	0.11	0.20	-0.35	0.46	0.17	-0.16	-0.10	0.10	0.05	0.19	0.15	0.37	1.00	-0.54	-0.08	0.09	0.31	0.17	0.16	0.31	-0.24	0.02	-0.05	-0.34	0.48	-0.21	0.24	0.18	0.13	0.09	-0.22
18 INEQUAL	-0.79	-0.56	-0.32	-0.68	-0.17	-0.80	0.57	-0.05	-0.51	-0.15	0.33	-0.70	-0.26	-0.15	0.01	-0.40	-0.54	1.00	0.41	-0.10	-0.49	-0.67	-0.69	-0.04	0.34	0.27	0.52	0.67	-0.28	0.23	-0.22	-0.64	-0.12	-0.43	0.29
19 LAAM	-0.30	-0.20	-0.10	-0.44	-0.10	-0.45	0.04	-0.20	-0.29	-0.11	0.04	-0.40	-0.04	0.04	0.02	-0.08	-0.08	0.41	1.00	0.09	-0.36	-0.25	-0.28	-0.23	0.09	-0.16	-0.01	0.23	0.16	-0.13	-0.13	-0.45	-0.16	0.09	-0.23
20 LANDLOCK	0.02	-0.01	0.02	0.08	-0.08	-0.02	-0.01	-0.11	-0.13	-0.18	-0.04	-0.04	0.28	-0.01	-0.15	0.23	0.09	-0.10	0.09	1.00	-0.17	0.00	-0.01	-0.07	-0.07	-0.16	-0.03	-0.17	-0.05	-0.07	0.29	-0.02	-0.01	-0.04	0.07
21 LFERT	0.63	0.49	0.27	0.34	-0.19	0.51	-0.28	0.33	0.51	0.12	-0.27	0.30	-0.21	0.36	0.03	0.31	0.31	-0.49	-0.36	-0.17	1.00	0.53	0.53	0.36	0.02	-0.04	-0.20	-0.38	0.15	-0.35	0.00	0.50	0.42	0.39	-0.11
22 LGDPPC	0.85	0.86	0.63	0.67	-0.03	0.82	-0.30	-0.12	0.76	0.51	-0.72	0.75	-0.03	0.10	-0.29	0.58	0.17	-0.67	-0.25	0.00	0.53	1.00	1.00	-0.04	-0.07	-0.25	-0.74	-0.68	0.08	-0.29	-0.28	0.60	0.16	0.79	-0.31
23 LGDPPCSQ	0.86	0.85	0.61	0.69	0.00	0.83	-0.31	-0.11	0.77	0.52	-0.69	0.77	-0.01	0.08	-0.29	0.55	0.16	-0.69	-0.28	-0.01	0.53	1.00	1.00	-0.04	-0.08	-0.27	-0.75	-0.69	0.08	-0.28	-0.27	0.62	0.15	0.77	-0.32
24 LPOPDENS	-0.02	-0.01	-0.15	-0.17	-0.33	-0.15	-0.10	0.41	0.02	-0.31	0.05	-0.16	-0.03	0.36	0.04	0.14	0.31	-0.04	-0.23	-0.07	0.36	-0.04	-0.04	1.00	-0.01	0.41	0.17	-0.13	0.08	-0.10	0.08	0.17	0.48	-0.05	0.15
25 OIL	-0.15	0.05	0.09	-0.24	-0.03	-0.30	0.46	0.14	0.00	-0.18	0.12	-0.22	-0.15	-0.15	-0.41	-0.17	-0.24	0.34	0.09	-0.07	0.02	-0.07	-0.08	-0.01	1.00	0.17	0.21	0.13	-0.17	-0.07	-0.07	-0.24	0.00	0.06	0.18
26 OILENERGY	-0.38	-0.20	-0.13	-0.36	-0.24	-0.38	0.35	0.35	-0.11	-0.11	-0.03	-0.34	-0.13	0.28	0.17	-0.16	0.02	0.27	-0.16	-0.16	-0.04	-0.25	-0.27	0.41	0.17	1.00	0.45	0.42	-0.39	0.10	-0.04	-0.29	0.53	-0.07	0.61
27 POLFREE	-0.65	-0.52	-0.25	-0.52	-0.01	-0.63	0.49	0.34	-0.56	-0.54	0.63	-0.78	-0.23	0.09	0.27	-0.26	-0.05	0.52	-0.01	-0.03	-0.20	-0.74	-0.75	0.17	0.21	0.45	1.00	0.67	-0.15	0.30	0.44	-0.58	0.12	-0.51	0.55
28 POPGR	-0.74	-0.50	-0.36	-0.66	0.00	-0.58	0.38	0.13	-0.41	-0.09	0.46	-0.69	-0.31	0.09	0.32	-0.43	-0.34	0.67	0.23	-0.17	-0.38	-0.68	-0.69	-0.13	0.13	0.42	0.67	1.00	-0.28	0.32	0.01	-0.59	0.13	-0.37	0.43
29 PRIMEDU	0.25	0.09	-0.02	-0.01	0.18	0.13	-0.42	0.18	0.08	-0.12	0.01	0.16	0.13	0.11	0.29	0.27	0.48	-0.28	0.16	-0.05	0.15	0.08	0.08	0.08	-0.17	-0.39	-0.15	-0.28	1.00	-0.21	0.12	0.23	-0.14	-0.08	-0.43
30 SAFRICA	-0.29	-0.31	-0.19	-0.25	-0.06	-0.04	0.06	-0.11	-0.22	0.10	0.29	-0.22	0.01	-0.15	0.01	-0.08	-0.21	0.23	-0.13	-0.07	-0.35	-0.29	-0.28	-0.10	-0.07	0.10	0.30	0.32	-0.21	1.00	-0.07	-0.21	-0.05	-0.34	0.02
31 SOCIALIST	-0.03	-0.01	0.08	0.08	0.22	-0.07	-0.12	0.14	-0.40	-0.60	0.56	-0.22	0.17	0.00	0.14	-0.01	0.24	-0.22	-0.13	0.29	0.00	-0.28	-0.27	0.08	-0.07	-0.04	0.44	0.01	0.12	-0.07	1.00	-0.11	-0.08	-0.24	0.24
32 SYSTEM	0.69	0.53	0.24	0.53	-0.01	0.68	-0.46	0.03	0.52	0.30	-0.29	0.65	0.16	0.25	0.01	0.32	0.18	-0.64	-0.45	-0.02	0.50	0.60	0.62	0.17	-0.24	-0.29	-0.58	-0.59	0.23	-0.21	-0.11	1.00	0.20	0.27	-0.32
33 TRADE	0.18	0.19	0.16	-0.15	-0.28	0.13	0.03	0.27	0.35	0.07	-0.15	-0.02	-0.21	0.77	0.16	0.20	0.13	-0.12	-0.16	-0.01	0.42	0.16	0.15	0.48	0.00	0.53	0.12	0.13	-0.14	-0.05	-0.08	0.20	1.00	0.31	0.32
34 URBREL	0.62	0.75	0.68	0.42	-0.07	0.52	-0.11	-0.15	0.58	0.36	-0.60	0.43	-0.21	0.26	-0.28	0.46	0.09	-0.43	0.09	-0.04	0.39	0.79	0.77	-0.05	0.06	-0.07	-0.51	-0.37	-0.08	-0.34	-0.24	0.27	0.31	1.00	-0.12
35 YRSOFFC	-0.31	-0.18	-0.06	-0.16	-0.14	-0.30	0.68	0.13	-0.17	-0.11	0.15	-0.33	-0.26	0.12	0.34	-0.08	-0.22	0.29	-0.23	0.07	-0.11	-0.31	-0.32	0.15	0.18	0.61	0.55	0.43	-0.43	0.02	0.24	-0.32	0.32	-0.12	1.00