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In recent years, extensive literature on the Environmental Kuznets Curve leading to optimistic policy conclusions has attracted great attention. However, the underlying cross-section estimations are not very reliable. Accordingly, this contribution uses time series data for a single country with dependable data quality: Germany. The results of the traditional reduced-form specification do not support the EKC hypothesis. However, with a specification in the tradition of error correction models, which are more appropriate in the presence of non-stationary time series, it is found that the typical EKC pattern can be confirmed.

Keywords: Environmental Kuznets Curve, Error Correction Model, Time Series Data
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1 Introduction

Recently, a series of empirical studies about the so-called Environmental Kuznets Curve (hereafter EKC) has been published.[1] The EKC hypothesis postulates that environmental pollution follows an inverted U-shaped curve relative to income. Put differently, environmental quality first decreases with rising income but, after a certain income level has been reached, it begins to recover again. However, the reported empirical results and conclusions are ambiguous. Some authors find evidence for an EKC for different air and water pollutants and other measurements of environmental degradation (e.g. Grossman and Krueger 1995, Selden and Song 1994, Cole et al. 1997). Others, on the other hand, report either monotonically increasing or decreasing relationships between pollution and per capita income, or even find no such relationship (e.g. Torras and Boyce 1998 and partly Shafik 1994). Nevertheless, the validity of the EKC hypothesis is crucial for possible policy implications. If the hypothesis does not apply, one could argue that "to save the environment and even economic activity from itself, economic growth must cease and the world must make a transition to a steady state economy"(Panayotou 2000, page 1). If, however, the hypothesis applies, the conclusion might be quite different: "But the strong correlation between incomes and the extent to which environmental protection measures are adopted demonstrates that, in the long run, the surest way to improve your environment is to become rich" (Beckerman 1992, page 491).

Most empirical studies on the EKC hypothesis use cross-country or panel data for their empirical estimations. But the fiercely criticised use of cross-country data suggests that only single-country studies could shed light on the validity of the EKC hypothesis (e.g. Roberts and Grimes 1997). The following arguments support this view. An EKC found by cross-country estimations could simply reflect the juxtaposition of a positive relationship between pollution and income in developing countries with a negative one in developed countries, and not a single relationship that applies to both categories of countries. Such an EKC would be a statistical artefact (Vincent 1997). This argument partly applies also to panel data estimations. Owing to the short length of available time series on pollution, the panel data sets typically contain little or no overlap between observations from developing and developed countries. Low-income observations come from developing countries; high-income observations, on the other hand, from developed countries (Vincent 1997). On account of this fact, the somewhat uncommon conclusion is drawn that for EKC studies time series estimations are to be preferred even to panel data estimations.[2] In principle, the disregard for this juxtaposition is a special case of parameter heterogeneity, which is a frequent problem in the cross-section growth context. It is questionable whether the homogeneity assumption that all estimated coefficients are country-invariant is appropriate for a broad spectrum of countries, reaching from poor developing countries to rich and highly industrialised nations.

[1]The EKC is named after Simon Kuznets (1955), who found a hump-shaped relationship between income and the inequality of income.

[2]This animadversion does, of course, not apply to panel data studies with a broad and overlapping data set.

Possibilities for avoiding the parameter heterogeneity problem are the use of specifications, which allow for varying coefficients, or – as in this paper – data limitation to one single country.[3]

More arguments for the use of time series data are provided by List and Gallet (1999). These authors find very different income turning points across the US states for sulphur dioxide and nitrogen oxide. In other words, the US states do not follow a uniform pollution path. Since US states are commonly and correctly assumed to be more homogenous than most samples of countries, this study backs up the advantage of time series estimations over cross-country studies. If the results of cross-section estimations are generalised, incorrect inferences about the further development of pollutant emissions or concentrations could be drawn and, therefore, misleading policies proposed. Similar conclusions are reported by Dijkgraaf and Vollebergh (1998) when comparing time series with panel estimations for carbon dioxide. Estimating the income-emission relation for OECD countries, they find that pooling countries in one panel can bias the estimates and, therefore, the results may not be reliable. Again, the cause of this distortion is the juxtaposition of different income-emission relationships within the pooled countries.

So far, there are only a few studies with time series data for a single country and, as in the case of cross-country studies, the results are mixed. Carson et al. (1997), using US state data between 1988 and 1994, find a negative relationship between seven types of air pollutant emissions and income. Since, for the period under consideration, the per capita income levels of the United States are clearly above the EKC turning points usually calculated by cross-country studies, these results are consistent with the EKC hypothesis. No support for the EKC supposition, however, is given by Vincent (1997). This author reports that the emission profiles that are actually observed in Malaysia do not coincide with those that are predicted by cross-country studies for a country with a per capita GDP like Malaysia. Mostly, the concentration path of pollutants is incorrectly predicted and the changes in pollutant emissions are vastly overstated by cross-country estimations. Applying a somewhat more sophisticated model specification, de Bruyn et al. (1998) find that economic growth has a negative effect on environmental quality, but, despite the increase in emissions due to economic growth, emissions are likely to decline over time, given sufficient technological progress or structural change. On this account, the authors reason that "the presumption that economic growth results in improvements in environmental quality is unsupported by evidence [...]". Unruh and Moomaw (1998) and Moomaw and Unruh (1997) find evidence that the carbon dioxide emission trajectories of sixteen OECD countries follow an inverted U-shaped curve; however, not with respect to income, but with respect to time. The change from an increasing to a decreasing relationship occurred in all countries around 1973 – the time of the first world-wide oil price shock. Unruh and Moomaw (1998, page 227) conclude that "emissions trajectories would be expected to follow a regular, incremental path until subjected to a shock that

[3] For a brief treatise on parameter heterogeneity in the growth context, see Temple (1999).

leads to the establishment of a new trajectory or attractor."[4] Perman and Stern (2003) use cointegration analysis to test the EKC hypothesis for sulphur emissions. These authors show that the general applicability of of the EKC hypothesis is not granted. The estimation results highly depend on the supposed model specification and on the data set. A historical perspective about the carbon dioxide emissions in Sweden from 1870 – 1997 (Lindmark 2002) shows that emission fluctuations can be explained mostly by technological and structural change, by economic growth and by changing prices. Recent and more comprehensive surveys of the empirical EKC literature are provided by Copeland and Taylor (2004), Dasgupta et al. (2002) and Stern (2004), among others.[5]

This paper, using time series data for Germany, aims at investigating the relationship between several pollutants and income within a single, developed country. In particular, the following questions are scrutinised. Are the doubts on the suitability of cross-country studies legitimate, i.e. are the results of time series estimations in line with those of cross-country studies? Is the widely used traditional reduced-form equation appropriate for time series estimations? To answer these questions, first the traditional form model with only one independent variable, namely gross domestic product (GDP), is estimated. The estimation results of this simple specification, which was first introduced by Grossman and Krueger (1993), give rise to the supposition that the development of environmental pressure is more complex and that the different stages of environmental degradation cannot be explained by per capita income alone. Therefore, other variables must have at least as much influence on the environment as income. Different possibilities, such as the incorporation of trade variables or gross value added by the industry sector, which are commonly proposed by theory, are evaluated.

Second, this paper contributes to the EKC literature by applying a model specification that can be regarded as a modified error correction model. The advantages of this specification are the distinction between two different influence channels and the more favourable estimation characteristics in the presence of serial correlation and non-stationarity. Although these results yield better results with regard to the estimation statistics and some evidence for a hump-shaped emission pattern is found, the empirical validity of the EKC hypothesis is not conclusively confirmed.

The remainder of this paper is organised as follows. In Section 2, the theoretical framework is set forth. Some explanatory notes to the data are provided in Section 3. In Section 4, the empirical results are presented and discussed. Finally, Section 5 concludes.

[4] However, since the included countries were selected on the basis that their pollution-income relations show evidence of a structural break around 1973, the estimation results are not very representative and, therefore, the conclusion should not be generalised.

[5] Compared to empirical EKC studies, theoretical EKC models are quite rare. Recent contributions are Andreoni and Levinson (2001), Smulders and Bretschger (2000), Brock and Taylor (2004), Bulte and van Soest (2001), Chimeli and Braden (2002), Egli and Steger (2004), Kelly (2003) or Lieb (2002).

2 Framework

The non-linear relationship between the indicators of environmental pollution and per capita income is usually specified in a reduced form such as:

$$E_t = \beta_0 + \beta_1 Y_t + \beta_2 Y_t^2 + \beta_3 Y_t^3 + \beta_4 Z_t + \varepsilon_t \qquad (1)$$

where E stands for the pollution indicator, Y for income and Z for other variables that are supposed to influence pollution; t denotes a time index and ε is the normally distributed error term. An EKC results from $\beta_1 > 0$, $\beta_2 < 0$, and $\beta_3 = 0$. The income level at which environmental degradation begins to decline is called income turning point (ITP). The ITP of an EKC is obtained by setting the first derivation (with respect to income) of equation (1) equal to zero and solved for income; this yields $-\beta_1/2\beta_2$.[6] With $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 > 0$ an N-shaped pattern is obtained, i.e. there is a second turning point, after which the environmental degradation rises again with increasing income. However, investigating the relationship between carbon dioxide and GDP for a subset of OECD countries, Moomaw and Unruh (1997) conclude that an N-shaped curve is more the result of polynomial curve fitting than a reflection of any underlying structural relation. In addition, if an N-shaped pattern is obtained, the second turning point usually occurs at relatively high per capita income levels reached only by very few countries; thus, these results should be viewed with caution. Furthermore, the incorporation of a cubic income term can cause econometric problems due to the multicollinearity of the income variables (linear, quadratic and cubed). Thus, both estimations with and without a cubed income term seem appropriate. An either monotonically increasing or decreasing relationship between income and environmental quality is achieved if only β_1 is significant (negative or positive sign, respectively), whereas the other estimators of the income variables, i.e. β_2 and β_3, remain insignificant.

While the incorporation of per capita income as an independent variable in single country studies seems undisputed, the choice of the other explanatory variables is not clear, since – contrary to cross-country studies – differences that are country-specific but consistent over time do not matter in time series. For example, it is unnecessary to control for population density, for oil exporting or former communist countries, for literacy rate or political rights. All these variables do not change, or at least not relevantly, over the time period under consideration.

As will be shown in Section 4 below, per capita income fails to satisfactorily explain the environmental degradation with regard to economic development. Therefore, the traditional reduced-form equation must be extended. Income can either be included directly in the model as a variable that summarises all effects associated with income, or it can be disaggregated into different channels through which income affects pollution (Grossman 1995). First, there is a scale effect. Ceteris paribus, more economic activity leads to increased environmental

[6] Under the assumption $\beta_3 = 0$. This term should be small relative to mean per capita income, in order for the EKC to turn down at achievable income levels. Moreover, dependent on the scaling of y, $|\beta_1| > |\beta_2|$ in order to get a rising curve segment at the beginning.

damage, since increasing output requires more natural resources as inputs and causes more emissions and waste as a by-product. Second, structural changes in the economy lead ceteris paribus to altered environmental pressure. During industrialisation (transformation from agricultural to industrial production), environmental degradation tends to increase, whereas during the deindustrialisation phase (from industry to services), the reverse occurs. This argument is based on the legitimate assumption that industrial production is more polluting than both the agricultural and the service sectors. This second channel is usually called the composition effect. Third, due to more research and development expenditure[7], economic growth is usually accompanied by technological progress. Therefore, a replacement of obsolete machineries and technologies with more environmentally friendly ones can be observed. This is labelled the technique effect. Since in this paper pollution data are in the form of aggregate emissions and not concentrations, there is no obvious way to separate scale and technique effects (Cole 2003).[8] Therefore, only the composition effect is specified separately [see equation (2) below].

Besides these income-related variables, which do not differ from cross-country studies, other variables influencing pollution come to the fore in studies with time series data. The displacement effect (also referred to as pollution haven hypothesis) relates to the possibility that developed countries may shift pollution-intensive production to developing countries with laxer environmental regulations and import those products. By doing so, developed countries cut back their domestic emissions without having to alter their consumption habits. But overall, there is no world-wide emission reduction or, in other words, only an illusion of sustainability is created (Rees 1994). The factor endowment hypothesis, however, counteracts the pollution haven hypothesis. It suggests that dirty production, which is usually capital intensive, is located where capital is more abundant, i.e. in developed countries. Antweiler et al. (2001) investigate the consequences of free trade on the environment and find empirical evidence that capital abundance is more important than lax environmental policy. However, Suri and Chapman (1998) incorporate the amount of imported manufactured goods as an additional explanatory variable and find that this leads to significantly higher income turning points than estimations without trade variables. The existence and importance of the displacement effect is also supported by a meta-analysis of twenty-five EKC studies by Cavlovic et al. (2000). If one controls for the countries' trade relations, higher EKC turning points are obtained.

Finally, the reunification of the former East German states with the West German states calls for a dummy variable, if one would also like to use more recent data. From 1992 onwards, the statistical data about pollutant emissions is only published for the reunified Germany and not separately for the two former German republics.

[7] The positive correlation between income and R&D expenditure can be traced back to rising preferences for environmental quality.

[8] With concentrations as pollution data, GDP per km^2 can be used as a proxy for scale and and per capita GDP to appraise technique effects (e.g. Panayotou). The approximation of environment-related technology levels with a time trend is not satisfactory, albeit this is sometimes done in empirical studies.

Taking into account the extensions discussed above, the traditional EKC specification [equation (1)] becomes:

$$E_t = \beta_0 + \beta_1 Y_t + \beta_2 Y_t^2 + +\beta_3 Y_t^3 + \beta_4 S_t + \beta_5 I_t + \beta_6 D_t + \varepsilon_t \tag{2}$$

where Y stands for income and now indicates the net income effect (scale and technique effect), S is the industry share of GDP and represents the composition effect, I is the sum of imports and exports of goods from pollution-intensive production relative to GDP and D is the reunification dummy.

If one uses time series data, two econometric problems – namely the assumption of no serial correlation[9] and of stationarity – must not be neglected. In time series studies, the assumption that errors corresponding to different observations are uncorrelated often fails to prove true. Therefore, one cannot use ordinary least squares as the estimation technique. The generalised least squares procedure (GLS) controls for serial correlation and is, therefore, widely applied in time series studies. Besides the favourable characteristics with regard to autocorrelation, the GLS method also produces best linear unbiased estimators if the assumption of homoscedasticity, i.e. equal variances of the error term, is not fulfilled. Therefore, all estimations of equation (2) are based on GLS.

Time series are often non-stationary. Non-stationary time-series can only be regressed on each other if they are cointegrated. Otherwise, the results may be spurious. Cointegration is given if both time series are non-stationary and a linear combination that is itself stationary exists between them. In other words, the non-stationary components of these variables neutralise each other. In our case, none of the considered pollutants is a stationary variable, nor are they cointegrated with GDP in the usual sense[10]. However, since we are not looking at a linear relationship between income and emissions, but rather at an inverted U-shaped or an N-shaped one, income squared and cubed should be added as additional variables while testing for cointegration. If the resulting residuals are stationary, the two time series can be viewed as quasi-cointegrated in the sense that the non-stationary components of the considered time series neutralise each other and, therefore, the estimation results are not spurious. By regressing each pollutant on GDP (with a linear, quadratic and partly a cubed term) and controlling for autocorrelation, the obtained residuals are indeed mostly stationary.[11] In the following, an estimation procedure is considered which deals with serial correlation and the non-stationarity of the time series in an appropriate way.[12]

All estimation specifications considered so far do not distinguish between a long-term income-emission relationship and short-term disturbances from the

[9]Unless otherwise stated, correlation stands for correlation of first order.

[10]If they were cointegrated in the usual sense, the relation between the two variables would be linear and, therefore, there would be no income turning point. The results of the Dickey Fuller tests for unit root are reported in Table A.1 in appendix available upon request.

[11]The detailed results are reported in Tables A.2 and A.3 in an appendix available upon request.

[12]The use of error correction models leads to optimal estimation properties with cointegrated time series. With quasi-cointegrated time series, the properties are still optimal.

long-term equilibrium path. A model specification that differentiates between these two effects is the so-called error correction model (ECM), which was popularised by Davidson et al. (1978) in estimating a consumption function for the UK. In the ECM specifications, the relationship between the endogenous variable and the explanatory variable is modelled as follows. The changes in the dependent variable are influenced by changes in the exogenous variable (channel one) and the deviation of the dependent variable from its long-term value in the previous period (channel two). For our purposes, the specification of the ECM equation must be modified, since first the hypothesised long-term relationship is not linear, but follows a hump-shaped or an N-shaped pattern, and second we have more than one exogenous variable (see also Perman and Stern 2003). Regarding the first channel, we have to include the changes of the squared and cubed income terms as well as of the industry share of GDP and of the trade openness variable. The second channel has to be enlarged analogously. This yields:

$$\begin{aligned}\Delta E_t \;=\;& \gamma_0 + \gamma_1 \Delta Y_t + \gamma_2 \Delta Y_t^2 + \gamma_3 \Delta Y_t^3 + \gamma_4 \Delta S_t + \gamma_5 \Delta I_t + \gamma_6 \Big(E_{t-1} \\ & - \alpha_0 - \alpha_1 Y_{t-1} - \alpha_2 Y_{t-1}^2 - \alpha_3 Y_{t-1}^3 - \alpha_4 S_{t-1} - \alpha_5 I_{t-1} \\ & - \alpha_6 D_{t-1} \Big) + \gamma_7 \Delta D_t + \varepsilon_t \end{aligned} \tag{3}$$

where Δ denotes a variable's first difference. The whole term in parenthesis, $(E_{t-1} - \alpha_0 - \alpha_1 Y_{t-1} - \alpha_2 Y_{t-1}^2 - \alpha_3 Y_{t-1}^3 - \alpha_4 S_{t-1} - \alpha_5 I_{t-1} - \alpha_6 D_{t-1})$, i.e. the deviation from the long-term relation, is called error correction term and coincides with the one-period lagged residuals of the above-mentioned traditional EKC equation [equation (2)].

To potentially obtain a hump-shaped pattern between environmental degradation and income or an EKC, respectively, the coefficient of the error correction term, γ_6, must be negative. This can be interpreted in the following way. If, in the previous period, the actual emissions were greater than the optimal long-term emissions, the error correction term becomes positive and, together with its negative coefficient, operates towards a smaller or even negative emission growth rate. If, however, the actual emissions were less than the optimal emissions, the error correction term becomes negative and, together with the negative sign of its coefficient, the reverse effect occurs. This does not mean that individuals intend to reduce environmental quality unnecessarily, but that due to socially optimal activities they put up with an increasing emission growth rate. For example, it may be optimal to invest in infrastructure equipment even though this causes higher emissions. In this case, income rises with investments, but emissions temporarily fall below the long-term equilibrium because pollution does not start immediately when the infrastructure is built up. An analogous reasoning applies for an N-shaped pattern. The coefficients of ΔY and ΔY^3, i.e. γ_1 and γ_3, are expected to be positive, whereas the coefficient of ΔY^2, i.e. γ_2, should be negative. As above, a higher industry sector share of GDP should lead to higher emissions. Thus, γ_4 is expected to be positive. γ_5 again determines the relative strength of the pollution haven hypothesis relative to the counteracting factor endowment hypothesis.

3 Data

Data Source

Since in this study environmental damage is the object of concern, aggregate emissions and not urban concentration are to be preferred, because they are more likely to relate to environmental damage rather than to damage human health (Ekins 1997). Therefore, per capita emission data for eight pollutants for the years 1966 – 1999 are used, namely sulphur dioxide (SO_2), nitrogen oxide (NO_x, as usually measured by nitrogen dioxide NO_2), carbon dioxide (CO_2), carbon monoxide (CO), ammonia (NH_3), methane (CH_4), particulate matter (PM) and non-methane volatile organic compounds (NMVOC). All pollutants are measured in kilograms. Per capita GDP is measured in Euros at 1991 prices, while the imports and exports of goods from pollution-intensive production[13] are set in relation to GDP. Gross value added by sector is gauged by percent of total value added. All data, i.e. emissions data, GDP, population data, gross value added by sectors, as well as import and export data, are taken from the Statistical Yearbooks for the Federal Republic of Germany (1966 – 2002). Because of availability limitations, all data from 1966 to 1991 represent only the former West Germany, whereas the data from 1992 onwards incorporate all sixteen German Länder.[14] Since empirical work with time series data requires observations over a longer period, one has to accept this data break. To restrict the sample to West Germany and/or up to 1991 is no real alternative, and observations for the years before 1966 are not available.

Descriptive Statistics

If one looks at the time profile of the emissions, several points stand out (see Figure 1). Without exception, all pollutant emissions declined in the last few years; however, the rate of the decrease is not equal among the pollutants or over time. In addition, there is no common turnaround for the eight pollutants. In particular, there is no turnaround in the year of reunification. On this account, a potential EKC would not be the result of the incorporation of former East Germany from 1992 on. In the case of CO_2 and SO_2, one observes a great leap in the first year of reunification. These emission paths can possibly be explained by the fact that the heavily polluting power stations of former East Germany stayed in operation for some years, whereas the replacement of vehicles, which were largely responsible for carbon monoxide and nitrogen oxide emissions, was carried out more quickly.

Figure 1 about here

[13] The following product categories are taken into account: raw materials (apart from foodstuffs), mineral fuels, lubricants, chemicals, manufactured goods, machine and vehicle construction, and various finished products.

[14] Notice that, due to data availability, the value of the dummy variable does not change in the year of German reunification, but only in 1992.

4 Empirical Results and Discussion

In a first step, different estimations of equation (2) were carried out for all eight pollutants, i.e. with and without the cubed income term and the additional explanatory variables, respectively. Because of serial correlation, generalised least squares (Cochrane-Orcutt procedure) is required as the estimation technique. Nevertheless, in most estimations the problem of serial correlation cannot be solved by GLS, meaning that the equations are misspecified and an interpretation of the estimated coefficients is not possible. Problems arise for SO_2, CO_2, PM, CH_4, NMVOC and mostly for CO. In addition, including a cubed income term causes a sign reversal for the income variables in some cases. These coefficients, however, are not significant with the exception of particulate matter. The reason for the sign reversal can be traced back to the very high correlation between the three income variables. Thus, in the following, only the successful examples of these estimations, i.e. the estimations for NO_x and NH_3, are reported and discussed. The results are shown in Tables 1 and 2, respectively.[15]

Table 1 about here

For the traditional reduced-form model with only GDP as explanatory variable and without a cubed income term [column (1)], positive linear and negative quadratic income coefficients are obtained. This results in a hump-shaped emissions profile, but only in the case of NO_x are the coefficients significant. The calculated turning point of the NO_x-EKC occurs at a per capita income of € 15,164 (in 1991 prices). This level of per capita income was reached around 1977 and corresponds to roughly USD 14,750 (in 1985 prices).[16] Allowing for a cubed income term [column (5)] results, on the one hand, in the loss of significance for NO_x but, on the other hand, the coefficients of NH_3 are now significant. With the positive coefficient of the cubed income term, the emission profile of ammonia is N-shaped. Therefore, two ITPs are obtained: the first occurs around € 17,500 (USD 17,000), which is somewhat higher than in the case of NO_x; the second emerges around € 23,700, i.e. it lies slightly outside the sample range.[17] The estimated pollution-income relations for NO_x and NH_3 are depicted in Figure 2. On the basis of these estimation results, the question on the appropriateness of a cubed income term cannot be conclusively answered. In the case of NH_3, the incorporation results in a change from an inverted U-shaped to an N-shaped pattern, while in the case of NO_x a sign reversal and a loss of significance are observed, presumably due to multicollinearity.[18]

Figure 2 about here

[15] The estimation results of the other six pollutants are reported in Tables A.4 - A.9 in an appendix available upon request.

[16] The amounts are first converted into USD using the annual mean exchange rate of 1991 (source: http://www.oanda.com) and then deflated using the implicit price deflator for GDP (source: Bureau of Economic Analysis, U.S. Department of Commerce).

[17] The income turning point of NH_3 is not calculated in column (1), since the income coefficients are not significant.

[18] A sign reversal and partly a loss of significance is also found for CO_2, PM, CH_4 and NMVOC.

In comparison with cross-country studies, the turning point of nitrogen oxide matches that of other estimations; in Selden/Song (1994), the curve turns down at about USD 11,000, in Cole et al. (1997) between 14,700 and USD 17,600 and, finally, Grossman (1995) reports a turning point of USD 18,453. Although Carson et al. (1997) report a monotonically decreasing relationship between NO_x emissions and GDP for the US, this result is not inconsistent with the EKC pattern found here, since they use only data from 1988 to 1994. In this period, the NO_x emissions in Germany decreased as well. This follows directly from the calculated income turning point, which was reached not later than 1977. Comparisons of the ITPs for ammonia with other estimations are not possible, since to my knowledge ammonia is not considered in any other EKC study.

Table 2 about here

When incorporating the gross value added of the industry sector [(columns (2) and (6)] the estimation results of NO_x do not change notably; the industry share shows no significant influence. However, the income coefficients are stable in size and the ITP is only slightly higher than before. In the case of ammonia, now both the estimation with and without cubed income are significant, with a slightly lower ITP in the latter case. Still, the GDP share of the industry sector does not have the predicted positive sign. This result is difficult to explain, since the assumption that the industry sector is more polluting than the agriculture and service sectors is plausible and not at all controversial in literature.

The estimation results of columns (3) and (7) reveal ambiguous information about the relative strength of the displacement effect and the factor endowment hypothesis. For NO_x no significant result is obtained. This could be interpreted in the sense that the two effects offset each other. For ammonia, however, a positive sign results. This means that with increasing trade openness emissions also rise. Therefore, the factor abundance hypothesis is supported. The calculated income turning points match those of the previous specifications. The estimations with both the GDP share of the industry sector as well as the trade openness do not give many new insights [columns (4) and (8)]. The main reason may be that the two variables are highly correlated (about 0.9). Apart from that, the same remarks as in the previous estimations apply here.

These estimations clearly show that the existence of an EKC for a single country cannot be supported on the basis of the traditional reduced-form specification. This result contradicts the majority of cross-country or panel data EKC studies. However, as outlined in Section 2 above, the reduced-form specification is not appropriate for a time series analysis without restrictions. More sophisticated specifications are to be preferred.

Table 3 about here

The results of equation (3), which follows the error correction model tradition, are set forth in Table 3. For each pollutant only its best fitted estimation is shown, since the different specifications yield similar results.[19] Concerning the

[19]The complete estimation results, i.e. all eight different estimations for each pollutant are reported in an appendix available upon request.

incorporation of additional explanatory variables, Table 3 shows that a cubed income term as well as a trade openness variable do not greatly improve the estimation's explanatory power. The industry sector share of GDP, on the other hand, improves the results in most cases.

Analysing the estimation results in detail, several things strike the observer's eye. First, the coefficients of the first differences of the income variables are mostly not significant. Only in the cases of NO_x, PM and NH_3 significant influences can be observed. However, the signs of the income variables are as expected. As before, the incorporation of a cubed income term sometimes leads to a sign reversal in the income variables. Again, this must be attributed to the multicollinearity of the income variables. Second, and contrary to the estimations of the traditional reduced-form model, here the significant coefficients for the industry sector share of GDP have the expected positive sign (with the exception of NO_x). This means that the more important the industry sector is, the higher are the emissions. Third, the absence and/or the non-significance of the trade openness variable confirms the results of the reduced-form estimations. Either foreign trade does not have an influence on emissions, or the factor abundance hypothesis and the pollution haven hypothesis offset each other.[20] Fourth and most importantly, the coefficients of the error correction term are all significant and – as expected – negative. Thus, these results can be interpreted in the sense that changes in income only have an influence through the second channel. Deviations from the long-term relationship, which is specified to be either hump-shaped or N-shaped, are corrected in the next period. Therefore, even if there is no direct influence through the first channel, the significant results of the second channel suggest an EKC pattern for these pollutants.[21]

However, there is one reason why this interpretation is debatable. If environmental degradation indeed follows a hump-shaped curve, this result should already have been found in equation (2). But there, the EKC hypothesis could only be verified for NO_x and NH_3. On the other hand, one can argue that if the distinction between the two different channels, i.e. income changes and deviations from the optimal long-term relation, is important, specifications where this differentiation is not made could lead to distorted results and that, therefore, estimation specification with different channels should be preferred.

5 Summary and Conclusions

Using time series data for Germany instead of cross-country or panel data and testing different specifications to gain new insights into the EKC hypothesis for different pollutants, the estimation results remain ambiguous. First, the traditional reduced-form model and some extensions with additional explanatory variables – namely the trade relations and the industry sector share of GDP – are estimated. For nitrogen oxide and mostly for ammonia, an EKC

[20] Exceptions are ammonia and nitrogen oxide: the positive coefficient of ammonia supports the factor endowment hypothesis, while the negative coefficient of nitrogen oxide (not shown in Table 3) endorses the pollution haven hypothesis.

[21] The hump-shaped pattern is traced back to the non-linear specification of the two influence channels in equation (3).

or N-shaped pattern is found, with income turning points around € 15,200 and 17,500, respectively. Thus, for these two pollutants, the results of most cross-country studies can be confirmed. However, and more importantly, the other six pollutants do not show clear results. Either the t-statistics are unsatisfactory, or the Durbin-Watson tests give rise to a rejection of these simple model specifications. Astonishingly, this is valid not only with respect to a possible EKC pattern, i.e. a positive linear income term together with a negative quadratic one, but also with respect to monotonically increasing or decreasing development paths of the considered harmful chemical emissions. These results indicate clearly that cross-country studies provide unreliable estimations. Second, and because of the variables' non-stationarity and motivated by error correction models, equations are estimated that distinguish between two different influence channels. But contrary to the well-known error correction models (e.g. for a consumption function), the long-term relationship is specified as a non-linear, i.e. hump-shaped function. The estimations show that the deviations from the long-term optimal value have a significant influence on pollutant emissions. Changes in income or the sectoral and/or foreign trade structure, however, do not have a prominent impact. Nevertheless, the results of the modified error correction model with the underlying non-linear long-term relation give some evidence for the existence of EKCs within a single country.

Summarising all presented estimations, one has to admit that the question of whether EKCs really exist for a single country is not conclusively answered. The estimations of the traditional reduced-form specification do no show a clear and consistent pattern. In addition, the estimation results are not very robust regarding the incorporation of additional explanatory variables. On the other hand, the modified error correction specification is more supportive of the EKC hypothesis. As a result, general policy recommendations with regard to the environment should only cautiolsy rely on the EKC approach.

In conclusion, two points must be addressed. First, the quality and, for the most part, quantity of the available data is limited. It would be helpful for empirical researchers if they could access a more widespread data pool. Second, it is likely that imported explanatory variables are still omitted in the model specifications. Future research and especially theoretical work on the EKC hypothesis for a single country may lead to more adequate model specifications. Further empirical studies should maybe adhere less to the traditional reduced-form model, but rather enlarge the well-known specifications with additional structural variables or use completely different approaches, e.g. non-linear estimation equations[22].

[22] Meaning non-linear in parameters.

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Table 1: Endogenous variable: per capita emissions of NO_x

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
const	-20.74 (0.76) (0.46)	-24.54 (0.88) (0.39)	11.05 (0.39) (0.70)	-13.91 (0.47) (0.64)	80.09 (1.07) (0.29)	69.84 (1.56) (0.13)	43.76 (1.02) (0.32)	69.59 (1.49) (0.15)
Y	9.1e-3*** (3.20) (0.00)	9.9e-3*** (2.90) (0.01)	8.5e-3*** (3.00) (0.01)	9.1e-3** (2.55) (0.02)	-1.1e-2 (0.82) (0.42)	-9.2e-3 (1.15) (0.26)	-8.0e-3 (1.01) (0.32)	-9.2e-3 (1.12) (0.27)
Y^2	-3.0e-7*** (4.00) (0.00)	-3.2e-7*** (3.41) (0.00)	-2.8e-7*** (3.71) (0.00)	-3.0e-7*** (3.03) (0.01)	9.3e-7 (1.22) (0.23)	1.0e-6** (2.13) (0.04)	9.4e-7* (1.96) (0.06)	1.0e-6** (2.06) (0.05)
Y^3					-2.4e-11 (1.67) (0.11)	-3.0e-11*** (3.15) (0.00)	-2.8e-11*** (2.93) (0.01)	-3.0e-11*** (3.03) (0.01)
S		-0.08 (0.34) (0.73)		-0.07 (0.27) (0.79)		-0.36** (2.24) (0.03)		-0.36* (1.74) (0.09)
I			-11.57 (1.21) (0.24)	-11.50 (1.18) (0.25)			11.89 (1.52) (0.14)	0.23 (0.02) (0.98)
D	-10.03*** (9.31) (0.00)	-10.20*** (8.53) (0.00)	-11.11*** (7.98) (0.00)	-11.23*** (7.34) (0.00)	-10.07*** (9.41) (0.00)	-11.02*** (9.86) (0.00)	-8.79*** (6.16) (0.00)	-10.99*** (6.15) (0.00)
adj. R^2	0.84	0.84	0.82	0.82	0.87	0.97	0.97	0.97
DW	1.93	1.90	1.83	1.82	1.99	1.69	1.74	1.69
N. of obs.	33	33	33	33	33	33	33	33
ρ	0.88	0.87	0.90	0.90	0.82	0.38	0.32	0.38
ITP 1[a]	15,164	15,321	15,182	15,371				

t-statistics and marginal significance levels in parenthesis
*, **, *** for significance at the 10%, 5% and 1% level
[a] in € at '91 prices

Table 2: Endogenous variable: per capita emissions of NH_3

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
const	6.31	-8.61***	-8.66***	-8.52***	-138.8***	-130.6***	-72.8***	-94.0***
	(0.81)	(2.95)	(3.40)	(3.72)	(5.01)	(3.52)	(3.87)	(3.99)
	(0.43)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Y	5.8e-4	2.6e-3***	2.0e-3***	2.1e-3***	2.3e-2***	2.1e-2***	1.2e-2***	1.5e-2***
	(0.75)	(8.62)	(7.25)	(8.11)	(5.16)	(3.71)	(4.10)	(4.22)
	(0.46)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Y^2	-2.3e-8	-7.7e-8***	-6.2e-8***	-6.7e-8***	-1.1e-6***	-1.1e-6***	-6.1e-7***	-7.8e-7***
	(1.18)	(9.17)	(8.35)	(9.17)	(4.92)	(3.51)	(3.83)	(3.98)
	(0.25)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Y^3					1.9e-11***	1.8e-11***	9.5e-12***	1.3e-11***
					(4.64)	(3.26)	(3.44)	(3.66)
					(0.00)	(0.00)	(0.00)	(0.00)
S		-0.10**		-0.03		-9.7e-3		0.04
		(4.55)		(1.09)		(0.32)		(1.37)
		(0.00)		(0.29)		(0.75)		(0.19)
I			4.56***	3.81***			3.14***	3.68***
			(6.00)	(3.60)			(4.24)	(4.36)
			(0.00)	(0.00)			(0.00)	(0.00)
D	-0.35**	-0.67***	0.14	0.01	-0.37***	-0.40***	-0.04	0.11
	(2.74)	(4.75)	(1.00)	(0.06)	(3.24)	(2.86)	(0.32)	(0.68)
	(0.01)	(0.00)	(0.33)	(0.96)	(0.00)	(0.01)	(0.75)	(0.51)
adj. R^2	0.73	0.97	0.97	0.98	0.95	0.95	0.98	0.98
DW	2.29	2.03	1.70	1.84	2.09	2.18	2.24	2.07
N. of obs.	24	24	24	24	24	24	24	24
ρ	0.80	-0.00	0.13	0.00	0.33	0.32	0.18	0.20
ITP 1[a]		16,947	16,319	16,357	18,093	17,575	16,969	17,124
ITP 2[a]					22,409	23,187	25,353	23,882

t-statistics and marginal significance levels in parenthesis
*, **, *** for significance at the 10%, 5% and 1% level
[a] in € at '91 prices

Table 3: Endogenous variable: emissions first difference

	SO_2	NO_x	CO_2	PM	CO	NH_3	CH_4	NMVOC
const	-2.87**	-0.48	-101.6	-0.10	-5.30***	0.09**	-1.76**	-0.71
	(2.28)	(1.23)	(1.46)	(0.42)	(2.89)	(2.78)	(2.81)	(1.13)
	(0.03)	(0.23)	(0.16)	(0.68)	(0.01)	(0.01)	(0.01)	(0.27)
ΔY	8.0e-3	5.9e-3*	2.8e-1	3.7e-3*	2.1e-3	1.8e-2***	7.3e-4	2.0e-3
	(1.19)	(1.88)	(0.57)	(1.98)	(0.04)	(6.93)	(0.11)	(0.30)
	(0.24)	(0.07)	(0.57)	(0.06)	(0.97)	(0.00)	(0.91)	(0.77)
ΔY^2	-2.4e-7	-1.8e-7*	-4.6e-6	-1.1e-7*	-1.3e-7	-9.5e-7***	-1.4e-8	-1.4e-7
	(1.21)	(1.97)	(0.32)	(1.89)	(0.04)	(6.55)	(0.08)	(0.34)
	(0.24)	(0.06)	(0.75)	(0.07)	(0.97)	(0.00)	(0.94)	(0.74)
ΔY^3					1.7e-12	1.6e-11***		2.4e-12
					(0.02)	(6.10)		(0.29)
					(0.98)	(0.00)		(0.78)
ΔS	-0.19		-11.48		2.12**	0.12***	0.17	
	(0.33)		(0.36)		(2.09)	(4.08)	(0.73)	
	(0.74)		(0.73)		(0.05)	(0.00)	(0.48)	
ΔI					-9.43	2.66***		
					(0.29)	(4.22)		
					(0.77)	(0.00)		
ECT^{b}	-0.36**	-0.18**	-0.63**	-0.18***	-0.36***	-0.58***	-0.59***	-0.52***
	(2.36)	(2.16)	(2.55)	(4.80)	(3.45)	(4.08)	(4.11)	(4.41)
	(0.03)	(0.04)	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
ΔD	28.86***	-9.28***	-113.5	1.30**	4.41	0.01	-17.12***	0.26
	(13.39)	(8.45)	(0.89)	(2.63)	(0.97)	(0.07)	(22.51)	(0.67)
	(0.00)	(0.00)	(0.38)	(0.01)	(0.34)	(0.95)	(0.00)	(0.51)
adj. R^2	0.87	0.77	0.33	0.57	0.49	0.92	0.97	0.42
DW	1.95	2.03	1.46	1.64	2.04	2.08	1.88	1.92
N. of obs.	32	32	28	32	32	23	23	32
ρ	0.56	0.19	0.48	0.23	0.29	-0.40	0.68	0.87

t-statistics and marginal significance levels in parenthesis
*, **, *** for significance at the 10%, 5% and 1% level
[b] ECT: particular error correction term, i.e. with or without Y^3, S and I.

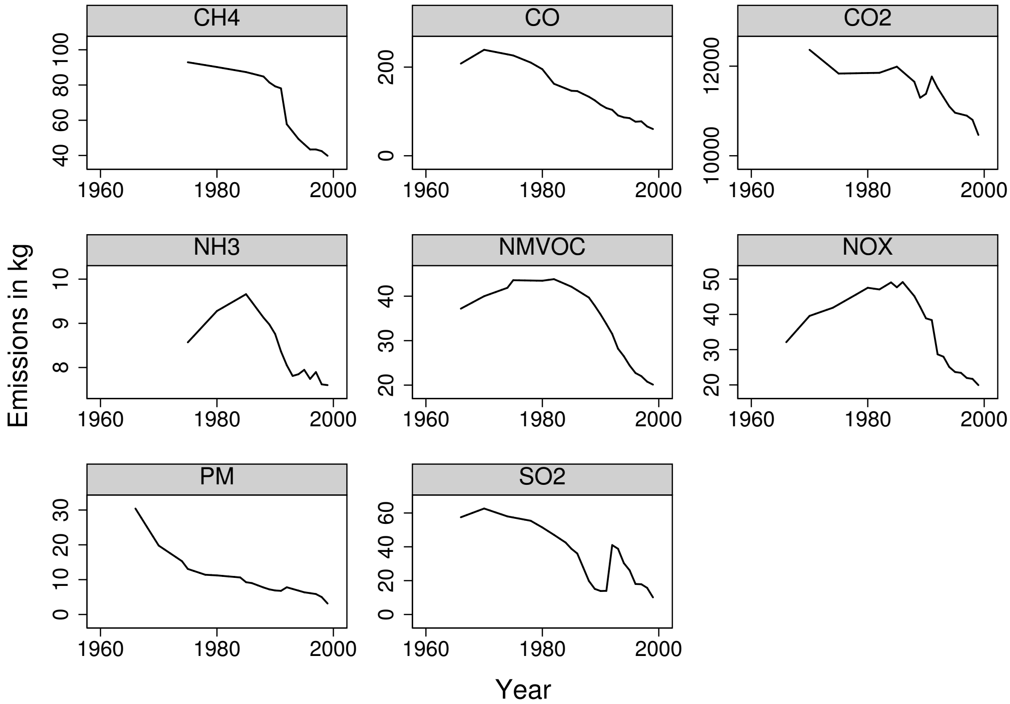

Figure 1: Time Profiles of the Pollutants

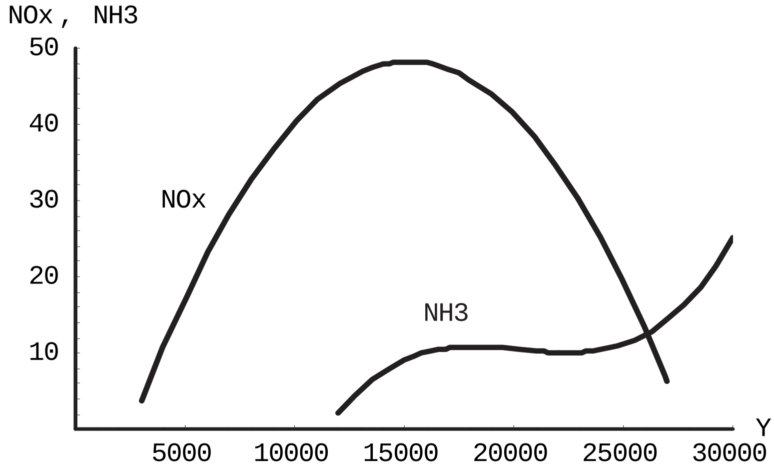

Figure 2: Estimated pollution-income relation for NO_x and NH_3

Referees' Appendix to "The Environmental Kuznets Curve – Evidence from Time Series Data for Germany"

Tests for unit root and quasi-cointegration

In Table A.1 the Dickey-Fuller tests for unit root of GDP and the eight considered pollutants are reported. As one can see, for all time series (with the exception of particulate matter) the null hypothesis of unit root cannot be rejected at the usual significance levels. Therefore, only the time series for particulate matter is a stationary one.

Table A.1: Dickey-Fuller test for unit root

	N. of obs.	Test Statistics	5% Critical Value*	Approx. p-value**
GDP	33	-0.901	-2.978	0.7876
SO_2	33	-0.272	-2.978	0.9294
NO_x	33	0.671	-2.978	0.9892
CO_2	29	0.496	-2.989	0.9848
PM	33	-6.545	-2.978	0.000
CO	33	1.976	-2.978	0.9986
NH_3	24	0.450	-3.000	0.9833
CH_4	24	0.700	-3.000	0.9898
NMVOC	33	3.182	-2.978	1.000

* The critical values are linearly interpolated from the table of values that appears in Fuller (1976).
** The MacKinnon approximate p-values use the regression surface published in MacKinnon (1994).

In Tables A.2 and A.3 the results of the tests for quasi-cointegration (as described in the main text) are reported. More precisely, each pollutant is regressed on GDP, GDP squared, GDP cubed (Table A.3 only) and the dummy variable for reunification using GLS (Cochrane-Orcutt procedure) as estimation technique. The resulting residuals of these regressions are then tested for unit root. If the null hypothesis of unit root can be rejected, the residuals can be considered as stationary. Analogous to a standard test for cointegration (see e.g. Pindyck/Rubinfeld 1998, page 513ff), stationary residuals are the critical condition for quasi-cointegration between the two considered time series. Here, as one can see, the following pollutants are cointegrated with GDP, at least at the ten percent significance level: (i) with a linear and quadratic GDP term: NO_x, CO_2, PM, CO, and NH_3; (ii) with a linear, quadratic and cubed GDP term: NO_x, CO_2, PM, NH_3 and nearly NMVOC.

Table A.2: Dickey-Fuller test for unit root (quasi-cointegration test I)

	N. of obs.	Test Statistics	5% Critical Value*	Approx. p-value**
SO_2	33	-2.377	-2.978	0.1484
NO_x	33	-2.650	-2.978	0.0830
CO_2	29	-2.872	-2.989	0.0487
PM	33	-9.949	-2.978	0.0000
CO	33	-2.835	-2.978	0.0535
NH_3	24	-3.651	-3.000	0.0049
CH_4	24	0.712	-3.000	0.9901
NMVOC	33	-2.135	-2.978	0.2306

* The critical values are linearly interpolated from the table of values that appears in Fuller (1976).
** The MacKinnon approximate p-values use the regression surface published in MacKinnon (1994).

Table A.3: Dickey-Fuller test for unit root (quasi-cointegration test II)

	N. of obs.	Test Statistics	5% Critical Value*	Approx. p-value**
SO_2	33	-2.219	-2.978	0.1993
NO_x	33	-3.262	-2.978	0.0167
CO_2	29	-2.963	-2.989	0.0385
PM	33	-9.640	-2.978	0.0000
CO	33	0.409	-2.978	0.9818
NH_3	24	-10.912	-3.000	0.0000
CH_4	24	0.511	-3.000	0.9852
NMVOC	33	-2.565	-2.978	0.1004

* The critical values are linearly interpolated from the table of values that appears in Fuller (1976).
** The MacKinnon approximate p-values use the regression surface published in MacKinnon (1994).

Additional Econometric Results

In the Tables A.4 to A.9 the estimation results of equation (2) for the pollutants SO_2, CO_2, PM, CO, CH_4 and NMVOC are reported. As stated in the main text, these estimation results should be interpreted with caution, since the Durbin-Watson statistics do not satisfy the usual significance criterions and the coefficients of the estimated variables are often not significant.

In the Tables A.10 to A.17 the complete estimation results of equation (3) for all pollutants are reported.

Table A.4: Endogenous variable: per capita emissions of SO_2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
const	-28.61	-59.25	-51.81	-54.10	-138.0	-132.2	-106.7	-103.0
	(0.56)	(1.02)	(1.10)	(0.90)	(0.67)	(0.65)	(0.55)	(0.49)
	(0.58)	(0.31)	(0.28)	(0.38)	(0.51)	(0.52)	(0.59)	(0.63)
Y	1.5e-2***	1.1e-2	1.8e-2***	1.1e-2	3.5e-2	2.4e-2	2.8e-2	2.0e-2
	(2.64)	(1.65)	(3.32)	(1.60)	(0.96)	(0.66)	(0.81)	(0.55)
	(0.01)	(0.11)	(0.00)	(0.12)	(0.35)	(0.51)	(0.42)	(0.59)
Y^2	-6.5e-7***	-4.7e-7***	-6.8e-7***	-4.6e-7**	-1.8e-6	-1.3e-6	-1.3e-6	-1.0e-6
	(3.96)	(2.46)	(4.54)	(2.30)	(0.85)	(0.59)	(0.63)	(0.46)
	(0.00)	(0.02)	(0.00)	(0.03)	(0.40)	(0.56)	(0.54)	(0.65)
Y^3					2.3e-11	1.5e-11	1.2e-11	1.0e-11
					(0.55)	(0.37)	(0.29)	(0.25)
					(0.59)	(0.71)	(0.77)	(0.80)
S		1.24**		1.06*		1.21**		1.05*
		(2.22)		(1.77)		(2.13)		(1.72)
		(0.03)		(0.09)		(0.04)		(0.10)
I			-43.62*	-27.52			-42.50	-26.72
			(1.76)	(1.06)			(1.67)	(1.00)
			(0.09)	(0.30)			(0.11)	(0.33)
D	26.04***	28.35***	21.82***	25.35***	25.88***	28.24***	21.84***	25.39***
	(8.25)	(8.99)	(5.55)	(5.96)	(8.08)	(8.78)	(5.47)	(5.87)
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
adj. R^2	0.84	0.84	0.87	0.83	0.83	0.83	0.86	0.82
DW	1.20	1.29	1.25	1.25	1.19	1.28	1.24	1.25
N. of obs.	33	33	33	33	33	33	33	33
ρ	0.70	0.76	0.67	0.78	0.71	0.76	0.68	0.79

t-statistics and marginal significance levels in parenthesis
*, **, *** for significance at the 10%, 5% and 1% level

Table A.5: Endogenous variable: per capita emissions of CO_2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
const	6.2e3*	4.4e3	6.0e3	4.4e3	3.4e4*	2.1e4	3.1e4*	2.1e4
	(1.72)	(1.41)	(1.71)	(1.37)	(2.01)	(1.11)	(1.79)	(1.09)
	(0.10)	(0.17)	(0.10)	(0.19)	(0.06)	(0.28)	(0.09)	(0.29)
Y	0.70*	0.60*	0.73*	0.61*	-3.93	-2.11	-3.53	-2.11
	(1.77)	(1.96)	(1.89)	(1.80)	(1.38)	(0.69)	(1.20)	(0.68)
	(0.09)	(0.06)	(0.07)	(0.09)	(0.18)	(0.49)	(0.24)	(0.51)
Y^2	-2.1e-5*	-1.7e-5*	-2.2e-5**	-1.7e-5*	2.3e-4	1.3e-4	2.1e-4	1.3e-4
	(2.01)	(1.98)	(2.10)	(1.86)	(1.47)	(0.80)	(1.31)	(0.78)
	(0.06)	(0.06)	(0.05)	(0.08)	(0.16)	(0.43)	(0.20)	(0.45)
Y^3					-4.6e-9	-2.8e-9	-4.3e-9	-2.8e-9
					(1.59)	(0.90)	(1.44)	(0.88)
					(0.13)	(0.38)	(0.16)	(0.39)
S		49.50*		48.67		41.43		40.46
		(1.91)		(1.64)		(1.48)		(1.25)
		(0.07)		(0.12)		(0.15)		(0.22)
I			-844.96	-73.78			-851.8	-85.86
			(0.69)	(0.06)			(0.71)	(0.06)
			(0.50)	(0.96)			(0.48)	(0.95)
D	-275.60*	-145.56	-354.27*	-155.23	-234.6	-143.6	-324.1	-155.3
	(1.87)	(0.94)	(1.84)	(0.68)	(1.59)	(0.92)	(1.66)	(0.66)
	(0.07)	(0.36)	(0.08)	(0.50)	(0.13)	(0.37)	(0.11)	(0.51)
adj. R^2	0.54	0.70	0.58	0.69	0.72	0.73	0.71	0.72
DW	1.33	1.49	1.34	1.48	1.42	1.49	1.42	1.49
N. of obs.	29	29	29	29	29	29	29	29
ρ	0.68	0.55	0.64	0.55	0.52	0.51	0.52	0.51

t-statistics and marginal significance levels in parenthesis
*, **, *** for significance at the 10%, 5% and 1% level

Table A.6: Endogenous variable: per capita emissions of PM

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
const	-11.72	-4.80	-13.24	-5.92	86.30**	84.36**	87.68**	88.77**
	(0.91)	(0.39)	(1.00)	(0.47)	(2.73)	(2.58)	(2.73)	(2.70)
	(0.37)	(0.70)	(0.33)	(0.64)	(0.01)	(0.02)	(0.01)	(0.01)
Y	2.7e-3*	1.3e-3	2.8e-3*	1.4e-3	-1.7e-2***	-1.6e-2***	-1.7e-2***	-1.8e-2***
	(1.99)	(0.89)	(2.00)	(0.91)	(2.99)	(2.79)	(3.09)	(3.04)
	(0.06)	(0.38)	(0.06)	(0.37)	(0.01)	(0.01)	(0.01)	(0.01)
Y^2	-9.1e-8**	-5.2e-8	-9.4e-8**	-5.5e-8	1.1e-6***	1.1e-6***	1.1e-6***	1.2e-6***
	(2.49)	(1.26)	(2.48)	(1.28)	(3.28)	(3.09)	(3.39)	(3.37)
	(0.02)	(0.22)	(0.02)	(0.21)	(0.00)	(0.01)	(0.00)	(0.00)
Y^3					-2.3e-11***	-2.2e-11***	-2.4e-11***	-2.4e-11***
					(3.52)	(3.35)	(3.63)	(3.62)
					(0.00)	(0.00)	(0.00)	(0.00)
S		0.16		0.16		0.03		-0.02
		(1.47)		(1.39)		(0.25)		(0.13)
		(0.15)		(0.18)		(0.81)		(0.90)
I			1.79	1.47			3.85	3.99
			(0.39)	(0.31)			(0.91)	(0.92)
			(0.70)	(0.76)			(0.37)	(0.37)
D	1.02*	1.30**	1.20*	1.44*	1.18**	1.21**	1.59**	1.59**
	(1.93)	(2.27)	(1.74)	(1.87)	(2.51)	(2.32)	(2.58)	(2.37)
	(0.06)	(0.03)	(0.09)	(0.07)	(0.02)	(0.03)	(0.02)	(0.03)
adj. R^2	0.36	0.50	0.31	0.46	0.39	0.37	0.39	0.37
DW	1.44	1.45	1.42	1.45	1.63	1.63	1.62	1.61
Number of obs.	33	33	33	33	33	33	33	33
ρ	0.86	0.83	0.86	0.84	0.90	0.89	0.91	0.91

t-statistics and marginal significance levels in parenthesis
*, **, *** for significance at the 10%, 5% and 1% level

Table A.7: Endogenous variable: per capita emissions of CO

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
const	237.89	119.85	200.80*	120.79	-6.9e3***	-490.5	-583.5*	-418.5
	(1.69)	(1.21)	(1.89)	(1.26)	(3.82)	(1.56)	(1.71)	(1.36)
	(0.10)	(0.24)	(0.07)	(0.22)	(0.00)	(0.13)	(0.10)	(0.19)
Y	9.5e-3	-1.2e-2	1.4e-2	-8.3e-3	1.4e-1**	9.9e-2*	1.5e-1**	9.0e-2
	(0.61)	(1.07)	(1.17)	(0.73)	(2.28)	(1.77)	(2.51)	(1.64)
	(0.55)	(0.30)	(0.25)	(0.47)	(0.03)	(0.09)	(0.02)	(0.11)
Y^2	-7.5e-7*	7.6e-8	-7.3e-7**	1.7e-8	-7.3e-6*	-6.4e-6*	-8.9e-6**	-5.7e-6*
	(1.74)	(0.23)	(2.19)	(0.05)	(1.96)	(1.97)	(2.45)	(1.80)
	(0.09)	(0.82)	(0.04)	(0.96)	(0.06)	(0.06)	(0.02)	(0.08)
Y^3					1.3e-10	1.2e-10*	1.6e-10**	1.1e-10*
					(1.68)	(1.99)	(2.22)	(1.80)
					(0.10)	(0.06)	(0.04)	(0.08)
S		5.57***		5.00***		5.28***		4.79***
		(6.02)		(5.32)		(6.02)		(5.31)
		(0.00)		(0.00)		(0.00)		(0.00)
I			-162.10***	-78.17*			-170.2***	-68.50*
			(3.09)	(1.92)			(3.45)	(1.73)
			(0.00)	(0.07)			(0.00)	(0.10)
D	-5.53	5.69	-20.72**	-2.88	1.40	4.79	-22.74***	-2.68
	(0.77)	(1.10)	(0.28)	(0.43)	(0.26)	(0.97)	(2.83)	(0.41)
	(0.45)	(0.28)	(0.02)	(0.67)	(0.80)	(0.34)	(0.01)	(0.68)
adj. R^2	0.82	0.91	0.91	0.92	0.26	0.93	0.95	0.93
DW	1.11	1.33	1.64	1.41	1.43	1.41	1.70	1.49
N. of obs.	33	33	33	33	33	33	33	33
ρ	0.77	0.78	0.70	0.79	0.99	0.77	0.59	0.77
ITP 1[a]							13,386	
ITP 2[a]							24,491	

t-statistics and marginal significance levels in parenthesis
*, **, *** for significance at the 10%, 5% and 1% level
[a] in € at '91 prices

Table A.8: Endogenous variable: per capita emissions of CH_4

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
const	-1.5e3***	42.29	-1.6e3***	43.27	-1.2e3**	379.7	-1.3e3**	379.7
	(3.28)	(0.40)	(3.45)	(0.39)	(2.57)	(0.86)	(2.73)	(0.83)
	(0.00)	(0.70)	(0.00)	(0.70)	(0.02)	(0.40)	(0.01)	(0.42)
Y	9.7e-3**	2.6e-3	9.3e-3**	2.5e-3	-1.7e-2	-5.1e-2	-2.0e-2	-5.1e-2
	(2.27)	(0.21)	(2.18)	(0.20)	(0.45)	(0.76)	(0.53)	(0.73)
	(0.03)	(0.83)	(0.04)	(0.85)	(0.66)	(0.46)	(0.60)	(0.47)
Y^2	-2.6e-7**	-1.4e-7	-2.5e-7**	-1.4e-7	1.2e-6	2.7e-6	1.4e-6	2.7e-6
	(2.19)	(0.45)	(2.11)	(0.42)	(0.59)	(0.80)	(0.67)	(0.77)
	(0.04)	(0.66)	(0.05)	(0.68)	(0.56)	(0.44)	(0.51)	(0.45)
Y^3					-2.7e-11	-5.0e-11	-3.0e-11	-5.0e-11
					(0.71)	(0.87)	(0.79)	(0.84)
					(0.48)	(0.39)	(0.44)	(0.41)
S		1.04**		1.04**		1.08**		1.08**
		(2.33)		(2.26)		(2.47)		(2.38)
		(0.03)		(0.04)		(0.02)		(0.03)
I			13.08	-0.40			13.71	-0.15
			(1.07)	(0.03)			(1.11)	(0.01)
			(0.30)	(0.98)			(0.28)	(0.99)
D	-18.89***	-19.14***	-17.48***	-19.18***	-18.89***	-19.23***	-17.42***	-19.25***
	(14.60)	(11.48)	(9.52)	(8.67)	(14.42)	(11.38)	(9.38)	(8.33)
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
adj. R^2	0.91	0.96	0.91	0.95	0.91	0.97	0.91	0.96
DW	1.16	1.50	1.16	1.50	1.21	1.49	1.22	1.49
N. of obs.	24	24	24	24	24	24	24	24
ρ	0.99	0.77	0.99	0.77	0.99	0.71	0.99	0.71

t-statistics and marginal significance levels in parenthesis
*, **, *** for significance at the 10%, 5% and 1% level

Table A.9: Endogenous variable: per capita emissions of NMVOC

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
const	2.76	17.29	0.61	14.26	57.33	60.33	54.44	56.93
	(0.13)	(0.79)	(0.03)	(0.63)	(0.99)	(1.11)	(0.91)	(1.02)
	(0.90)	(0.44)	(0.98)	(0.53)	(0.33)	(0.28)	(0.37)	(0.32)
Y	6.5e-3***	3.1e-3	6.6e-3***	3.3e-3	-3.9e-3	-5.1e-3	-3.5e-3	-4.9e-3
	(2.95)	(1.19)	(2.94)	(1.23)	(0.38)	(0.53)	(0.34)	(0.49)
	(0.01)	(0.25)	(0.01)	(0.23)	(0.71)	(0.60)	(0.74)	(0.63)
Y^2	-2.4e-7***	-1.5e-7**	-2.5e-8***	-1.5e-7**	3.9e-7	3.6e-7	3.7e-7	3.5e-7
	(4.22)	(2.08)	(4.15)	(2.12)	(0.65)	(0.63)	(0.60)	(0.60)
	(0.00)	(0.05)	(0.00)	(0.04)	(0.52)	(0.53)	(0.55)	(0.56)
Y^3					-1.3e-11	-1.0e-11	-1.2e-11	-9.9e-12
					(1.07)	(0.90)	(1.02)	(0.87)
					(0.30)	(0.38)	(0.32)	(0.39)
S		0.41**		0.41**		0.39*		0.39*
		(2.05)		(2.05)		(2.00)		(2.01)
		(0.05)		(0.05)		(0.06)		(0.06)
I			3.50	4.35			3.10	4.23
			(0.46)	(0.60)			(0.41)	(0.58)
			(0.65)	(0.55)			(0.69)	(0.57)
D	-2.60***	-1.88**	-2.28**	-1.46	-2.65***	-1.91**	-2.37**	-1.50
	(3.10)	(2.17)	(2.06)	(1.30)	(3.14)	(2.18)	(2.14)	(1.31)
	(0.00)	(0.04)	(0.05)	(0.21)	(0.00)	(0.04)	(0.04)	(0.20)
adj. R^2	0.73	0.73	0.73	0.73	0.77	0.75	0.77	0.75
DW	1.47	1.33	1.45	1.35	1.57	1.43	1.55	1.44
N. of obs.	33	33	33	33	33	33	33	33
ρ	0.90	0.92	0.90	0.91	0.88	0.91	0.87	0.90

t-statistics and marginal significance levels in parenthesis
*, **, *** for significance at the 10%, 5% and 1% level

Table A.10: Endogenous variable: first difference of SO_2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
const	-2.40**	-2.87**	-2.19*	-2.62*	-2.39**	-2.85**	-2.19**	-2.61*
	(2.24)	(2.28)	(1.91)	(1.89)	(2.26)	(2.26)	(1.89)	(1.86)
	(0.03)	(0.03)	(0.07)	(0.07)	(0.03)	(0.03)	(0.07)	(0.08)
ΔY	8.6e-3	8.0e-3	8.1e-3	6.0e-3	2.3e-2	8.7e-3	2.3e-2	8.7e-3
	(1.36)	(1.19)	(1.24)	(0.86)	(0.67)	(0.25)	(0.65)	(0.24)
	(0.19)	(0.24)	(0.23)	(0.40)	(0.51)	(0.81)	(0.52)	(0.81)
ΔY^2	-2.7e-7	-2.4e-7	-2.5e-7	-1.8e-7	-1.2e-6	-2.6e-7	-1.2e-6	-3.3e-7
	(1.37)	(1.21)	(1.23)	(0.86)	(0.54)	(0.12)	(0.54)	(0.15)
	(0.18)	(0.24)	(0.23)	(0.40)	(0.59)	(0.91)	(0.59)	(0.88)
ΔY^3					1.7e-11	-1.7e-14	1.8e-11	2.9e-12
					(0.40)	(0.00)	(0.43)	(0.07)
					(0.69)	(1.00)	(0.67)	(0.95)
ΔS		-0.19		-0.06		-0.22		-0.07
		(0.33)		(0.10)		(0.37)		(0.11)
		(0.74)		(0.93)		(0.72)		(0.91)
ΔI			-26.43	-22.98			-26.58	-22.37
			(1.27)	(1.16)			(1.26)	(1.10)
			(0.22)	(0.26)			(0.22)	(0.28)
ECT^{b}	-0.27	-0.36**	-0.33*	-0.39**	-0.27	-0.36**	-0.34*	-0.38**
	(1.68)	(2.36)	(1.80)	(2.33)	(1.63)	(2.29)	(1.81)	(2.27)
	(0.10)	(0.03)	(0.08)	(0.03)	(0.12)	(0.03)	(0.08)	(0.03)
ΔD	28.74***	28.86***	26.70***	27.12***	28.83***	28.85***	26.78***	27.16***
	(12.81)	(13.39)	(9.90)	(10.46)	(12.53)	(13.03)	(9.76)	(10.21)
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
adj. R^2	0.86	0.87	0.86	0.87	0.85	0.87	0.86	0.86
DW	1.94	1.95	1.90	1.91	1.95	1.95	1.89	1.91
N. of obs.	32	32	32	32	32	32	32	32
ρ	0.51	0.56	0.54	0.60	0.49	0.54	0.54	0.59

t-statistics and marginal significance levels in parenthesis
*, **, *** for significance at the 10%, 5% and 1% level
[b] ECT: particular error correction term, i.e. with or without Y^3, S and I.

Table A.11: Endogenous variable: first difference of NO_x

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
const	-0.48	-1.02*	-0.93*	-1.26	-0.40	-0.40	0.12	-0.12
	(1.23)	(1.96)	(1.75)	(0.82)	(1.06)	(0.83)	(0.31)	(0.24)
	(0.23)	(0.06)	(0.09)	(0.42)	(0.30)	(0.41)	(0.76)	(0.81)
ΔY	5.9e-3*	6.1e-3*	2.2e-3	5.8e-3*	-2.5e-2	-6.1e-3	-3.6e-3	-6.6e-3
	(1.88)	(1.86)	(0.70)	(1.83)	(1.36)	(0.44)	(0.27)	(0.50)
	(0.07)	(0.07)	(0.49)	(0.08)	(0.19)	(0.66)	(0.79)	(0.62)
ΔY^2	-1.8e-7*	-1.7e-7*	-6.0e-8	-1.6e-7	1.7e-6	8.0e-7	6.0e-7	8.2e-7
	(1.97)	(1.80)	(0.64)	(1.66)	(1.57)	(0.94)	(0.73)	(0.99)
	(0.06)	(0.08)	(0.53)	(0.11)	(0.13)	(0.36)	(0.47)	(0.33)
ΔY^3					-3.7e-11*	-2.4e-11	-1.9e11	-2.4e-11
					(1.77)	(1.39)	(1.18)	(1.46)
					(0.09)	(0.18)	(0.25)	(0.16)
ΔS		-0.41		-0.33		-0.47*		-0.37
		(1.46)		(1.48)		(1.74)		(1.41)
		(0.16)		(0.15)		(0.10)		(0.71)
ΔI			-18.21**	-17.41**			-11.46	-15.30*
			(2.09)	(2.34)			(1.40)	(1.82)
			(0.05)	(0.03)			(0.18)	(0.08)
ECT^{b}	-0.18**	-0.26**	-0.23**	-0.72***	-0.32**	-0.71***	-0.78***	-0.79***
	(2.16)	(2.35)	(2.65)	(3.29)	(2.50)	(3.08)	(3.75)	(3.50)
	(0.04)	(0.03)	(0.01)	(0.00)	(0.02)	(0.01)	(0.00)	(0.00)
ΔD	-9.28***	-9.29***	-10.51***	-10.42***	-9.46***	-9.70***	-10.39***	-10.96***
	(8.45)	(8.97)	(8.61)	(10.58)	(8.80)	(9.88)	(8.85)	(9.41)
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
adj. R^2	0.77	0.77	0.78	0.85	0.77	0.80	0.81	0.82
DW	2.03	2.10	2.17	2.17	2.04	1.92	2.02	1.96
N. of obs.	32	32	32	32	32	32	32	32
ρ	0.19	0.42	0.49	0.88	0.21	0.32	0.37	0.36

t-statistics and marginal significance levels in parenthesis

*, **, *** for significance at the 10%, 5% and 1% level

[b] ECT: particular error correction term, i.e. with or without Y^3, S and I.

Table A.12: Endogenous variable: first difference of CO_2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
const	-67.39	-101.6	-67.76	-101.9	-76.83	-108.2	-75.06	-110.1
	(1.04)	(1.46)	(1.04)	(1.37)	(1.32)	(1.48)	(1.20)	(1.40)
	(0.31)	(0.16)	(0.31)	(0.19)	(0.20)	(0.15)	(0.24)	(0.18)
ΔY	0.18	0.28	0.16	0.28	-2.17	-2.19	-2.04	-2.22
	(0.36)	(0.57)	(0.33)	(0.55)	(0.57)	(0.55)	(0.52)	(0.54)
	(0.72)	(0.57)	(0.75)	(0.59)	(0.58)	(0.59)	(0.61)	(0.59)
ΔY^2	-2.7e-6	-4.6e-6	-2.1e-6	-4.5e-6	1.3e-4	1.4e-4	1.2e-4	1.4e-4
	(0.18)	(0.32)	(0.14)	(0.31)	(0.59)	(0.60)	(0.54)	(0.59)
	(0.86)	(0.75)	(0.89)	(0.76)	(0.56)	(0.56)	(0.59)	(0.56)
ΔY^3					-2.5e-9	-2.6e-9	-2.3e-9	-2.7e-9
					(0.60)	(0.62)	(0.55)	(0.61)
					(0.55)	(0.54)	(0.59)	(0.55)
ΔS		-11.48		-11.85		-15.35		-16.35
		(0.36)		(0.35)		(0.45)		(0.45)
		(0.73)		(0.73)		(0.66)		(0.66)
ΔI			-337.8	-9.69			-346.8	58.14
			(0.30)	(0.01)			(0.30)	(0.05)
			(0.77)	(0.99)			(0.77)	(0.96)
ECT^{b}	-0.46*	-0.63**	-0.51*	-0.62**	-0.52*	-0.60**	-0.55*	-0.60**
	(1.90)	(2.55)	(1.96)	(2.45)	(1.97)	(2.33)	(1.97)	(2.23)
	(0.07)	(0.02)	(0.06)	(0.02)	(0.06)	(0.03)	(0.06)	(0.04)
ΔD	-155.7	-113.5	-173.0	-115.2	-126.6	-115.9	-157.3	-112.9
	(1.20)	(0.89)	(1.12)	(0.75)	(0.94)	(0.88)	(0.99)	(0.72)
	(0.24)	(0.38)	(0.27)	(0.46)	(0.36)	(0.39)	(0.33)	(0.48)
adj. R^2	0.28	0.33	0.25	0.30	0.25	0.29	0.23	0.26
DW	1.47	1.46	1.46	1.46	1.52	1.51	1.50	1.50
N. of obs.	28	28	28	28	28	28	28	28
ρ	0.49	0.48	0.48	0.49	0.42	0.47	0.44	0.47

t-statistics and marginal significance levels in parenthesis
*, **, *** for significance at the 10%, 5% and 1% level
[b] ECT: particular error correction term, i.e. with or without Y^3, S and I.

Table A.13: Endogenous variable: first difference of PM

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
const	-0.10	-0.18	-0.13	-0.25	-0.15	-0.23	-0.16	-0.27
	(0.42)	(0.70)	(0.54)	(0.92)	(0.55)	(0.73)	(0.56)	(0.79)
	(0.68)	(0.49)	(0.59)	(0.37)	(0.58)	(0.47)	(0.58)	(0.44)
ΔY	3.7e-3*	3.6e-3*	3.7e-3*	3.8e-3*	-1.7e-2**	-1.6e-2*	-1.8e-2**	-1.8e-2**
	(1.98)	(1.91)	(1.94)	(1.98)	(2.19)	(2.05)	(2.37)	(2.42)
	(0.06)	(0.07)	(0.06)	(0.06)	(0.04)	(0.05)	(0.03)	(0.02)
ΔY^2	-1.1e-7*	-9.9e-8*	-1.1e-7*	-1.1e-7*	1.1e-6**	1.1e-6**	1.1e-6**	1.2e-11**
	(1.89)	(1.84)	(1.86)	(1.91)	(2.46)	(2.35)	(2.66)	(2.75)
	(0.07)	(0.08)	(0.07)	(0.07)	(0.02)	(0.03)	(0.01)	(0.01)
ΔY^3					-2.3e-11**	-2.2e-11**	-2.4e-11***	-2.5e-11***
					(2.73)	(2.61)	(2.90)	(3.00)
					(0.01)	(0.02)	(0.01)	(0.01)
ΔS		0.02		-0.02		-0.06		-0.10
		(0.12)		(0.14)		(0.43)		(0.73)
		(0.91)		(0.89)		(0.67)		(0.47)
ΔI			4.71	4.82			4.84	5.47
			(1.09)	(1.13)			(1.13)	(1.24)
			(0.29)	(0.27)			(0.27)	(0.23)
ECT[b]	-0.18***	-0.24***	-0.17***	-0.23***	-0.10***	-0.10***	-0.09***	-0.08***
	(4.80)	(4.92)	(4.71)	(4.88)	(2.87)	(2.87)	(2.84)	(2.82)
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
ΔD	1.30**	1.33***	1.73**	1.74***	1.29**	1.25**	1.74**	1.75**
	(2.63)	(2.76)	(2.70)	(2.86)	(2.58)	(2.47)	(2.72)	(2.71)
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)	(0.01)	(0.01)
adj. R^2	0.57	0.56	0.56	0.55	0.60	0.58	0.60	0.58
DW	1.64	1.73	1.64	1.75	1.81	1.83	1.81	1.84
N. of obs.	32	32	32	32	32	32	32	32
ρ	0.23	0.29	0.24	0.29	0.21	0.22	0.21	0.21

t-statistics and marginal significance levels in parenthesis
*, **, *** for significance at the 10%, 5% and 1% level
[b] ECT: particular error correction term, i.e. with or without Y^3, S and I.

Table A.14: Endogenous variable: first difference of CO

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
const	-6.34***	-5.31***	-5.78***	-5.43***	-7.94	-5.07***	-5.13***	-5.30***
	(3.63)	(3.02)	(3.34)	(2.93)	(0.05)	(2.92)	(2.95)	(2.89)
	(0.00)	(0.01)	(0.00)	(0.01)	(0.96)	(0.01)	(0.01)	(0.01)
ΔY	2.2e-2*	4.2e-3	1.4e-2	1.4e-3	1.3e-1**	1.9e-2	7.1e-2	2.1e-3
	(1.97)	(0.38)	(1.29)	(0.12)	(2.36)	(0.33)	(1.23)	(0.04)
	(0.06)	(0.71)	(0.21)	(0.91)	(0.03)	(0.75)	(0.23)	(0.97)
ΔY^2	-6.2e-7*	-1.6e-7	-4.2e-7	-7.3e-8	-7.0e-6*	-1.0e-6	-3.8e-6	-1.3e-7
	(1.80)	(0.51)	(1.29)	(0.23)	(2.01)	(0.30)	(1.08)	(0.04)
	(0.08)	(0.61)	(0.21)	(0.82)	(0.06)	(0.77)	(0.29)	(0.97)
ΔY^3					1.2e-10*	1.7e-11	6.5e-11	1.7e-12
					(1.73)	(0.26)	(0.94)	(0.02)
					(0.10)	(0.80)	(0.36)	(0.98)
ΔS		2.19**		2.19**		2.18**		2.12**
		(2.18)		(2.15)		(2.18)		(2.09)
		(0.04)		(0.04)		(0.04)		(0.05)
ΔI			-24.13	-10.37			-35.53	-9.43
			(0.68)	(0.32)			(1.02)	(0.29)
			(0.50)	(0.76)			(0.32)	(0.77)
ECT^{b}	-0.16	-0.25***	-0.36***	-0.27***	1.7e-4	-0.33***	-0.47***	-0.36***
	(1.61)	(3.37)	(2.84)	(3.60)	(0.01)	(3.21)	(3.25)	(3.45)
	(0.12)	(0.00)	(0.01)	(0.00)	(0.99)	(0.00)	(0.00)	(0.00)
ΔD	4.70	4.90	2.92	4.00	3.67	5.29	2.13	4.41
	(1.11)	(1.33)	(0.60)	(0.86)	(0.77)	(1.17)	(0.45)	(0.97)
	(0.28)	(0.19)	(0.56)	(0.40)	(0.45)	(0.16)	(0.66)	(0.34)
adj. R^2	0.15	0.45	0.25	0.47	0.29	0.47	0.29	0.49
DW	2.18	2.05	2.08	2.06	2.02	2.04	2.05	2.04
N. of obs.	32	32	32	32	32	32	32	32
ρ	0.43	0.29	0.46	0.28	0.14	0.30	0.47	0.29

t-statistics and marginal significance levels in parenthesis
*, **, *** for significance at the 10%, 5% and 1% level
[b] ECT: particular error correction term, i.e. with or without Y^3, S and I.

Table A.15: Endogenous variable: first difference of NH_3

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
const	8.5e-6	0.06	0.01	0.07	0.02	0.12**	-0.01	0.09**
	(0.00)	(1.04)	(0.19)	(1.48)	(0.74)	(2.74)	(0.27)	(2.78)
	(1.00)	(0.31)	(0.85)	(0.16)	(0.47)	(0.01)	(0.79)	(0.01)
ΔY	8.0e-4	1.0e-3	2.2e-3***	2.0e-3***	1.6e-2***	2.2e-2***	9.7e-3*	1.8e-2***
	(1.34)	(1.30)	(4.79)	(4.16)	(3.95)	(5.53)	(1.77)	(6.93)
	(0.20)	(0.21)	(0.00)	(0.00)	(0.00)	(0.00)	(0.10)	(0.00)
ΔY^2	-2.7e-8	-3.5e-8	-6.5e-8	-6.1e-8***	-8.2e-7	-1.2e-6	-4.7e-7	-9.5e-7***
	(1.73)	(1.72)	(5.34)	(4.92)	(3.71)	(5.28)	(1.60)	(6.55)
	(0.10)	(0.10)	(0.00)	(0.00)	(0.00)	(0.00)	(0.13)	(0.00)
ΔY^3					1.3e-11***	1.9e-11***	7.1e-12	1.6e-11***
					(3.41)	(4.97)	(1.38)	(6.10)
					(0.00)	(0.00)	(0.19)	(0.00)
ΔS		0.03		0.05*		0.11**		0.12***
		(0.83)		(1.75)		(2.75)		(4.08)
		(0.42)		(0.10)		(0.01)		(0.00)
ΔI			3.65***	2.86***			2.49***	2.66***
			(3.52)	(3.22)			(3.01)	(4.22)
			(0.00)	(0.01)			(0.01)	(0.00)
ECT^{b}	-0.19**	-0.85***	-0.77***	-0.95***	-0.44***	-0.41***	-1.22***	-0.58***
	(2.50)	(4.57)	(2.95)	(4.08)	(3.17)	(3.35)	(4.90)	(4.08)
	(0.02)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)
ΔD	-0.46***	-0.26**	-0.02	-0.02	-0.45***	-0.30***	-0.05	0.01
	(3.80)	(2.59)	(0.16)	(0.19)	(4.18)	(2.90)	(0.43)	(0.07)
	(0.00)	(0.02)	(0.88)	(0.85)	(0.00)	(0.01)	(0.67)	(0.95)
adj. R^2	0.69	0.62	0.69	0.72	0.76	0.83	0.72	0.92
DW	2.03	2.28	1.95	1.77	2.04	1.98	1.87	2.08
N. of obs.	23	23	23	23	23	23	23	23
ρ	-0.34	0.55	-0.04	0.12	-0.36	-0.35	0.26	-0.40

t-statistics and marginal significance levels in parenthesis
*, **, *** for significance at the 10%, 5% and 1% level
[b] ECT: particular error correction term, i.e. with or without Y^3, S and I.

Table A.16: Endogenous variable: first difference of CH_4

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
const	-71.19	-1.76**	-70.94	-1.76**	38.61	-1.81***	-20.40	-1.80**
	(0.93)	(2.81)	(1.01)	(2.71)	(0.33)	(2.96)	(0.22)	(2.83)
	(0.37)	(0.01)	(0.33)	(0.02)	(0.75)	(0.01)	(0.83)	(0.01)
ΔY	7.0e-4	7.3e-4	1.7e-3	6.0e-4	-8.7e-2	-4.5e-2	-7.0e-2	-4.5e-2
	(0.08)	(0.11)	(0.20)	(0.09)	(1.06)	(0.73)	(0.73)	(0.71)
	(0.94)	(0.91)	(0.85)	(0.93)	(0.30)	(0.48)	(0.48)	(0.49)
ΔY^2	-1.9e-19	-1.4e-8	-3.3e-8	-1.1e-8	4.6e-6	5.4e-6	3.8e-6	5.4e-6
	(0.01)	(0.08)	(0.14)	(0.06)	(1.05)	(0.74)	(0.73)	(0.72)
	(0.99)	(0.94)	(0.89)	(0.95)	(0.31)	(0.47)	(0.48)	(0.48)
ΔY^3					-8.7e-11	-4.3e-11	-6.6e-11	-4.3e-11
					(1.04)	(0.76)	(0.72)	(0.73)
					(0.31)	(0.46)	(0.48)	(0.48)
ΔS		0.17		0.17		0.20		0.20
		(0.73)		(0.70)		(0.83)		(0.80)
		(0.48)		(0.50)		(0.42)		(0.43)
ΔI			8.68	-0.44			6.84	-0.80
			(0.84)	(0.06)			(0.68)	(0.10)
			(0.42)	(0.96)			(0.51)	(0.92)
ECT^{b}	0.05	-0.59***	0.04	-0.59***	-0.03	-0.58***	0.01	-0.58***
	(0.90)	(4.11)	(0.99)	(3.89)	(0.35)	(3.89)	(0.20)	(3.68)
	(0.38)	(0.00)	(0.34)	(0.00)	(0.74)	(0.00)	(0.85)	(0.00)
ΔD	-17.68***	-17.12***	-17.07***	-17.15***	-17.16***	-17.13***	-16.83***	-17.18***
	(16.34)	(22.51)	(12.35)	(18.23)	(16.57)	(21.64)	(12.75)	(17.49)
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
adj. R^2	0.94	0.97	0.94	0.97	0.95	0.97	0.94	0.97
DW	1.70	1.88	1.73	1.88	1.80	1.83	1.79	1.83
N. of obs.	23	23	23	23	23	23	23	23
ρ	0.52	0.68	0.46	0.68	0.72	0.65	0.63	0.65

t-statistics and marginal significance levels in parenthesis

*, **, *** for significance at the 10%, 5% and 1% level

[b] ECT: particular error correction term, i.e. with or without Y^3, S and I.

Table A.17: Endogenous variable: first difference of NMVOC

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
const	-0.83	-1.46**	-0.77	-1.34**	-0.71	-1.22*	-0.66	-1.11*
	(1.29)	(2.23)	(1.11)	(2.10)	(1.13)	(1.96)	(0.99)	(1.79)
	(0.21)	(0.04)	(0.28)	(0.05)	(0.27)	(0.06)	(0.33)	(0.09)
ΔY	-8.8e-5	-1.9e-3	9.5e-5	-1.8e-3	2.0e-3	2.9e-3	2.1e-3	2.8e-3
	(0.07)	(1.39)	(0.07)	(1.26)	(0.30)	(0.41)	(0.31)	(0.38)
	(0.95)	(0.18)	(0.95)	(0.22)	(0.77)	(0.69)	(0.76)	(0.71)
ΔY^2	-1.6e-8	3.5e-8	-2.1e-8	3.1e-8	-1.4e-7	-2.7e-7	-1.4e-7	-2.5e-7
	(0.38)	(0.84)	(0.49)	(0.72)	(0.34)	(0.60)	(0.34)	(0.56)
	(0.71)	(0.41)	(0.63)	(0.48)	(0.74)	(0.55)	(0.74)	(0.58)
ΔY^3					2.4-12	5.9e-12	2.3e-12	5.5e-12
					(0.29)	(0.67)	(0.27)	(0.61)
					(0.78)	(0.51)	(0.79)	(0.55)
ΔS		0.19*		0.20*		0.22**		0.23**
		(1.88)		(1.88)		(2.07)		(2.10)
		(0.07)		(0.07)		(0.05)		(0.05)
ΔI			-0.04	-0.24			-0.78	-1.00
			(0.01)	(0.07)			(0.23)	(0.28)
			(0.99)	(0.95)			(0.82)	(0.78)
ECT^{b}	-0.50***	-0.45***	-0.51***	-0.46***	-0.52***	-0.46***	-0.54***	-0.48***
	(4.63)	(4.20)	(4.46)	(4.13)	(4.41)	(3.94)	(4.27)	(3.89)
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
ΔD	0.25	0.37	0.25	0.35	0.26	0.40	0.20	0.33
	(0.65)	(0.94)	(0.53)	(0.74)	(0.67)	(1.01)	(0.43)	(0.68)
	(0.52)	(0.36)	(0.60)	(0.47)	(0.51)	(0.32)	(0.67)	(0.50)
adj. R^2	0.43	0.40	0.41	0.38	0.42	0.40	0.40	0.38
DW	1.97	2.13	1.99	2.13	1.92	2.11	1.91	2.06
N. of obs.	32	32	32	32	32	32	32	32
ρ	0.87	0.86	0.88	0.86	0.87	0.86	0.88	0.86

t-statistics and marginal significance levels in parenthesis
*, **, *** for significance at the 10%, 5% and 1% level
[b] ECT: particular error correction term, i.e. with or without Y^3, S and I.

References

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