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WORKING PAPER

Environmental quality and economic growth

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ABSTRACT

This paper uses 5-year non-overlapping emissions growth equations for sulphur and carbon dioxide to estimate the impact of economic growth on environmental quality. It is shown that the impact of economic growth on emissions growth depends on the level of income. Economic growth reduces emissions once a country reaches a certain level of income, a conclusion that seems to support the environmental Kuznets Curve Hypothesis both in the direction of the impact as well as in the estimated income level. This paper also suggests that demand for environmental quality depends on the level of environmental damage. The significance of other variables (e.g. black market premium or tariffs on imports) suggests that there might be some 'win-win' situations: reducing these variables is advantageous for both economic growth and environmental quality.

Keywords: Economic growth, Environmental quality, Environmental Kuznets Curve

JEL: O11, O13

1. Introduction

Literature with respect to the Environmental Kuznets Curve is far from conclusive. First of all, there is still uncertainty with respect to the exact income turning points that are associated with a peak in environmental degradation. Secondly, as argued by Panayotou (1997), there have only been modest attempts to include policy variables into a model that tries to explain the income environment relationship. Thirdly, as Stern and Common (2001) argue, estimates that use the levels of environmental pollution and income might be spurious if there is no global cointegration relation among income and environment.

This paper addresses some of these issues. First of all, as suggested by Stern and Common, it uses growth rates instead of levels to estimate an ECK. Secondly, as suggested by Panayotou (1997) and Munasignhe (1999) it adds a number of policy variables to the model. The overall conclusion supports the EKC-hypothesis. From the conclusion, a number of 'win-win' situations seem to emerge. They suggest that governments, to some extent, have the ability to pursue policies that promote economic growth in an environmentally friendly, i.e. less emissions intense, way.

2. The EKC: a review of the main literature

The Environmental Kuznets Curve (EKC) hypothesis has generated a vast amount of research into the existence of an income level that is associated with a peak in environmental degradation. Although such a turning point has been identified for various pollutants[1], there is still quite some uncertainty with respect to those income levels, the peak level of environmental harm associated with the income turning point and the mechanisms behind the EKC.

2.1. Mechanisms behind the EKC

Most of the EKC literature focuses on reduced form regressions (Stern, D. (1996); De Bruyn, van den Bergh and Opschoor (1998)). These regressions explain the level of environmental pollution, measured as per capita emissions or concentrations, as a function of income, income squared often, income cubed and a limited number of control variables such as country or time specific dummy variables or variables which are included to correct for differences in the way emissions are measured (e.g. Holtz-Eakin and Selden (1992), Selden and Song (1994), Shafik (1994), Grossman and Krueger (1995), Stern and Common (2001), Harbaugh, Levinson and Wilson, (2001)). These variables capture scale, composition and technique effects. At first, the increasing scale of economic activity as well as its changing composition from agricultural towards

[1] see Stern (1996), Borghesi (1999), Stagl (1999) or Panayotou (2000) for a review.

industrial economies generates more pollution. However, as income rises, demand for environmental quality increases and more stringent environmental regulation leads to a replacement of old technologies by environmentally less harmful ones. This technology effect, together with the changing composition away from an industrial towards a post-industrial economy puts downward pressure on pollution. Eventually, as income passes some threshold level, better techniques, in part due to an increased demand for environmental quality, and composition effects outweigh the scale effect and environmental quality increases with growth.

Panayotou, Peterson and Sachs' (2000) results seem to suggest that structural change i.e. the composition of economic activity plays an important role in explaining the EKC. They find that the accumulation of non-residential capital results in rising emissions as a country industrialises but contributes to lower emissions in the post-industrial stage. They also find that trade increases emissions at first but reduces them at a high level of income. Cole (2000a) finds that the EKC could be the result of a falling share of manufacturing output in GDP and a change of the manufacturing output away from 'dirty' sectors. Gale and Mendez (1998) provide further evidence of the composition effect. They explain sulphur dioxide emissions using income and scale variables as well as endowment data for physical capital, non-professional and literate workers and land. Their results suggest that greater capital abundance favours capital intensive and generally more polluting production whereas land and labour abundance is associated with environmentally less harmful activities.

Obviously, if the changing composition of economic activity merely reflects the relocation of some industrial activities away from relatively rich countries towards poorer countries, the composition effect would eventually end. Indeed if, as Rothman (1998) notes, demand for environmental quality does not lead to a shift towards a cleaner production process, but to a movement of this process to another country, rich countries are basically 'passing the buck'. Cole (2000a,b) offers some evidence that seems to suggest that the declining share in dirty manufacturing is not due to industrial relocation (i.e. the pollution haven hypothesis). He finds that rising income levels are associated with a falling income elasticity of demand for pollution intensive products.

The effect of income on demand for environmental quality is approached through the income elasticity of the demand for environmental quality. It has been analysed in several ways. Komen et al. (1997) for instance use the public research and development budget aimed at protecting the environment from degradation as a proxy for the 'demand for environmental quality'. Their estimates suggest that income has a positive impact on R&D budgets in OECD countries. Others have focused on income inequality and the distribution of power. Magnani (2000) shows that the overall income elasticity of demand for environmental quality depends on both absolute as well as the relative income. In terms of the EKC, her results would suggest that the position and slope of the

EKC depends on the way economic growth influences income inequality within a country. Her results confirm those of Torras and Boyce (1998) who find that income inequality reduces environmental quality in low-income countries. They also find that equality with respect to political power (measured as the literacy rate and political rights) improves environmental quality. Ravallion et al. (2000) reasserts results that indicate that the income elasticity of emissions is a positive function of income inequality and a negative function of the overall income level.

Most models capture the impact of technology through the inclusion of a time trend. One exception is De Bruyn (1997) who decomposes the emissions/output ratio for commercial sulphur dioxide emissions and finds that basically all of the reduction is due to technological change. However, as Panayotou (2000) notes, the two countries that de Bruyn studies (West-Germany and the Netherlands) as well as the time period (1980-1990) suggest that the data came from two examples where most of the structural change had already been accomplished.

2.2. Income turning points

There is, however, still no certainty about the existence of a 'universal' income level that is associated with a peak in environmental degradation. Stern and Common (2001) for instance find turning points for sulphur dioxide emissions well within the range reported in previous studies (real 1990 USD 9.239) when they restrict their sample to OECD countries. When they focus on non-OECD countries however, their estimated turning points are well above real 1990 USD 340.000. Harbaugh, Levinson and Wilson (2001) find that the data are far less robust than has been claimed. When they change the specification of the basic EKC, they find that the shape of the income-environmental relationship alters quite substantially. Their results and those of Stern and Common suggest that it might be worthwhile to account for the differences in economic development. Roberts and Grimes (1997) show that overall economic and political factors might have become more important over the period between 1962 and 1991. For each of these years, they ran an EKC regression and found that the overall fit decreases steadily over that period. Even within a developed country there is some evidence that seems to suggest that it is important to take into account region specific variables. List and Gallet (1999) estimate EKC equations for some air pollution variables for US States and find a wide variety of turning points. These results suggest that the income-environment relationship depends on income as well as a number of other variables such as, for instance, the stage of development or the policy environment.

2.3. Shifting the EKC: the role of policy

Because the analysis is done in the levels, most literature is not able to draw conclusions with respect to the amount of environmental degradation that is associated with that level. However, as Arrow et al. (1995), Panayotou (1997) or Munasinghe (1999) have argued, there is no guarantee that the peak pollution level would not harm the environment in an irreversible way. Munasinghe (1999) and Panayotou (1997) argues that it might be very important to find ways to 'tunnel through' the EKC, i.e. to find ways that would allow countries to grow in a way that is less harmful for the environment; or, in terms of the EKC, ways that decrease the slope of the EKC for each level of income. Munasinghe (1999) mentions the fact that there might be situations in which private decision making, due to imperfections in the economy, results in environmental degradation that exceeds the socially optimal level. He argues that improving the access to information, the strengthening of education or the encouragement of public participation in environmental decision-making might increase the willingness to pay for a cleaner environment. He also refers to the lack of information about less polluting technologies, inadequate human resources or distorted input price signals as potentially causing environmental pollution beyond the optimal level. This seems to suggest that policy induced abatement and R&D depends on the overall level of knowledge about environmental matters or the lack of price distortions. Abatement might also be a 'side-effect' of sound economic policies that reduce market imperfections, i.e. 'win-win-situations' where economic policies might have both a positive impact on economic growth and a negative impact on pollution levels.

With respect to environmental damage, Kaufman et al. (1998) argue that it is important to differentiate between emissions on the one hand and the concentration of polluting substances on the other. They argue that emissions as such do not cause damage to the environment and human health. Environmental damage is caused by the concentration of polluting substances. The only way to reduce the concentration of sulphur dioxide is through emission reductions. These lower emission levels follow from the fact that consumers increase the desired level of environmental quality or because the benefits of reducing concentrations outweigh the costs of doing so. If that is the case, policy induced R&D abatement will not only depend on income, but on the level of damage as well.

2.4. Methodology

Stern and Common (2001) question the methodology. They argue that estimates of the Environmental Kuznets Curve in levels might be spurious if there is no cointegrating relationship among the variables. If, as they argue, the likelihood that there is one global cointegrating vector is limited, the income-environment relationship should be estimated in first differences. First differencing the data has the additional advantage it removes country specific stochastic trends.

2.5. Conclusions and an outline of our approach

The results of the literature seem to suggest that it could be important to take into account more country specific variables such as, for instance, polity-variables or environmental damage when estimating income turning points. Secondly, in order to become a policy tool, the research has to be able to conclude with respect to the slope of the EKC or with respect to the environmental degradation at the peak. This paper adds country specific variables to a model that explains the 5-year growth rates of per capita emissions within a framework that is closely linked with the EKC. It uses 5-year averages as they suffer less from noise created by short-term shocks and they allow to combine the EKC framework with the economic growth literature. To our knowledge, it is the first time that such an attempt has been made.

Our results will be in line with previous estimates with respect to income turning points. We will show that demand for environmental regulation depends, as Kaufmann et al. (1998) suggested, on the amount of environmental damage. Our results further suggest that polity variables have little additional effect on emissions growth once the level of income is taken into account. As suggested by Munasinghe (1999), the evidence presented here indicates that market imperfections are important with respect to emissions growth. It is further argued that the level of development has a significant effect on emissions growth beyond the impact implied by per capita income. Poor countries tend to experience higher emissions growth rates compared to rich countries. As such, the results seem to suggest that the EKC can be useful as a policy tool. In line with the evidence presented by Harbaugh, Levinson and Wilson (2001) the results further suggest that the estimates of the income turning points largely depend on the functional form.

The remainder of this paper is organised as follows: the third section presents the hypothesis, methodology and data. The fourth section presents the main results. The fifth section presents a number of robustness tests. The last section concludes.

3. Hypothesis, data and methodology

3.1. Hypothesis

Per capita emissions can be written as the product of per capita income and the emission intensity (de Bruyn et al. (1998):

$$\frac{E_{jt}}{POP_{jt}} = \frac{Y_{jt}}{POP_{jt}} I_{jt}; I_{jt} = \frac{E_{jt}}{Y_{jt}} \quad \textbf{(1)}$$

where E equals emissions, POP population, Y total income and I emission intensity of income, j is a country specific subscript and t indicates time.

As de Bruyn et al. (1998) note, "*intensity will change with the changing composition of economic activities, technologies and processes of material and energy substitution*." Assuming that the composition of economic activity changes from mainly agricultural in the least developed countries towards a mainly industrial one in later stages of economic development and mainly services in the high income group, we could model the composition of economic activity as depending on the level of income: $c(Y)$.

With respect to the emission intensity of output, the discussion in the previous section suggests that we should expect the emission intensity of output to decrease if income rises, as demand for environmental quality seems to be a positive function of income. We also expect demand for environmental quality to be higher in those countries where pollution already causes environmental damage (D) and where knowledge (K) on environmental issues it already high. We will model demand for environmental quality (Q) as

$$Q\left(\overset{+}{Y}, \overset{+}{D}, \overset{+}{K}\right) \quad \textbf{(2)}$$

where a '+' or '-' indicates the direction of the impact, i.e. the sign of the derivative of the income elasticity with respect to that variable.

The arguments presented by Munasinghe (1999) and Magnani (2000) suggest that environmental regulation depends not only on demand for environmental quality but also seems to be a positive function of the power equality and the ability of the public to participate in environmental decision-making. It follows that policy induced technology (T) that lowers emissions intensity depends on the income elasticity of the demand for environmental quality and the way in which a higher demand is translated into environmental regulation. We will introduce the structure of government (P) to model the way in which environmental regulation is aligned with popular demand (the higher P, the more aligned the environmental regulation is). We will further assume that the emissions intensity depends on the existence of imperfection in the economy (M). Market imperfections could, as suggested by Munasinghe (1999), reduce the impact of new environmental regulations through the existence of subsidies.

If we introduce (1) in growth rates, i.e. $\dot{e} = \dot{y} + \dot{i}$ we can summarize our model as

$$\dot{e} = \dot{y} + \frac{d \ln\left[I\left(\overset{\pm}{C}, \overset{-}{T} \right) \right]}{dt}$$

$$C = C(Y) \qquad \textbf{(3)}$$

$$T = T\left(\overset{+}{Q}\left(\overset{+}{Y}, \overset{+}{D}, \overset{+}{K} \right), \overset{+}{P}, \overset{-}{M} \right)$$

where $\pm$ indicates the sign of the impact is undecided.

From (3), it follows that emissions will grow fast in countries that experience a high growth rate of income (scale effect). The impact of growth on emissions will be smaller in countries that are relatively rich as these countries enjoy a composition of economic activity which is relatively services based and because demand for environmental quality will be higher *ceteris paribus*. We also expect that emissions growth will be smaller in those countries where environmental damage is high, where the general knowledge on environmental issues is well developed, where the structure of policy-making is adaptive to the needs and demand of the general population and where market imperfections are relatively unimportant.

What these various hypotheses mean in terms of the EKC is shown in figure 1.

Figure 1: Implications of (3) for the EKC

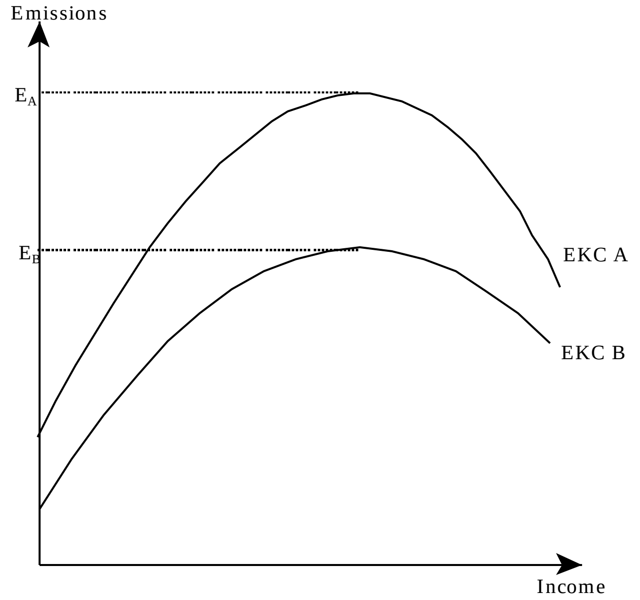

Figure 1 shows 2 environmental Kuznets curves. The higher one, EKC A, has a higher level of emissions for each level of income compared to the lower one, EKC B. In terms of the model in (3), EKC A would be the EKC of a country where market imperfections are relatively important, where the structure of government is not adaptive to environmental policy demands of the general population or where demand for environmental quality is not high. Figure 1 also shows how, if the various hypothesis underlying the model in (3) proof to be correct, the EKC might be transformed into a policy tool. If a country grows along EKC A and is characterised by relatively high market imperfections, reducing those imperfection would allow that country to move from EKC A to EKC B. Obviously, this would be highly relevant if the level of emissions at the top of EKC A, E_A, harms the environment in an irreversible way.

The model presented in (3) could be estimated using equation (4):

$$\dot{e}_{it} = b_0 t + b_1 \dot{y}_{it} + b_2 \dot{y}_{it} \ln(y_{it}) + b_3 \ln(D_{it}) + b_4 K_{it} + b_5 C_{it} + b_6 P_{it} + b_7 M_{it} + V_{it} \qquad \textbf{(4).}$$

In (4), b_0 represents the impact of exogenous technological progress. We would expect that $b_0 < 0$ if exogenous technological progress contributes to lower emission growth; $b_0 = 0$ if non-policy induced technological progress does not have an impact on emission intensity and $b_0 > 0$ if exogenous technological progress increases overall emissions intensity. The 'pure scale' effect is measured through the estimate of b_1. The impact of rising income levels on the composition of economic activity as well as on the demand for environmental quality will have an impact on emissions through b_2. Differentiating (4) with respect to the growth rate of income and assuming no other interaction effect, yields $b_1 + b_2 \ln(y_{it})$. The emissions growth rate equals zero if $\ln(y_{it}) = \frac{b_1}{-b_2}$ and will start to decline once income rises above this level if $b_2 < 0$. To confirm to EKC, we would need $b_1 > 0$ and $b_2 < 0$. If demand for environmental quality depends on the overall level of environmental damage, we expect $b_3 < 0$. If general knowledge on environmental issues reduces emission growth, $b_4 < 0$. If $b_6 < 0$, government structure reduces emissions growth for a given level of environmental damage and income. As market imperfections are expected to increase emissions growth we expect $b_7 > 0$. The estimate of b_5 is undetermined. If the composition of economic activity that is independent of the level of income were more pollution intensive, we would expect the estimate to be positive.

The model presented in (4) relates fairly closely to the Environmental Kuznets Curve when it is estimated in levels. Let's write the levels-EKC, which is usually estimated, as $\ln(e_{it}) = a_i + a_t + a_1 \ln(y_{it}) + a_2 [\ln(y_{it})]^2 + e_{it}$. In the levels-EKC, $"_i$ is a country-specific, time invariant intercept and $"_t$ is a time specific intercept. Differentiating this equation with respect to time yields $\dot{e}_{it} = da_t/dt + a_1 \dot{y}_{it} + 2a_2 \dot{y}_{it} \ln(y_{it}) + de_{it}/dt$. If the first term on the right hand side is a constant, technological progress is assumed to be constant over time. A stochastic process is modelled with a time dependent term (which is the model in equation (4)). The original levels-EKC captures all the effects in (3) through the coefficient estimates for the income variable. Equation (4) on the other hand allows for these effects to have an impact beyond the one that is captured by the income variable.

3.2. Data

We have estimated equation (4) using data for per capita sulphur dioxide emissions and per capita carbon dioxide emissions. The sulphur dioxide emissions are from A.S.L. and Associates (Lefohn A.S., Husar J.D., and Husar R.B. (1999)), carbon dioxide emissions are from the Carbon Dioxide Information and Analysis Center (CDIAC) at the Oak Ridge National Laboratory (Marland, G., Boden, T.A., Andres, R. J. (2001)). Primarily the length of the available series and the coverage of different countries inspired the choice of these two pollutants. Growth rates are calculated over non-overlapping 5 year periods 1960-1965, 1965-1970, 1970-1975, 1975-1980, 1980-1985 and 1985-1990 as the difference in the natural logarithm in the last year of a period minus the log in the first year of a period divided by 5. The choice to use averages over 5-year periods was in part inspired by the fact that a number of channels through which income and income growth have an impact on emissions growth take time and in part by data and econometric considerations. We have also considered the use of longer periods, e.g. averages over 10 years. As these would underestimate the income turning points, 5 year averages seemed to offer the best choice. The use of shorter periods was not possible as some of the data is only available for 5 year intervals.

Table 1 summarizes the growth rates of both per capita sulphur dioxide and carbon dioxide emissions.

**Table 1: average annual per capita growth rates of SO_2 and CO_2*

	Sulphur dioxide	*Carbon dioxide*
Mean	0,02614	0,04016
Median	0,01779	0,03540
Standard deviation	0,10880	0,05216
Correlation	*Sulphur dioxide*	*Carbon dioxide*
Sulphur dioxide	1	0,4759
Carbon dioxide	0,4759	1

(*) data are averages using 5-year non overlapping periods calculated as the difference in the natural logarithm between the last and first year of that period divided by 5.

Exogenous technological progress is measured using a linear time index that takes the value 5 for the first period and adds 5 for each period thereafter.

Population and per capita GDP (income) in constant 1985 USD are from the Penn World Tables (Mark 5.6a). Environmental damage is measured as emissions per square kilometre (ton of sulphur emissions and carbon emissions). Area data are from the World Development Indicators (World Bank (1998)). Table 2 summarizes these variables. A major drawback of this definition of concentration is the fact that both sulphur and carbon dioxide emissions are internationally mobile and measured concentrations in one country might be different from the concentrations as calculated here. Secondly, as an indicator of environmental harm, emissions do not take into account the capacity of the natural environment to absorb them. Emissions per square kilometre as may thus not fully reflect environmental damage. This could be important for some areas if their import/export ratio of sulphur and carbon dioxide emissions is highly skewed or if the capacity of the environment is significantly different from the capacity in other countries. Using measured concentrations on the other hand suffers from some drawbacks as well. Concentrations are measured on a city level and economic data on income, growth, composition of economic activity etc. generally are not available in such detail.

Table 2: Concentration of pollution (kg per square km).

	Sulphur dioxide	*Carbon dioxide*
Mean	4,7949	302,0733
Median	0,3440	21,6881
Standard deviation	27,4943	1388,0350
Correlation	*Sulphur dioxide*	*Carbon dioxide*
Sulphur dioxide	1	0,9794
Carbon dioxide	0,9794	1

The knowledge variable equals average schooling years in the female and male population older than 25 (Barro and Lee (1994)). The variable is expressed as a ratio of female to male schooling and serves as a proxy for societies where both supply of knowledge and demand for knowledge on environmental matters or less polluting technology are low, i.e. societies where environmental matters are not particularly high on the agenda. The schooling ratio seems to fit this description. The coefficient of correlation between the ratio of female schooling to male schooling and the ratio of per capita GDP to the per capita GDP in the USA is 0.64 (relative GDP from the Penn World Tables 5.6a). This suggests that the schooling ratio is associated with less developed countries although relative GDP seems to measure something different than the schooling ratio. With respect to geography data, the difference between schooling of both sexes seems to correlate more closely with a dummy variable that equals 1 if the country is an African country (correlation coefficient –0.61). The ratio correlates positively with other measures of schooling and especially female schooling (coefficient of correlation 0.80). With male schooling the coefficient of correlation equals 0.67. This seems to suggest that the schooling ratio is associated with poorly educated societies in less developed countries. The coefficient of correlation between the ratio of female schooling to male schooling and the competitiveness of participation variable, a variable that will be discussed below, is 0.61. Low schooling ratios are especially found in nonurban areas as the coefficient of correlation between the ratio and the percentage of the population living in nonurban areas (calculated from the World Bank (1998)) is –0.53. Although most of these correlation coefficients are similar if one splits the sample based on the median of relative GDP (which equals 28%), one noticeable difference is the fact that in ‘rich’ countries, the ratio of female to male schooling is much more related to the ratio of workers to total population (taken from Barro and Lee (1994)) than that is the case in ‘poor’ countries. The relative schooling ratio seems to be smaller in the least developed countries with a generally poorly educated population living in nonurban areas and where political opposition is the least allowed. Low schooling ratios seem to be indicative of a situation where knowledge on environmental problems is difficult to spread (low level of education of the population, large nonurban areas and relatively autocratic regimes) both through normal news media as well as through information campaigns, for instance through NGO’s. They also reflect countries where the need to have information on less polluting technologies is less relevant as production in nonurban areas can be expected to be local i.e. not technology or scale intensive. The variable does not reflect ‘knowledge’ as such. It does, however, reflect a situation in which knowledge cannot be expected to be high, because the value of such information is low and/or the costs associated with its distribution are high. Although far from perfect, it has the advantage over other schooling variables that it does not assume that ‘environmental matters’ are part of the curriculum.

Government structure data are from the Polity IV dataset (Marshall, M. G., Jaggers, K. (2000)). The major advantage of this dataset is its level of detail. Polity data are grouped into indicators of democracy and autocracy and authority characteristics. The former are based on 3 sets of data: DEMOC (an 11 point scale which is constructed additively and reflects the general openness of political institutions), AUTOC (an 11 point scale reflecting the closeness) and DURABLE, an indicator which is calculated as the number of years since the last regime transition. The POLITY variable is calculated as the difference between AUTOC and DEMOC and measures the openness of a political structure on a scale from –10 to +10. With respect to the authority characteristics, the PARREG (regulation of participation) variable measures the extent to which there are binding rules on when, whether and how political preferences are expressed. This variable is a 5 category scale which ranges from unregulated, i.e. “*political participation is fluid; there are no enduring national political organisations and no systemic regime controls on political activity. Political groupings tend to form around particular leaders, regional interests, religious or ethnic or clan groups; but the number and relative importance of such groups in national political life varies substantially over time*” to regulated, i.e. “*relatively stable and enduring political groups regularly compete for political influence and positions with little use of coercion. No significant groups, issues* *or types of conventional political action are regularly excluded from the political process.*" The PARCOM (competitiveness of participation) variable refers "*to the extent to which alternative preferences for polity and leadership can be pursued in the political arena*". A low value for this variable (1) implies that "*no significant oppositional activity is permitted outside the ranks of the regime and ruling party*" whereas a high score (5) implies that "*there are relatively stable and enduring, secular political groups which regularly compete for political influence at the national level; ruling groups and coalitions regularly, voluntarily transfer central power to competing groups*". The Polity IV data manual argues "*by combining the scores on Regulation of Political Participation and the Competitiveness of Participation a relatively detailed picture of the extent of political competition and opposition emerges*". As table 3 shows, the correlation between these different measures of political structure is far from perfect. Although the competitiveness of participation variable seems to be associated with higher income as measured by the log of per capita GDP, table 3 seems to suggest that the correlations between other polity measures are anything but perfect. There does not seem to be much evidence to suggest that political structure is highly correlated with the black market premium variable (BMP) which is the indicator used to measure market imperfections.

Table 3: Political structure: correlation between various measures

	Autoc	*Democ*	*Durable*	*Parcom*	*Parreg*	*GDP*	*BMP*
Autoc	1.0000						
Democ	-0.9278	1.0000					
Durable	-0.3921	0.5449	1.0000				
Parcom	-0.8775	0.9245	0.5334	1.0000			
Parreg	-0.0872	0.3342	0.5062	0.4479	1.0000		
GDP	-0.5228	0.6401	0.5944	0.7042	0.5749	1.0000	
BMP	0.3221	-0.3308	-0.2701	-0.4228	-0.2840	-0.4482	1.0000

The black market premium is our first indicator of price distortions. It is measured in local currency and is calculated as the black market exchange rate over the official exchange rate minus 1 (Barro and Lee (1994)). There are a number of such distortions that could influence emissions. Fossil fuels for instance, which are quoted in dollar terms in international markets, are too cheap when converted into official local currencies relative to its 'unofficial' local market price. A second indicator of distortions is the Own-Import Weighted tariff rates on intermediate inputs and capital goods (OWTI), which is taken from Barro and Lee (1994) and is only available for the entire period. Tariffs on intermediate inputs and especially capital goods increase the price of new, imported, capital that could increase the age or reduce the efficiency of the available stock of capital compared to countries where these tariffs are inexistent or much lower. Tariffs on intermediate inputs offer protection to local companies. This could reduce efficiency in general and environmental efficiency in particular.

The composition of economic activity was somewhat more difficult to capture as it involves identifying variables that in all likelihood have an impact on the composition of economic activity and which can capture the composition of economic activity beyond the impact of the income level. Our first variable is the share of government consumption (Penn World Tables 5.6a). We could assume that government consumption is services related and thus less emission intensive. Secondly, we used a measure of the amount of available labour: the active population as a percentage of total population. As Gale and Mendez (1998) have shown, a relative abundance of labour could lead to less pollution. The percentage of the population living in urban areas is our third indicator of the composition of economic activity. We assume that the percentage of people living in urban areas has a positive impact on emissions growth as large urban centres attract more traffic.

For both the sulphur dioxide sample and the carbon dioxide sample a total of 280 observations is available for a set of 53 countries (see Appendix A). We have chosen to restrict the dataset to observations that were available for both measures of pollution. Estimates of various coefficients are thus based on exactly the same dataset. The dependent variable was in each case a 5-year average growth rate of the environmental pollutant. With the exception of economic growth, all independent variables refer to the first year of that period. In other words, the growth rate of sulphur dioxide emissions over the 5-year period 1980-1985 is explained using variables that refer to 1980 etc.. The main advantage of this procedure is that the direction of causation is clear, as future emissions can have no impact on current concentrations.

3.3. Methodology

With respect to the economic growth variable, there is, however, still a problem. It is highly likely that the error term in (4) is correlated with economic growth as growth is measured over the same 5-year time period as emissions. This is not the case with respect to all other independent variables as they are measured in the first year of a 5-year period. A solution would be to look for an instrument that correlates with economic growth but not with the error term in (4). The instrument that serves this purpose best seems to be the predicted growth rate from a growth regression over the same 5 year periods as (4) and with explanatory variables measured in the base year. The predicted growth rates from such a regression are expected to correlate well with the actual growth rate. Correlation with the error term in (4) should however be limited.
The construction of the instrument was based on Barro and Sala-i-Martin (1995) and Barro (1997). We have estimated an economic growth equation for each 5 year period and for each country available in the emissions sample. We have done so using the average annual economic growth over those 5 year periods with explanatory variables from the first year of the 5 year period. We use the predicted values in the second step as an instrument to estimate the emissions growth equation. The explanatory variables used to estimate (5) were largely taken from Barro (1997) and include: the openness of

the economy (Penn World Tables 5.6a) measured as the ratio of the sum of exports and imports to national GDP, the log of the fertility rate, the log of the life expectancy, the average distance in 1000 km to capitals of world 20 major exporters weighted by values of bilateral imports (1 observation per country) and a dummy for African countries (Barro and Lee (1994)). We also use variables which have already been discussed: per capita GDP, the Government Consumption Share of GDP (Government share), Own Weighted Tariff on intermediate inputs and capital goods, black market premium, female and male schooling, regulation of participation, competitiveness of participation and the durability measure from the Polity dataset. The last three variables are used instead of the democracy index used by Barro (1997) because they are used in the estimates of (4). We refer to Barro and Sala-i-Martin (1995) or Barro (1997) for a discussion with respect to the variables used in the growth regression (5).

We have estimated (4) with White Heteroskedasticity consistent standard errors. We have also used the two-step procedure outlined in Green (1997) and Murphy and Topel (1985). The Murphy and Topel two-step procedure did not have a significant impact on the estimates of the standard errors. Note that Panel data procedures were not available to us as they use the country specific average for a particular variable (Green (1997)). Because our measure for tariffs is only available for the entire period, subtracting the country specific average would yield 0 for all countries.

Data which came from Barro and Lee (1994) are only available for 5-year periods or for the years 1960, 1965, 1970, 1975, 1980 and 1985.

4. Results

Before we proceed with the estimation results for the emission growth regressions, we will first report on the results of our instrument, i.e. on the results of the growth equation (5).

4.1. Instrument

Table 4 reports the results for a growth equation that is similar to the one estimated by Barro (1997).

Table 4: Growth regression*

	Coefficient	t-stats
Log of per capita GDP	-0,0290	-5,3414
Log of life expectancy	0,0714	6,3738
Log of fertility	-0,0113	-2,1043
Male schooling	0,0051	2,1100
Female schooling	-0,0059	-2,3987
Government share	-0,0007	-1,9408
Openness	0,0000	0,1084
Distance	-0,0009	-1,4496
Own weighted tariff	-0,0165	-2,1280
Black market premium	-0,0298	-5,9540
Regulation of part.	0,0045	1,8454
Competitiveness of part.	0,0004	0,2363
Durability	0,0000	0,5160
African dummy	-0,0145	-1,9743
R^2	0,3793	
Adj. R^2	0,3490	
Obs.	280	

(*) Appendix B summarizes the variables used in this regression; t-stats are calculated based on White heteroscedasticity consitent standard errors.

The results presented in table 4 are in line with the estimates reported in Barro and Sala-I-Martin (1995) and Barro (1997). Growth rates in rich countries are, all other things equal, on average smaller (i.e. table 4 offers evidence of conditional convergence). The schooling variables are both significant and have the usual sign. Male schooling enters positively, female schooling negatively. As Barro and Sala-I-Martin (1995) argue "a large spread between male and female attainment is a good measure of backwardness". Note that the spread, expressed as a ratio, is the knowledge variable that will be used as an explanatory variable in (4).

If government consumption is important in terms of GDP, countries tend to grow less rapidly. In general, this seems to suggest that non-productive spending and its associated taxation undermine growth (Barro (1997)). The openness variable is not significant at a reasonable level. Most probably, this is due to the fact that the distance and own weighted tariff variables, account for much of the effect. The latter two have a negative impact on growth. Countries grow less rapidly if the distance between them and the world's most important trading countries is large and if their tariff on intermediate inputs and capital goods is high. Obviously high import tariffs on intermediate goods and especially on capital goods reduce investment through the impact on the initial investment costs. High tariffs on intermediate goods offer protection for local producers and could allow them to be less efficient compared to foreign efficiency levels.

The black market premium proxies market imperfections that have a significant negative impact on growth. The two political structure variables are both positive although only competitiveness of participation if significant. Barro (1997) finds a non-linear relation between the level of democracy and economic growth with democracy enhancing growth up until it reaches a level comparable to that in Mexico in 1994. Political liberalization reduces growth after those levels. Barro (1997) argues that this non-linear relationship might be due to the fact that in autocratic countries, more political rights might induce investment whereas in highly democratic countries, the advantage of additional investment due to the lower impact of government is less than the impact of income redistribution. The non-linear relationship is not significant here. First of all, notice from table 3 that the competitiveness of participation and the regulation of participation are positively correlated. If we look back at the actual definitions of the latter, it is worthwhile to remember that the highest values for the regulation of participation variable are for regimes that are characterized by "*relatively stable political groups that compete* for political influence and positions with little use of coercion". The low values are for regimes with "*unstable political groups around particular leaders, regional interests, religious or ethnic of clan groups*". The evidence presented so far suggests that the regulation of participation variable catches the effect of the stability of the political system with respect to the issues that the system has to deal with. Once this effect is accounted for, stability of political groupings, measured through the competitiveness of participation variable does no longer appear significant. One could assume that the focus on various special interests of personal, religious or ethnic nature consumes time, energy and money on issues that do not always favour long-term growth. The absence of a high negative correlation with the durable variable seems to suggest that even in countries that are characterised by a low regulation of participation variable, these situations last quite a long time. The results with respect to the political structure seem to suggest that stable regimes that can focus on issues of general interest to the population will tend to grow faster.

4.2. Results for emissions growth

The economic growth regression in table 4 was used to estimate equation (6) using the variance-covariance matrix given by (7) for both per capita sulphur dioxide and par capita carbon dioxide emission growth rates. Exogenous technological progress was proxied by a linear time trend. The predicted values from (5) where used as proxy variables for the growth rate.

Table 5: Growth of per capita SO_2 and CO_2 emissions

	Sulphur Dioxide		*Carbon dioxide*	
	Coefficient	*t-stat*	*Coefficient*	*t-stats*
Time	-0,0015	-2,2775	-0,0014	-5,0464
Growth	11,3217	2,4563	4,9640	2,6828
*Growth*log per cap. GDP*	-1,2328	-2,0744	-0,4949	-2,3022
Log of Concentration	-0,0106	-1,9143	-0,0011	-0,6739
Own weighted tariff	-0,0537	-1,0556	0,0293	2,2648
Black market premium	0,0046	0,1512	0,0276	1,5966
Government share	-0,0000	-0,0225	-0,0018	-3,0091
Urban population	0,0010	1,8683	0,0002	0,6965
Active population	0,0419	0,3161	0,0765	1,1851
Ratio female to male sch.	-0,1230	-2,4805	-0,0392	-1,9107
Regulation of part.	-0,0051	-0,6791	-0,0002	-0,0876
Competitiveness of part.	0,0068	1,1614	-0,0015	-0,5784
R^2	0,24		0,34	
Adj. R^2	0,21		0,31	
Obs.	280		280	
Income turning point	9.734		22.694	

Note: Income turning point in real 1985 purchasing power parity USD; appendix B summarizes the data used to calculate the estimates. T-stats are calculated using White heteroskedasticity consistent standard errors.

In order to be able to interpret the various results in more detail, we ran one additional regression. We have tried to explain the share of carbon dioxide emissions from solid fuels, liquid fuels and gas. These shares, which are calculated from Lefohn, Husar and Husar (1999) and Marland, Boden and Andres (2001), act as instruments for the efficiency of fuel use as carbon dioxide emissions, as opposed to sulphur dioxide emissions, can't be separated from fuel. The explanatory variables are a dummy variable for a country which has a positive entry for carbon dioxide emissions from flaring, a constant, a time trend, per capita GDP, per capita GDP squared, the ratio of per capita GDP to per capita GDP in the United States, the schooling ratio, the own weighted tariff on intermediate imports and capital goods, the black market premium, government share of consumption, regulation of participation, competitiveness of participation and the share of active population. Per capita GDP and the square of per capita GDP are added to capture the pure income effect that is also present in the estimation of equation (4). If both of these variables were excluded, there would always be the possibility that the remaining variables, and especially ratio of schooling and relative GDP capture some of the pure income effects. All other variables have also been used to estimate equation (4) with the exception of concentration. Table 6 reports the results.

Table 6: Share of solid fuels, liquid fuels and gas in CO_2 emissions*

	Share of CO_2 emissions from solid fuels	*Share of CO_2 emissions from liquid fuels*	*Share of CO_2 emissions from gas*
Constant	-4,5058 *(-3,2133)*	2,7590 *(1,4916)*	1,8712 *(2,5213)*
Time	-0,0030 *(-1,3909)*	0,0028 *(-1,0648)*	0,0017 *(2,0190)*
Log per capita GDP	1,0220 *(2,7452)*	-0,3670 *(-0,7266)*	-0,4521 *(-2,1733)*
Log per cap. GDP squared	-0,0734 *(-2,8306)*	0,0228 *(0,6302)*	0,0304 *(2,0728)*
Relative GDP	0,0043 *(2,6660)*	-0,0021 *(-0,7443)*	0,0005 *(0,4152)*
Ratio female to male sch.	-0,1462 *(-2,4612)*	0,1907 *(2,6365)*	0,0157 *(0,5857)*
Own weighted Tariff	0,2000 *(2,7618)*	-0,1631 *(-2,3158)*	-0,0133 *(-0,5463)*
Black market premium	0,0257 *(0,5738)*	-0,0797 *(-1,3064)*	0,0376 *(1,5981)*
Government share	0,0087 *(2,9170)*	-0,0053 *(-1,7594)*	-0,0033 *(-3,5061)*
Reg. of part.	0,0028 *(0,1530)*	0,0133 *(-0,6696)*	-0,0067 *(-0,9352)*
Comp. of part.	0,0554 *(4,8536)*	-0,0466 *(-3,7902)*	-0,0024 *(-0,5742)*
Active	1,3260 *(4,7674)*	-0,5879 *(-1,6998)*	-0,2785 *(-1,9186)*
Dummy for flaring	-0,0356 *(-1,5702)*	-0,0979 *(-3,9849)*	0,0907 *(6,5017)*
R^2	0,33	0,24	0,48
Adj. R^2	0,30	0,21	0,45
Income turning point (USD 1985)	1.046 *max*	*3.062* *min*	1.674 *min*

(*) t-stats in parentheses based on White heteroskedasticity-consistent standard errors and covariance, *max* and *min* in the last row refer to the income turning point and indicate whether it is a maximum or minimum, turning points in italics are not significant.

From table 6, it can be seen that the share of carbon dioxide emissions from solid fuels decreases steadily once the economy reaches an income level of 1985 USD 1.046 (which is within the sample range). Once this level is reached, the share of carbon dioxide emissions from gas and liquid fuels increases. The evidence presented in table 6 further suggests that income is not sufficient to explain fossil fuel use. Solid fuel use is associated with less developed economies that lack knowledge on environmental matters. These economies are further associated with governments that are important in terms of their consumption as a percent of GDP and face democratic opposition. Their active population is large in terms of total population. These results are in line with those of Cole (2000a). He concluded that developed economies saw a declining share of both manufacturing activity and within manufacturing, a declining share of dirty manufactures. He also noted that demand for dirty products seems to be decreasing once a threshold level of income is reached. From the evidence with respect to the significance and sign of the income terms for various fuel types in table 6 similar conclusion follow.

We return now to table 5. For both sulphur and carbon dioxide emissions, economic growth is an important explanatory variable. The income turning points that are implied by the estimates are broadly in line with previous estimates. Selden and Song (1994) for instance found income turning points for sulphur dioxide emissions of 1985 USD 8.709 to 1985 USD 10.681. Using the data from A.S.L. and Associates as we do, Stern and Common (2001) find income turning points of 1990 USD 101.166 for their entire sample, 1990 USD 9.181 when they use only the OECD countries and 1990 USD 908.178 for the non-OECD sample. When they restrict their sample to those countries used by Selden and Song (1994), they find income turning points of 1990 USD 9.265 to 9.702. With respect to carbon dioxide emissions, Holtz-Eakin and Selden (1992), using the same CDIAC data source as we do here, find income turning point of 1985 USD 35.428. The evidence suggests that during the early stages of development, the scale and composition effect dominate the income effect and emissions have positive growth rates. As countries become richer, the composition of economic activity contributes to lower emission growth rates. Eventually, the scale effect is dominated by the composition and income effect and emissions have negative growth rates. The significance of the other variables however suggests that income itself does not guarantee sustainable progress. Note also that, as the turning points are calculated from the estimated growth equation, the turning points should not be interpreted without due care.

Technology seems to have lowered growth of both pollutants. Notice that the impact of technology seems to be of similar magnitude for both pollutants.

The ratio of female to male schooling is the last variable that is negative and significant for both pollutants. As an indicator of knowledge on environmental matters, the estimates seem to be in line with the arguments presented by Munasinghe (1999) with respect to the general level of knowledge. Replacing the schooling ratio by the total number of years a person spends in school does however not return a significant schooling variable. As already argued, this result does not seem to be surprising as nothing guarantees that 'environmental matters' are part of the curriculum. As already argued, the schooling ratio does not measure 'knowledge' as such but serves as a proxy for an environment were knowledge on environmental matters or less polluting technologies is difficult to spread. Low schooling ratios are most probably also indicative of the lack of demand for such information. To make sure that the knowledge variable captures something different than the 'level of backwardness' in terms of per capita GDP and to test whether the effect is equal across countries irrespective of their level of development, we ran one additional test that controls for relative GDP. We created a dummy variable (GDP dummy) that equals 1 if relative per capita GDP is less than the median value of the ratio of per capita GDP to per capita GDP in the United States (relative GDP). Using the GDP dummy, we created two additional variables. The first one equals the female-male schooling ratio times the dummy (schooling ratio if relative per capita GDP < median). The other equals the schooling ratio if the relative GDP is higher than the median value and zero otherwise. The impact of this procedure on the estimates of the coefficients of the other variables in the equation was limited. A Wald test was not able to refute the hypothesis that the income turning points were equal to those reported in table 5. Table 7 reports the regression coefficients for the new variables that were added. Appendix C reports the full regression results.

Table 7: Estimates for the ratio of female to male schooling

	Sulphur Dioxide		*Carbon dioxide*	
	Coefficient	*t-stat*	*Coefficient*	*t-stats*
Schooling ratio if relative per capita GDP > median	-0,1125	-2,1083	-0,0537	-2,3051
Schooling ratio if relative per capita GDP < median	-0,1281	-2,4760	-0,0309	-1,5527

As can be seen from table 7, controlling for income does not seem to have an impact on the estimates of the coefficients. The estimates presented in table 7 are of similar magnitude to those presented in table 5. Both tables suggest that the mechanism that is at work here is ‘universal’ i.e. it is not peculiar to an income group. The evidence in table 6 with respect to the ratio of female to male schooling suggests that a low ratio is associated with a high share of solid fuels in total fuel consumption. The importance of liquid fuels on the other hand seems to rise as the ratio of female to male schooling increases. Although only limited in magnitude, the relative income level has a positive impact on solid fuel consumption. The significance of the relative schooling measure seems to suggest that the lack of knowledge (and the lack of any need for such a knowledge) is associated with, from an environmental point of view, inefficient and relatively dirty use of fossil fuels. In less developed regions, where services are still unimportant and agriculture is still the dominant economic activity, industrial activity is oriented towards ‘dirty’ manufacturing or the technology used in ‘clean’ manufacturing is relatively inefficient both in the type of fuels used as well as the amount of fuels used. Countries that lack knowledge and information on environmental matters are more polluting. As the schooling ratio is associated with less developed, nonurban and poorly educated areas, it could be worthwhile if development policies include environmental elements through, for instance, training with respect to environmentally friendly ways of production or the diffusion of more efficient technologies. The evidence presented here clearly suggests that in those societies, there seem to be ‘low hanging fruits’ in terms of environmental performance that should be harvested.

The political structure variables have no direct effect on the emissions levels. The regulation of participation variable has the expected sign but is not significantly different from zero[2]. Although this might seem puzzling at first, it is worthwhile to remember that a significant sign would imply that these variables have an effect even after the level of concentration and income is taken into account. The evidence presented here does seem to suggest that for a given level of income and a given concentration of emissions, the political structure does not seem to have any direct impact on emission levels. According to these findings, policy is demand-led and demand seems to be driven by income and damage. Political structures do not alter the emission level as such but do not stand in the way of a reduction once concentrations are sufficiently damaging and income levels sufficiently high. Note however that the regulation of participation variable does have a positive effect on economic growth and should increase the speed with which a given country reaches the income level that is associated with a peak in emissions. Note also that competitiveness of participation has a positive impact on the share of solid fuels and a negative one on the share of liquid fuels.

The active share of the population does not have a significant effect on emissions growth for both pollutants. This does not however imply that the share of active population would not have an impact on environmental quality. As table 6 shows, the higher the share of active population, the higher the share of coal and the lower the share of natural gas in the fuel mix.

With respect to the other variables that have an impact on abatement, there seems to be quite some difference between the two pollutants. For sulphur dioxide emissions, concentration seems be an important explanatory variable whereas this is not the case for carbon dioxide emissions. This result is in line with the fact that carbon dioxide concentrations do not cause country specific harm whereas sulphur dioxide emissions have damaging effects locally. The estimate seems to be in line with the evidence presented by Kaufman et al. (1998).

The estimates suggest that sulphur dioxide and carbon dioxide emissions respond differently to tariffs on capital goods and intermediate imports. The level of tariffs does not influence sulphur dioxide emissions growth. Carbon dioxide emissions on the other hand seem to grow faster if countries have high tariffs on capital goods and intermediate inputs. Note also from table 6 that the share of solid fuels is higher in countries with high import tariffs while the share of liquid fuels seems to be lower in countries with high import tariffs. To see whether the level of development can explain this difference and to check whether the coefficient for a single pollutant is stable across levels of development, regression (6) was re-estimated with two new variables to replace the

[2] We tested for various measures of political structure. Using the autocracy and democracy index or the polity variable instead of the regulation and competitiveness of participation variable did not change the results.

tariff variable. The first variable is equal to the tariff variable for countries with relative per capita GDP equal to or higher than the median level and 0 for all other countries. The other variable is equal to the tariff variable if relative per capita GDP is smaller than the median level and 0 otherwise. Table 8 reports the results. The estimates were again reasonably stable. A Wald test shows that the estimated income turning points were equal to those in table 5. All other variables were comparable to those reported in table 5 both with respect to their magnitude as with respect to their direction of impact (see appendix C).

Table 8: Growth of SO_2 and CO_2 emissions: impact of tariffs

	Sulphur Dioxide		*Carbon dioxide*	
	Coefficient	*t-stat*	*Coefficient*	*t-stats*
tariff if relative per capita GDP >Median	-0,0465	-1,1586	0,0127	0,7338
tariff if relative per capita GDP <Median	-0,0526	-1,0890	0,0270	2,0748

As can be seen from table 8, the results for sulphur seem to suggest that they are fairly general across levels of development. For carbon dioxide, the estimates suggest that the own weighted tariff on capital goods and intermediate inputs is especially relevant for countries whose relative per capita GDP was below the median level.

The sign and significance of the tariff variable is the result of two impacts. On the one hand, as Cole (2000a) and Gale and Mendez (1998) have shown, rising costs of capital, for instance through tarification of imports of capital goods, reduce the overall pollution intensity of manufacturing. On the other hand, one could assume that higher tariffs on intermediate inputs but especially on capital goods increase the average age of the capital stock and thus reduce its overall efficiency. Table 6 seems to suggest that the latter effect dominates the former. The coefficient for the tariff variable is positive and significant for the share of solid fuels while it is negative and significant for the share of liquid fuels. Countries with a high tariff seem to be characterised by a fuel composition that is directed towards solid fuels whereas low tariffs seem to be associated with a liquid fuel based composition. For sulphur dioxide, the positive effect on pollution due to the relative inefficiency and the negative effect on pollution due the lower capital intensity are more or less balanced, as the tariff variable is not significant. For carbon dioxide emissions on the other hand, the relative inefficiency in the type of fuel used and most probably the amount of fuel used outweighs the effects from lower capital intensity. If the own weighted tariff on capital goods and intermediate inputs can be considered an 'imperfection' in the sense of Munasinghe (1999), lowering the tariffs would allow countries to 'tunnel through' the Kuznets curve, i.e. reach the income turning point but at a lower level of pollution. Lowering the tariffs on capital goods and intermediate inputs might offer a ‘win-win’ situation. As table 4 has shown, lower tariffs increase economic growth. The evidence presented here suggests that lower tariffs, for given output, could be beneficial for the environment as well.

The black market premium, a measure for market imperfections, has a positive impact on carbon dioxide emissions growth. The significance of the estimate is however limited (11%). Sulphur dioxide emissions on the other hand do not respond to differences between the official exchange rate and the black market exchange rate. When we add the square of the black market premium to the equation, table 9 reveals that the estimate is positive and significant for both sulphur dioxide and carbon dioxide emissions growth.

Table 9: Market imperfections: black market premium and its square

	Sulphur Dioxide		*Carbon dioxide*	
	Coefficient	*t-stat*	*Coefficient*	*t-stats*
Time	-0,0015	-2,2109	-0,0014	-4,9425
Growth	12,919	2,5384	5,8938	3,2053
*Growth*log per cap. GDP*	-1,4570	-2,2005	-0,6250	-2,9540
Log of Concentration	-0,0108	-1,9677	-0,0016	-1,0103
Own weighted tariff	-0,0526	-1,0620	0,0293	2,3416
Black market premium	-0,0849	-1,2077	-0,0287	-1,3576
Black market premium sq.	0,0478	1,7093	0,0300	3,4304
Government share	0,0003	0,2110	-0,0015	-2,6692
Urban population	0,0011	1,9425	0,0002	0,7872
Active population	0,0592	0,4561	0,0876	1,4054
Regulation of part.	-0,0047	-0,6116	-0,0001	-0,0423
Competitiveness of part.	0,0057	1,0257	-0,0021	-0,8027
Ratio of female to male sch.	-0,1297	-2,5451	-0,0442	-2,1579
R^2	0,25		0,36	
Adj. R^2	0,22		0,33	
Obs.	280		280	
Income turning point	7.092		12.441	
Wald test(**)	0,1852		1,0958	
	0,6672		0,2961	

Note: Income turning point in real 1985 purchasing power parity USD; appendix B summarizes the data used to calculate the estimates. T-stats are calculated using White heteroskedasticity consistent standard errors. (**) Test for the equality of turning points reported in table 5 and those obtained from the regression reported in table 9. First the Wald test statistic is reported, below its probability.

The significance of the square of the black market premium seems to suggest that market imperfections are especially relevant in terms of environmental performance if they are important. Small imperfections do not seem to have a significant impact on pollution intensity.

Table 6 suggests that the black market premium does not have an impact on the overall fuel mix. The most likely mechanism through which the black market premium has an impact is the amount of fuel consumption. As already argued, if the official USD exchange rate allows fuel to be imported below the ‘market’ level, one could assume that the ‘wrong’ price signal does not guarantee an optimal fossil fuel use. Differentiating again between countries with relative per capita GDP below and above the median values, table 10 does not reveal any impact of the level of development (full results are in appendix C).

Table 10: Growth of SO_2 and CO_2 emissions: impact of the black market premium

	Sulphur Dioxide		*Carbon dioxide*	
	Coefficient	*t-stat*	*Coefficient*	*t-stats*
Without the square of the Black Market Premium				
Black market premium if relative per capita GDP >Median	0,0149	0,4559	0,0237	1,5013
Black market premium if relative per capita GDP <Median	0,0031	0,0935	0,0282	1,5294
Adding Black Market premium squared				
Black market premium	-0,0928	-1,2666	-0,0274	-1,2279
Black market premium squared if relative per capita GDP >Median	0,0786	1,9569	0,0249	1,7069
Black market premium squared if relative per capita GDP <Median	0,0488	1,7504	0,0298	3,3742

The estimates presented in table 10 indicate that the impact on emissions growth of market imperfections measured through the black market premium is stable across levels of development. With respect to sulphur dioxide emissions however, the evidence seems to suggest that a black market premium will have a larger effect in developed countries.

The share of government consumption in GDP seems to be associated with lower growth rates for carbon dioxide emissions. Although table 6 suggests government consumption is also associated with a higher share of solid fuels in the overall fuel mix, the impact on the growth rate is negative. As table 11 shows, the stability of the coefficients both in their magnitude and direction as well as their significance when the development dimension is introduced, suggests that the way in which government consumption affects emission growth is more or less universal (full results are in appendix C). In line with our assumption, government consumption seems to be services based and less polluting. Note however that the impact is rather small in economic terms.

Table 11: Growth of SO_2 and CO_2 emissions: impact of government share of GDP

	Sulphur Dioxide		*Carbon dioxide*	
	Coefficient	*t-stat*	*Coefficient*	*t-stats*
Government share if relative per capita GDP >Median	0,0021	0,8795	-0,0025	-3,2781
Government share if relative per capita GDP <Median	-0,0002	0,8795	-0,0016	-2,6278

The percentage of people living in urban areas is positively associated with sulphur dioxide emissions growth and is insignificant with respect to carbon dioxide emissions. As table 12 shows, development does have an impact (full results are in appendix C).

Table 12: Growth of SO_2 and CO_2 emissions: impact of the percentage of people living in Urban areas

	Sulphur Dioxide		*Carbon dioxide*	
	Coefficient	*t-stat*	*Coefficient*	*t-stats*
Urban population if relative per capita GDP >Median	0,0011	1,8473	-0,0000	-0,2795
Urban population if relative per capita GDP <Median	0,0010	1,6154	0,0004	1,1967

The results for sulphur dioxide emissions are not significantly different from those reported in table 5. For carbon dioxide emissions however, differentiating the urban population with respect to the level of development lowers the significance of both the tariff variable as well as the black market premium variable. The direction and magnitude however are comparable. The level of development does not change the extent to which the urban population affects the growth rate of sulphur or carbon dioxide emissions. Most probably this is due to the fact that large urban centers attract more traffic that might be 'cleaner' in developed regions. On the other hand, gas might be more widespread for heating purposes. When re-estimating the regression for which results were reported in table 6 and including the development differentiated urban population variables, the results (not reported), although not significant, show a positive sign for the share of carbon emissions from liquid fuels for developed regions and a negative sign for less developed regions. The share of carbon emissions from gas on the other hand showed the opposite signs. Although far from being conclusive, there are some elements that seem to suggest that urban areas increase emissions growth because of the traffic flows and, in less developed regions, because of the low amount of natural gas used, for instance for heating purposes.

5. Additional robustness tests

We have already mentioned that the results seem to be robust for changes in variables. In order to investigate this further, we have estimated a number of additional regressions, always adding 1 or more variables to the original equation (6). First of all, in order to see whether the residual from equation (5) has an impact on emissions growth we added two additional variables to the equation, one which equals the residuals if they where positive and 0 otherwise and one which was a copy of the residuals if they were negative and 0 otherwise. This test allows to see whether the use of instrument variables has a significant impact on the results and whether countries which have grown 'beyond' their predicted level have done so in a pollution intensive way. If this were the case, we would expect the coefficient on the positive residual to be higher in absolute terms than the one on the negative residual. If both these coefficients equal 0, we could argue that the emissions growth is driven by 'structural' economic growth and that occasional circumstances do not change the pollution profile of a country. Table 13 reports the results of this exercise.

Table 13: Impact of the residual economic growth on emissions

	Sulphur Dioxide		*Carbon dioxide*	
	Coefficient	*t-stat(*)*	*Coefficient*	*t-stats(*)*
Time	-0,0009	-1,3023	-0,0007	-3,0661
Growth	11,198	2,3952	5,0304	2,8587
*Growth*log per cap. GDP*	-1,2051	-1,9758	-0,4871	-2,2910
Log of concentration	-0,0110	-1,9630	-0,0024	-1,6059
Own weighted tariff	-0,0486	-0,9490	0,0312	2,6518
Black market premium	0,0059	0,1857	0,0286	1,7921
Government share	-0,0002	-0,1619	-0,0019	-3,8999
Urban population	0,0011	1,8576	0,0002	0,6989
Active population	0,0031	0,0227	0,0228	0,3772
Regulation of part.	-0,0042	-0,5592	0,0003	0,1264
Competitiveness of part.	0,0068	1,2074	-0,0008	-0,3912
Ratio of female to male sch.	-0,1209	-2,3154	-0,0250	-1,15300
Economic growth res.$ 0	1,1849	3,3589	0,9266	4,5523
Economic growth res. < 0	0,3203	0,7286	1,0131	6,9474
R^2	0,26		0,52	
adj. R^2	0,23		0,50	
Obs.	280		280	
Income turning point	10.852		31.553	
Wald-test(**)	0,0104		0,0578	
	0,9185		0,8100	

(*) t-stats are calculated using White Heteroskedasticity consistent standard errors; (*)Income turning point in real 1985 purchasing power parity USD; Test for the equality of turning points reported in table 5 and those obtained based on the regression reported in table 13. First the Wald test statistic is reported, below its probability.

The results in table 13 are comparable to those presented in table 5, which is further evidence of the fact that the basic regression is robust. The added terms are both significant for carbon dioxide emissions and only significant for the positive economic growth residual for sulphur dioxide emissions. None of the significant coefficients is statistically different, in absolute value, from each other. Negative surprises in terms of economic growth do not have an impact on the sulphur dioxide emissions growth.

A second test for the robustness of the results is reported in table 14. To see whether the results are robust for differences in fuel mix, we added the share of carbon dioxide from solid fuels, from liquid fuels, from gas and a dummy for the presence of carbon dioxide emissions from flaring to equation 6. With the exception of the dummy for flaring in the carbon dioxide regression, none of the variables that were added enter significantly. They also do not seem to have an impact on the direction, significance nor magnitude of the other variables. As was the case with the residual however, the estimate for the black market premium becomes significant.

Table 14: Impact of the initial fuel mix

	Sulphur Dioxide		*Carbon dioxide*	
	Coefficient	*t-stat(*)*	*Coefficient*	*t-stats(*)*
Time	-0.001283	-1.762597	-0.001686	-4.787902
Growth	11.54592	2.439029	4.525481	2.283905
*Growth*Log per cap. GDP*	-1.249915	-2.047291	-0.411300	-1.763647
Log of concentration	-0.012673	-1.874606	-0.001071	-0.514341
Own weighted tariff	-0.057026	-1.181740	0.025778	1.651633
Black market premium	0.006130	0.184927	0.034124	2.008109
Government share	-0.000203	-0.118251	-0.001537	-2.496319
Urban population	0.001209	1.894469	0.000140	0.379572
Active population	0.039788	0.279470	0.091352	1.206797
Regulation of part.	-0.005186	-0.649760	-0.000229	-0.066121
Competitiveness of part.	0.005675	0.934261	-0.001699	-0.616853
Ratio of female to male sch.	-0.119395	-2.331495	-0.036583	-1.788622
Share of solid fuels	0.007172	0.090154	-0.014152	-0.312985
Share of liquid fuels	-0.029386	-0.336930	-0.015336	-0.345012
Share of natural gas	-0.025806	-0.251668	-0.004178	-0.072397
Dum. Flaring	-0.002286	-0.139735	0.012758	1.759331
R^2	0,24		0,35	
adj. R^2	0,20		0,32	
Obs.	280		280	
Income turning point	10.273		60.047	
Wald-test(**)	0,0031		0,3424	
	0,9555		0,5589	

(*) t-stats are calculated using White Heteroskedasticity consistent standard errors; (**) Income turning point in real 1985 purchasing power parity USD; Test for the equality of turning points reported in table 5 and those obtained based on the regression reported in table 14. First the Wald test statistic is reported, below its probability

In a third test, we added dummy variables for African countries and OECD member states. Table 15 reports the results. The evidence presented in table 15 seems to support the overall conclusion. With the exception of the OECD dummy in the per capita sulphur dioxide emissions growth equation, none of the added terms are significant. The own weighted tariff variable nor the black market premium variable are significant in the carbon dioxide equation. The square of the black market premium however still is (not reported here).

Table 15: Dummy variables for African countries and OECD member states

	Sulphur Dioxide		*Carbon dioxide*	
	Coefficient	*t-stat(*)*	*Coefficient*	*t-stats(*)*
Time	-0.001148	-1.738023	-0.001555	-5.125847
Growth	13.50014	2.668135	4.445558	2.335726
*Growth*Log per cap. GDP*	-1.496223	-2.369977	-0.441386	-1.998495
Log of concentration	-0.013604	-2.286835	-0.000625	-0.334649
Own weighted tariff	-0.025289	-0.609525	0.017998	1.107010
Black market premium	0.022742	0.725891	0.024439	1.374801
Government share	0.000281	0.167467	-0.001641	-2.497240
Urban population	0.001362	2.142074	0.000148	0.422293
Active population	-0.006428	-0.046706	0.093066	1.387328
Regulation of part.	-0.006442	-0.832047	0.001705	0.491655
Competitiveness of part.	0.001954	0.337716	-0.000446	-0.162688
Ratio of male to female sch.	-0.130353	-2.837233	-0.047691	-2.030745
Africa	-0.023723	-0.686210	-0.008929	-0.604436
OECD	-0.047032	-1.900738	0.013140	1.358881
R^2	0,26		0,35	
adj. R^2	0,22		0,32	
Obs.	280		280	
Income turning point	8.290		23.666	
Wald-test(**)	0,0593		0,0014	
	0,807		0,9699	

(*) t-stats are calculated using White Heteroskedasticity consistent standard errors; (*) Income turning point in real 1985 purchasing power parity USD; Test for the equality of turning points reported in table 5 and those obtained based on the regression reported in table 15. First the Wald test statistic is reported, below its probability

The last robustness test adds a number of interaction terms in the level of damage, the polity variable and the knowledge variable. Table 16 reports the results. We use polity as our indicator of political structure as the use of both the regulation of participation and the competitiveness of participation variable would only add to the linear dependency that already exists between the various interaction terms.

The evidence presented in table 16 suggests that the interaction terms are significant for sulphur dioxide whereas they are not for carbon dioxide. From the interaction terms, one can conclude that the impact of polity on sulphur dioxide emissions growth will be larger in those countries, whose environment already suffers from damage, whose population in knowledgeable on environmental matters. Increasing the knowledge on environmental issues will have a larger impact on emissions growth in countries whose government responds to popular demand. This will especially be the case if ‘popular’ demand is becoming increasingly aware of the damage caused by high levels of concentration of polluting substances.

The interaction terms are less relevant for carbon dioxide emissions growth. Only the interaction in concentration of carbon dioxide, knowledge and polity turns out to be significant.

The estimates for the variables that reflect imperfections do not change compared to the estimates presented in this text. Again, this seems to confirm the fact that market imperfections as measured through the black market premium and the own weighted tariff, especially if they are important, increase the pollution intensity of economic growth.

Table 16: Adding the possibility of interactions

	Sulphur Dioxide		*Carbon dioxide*	
	Coefficient	*t-stat(*)*	*Coefficient*	*t-stats(*)*
Time	-0.001466	-2.274702	-0.001784	-5.610038
Growth	14.38044	2.791087	5.859000	3.171640
*Growth*Log per cap. GDP*	-1.655836	-2.460788	-0.607233	-2.807546
Log of concentration	-0.005811	-0.679132	0.003953	1.497509
Own weighted tariff	-0.054424	-1.288575	0.032986	2.571829
Black market premium	-0.089211	-1.347494	-0.034821	-1.573433
Black market premium sq.	0.056216	2.030724	0.033376	3.793601
Government share	0.001040	2.022494	0.000307	0.882760
Urban population	0.050675	0.328486	0.036773	0.643532
Active population	0.074245	1.924944	0.007175	0.717707
Polity	-0.015910	-0.149429	-0.048060	-0.953264
Ratio of female to male sch.	0.004713	0.408001	-0.003322	-0.843993
Log of concentration *Ratio of female to male sch.*	0.007777	1.860125	0.001037	0.921779
Log of concentration *Polity*	-0.088130	-2.069541	-0.012127	-0.976003
Ratio of female to male sch. *Polity*	-0.009384	-2.032415	-0.001595	-1.136568
Log of concentration *Ratio of female to male sch.* *Polity*	-0.001466	-2.274702	-0.001784	-5.610038
R^2	0,31		0,37	
Adj. R^2	0,27		0,34	
Obs.	280		280	
Income turning point	5.911		15.509	
*Wald test***	0,8100		0,3132	
	0,3689		0,5761	

(*) t-stats are calculated using White Heteroskedasticity consistent standard errors; (**) Income turning point in real 1985 purchasing power parity USD; Test for the equality of turning points reported in table 5 and those obtained based on the regression reported in table 16. First the Wald test statistic is reported, below its probability

6. Conclusion

We have estimated emission growth equations for 5-year non-overlapping periods for sulphur and carbon dioxide. To estimate the growth regressions we used the predicted values from an economic growth regression as instruments for economic growth. Both the economic growth regression and the emission estimates clearly suggest a number of conclusions.

First of all, the results suggest that for both sulphur and carbon dioxide emissions, the impact of economic growth on emissions growth depends on the level of income. If we do not take into account the other variables, sulphur dioxide emissions will start to show negative growth rates once income levels reach 1985 USD 9.731 while carbon dioxide emissions will grow until income reaches 1985 USD 22.694. However, the evidence also shows that these income levels should be interpreted very carefully. The income variable does not however capture the full impact of development on emissions.

For a given level of income, the significance of the concentration variable for sulphur dioxide emissions supports the hypothesis that demand for environmental quality depends on the level of environmental damage. The insignificance of the polity variables, together with the significance of the level of income and environmental damage variable suggests that policy is demand-led. Policy does not seem to go beyond the level of emission reductions that is supported by popular demand. Polity does however have an impact on the level of economic growth and the level of income.

From the various tables, a couple of 'win-win' situations seem to emerge. The significance of the black market premium and especially its square and tariff variable in both the economic growth and carbon dioxide emissions growth regressions indicate that sound economic policies offer both improved economic growth as well as less environmental harm for given output. Tariffs on capital goods and intermediate inputs lower capital intensity on the one hand but reduce efficiency on the other. With respect to carbon dioxide emissions, the latter effect seems to be the dominant one while both effects are more or less equally important with respect to sulphur dioxide emission growth. Market imperfections, especially if they are important, seem to be associated with higher growth rates of both sulphur and carbon dioxide emissions. Sound economic policies, that do not offer scope for black market exchange rates that are out of line with official exchange rates, increase economic growth and reduce environmental harm.

Another important conclusion that seems to emerge from the analysis offered here is the fact that knowledge, measured as the ratio of female to male schooling, offers the possibility, especially in the least developed countries, to harvest low hanging fruits in environmental terms through programs that increase the overall knowledge on environmental matter and the existence of less polluting 'ways of doing things'.

The size of the government, as measured through the share of government consumption in GDP is significant as an explanatory variable in a statistical sense for carbon dioxide emissions growth. The evidence suggests that the size of government lowers emissions growth. The impact, however, is rather small.

The evidence suggests that the modern international economic order with its tendency towards free trade through the WTO could be less polluting than a world of closed economies. The results further suggest that economic policies that remove price distortions could reduce emissions growth. Whether those policies are increasing the size of government or reducing it, does not seem to be relevant from an environmental point of view. The evidence is also indicative of the fact that globalizing the economy should take into account the least developed regions as a general lack of knowledge on environmental matters and technology seems to be accompanied by more pollution intensive ways of production. As a lack of this knowledge seems to be associated with less developed countries with, especially in Africa, this argues that the inclusion of environmental elements into development policies. In line with previous research, these results also warn not to put too much emphasis on income growth, as an alternative for environmental policy if such a growth policy is not accompanied by measures that reduce the overall emissions intensity.

This paper argues that the EKC framework can be transformed into a policy tool. The evidence presented here, however, is far from conclusive and suggests a number of recommendations for further research. First of all, some of the variables should be analyzed in more detail. Government consumption for instance reflects various forms of consumption, some of which might be more polluting than others. Variables such as own weighted tariff or black market premium should be further analyzed to examine the impact of different distortions on emissions growth. Secondly, some variables could be added that reflect overall government policy. Does privatizing or liberalizing affect emissions growth?

Appendix A

Years refer to the first year of a 5-year period.

Country	Year	Country	Year
ALGERIA	1965	CHILE	1985
ALGERIA	1970	COLOMBIA	1960
ALGERIA	1975	COLOMBIA	1965
ALGERIA	1980	COLOMBIA	1970
ALGERIA	1985	COLOMBIA	1975
ARGENTINA	1960	COLOMBIA	1980
ARGENTINA	1965	COLOMBIA	1985
ARGENTINA	1970	CYPRUS	1960
ARGENTINA	1975	CYPRUS	1970
ARGENTINA	1980	CYPRUS	1975
ARGENTINA	1985	CYPRUS	1980
AUSTRIA	1960	CYPRUS	1985
AUSTRIA	1965	DENMARK	1960
AUSTRIA	1970	DENMARK	1965
AUSTRIA	1975	DENMARK	1970
AUSTRIA	1980	DENMARK	1975
AUSTRIA	1985	DENMARK	1980
BELGIUM	1960	DENMARK	1985
BELGIUM	1965	EGYPT	1975
BELGIUM	1970	FINLAND	1960
BELGIUM	1975	FINLAND	1965
BELGIUM	1980	FINLAND	1970
BELGIUM	1985	FINLAND	1975
BOLIVIA	1960	FINLAND	1980
BOLIVIA	1965	FINLAND	1985
BOLIVIA	1970	FRANCE	1960
BOLIVIA	1975	FRANCE	1965
BOLIVIA	1980	FRANCE	1970
BOLIVIA	1985	FRANCE	1975
BRAZIL	1960	FRANCE	1980
BRAZIL	1965	FRANCE	1985
BRAZIL	1970	GERMANY	1960
BRAZIL	1975	GERMANY	1965
BRAZIL	1980	GERMANY	1970
BRAZIL	1985	GERMANY	1975
CANADA	1960	GERMANY	1980
CANADA	1965	GERMANY	1985
CANADA	1970	GHANA	1960
CANADA	1975	GHANA	1965
CANADA	1980	GHANA	1970
CANADA	1985	GHANA	1975
CHILE	1960	GHANA	1980
CHILE	1965	GHANA	1985
CHILE	1970	GREECE	1960
CHILE	1975	GREECE	1965
Country	**Year**	**Country**	**Year**
CHILE	1980	GREECE	1970

GREECE	1975	KUWAIT	1980
GREECE	1980	MALAYSIA	1970
GREECE	1985	MALAYSIA	1975
GUATEMALA	1960	MALAYSIA	1980
GUATEMALA	1965	MALAYSIA	1985
GUATEMALA	1970	MEXICO	1960
GUATEMALA	1975	MEXICO	1965
GUATEMALA	1980	MEXICO	1970
INDIA	1960	MEXICO	1975
INDIA	1965	MEXICO	1980
INDIA	1970	MEXICO	1985
INDIA	1975	MOZAMBIQUE	1975
INDIA	1980	MOZAMBIQUE	1980
INDIA	1985	NETHERLANDS	1960
INDONESIA	1965	NETHERLANDS	1965
INDONESIA	1970	NETHERLANDS	1970
INDONESIA	1975	NETHERLANDS	1975
INDONESIA	1980	NETHERLANDS	1980
INDONESIA	1985	NETHERLANDS	1985
IRELAND	1960	NICARAGUA	1960
IRELAND	1965	NICARAGUA	1965
IRELAND	1970	NICARAGUA	1970
IRELAND	1975	NICARAGUA	1975
IRELAND	1980	NZ	1960
IRELAND	1985	NZ	1965
ITALY	1960	NZ	1970
ITALY	1965	NZ	1975
ITALY	1970	NZ	1980
ITALY	1975	NZ	1985
ITALY	1980	PERU	1960
ITALY	1985	PERU	1965
JAPAN	1960	PERU	1970
JAPAN	1965	PERU	1975
JAPAN	1970	PERU	1980
JAPAN	1975	PHILIPPINES	1960
JAPAN	1980	PHILIPPINES	1965
JAPAN	1985	PHILIPPINES	1970
KENYA	1965	PHILIPPINES	1975
KENYA	1970	PHILIPPINES	1980
KENYA	1975	PHILIPPINES	1985
KENYA	1980	PORTUGAL	1960
KENYA	1985	PORTUGAL	1965
KOREA	1960	PORTUGAL	1970
KOREA	1965	PORTUGAL	1980
KOREA	1970	PORTUGAL	1985
KOREA	1975	SINGAPORE	1960
KOREA	1980	TUNISIA	1960
Country	**Year**	**Country**	**Year**
KOREA	1985	TUNISIA	1965
SINGAPORE	1965	TUNISIA	1970
SINGAPORE	1970	TUNISIA	1975
SINGAPORE	1975	TUNISIA	1980

SINGAPORE	1980	TUNISIA	1985
SINGAPORE	1985	TURKEY	1965
SPAIN	1960	TURKEY	1970
SPAIN	1965	TURKEY	1975
SPAIN	1970	TURKEY	1980
SPAIN	1980	TURKEY	1985
SPAIN	1985	U.K.	1960
SRI LANKA	1960	U.K.	1965
SRI LANKA	1965	U.K.	1970
SRI LANKA	1970	U.K.	1975
SRI LANKA	1975	U.K.	1980
SRI LANKA	1980	U.K.	1985
SRI LANKA	1985	URUGUAY	1960
SWEDEN	1960	URUGUAY	1965
SWEDEN	1965	URUGUAY	1970
SWEDEN	1970	URUGUAY	1975
SWEDEN	1975	URUGUAY	1980
SWEDEN	1980	URUGUAY	1985
SWEDEN	1985	USA	1960
SWITZERLAND	1960	USA	1965
SWITZERLAND	1965	USA	1970
SWITZERLAND	1970	USA	1975
SWITZERLAND	1975	USA	1980
SWITZERLAND	1980	USA	1985
SWITZERLAND	1985	VENEZUELA	1960
SYRIA	1965	VENEZUELA	1965
SYRIA	1970	VENEZUELA	1970
SYRIA	1975	VENEZUELA	1975
SYRIA	1980	VENEZUELA	1980
SYRIA	1985	VENEZUELA	1985
TANZANIA	1965	ZAIRE	1965
TANZANIA	1970	ZAIRE	1970
TANZANIA	1975	ZAIRE	1975
TANZANIA	1980	ZAIRE	1980
THAILAND	1960	ZAMBIA	1965
THAILAND	1965	ZAMBIA	1970
THAILAND	1970	ZAMBIA	1975
THAILAND	1975	ZAMBIA	1980
THAILAND	1980	ZAMBIA	1985
THAILAND	1985	ZIMBABWE	1970
TRINIDAD&TOBAGO	1975	ZIMBABWE	1975
TRINIDAD&TOBAGO	1980	ZIMBABWE	1980
TRINIDAD&TOBAGO	1985	ZIMBABWE	1985

Appendix B: Summary of data

Table B.1a: Growth regression (equation (6), table 4): summary data

	Log of per capita GDP	*Log of life expectancy*	*Log of fertility*	*Male schooling*	*Female schooling*	*Govern. share of GDP*	*Distance*
Mean	8.179617	4.144509	1.276660	5.517486	4.524654	15.49714	5.581154
Median	8.276348	4.207672	1.268275	5.203500	4.236000	14.15000	6.224000
Maximum	9.904387	4.347694	2.079442	12.35800	11.93500	42.00000	11.51800
Minimum	5.916202	3.749504	0.246860	0.701000	0.081000	5.800000	1.267000
Std. Dev.	0.927372	0.160585	0.517185	2.574065	2.903231	6.177186	2.802814
Skewness	-0.295277	-0.767169	-0.110560	0.392827	0.437805	1.546936	0.099169
Kurtosis	2.035911	2.395206	1.670429	2.433276	2.230340	6.134857	1.743080
Jarque-Bera	14.91258	31.73298	21.19427	10.94834	15.85580	226.3261	18.89052
Probability	0.000578	0.000000	0.000025	0.004194	0.000361	0.000000	0.000079
Obs.	280	280	280	280	280	280	280
Abrev	GDP	Life	Fertility	Male Sch.	Fema. Sch.	Govern.	Distance

	Own weighted tariff	*Black market premium*	*Regulation of part.*	*Comp. of part.*	*Durability*	*Africa dummy*
Mean	1.154082	0.183346	3.985714	3.278571	24.39643	0.150000
Median	1.125500	0.033450	4.000000	3.000000	15.00000	0.000000
Maximum	2.318994	2.708500	5.000000	5.000000	85.00000	1.000000
Minimum	1.012001	0.000000	2.000000	0.000000	0.000000	0.000000
Std. Dev.	0.200435	0.351013	1.057391	1.635484	24.62282	0.357711
Skewness	4.223858	3.433106	-0.718682	-0.226311	1.023678	1.960392
Kurtosis	24.77298	18.04950	2.273463	1.475148	2.800987	4.843137
Jarque-Bera	6363.311	3192.376	30.26181	29.51715	49.36485	218.9799
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Obs.	280	280	280	280	280	280
Abrev.	Tariff	BMP	Reg. Part.	Comp. part.	Durable	Africa

Table B.1b: Growth regression (equation (5), table 4): correlation coefficients(*)

	GDP	Life	*Fertility*	*Male Sch.*	*Fema. Sch.*	*Govern.*	*Distance*
GDP	1.000000						
Life	0.881425	1.000000					
Fertility	-0.813873	-0.865565	1.000000				
Male. Sch.	0.765699	0.762681	-0.793593	1.000000			
Fema. Sch.	0.805961	0.782816	-0.799672	0.965765	1.000000		
Govern.	-0.431215	-0.381216	0.257392	-0.160169	-0.198756	1.000000	
Distance	-0.478109	-0.446303	0.453572	-0.258693	-0.271093	0.170160	1.000000
Tariff	-0.477530	-0.461438	0.408733	-0.329717	-0.363145	0.319201	0.369220
BMP	-0.448252	-0.469806	0.455790	-0.384195	-0.397864	0.437251	0.282022
Reg. Part.	0.574966	0.513947	-0.556117	0.496585	0.539151	-0.104816	-0.453485
Comp. part.	0.704267	0.649138	-0.692650	0.677694	0.710675	-0.266964	-0.447050
Durable	0.594432	0.503789	-0.530123	0.678551	0.697871	-0.107011	-0.366500
Africa	-0.564452	-0.567511	0.502397	-0.485441	-0.497061	0.532887	0.147940

(*) Names refer to the Abrev. Row in the summary of data table.

	Tariff	*BMP*	*Reg. Part.*	*Comp. part.*	*Durable*	*Africa*
GDP						
Life						
Fertility						
Male. Sch.						
Fema. Sch.						
Govern.						
Distance						
Tariff	1.000000					
BMP	0.213542	1.000000				
Reg. Part.	-0.536615	-0.284017	1.000000			
Comp. part.	-0.240132	-0.422874	0.447917	1.000000		
Durable	-0.234076	-0.270150	0.506274	0.533411	1.000000	
Africa	0.108706	0.552139	-0.060647	-0.488288	-0.218789	1.000000

Table B.2a: Emission equation (equation (5), table 5): Summary of data

	Time	*Predicted Growth*	*Interaction Growth GDP*	*Log of Concent. SO*	*Log of Concent. CO*	*Urban population*	*Active Population*	*Ratio of Male Sch. To Fema. Sch.*
Mean	12.91071	0.023322	0.191241	-8.047679	-3.580427	55.03571	0.584841	0.746193
Median	15.00000	0.024977	0.206432	-7.974717	-3.831083	56.45000	0.586248	0.828747
Maximum	25.00000	0.067574	0.516695	-1.134579	2.606447	100.0000	0.702944	1.055436
Minimum	0.000000	-0.061065	-0.420335	-17.19831	-8.283391	5.300000	0.443744	0.100372
Std. Dev.	8.285404	0.018414	0.146351	2.282121	2.163179	23.84419	0.062236	0.236597
Skewness	-0.061706	-1.091883	-1.070405	-0.050822	0.240947	-0.134171	-0.156162	-0.805869
Kurtosis	1.800034	5.933307	5.162688	3.568929	2.653408	2.004464	1.822951	2.517884
Jarque-Bera	16.97674	156.0198	108.0367	3.896808	4.110718	12.40284	17.30156	33.01825
Probability	0.000206	0.000000	0.000000	0.142501	0.128047	0.002027	0.000175	0.000000
Observations	280	280	280	280	280	280	280	280
Abrev.	Time	P. Growth	I. Gr. GDP	Con. SO	Con. CO	Urban	Active	Ratio Sch.

Table B.2b: Emission equation (equation (5), table 5): Correlation coefficients

	Time	*P. Growth*	*I. Gr. GDP*	*Con. SO*	*Con. CO*	*Tariff*	*BMP*
Time	1.000000						
P. Growth	-0.170416	1.000000					
I. Gr. GDP	-0.137190	0.986117	1.000000				
Con. SO	0.106873	0.246432	0.336422	1.000000			
Con. CO	0.160394	0.330542	0.426009	0.880241	1.000000		
Tariff	0.001603	-0.243438	-0.308333	-0.280459	-0.319133	1.000000	
BMP	0.115201	-0.702419	-0.727405	-0.354201	-0.433484	0.213542	1.000000
Govern.	0.153216	-0.383971	-0.410748	-0.195706	-0.358516	0.319201	0.437251
Urban	0.116673	-0.002828	0.100541	0.603050	0.642064	-0.389078	-0.352695
Active	0.146748	0.279713	0.392106	0.619641	0.710382	-0.327220	-0.443957
Ratio Sch.	0.080205	0.060758	0.145592	0.395924	0.448443	-0.376688	-0.395134
Reg Part.	0.027265	0.183042	0.278327	0.316856	0.388044	-0.536615	-0.284017
Comp.Part.	0.029880	0.153087	0.256333	0.517172	0.576657	-0.240132	-0.422874

	Govern.	*Urban*	*Active*	*Ratio Sch.*	*Reg. Part.*	*Comp. Part.*
Time						
P. Growth						
I. Gr. GDP						
Con. SO						
Con. CO						
Tariff						
BMP						
Govern.	1.000000					
Urban	-0.367096	1.000000				
Active	-0.265933	0.644212	1.000000			
Ratio Sch.	-0.343086	0.631460	0.637309	1.000000		
Reg Part.	-0.104816	0.465964	0.519387	0.393703	1.000000	
Comp.Part.	-0.266964	0.533167	0.655540	0.610484	0.447917	1.000000

Appendix C: Full regression results for tables used in the body of the text

Table C.1: Full regression results for table 7

	Sulphur Dioxide		*Carbon dioxide*	
	Coefficient	*t-stat(*)*	*Coefficient*	*t-stats(*)*
Time	-0.001440	-2.096544	-0.001630	-5.024422
Growth	11.55267	2.375797	4.656657	2.573418
*Growth*Log per cap. GDP*	-1.243327	-2.052590	-0.484593	-2.291922
Log of concentration	-0.011107	-1.811897	-3.61E-05	-0.018952
Own weighted tariff	-0.050192	-1.081042	0.024389	1.837992
Black market premium	0.008731	0.297342	0.021799	1.316969
Government share	8.79E-05	0.049881	-0.001919	-3.210915
Urban population	0.001075	1.830479	0.000253	0.731447
Active population	0.026875	0.200353	0.095036	1.459831
Regulation of part.	-0.006702	-0.790764	0.001911	0.531731
Competitiveness of part.	0.005930	1.013630	-0.000308	-0.115844
Ratio female to male sch. If relative per capita GDP > median	-0.112587	-2.108361	-0.053746	-2.305157
Ratio female to male sch. If relative per capita GDP <median	-0.128185	-2.476005	-0.030958	-1.552708
R^2	0,24		0,35	
adj. R^2	0,21		0,32	
Obs.	280		280	
Income turning point 1985 USD	10.848		14.904	
Wald-test(**)	0,0140		0,2269	
	0,9056		0,6361	

(*) t-stats are calculated using White Heteroskedasticity consistent standard errors; (**) Test for the equality of turning points reported in table 5 and those obtained from the regression reported in table C.1. First the Wald test statistic is reported, below its probability.

Table C.2: Full regression results for table 8

	Sulphur Dioxide		*Carbon dioxide*	
	Coefficient	*t-stat(*)*	*Coefficient*	*t-stats(*)*
Time	-0.001495	-2.194219	-0.001571	-5.007090
Growth	11.46585	2.332319	4.645547	2.572474
*Growth*Log per cap. GDP*	-1.242617	-2.020540	-0.475022	-2.247836
Log of concentration	-0.010834	-1.812118	-0.000406	-0.223519
tariff if relative per capita GDP >Median	-0.046535	-1.158669	0.012758	0.733810
tariff if relative per capita GDP <Median	-0.052689	-1.089077	0.027055	2.074859
Black market premium	0.006462	0.219582	0.023566	1.435570
Government share	5.02E-05	0.027653	-0.001960	-3.245838
Urban population	0.001075	1.818471	0.000266	0.761576
Active population	0.034556	0.260214	0.091341	1.416392
Regulation of part.	-0.005807	-0.715255	0.001136	0.326991
Competitiveness of part.	0.006544	1.139760	-0.000903	-0.343442
Ratio of female to male sch.	-0.124888	-2.477998	-0.034495	-1.740165
R^2	0,24		0,34	
adj. R^2	0,20		0,31	
Obs.	280		280	
Income turning point 1985 USD	10.169		17.670	
Wald-test(**)	0,0024		0,0487	
	0,9609		0,8253	

(*) t-stats are calculated using White Heteroskedasticity consistent standard errors; (**) Test for the equality of turning points reported in table 5 and those obtained from the regression reported in table C.2. First the Wald test statistic is reported, below its probability.

Table C.3a: Full regression results for table 10 (without BMP squared)

	Sulphur Dioxide		*Carbon dioxide*	
	Coefficient	*t-stat(*)*	*Coefficient*	*t-stats(*)*
Time	-0.001531	-2.278382	-0.001473	-5.034743
Growth	11.13627	2.422919	5.031782	2.655667
*Growth*Log per cap. GDP*	-1.206865	-2.044428	-0.504434	-2.296899
Log of concentration	-0.010704	-1.908754	-0.001109	-0.651917
Own weighted tariff	-0.053388	-1.051451	0.029213	2.250984
Black market premium if relative per capita GDP >Median	0.014938	0.455921	0.023757	1.501332
Black market premium if relative per capita GDP <Median	0.003129	0.093577	0.028232	1.529415
Government share	-3.97E-06	-0.002429	-0.001811	-2.998201
Urban population	0.001071	1.791628	0.000249	0.699729
Active population	0.040500	0.304555	0.076946	1.193120
Regulation of part.	-0.004961	-0.631432	-0.000385	-0.113245
Competitiveness of part.	0.006740	1.146964	-0.001493	-0.560614
Ratio of female to male sch.	-0.124349	-2.467852	-0.038803	-1.884740
R^2	0,24		0,34	
adj. R^2	0,20		0,31	
Obs.	280		280	
Income turning point 1985 USD	10.172		21.484	
Wald-test(**)	0,0021		0,0035	
	0,9630		0,9523	

Table C.3b: Full regression results for table 10 (with BMP squared)

	Sulphur Dioxide		*Carbon dioxide*	
	Coefficient	*t-stat(*)*	*Coefficient*	*t-stats(*)*
Time	-0.001488	-2.162982	-0.001451	-4.916332
Growth	12.42744	2.459156	5.967822	3.174059
*Growth*Log per cap. GDP*	-1.392003	-2.122127	-0.634854	-2.927822
Log of concentration	-0.011182	-1.990213	-0.001641	-0.974290
Own weighted tariff	-0.051110	-1.036520	0.029071	2.301616
Black market premium	-0.092883	-1.266623	-0.027419	-1.227904
Black market premium squared if relative per capita GDP >Median	0.078668	1.956933	0.024946	1.706930
Black market premium squared if relative per capita GDP <Median	0.048882	1.750417	0.029819	3.374225
Government share	0.000404	0.236144	-0.001578	-2.669916
Urban population	0.001076	1.851098	0.000278	0.798632
Active population	0.057418	0.442681	0.087577	1.402728
Regulation of part.	-0.004196	-0.534162	-0.000241	-0.073231
Competitiveness of part.	0.005237	0.945535	-0.002051	-0.768380
Ratio of female to male sch.	-0.133224	-2.562506	-0.043649	-2.134499
R^2	0,25		0,34	
adj. R^2	0,22		0,31	
Obs.	280		280	
Income turning point 1985 USD	7.538		12.092	
Wald-test(**)	0,1062		1,2452	
	0,7447		0,2654	

(*)t-stats are calculated using White Heteroskedasticity consistent standard errors; (**) Test for the equality of turning points reported in table 5 and those obtained from the regression reported in table C.3. First the Wald test statistic is reported, below its probability.

Table C.4: Full regression results for table 11

	Sulphur Dioxide		*Carbon dioxide*	
	Coefficient	*t-stat(*)*	*Coefficient*	*t-stats(*)*
Time	-0.001351	-1.986609	-0.001551	-4.929994
Growth	11.62405	2.497342	4.886910	2.683794
*Growth*Log per cap. GDP*	-1.235017	-2.085844	-0.498549	-2.339403
Log of concentration	-0.011779	-2.006658	-0.000462	-0.238506
Own weighted tariff	-0.040083	-0.848110	0.024831	1.791273
Black market premium	0.013489	0.450667	0.024644	1.470164
Government share if relative per capita GDP >Median	0.002111	0.879515	-0.002510	-3.278118
Government share if relative per capita GDP <Median	-0.000295	-0.184881	-0.001674	-2.627871
Regulation of part.	0.001002	1.666753	0.000266	0.757859
Competitiveness of part.	0.018245	0.137690	0.082846	1.283239
Urban population	-0.008256	-1.057692	0.000791	0.226123
Ratio female to male sch.	0.003764	0.622637	-0.000542	-0.196314
Active population	-0.133011	-2.621653	-0.035272	-1.763713
R^2	0,25		0,34	
adj. R^2	0,21		0,31	
Obs.	280		280	
Income turning point 1985 USD	12.235		18.074	
Wald-test(**)	0,0534		0,6628	
	0,8174		0,8021	

(*) t-stats are calculated using White Heteroskedasticity consistent standard errors; (**) Test for the equality of turning points reported in table 5 and those obtained from the regression reported in table C.4. First the Wald test statistic is reported, below its probability.

Table C.5: Full regression results for table 12

	Sulphur Dioxide		*Carbon dioxide*	
	Coefficient	*t-stat(*)*	*Coefficient*	*t-stats(*)*
Time	-0.001507	-2.243131	-0.001708	-5.274443
Growth	11.38243	2.363409	4.556211	2.666910
*Growth*Log per cap. GDP*	-1.234341	-2.058703	-0.493198	-2.399185
Log of concentration	-0.010841	-1.661075	0.001361	0.630336
Own weighted tariff	-0.052771	-1.130020	0.022393	1.732508
Black market premium	0.006041	0.213437	0.017431	1.129879
Government share	-1.77E-08	-1.00E-05	-0.001934	-3.314198
Urban population if relative per capita GDP >Median	0.001127	1.847314	-8.05E-05	-0.279505
Urban population if relative per capita GDP <Median	0.001057	1.615413	0.000459	1.196738
Active population	0.037187	0.280267	0.104867	1.671909
Regulation of part.	-0.005669	-0.679127	0.003357	0.922553
Competitiveness of part.	0.006621	1.136982	-5.04E-05	-0.019297
Ratio female to male sch.	-0.123715	-2.476859	-0.032375	-1.715664
R^2	0,24		0,37	
adj. R^2	0,21		0,34	
Obs.	280		280	
Income turning point 1985 USD	10.111		10.281	
Wald-test(**)	0,0018		1,0563	
	0,9653		0,3049	

(*) t-stats are calculated using White Heteroskedasticity consistent standard errors; (**) Test for the equality of turning points reported in table 5 and those obtained from the regression reported in table C.5. First the Wald test statistic is reported, below its probability.

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