Empirical Analysis of National Income and So_2 Emissions in Selected European Countries

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Summary

Data on GDP per capita and sulfur emissions for twelve European countries were analyzed to determine the relationship between emissions and income in these countries. As a whole, the relationship between sulfur emissions and per capita income is a fourth order polynomial and not a quadratic one as found in most studies. When countries were examined individually, seven out of the twelve countries depicted the same relationship. Looking closely at the regulations restricting sulfur emissions in the UK, the impact of all regulations supported the inverted U-shaped Kuznets curve. Individually, however, it is found that only two regulations have statistically significant impacts: Smoke Abatement Act in 1926 (reduced the amount of sulfur associated with a given level of GDP); and Clean Air Act in 1956 (increased the amount of sulfur emissions associated with a given level of GDP).

Keywords: Environmental Kuznet's Curve, Europe, Sulfur dioxide emission

JEL: C33, Q53, Q58

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1. Introduction

In this paper the following work is reported:

A. Data were collected on GDP and GDP per capita going back to 1850 for selected European Countries. Data were also collected on sulfur emissions for the same period and for the same countries. The data were analyzed to see what long term relationships could be ascertained between the emissions and economic output and growth.

B. Econometric analyses were employed to test the hypothesis that the environmental Kuznets curve exists in the selected European countries. Furthermore, the empirical analyses allow us: to obtain a point estimate of the impact of income on sulfur emissions, and regulations on income; and to determine whether the impacts are significant statistically. The particularly steps taken are:
   1. Panel regressions of sulfur emissions against GDP and higher order terms of GDP.

   2. Separate Ordinary Least Squares (OLS) estimations for each of the 12 countries.

   3. Using only the UK data, regression of sulfur emissions against GDP and higher order terms of GDP, as well as dummies for years in which new regulations were passed to restrict sulfur emissions. Also, the effect of regulations on per capita income was empirically analyzed.

The paper reports on the results of this work. Section 2 describes the data. Section 3 describes the relationships between emissions and GDP, and Section 4 reports on the environmental legislation relating to sulfur and its possible impacts on GDP. Section 5 shows the results of econometric analysis on the relationships among per capita income, sulfur emissions and regulations. Section 6 concludes.

Annex 1 provides the raw data and list of air regulations. Annex 2 provides the graphs.

2. The Data

2.1 Per capita Gross Domestic Product (1820, 1850, 1870-2001)

The per capita GDP data of the European countries were gathered from Angus Maddison's web page at http://www.eco.rug.nl/~Maddison/. Income is measured in 1990 international Geary-Khamis dollars[1]. In some cases, gaps in the GDP estimates are filled by imputation. For example, per capita GDP movement in Switzerland was assumed to be parallel with that of Germany for 1871-1998. Data for countries like Finland and Italy for 1850 were interpolated between the 1820 and 1870 estimates for these countries.

[1] Or purchasing power parity (PPP) dollars

2.2 Sulfur Emissions (1850 to 1999)

The sulfur emissions data for the European countries were obtained from David Stern's web page at http://www.rpi.edu/~sternd/datasite.html. Sulfur data estimates are obtained in two ways: (a) by compiling available data from published sources; and (b) by using a decomposition model, the first differences Kuznets curve model, or simple extrapolation of the growth rate of emissions to impute unavailable data. The primary source for the data between 1850 and 1979 is the ASL and Associates database; while the data between 1980 and 1999 were primarily obtained from the Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air pollutants in Europe (EMEP). The estimates of sulfur emissions have a common unit of thousands of metric tons per annum. A more detailed description about the data and estimation methods can be found in David Stern's website[2].

For the broader purposes of this study, sulfur is used as a proxy for environmental pollution. The intent is to see how emissions of a major pollutant respond to regulations and how emissions are related to GDP. Although one would not expect exactly the same effects for other pollutants, the general lessons learnt from this analysis can be expected to apply more broadly.

The GDP and sulfur data are given in Annex One for the following 12 countries: Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, Sweden, Switzerland and the United Kingdom.

The *per capita* GDP from 1820 to 2001 are given in Annex Table 1, which is a remarkable dataset, assembled with great effort and care by Angus Maddison. It shows that the *per capita* GDP terms, which is a measure of economic living standards, rose by an average of 15.7 times over these 181 years, with a minimum of 11.8 for the UK and 25.2 for Finland (the UK was already quite industrialized in 1820 and Finland was largely agricultural at that time). The average annual growth rate for the 12 countries is 1.5 percent and the rates are much more closely bunched than the ratios of 2001 to 1820 *per capita* GDP. The lowest rate is 1.4 percent (UK) and the highest is 1.8 percent (Finland).

The sulfur emissions data are given from 1850 to 1999 in Annex Table 2. Unlike the GDP data, they do not show a general upward trend, but rather an increase up to a certain year and then decline. The year of maximum emissions varies, but for 9 of the countries it is in the period 1970-1985. For the UK it was 1955, for Switzerland, 1939 and for Austria, 1908. The growth in emissions over the whole period is small in most countries and even negative in the case of the UK – i.e., the emissions of sulfur in 1999 in that country were less than in 1850!

From this, one can see that emissions and GDP are not positively related over the whole period. In the next section we will look at the relationship in more detail.

[2] http://www.rpi.edu/~sternd/Sulfur.pdf

3. Relationships Between *Per Capita* GDP and Sulfur.

Figures A1 to A12 in Annex Two show the sharp disjuncture in the relationship by country. Essentially after the Second World War *per capita* GDP started to grow quite sharply but sulfur emissions, which hitherto had grown faster than this measure of GDP, started to grow more slowly and eventually to decline. The pattern is related in each country, with the most pronounced declines post 1970s (with the exception of Switzerland the UK, where the decline began much earlier.

Figures B1 to B12 plot the real *per capita* GDP against the level of sulfur emissions. As expected, the relationship shows something of an "inverted U". Emissions rise against *per capita* GDP to some point, after which as the GDP increases, emissions tail off. This is of course the well-known 'Environmental Kuznets Curve' relationship but we should be careful. All the graphs show more than one turning point, suggesting a higher order polynomial as being appropriate. Further work using econometric techniques will be needed to analyze this relationship.

Figures C1 to C12 plot the annual rates of growth of sulfur and real *per capita* GDP. The graphs are interesting in showing a short-term correlation (i.e., year on year growth in GDP correlates with year on year growth in sulfur). However, since the 1950s, the relationship has weakened and diverted in terms of levels. While it is still true that the annual growth rates are correlated, and a year when GDP *per capita* growth increases is also one when sulfur growth increases, the latter is from a much lower base growth rate – often from a negative growth rate.

Figures D1 to D12 plot the Percentage growth in sulfur emissions against the percentage growth in *per capita* GDP. The purpose here is to show a lack of clear relationship. The points are to found predominantly in the positive sulfur growth/positive GDP *per capita* growth **and** negative sulfur growth/positive GDP *per capita* growth. In Figure E1 we show, for the United Kingdom, the points pre 1957 and post 1957 in different colors. We do that to show that the post 1957 points are mainly in the negative sulfur growth/positive GDP *per capita* growth quadrant.

4. Impact of Environmental Legislation on Sulfur.

Annex Table 3 gives the key dates of legislation that could have impacted on sulfur emissions in the UK from 1820 onwards and *Annex* Table 4 gives the same (but less complete) information for other European countries. The UK legislation is most instructive in showing that attempts to control sulfur emissions go back to 1821 -- almost as far back as the records for GDP. Indeed there were measures earlier than that – in the 13th Century for example - but they are not recorded here, as our GDP series do not go back that far.

The interesting question is how these Acts have affected the sulfur-GDP relationship. Figure E2 in Annex Two is plotted for the UK but with the dates of some of the key Acts shown. The most pronounced decline in emissions took place in 1926, following the smoke abatement act, but this was only a temporary drop returned to more or less the same levels after that. Years of the Acts from 1956 onwards show a steady decline in emissions but no sudden jump in the *per capita* GDP series. We can conclude from this that the controls on sulfur have made a major contribution to reducing this pollutant, but have not made a major dent in the growth of real living standards.

This analysis is interesting and very instructive about long-term relationships. The lesson for the carbon debate is that it is possible to reduce emissions of a key byproduct of a modern economy, without sacrificing long-term growth. The analysis can and should be sharpened with econometric work to see when, and to what extent, the legislation has influenced GDP and GDP growth, as presented in the subsequent sections.

5. Econometric model and results

5.1 All Countries

Table 1 gives the descriptive statistics for *per capita* GDP and *per capita* sulfur emissions for the 12 countries individually and for them as a group. Using the information from all countries, the panel data estimation technique is used to deal with inter-country heterogeneity in the analysis. An attractive facet of panel data is the creation of more variability by combining variation across countries with variation over time thus alleviating multi-collinearity problems and providing a more efficient estimation (Kennedy, 2000). Several other advantages of using the panel data are mentioned in the literature.

There are two panel data estimations: fixed effects and random effects. The fixed effects estimator allows the intercept to differ across the cross-section units by estimating different constants for each cross-section. The random effects model also assumes a different intercept for each cross-section, but the intercepts are interpreted in a different manner. This model considers the intercepts as having been drawn from a 'bowl' of possible intercepts. Consequently, these intercepts may be taken as random and treated as if they were part of the error term. As a result, the specification has an overall intercept, a set of explanatory variables with their respective coefficients, and a composite error term. The composite error has two parts: a random intercept term and the traditional random error (Kennedy, 2000). To determine which estimation method is appropriate given the available information, we begin by testing the null hypothesis that the intercepts are equal. If the null is accepted, the data are pooled and Ordinary Least Squares (OLS) is the appropriate estimation method to employ. If the null hypothesis is rejected, a Hausman test is applied to test if the random effects estimator is unbiased – this means that there is no correlation between the composite error and the regressor. If the null is accepted, the random effects estimator is used; if the null is rejected, the fixed effects estimator is used.

Most studies model the emissions as a quadratic or cubic function of per capita income. However, this paper establishes the model based on the general distribution of the raw data. Figure 1 shows the plot of per capita income against per capita sulfur emissions in all of the twelve countries.

The appropriate order of the function is not very clear from visually inspecting the data; hence, country-level emissions were modeled in two ways: as a quadratic function of per capita income, and as a 4th order polynomial function of per capita income. Equations 1 and 2 give the two specifications. These will be compared later to determine which one is a better fit for the data.

$$SULFURPC_{it} = \beta_0 + \phi_j CS_i + \delta_k TS_i + \beta_2 GDPPC_{it} + \beta_3 GDPPC_{it}^2 + \varepsilon_{it} \qquad \text{(Eq. 1)}$$

$$SULFURPC_{it} = \theta_0 + \varphi_j CS_i + \sigma_k TS_i + \theta_3 GDPPC_{it} + \theta_4 GDPPC_{it}^2 + \theta_4 GDPPC_{it}^3 + \theta_4 GDPPC_{it}^4 + \mu_{it} \qquad \text{(Eq. 2)}$$

where CSi - country dummy variable
TSi – time dummy variable
i – country = Austria, …, UK
t – year = 1870, 1871, …, 1999

Note that other studies use only a dummy variable for time. However, this paper also included a dummy variable for each country in order to deal with the heterogeneity across countries.

Equations 1 and 2 were run and an F-test was performed on the country and time dummy variables to determine whether a pooled or panel regression is appropriate. The F-test rejects the null hypothesis of homogeneity across each country and each time period, which indicates that OLS is not applicable but panel data estimation via fixed effects or random effects. Then, the Hausman test was employed to test the null hypothesis that there is no correlation between the composite error and explanatory variables. Under the null hypothesis, the random effects model is applicable. The Hausman test rejected the null hypothesis, which means that the fixed effects model is appropriate. Therefore, only the fixed coefficient estimates are provided (Table 2).

Furthermore, the White Test was performed to test for heteroskedasticity. The null hypothesis of homoskedasticity was rejected, which means that even if the estimators remain unbiased, their significance is no longer reliable because the variance is biased. Therefore, a White heteroskedasticity consistent covariance estimator was used in the fixed effects model to generate standard errors that are robust to heteroskedasticity.

Based on the adjusted R-squared, the per capita emissions as a 4th order polynomial function of per capita income (Eq. 2) is a better fit for the available data on the 12 European countries. Figure 2 plots the predicted dependent variable against per capita income.3

5.2 Individual countries

Individual regressions were performed on each country to closely examine the environmental Kuznet's curve evidence at the country level. The model specifications used are the following:

[3] The predicted dependent variable was derived by using the intercept and slope coefficients only.

$$SULFURPC_{it} = \alpha + \beta_1 GDPPC_{it} + \beta_2 GDPPC_{it}^2 + \varepsilon_{it} \quad \text{(Eq. 3)}$$

$$SULFURPC_{it} = \phi + \theta_1 GDPPC_{it} + \theta_2 GDPPC_{it}^2 + \theta_3 GDPPC_{it}^3 + \theta_4 GDPPC_{it}^4 + \mu_{it} \quad \text{(Eq. 4)}$$

Ordinary Least Squares was used to estimate the above equations. Table 3 shows the summary of country-level coefficient estimates. The choice of the model for a given country was based on the following criteria: (a) comparing the relative magnitude of adjusted R-squared; and (b) testing the null hypothesis that the third and fourth order income terms are insignificantly different from zero. For 4 countries (Finland, Germany, Italy and Netherlands), Equation 3 was employed because: (a) its adjusted R-squared is higher relative to Equation 4; and (b) F-test on the 3rd and 4th order income variables are insignificantly different from zero at 10% level.

5.3 United Kingdom data and air regulations

There is available information for United Kingdom on regulations focusing on air quality (see Annex Tables 3 and 4 for details). These regulations have a component targeted to reduce sulfur emissions, hence they were introduced as explanatory variables in the estimation to determine empirically their impact on sulfur emissions in the UK. The model specifications explored are those that capture the short-term effects of the regulation (Eq. 5) and the long run effects of the regulation (Eq. 6):

$$Sulfur = \alpha + \beta_1 GDPPC + \beta_2 GDPPC^2 + \beta_3 GDPPC^3 + \beta_4 GDPPC^4 + \theta_k AR_t + \varepsilon \quad \text{(Eq. 5)}$$

where AR_t – dummy variable for the *t* period when a particular air regulation was implemented;
AR_t = 1 if *t; zero* otherwise
t – year = 1874, 1926, 1956, 1968, 1972, 1974, 1979, 1980, ….

$$Sulfur = \phi_0 + \varphi_1 GDPPC + \phi_2 GDPPC^2 + \phi_3 GDPPC^3 + \phi_4 GDPPC^4 + \sigma_k AR_t + \varepsilon \quad \text{(Eq. 6)}$$

where AR_t – dummy variable; To represent the long-term effect of an implemented an air regulation, a dummy variable is introduced, where a value of "1" is assigned for the starting year of the regulation and the years after that; and "zero" otherwise.

t – start year = 1874, 1926, 1956, 1968, 1972, 1974, 1979, 1980, ….

Table 4 shows the regression results from Equation 5 and Equation 6. The coefficient estimates of per capita GDP variables from both equations are statistically significant at 1%.

Each dummy variable in Equation 5 was introduced to capture any **short-term effect** of a particular air regulation. This means that the effect of air regulation on sulfur emissions is experienced only in the year it was implemented. **Regression results show that only 2 of the dummy variables have coefficient estimates that are statistically significant at 10% level of significance.** These are for the air regulation implemented in *1926* and *1956*. In contrast, the dummy variables in Equation 6 intend to capture any **long-term effect** of a particular air regulation, i.e., the regulation's impact is experienced on the year it was implemented and on the succeeding years. **Regression results show that only 1 out of the 17 dummy variables have coefficient estimates that are statistically significant at 1% level of significance. This is for the air regulation implemented in *1926*.**

An F-test on the statistically insignificant coefficient estimates was performed to test the null hypothesis that the joint effect of the corresponding variables is insignificantly different from zero[4]. For both equations, the test result rejected the null hypothesis at 1% level of significance. This means that although each variable has insignificant individual effects, the said variables have a *collective* significant effect on the dependent variable (sulfur emissions). Furthermore, results from both equations accept the environmental Kuznets curve hypothesis – that there is an inverted U-shape relationship between an environmental degradation indicator (e.g., sulfur emission) and per capita income.

5.4 Effect of Regulation on the Per Capita Income

The above analysis looks at how the sulfur regulations affected the environmental Kuznets curve and finds that, in general, the effects have been small with most regulations not having any effects on the sulfur/GDP relationship, but one (1926) reducing the amount of sulfur associated with a given level of GDP and one (1956) increasing the amount of sulfur associated with a given level of GDP. In neither case, however, has the direct relationship between GDP and the regulation been examined. This is done in below, where the short-term and long-term effects of the regulations on the per capita GDP growth of United Kingdom are estimated. The difference between short-term and long-term effects is provided by the assignment of dummy variables. The general model is as follows:

$$UK\_GDPPC = \beta_0 + \beta_1 t + \beta_2 t^2 + \beta_3 t^3 + \phi_j AR_j + \varepsilon \qquad \text{(Eq. 7)}$$

where t – trend variable[5]

AR_j – dummy variable for the *j* period when a particular air regulation was implemented

For the short-term effect:

$AR_j = 1$ if *j; zero* otherwise

j – year = 1874, 1926, 1956, 1968, 1972, 1974, 1979, 1980, ….

This means that the effect of air regulation on sulfur emissions is experienced only in the year it was implemented.

For the long-term effect:

AR_j – 1 is assigned for the starting year of the regulation and the years after that; and "zero" otherwise.

j – start year = 1874, 1926, 1956, 1968, 1972, 1974, 1979, 1980, ….

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[4] From Eq. 5, Ho: $\hat{\theta}_1 = \hat{\theta}_4 = ... = \hat{\theta}_{17} = 0$; from Eq. 6, Ho: $\hat{\theta}_1 = \hat{\theta}_3 = ... = \hat{\theta}_{17} = 0$

[5] Higher order trend variables (e.g., t^4, t^5, …) were found to be statistically insignificant.

This infers that the regulation's impact is experienced from the year it was implemented and carried over the succeeding years.

A check for the appropriate functional form, through Box-Cox regression, was conducted. This is done to find out if a linear or a semi-log functional form is more appropriate to examine the model described above. The null hypothesis of linearity (supporting a linear form) was accepted at 5% level of significance. Table 5 presents the regression results that capture the regulations' short-term and long-term effects. Significant coefficient estimates at 10% level were highlighted.[6]

The model that incorporates *the long-term effects of the regulations appears to be a better fit* for the available data based on the R-squared and Adjusted R-squared values, which are both higher relative to those of the model with short-term regulation effects. The trend variable in this model infers a sustained upward or downward movement in the behavior of per capita GDP. Results show that over the period 1870 to 1999, on average, the per capita GDP increased at the absolute rate of about 71 GK$ per annum. Therefore, over the said period, there was an upward trend in per capita GDP. Now, looking at the regulation variables, the regulations that were implemented on 1980 and 1990 have a significant long-term negative impact on per capita GDP; while those that were implemented on 1985 and 1988 have a significant long-term positive impact.

It must be noted that interpreting the results in Table 5 should be treated with utmost caution because other variables that have significant influence on per capita GDP were not included in the estimation due to unavailability; for example, capital share, labor share, total factor productivity, etc. By not including these variables, the coefficient estimates are biased. Furthermore, there are other variables that may serve as proxy to environmental regulation such as government expenditures for pollution abatement and control.

6. Conclusions

This report has the following results:

6.1 For the 12 European countries as a whole, the appropriate relationship between per capita sulfur emissions and GDP is a fourth order polynomial and not a quadratic one. The best fit equation implies that

a. the fixed effects regression has a better fit than the random effects regression. With fixed effects, the intercept terms for each country are allowed to vary implying that the per capita sulfur emissions–GDP per capita relationship will differ from country to country by a shift factor;
b. the 'turning point for the sulfur-GDP relationship is much lower than previously thought – around $7,000 and not $15,000; and
c. there is second turning point at a much higher income level – about $25,000, but with lower sulfur emissions.

[6] Regression results for the semi-log model are presented in the Appendix.

6.2 The individual country regressions support a fourth order polynomial for all the countries except Austria, Finland, Germany, Italy and the Netherlands. Of these five, there is no relationship for Austria and for the other four, the relationship is a quadratic one. For the countries where there is a quadratic fit the turning point is between approximately $10,000 and $14,000; whereas for the countries with a fourth order fit, the turning point is between about $5,000 and $10,000.

6.3 For the UK, an analysis was carried out to see if regulations limiting sulfur emissions had an impact on the relationship between sulfur and GDP. Individually only two regulations had any impact – the one in 1926 reduced the amount of sulfur associated with a given level of GDP and one in 1956 increased the amount of sulfur associated with a given level of GDP. The other regulations did not have any impact although as a group all the regulations did shift the Kuznets curve down.

6.4 An attempt was made to see if there was any direct relationship between GDP and the sulfur regulations. The simple trend analysis showed no impact for most regulations. The regulation**s** that were implemented on 1980 and 1990 have a significant long-term negative impact on per capita GDP; while those that were implemented on 1985 and 1988 have a significant long-term positive impact. These results should be treated with utmost caution because other variables that have significant influence on per capita GDP were not included in the estimation. Excluding these variables in the estimation will yield biased coefficient estimates. Also, there are other variables that may serve as proxy to environmental regulation; for example, pollution abatement and control expenditures by the government.

6.5 In general, the regression results support the view that a sharp decline in sulfur emissions in the latter part of the 20th century was consistent with continued growth in GDP, and the individual regulations limiting emissions did not have a major impact on the growth of GDP.

6.6 It is difficult to see why some countries show fourth order relationship without undertaking some further work. In some countries sulfur emissions declined earlier while GDP continued to grow, and then, there was a second phase of growth when emissions started to rise again. This needs further investigation. Also, further work is needed in terms of investigating the reasons why some air regulations have negative impacts on GDP. A closer examination of the institutional changes, technological changes and political economy changes that occurred over the years in the focus countries may be warranted.

Table 1. Descriptive statistics.

Countries	Per capita GDP				Per capita sulfur			
	Mean	Std dev	Max	Min	Mean	Std dev	Max	Min
All 12 countries	7,192	5,897	31,773	1,110	0.023	0.019	0.134	0.001
Austria	6,105	5,161	19,608	1,725	0.037	0.027	0.134	0.003
Belgium	7,031	4,897	19,978	2,682	0.029	0.009	0.049	0.009
Denmark	7,599	5,807	22,417	1,993	0.020	0.009	0.044	0.004
Finland	5,458	5,158	19,058	1,110	0.016	0.016	0.061	0.001
France	6,799	5,549	20,269	1,876	0.018	0.007	0.030	0.006
Germany	10,139	8,648	31,773	2,217	0.036	0.011	0.051	0.005
Italy	5,615	5,121	18,432	1,467	0.013	0.009	0.038	0.003
Netherlands	7,328	5,110	20,976	2,649	0.012	0.006	0.025	0.003
Norway	6,587	6,214	23,922	1,432	0.013	0.007	0.030	0.003
Switzerland	6,940	5,529	19,652	1,664	0.014	0.007	0.031	0.003
Sweden	9,076	6,607	21,886	2,176	0.011	0.006	0.026	0.002
United Kingdom	7,631	4,306	19,223	3,191	0.058	0.015	0.077	0.010

Notes: Sulfur emission is measured in metric ton.

Table 2. Summary of coefficient estimates from Equations 1 and 2.

Explanatory Variables	Quadratic	4^{th} Order
GDPPC	1.88E-06	1.83E-05
$GDPPC^2$	-6.17E-11	-2.20E-09
$GDPPC^3$	-	1.00E-13
$GDPPC^4$	-	-1.52E-18
Turning point of the peak	GK$15236.33	GK$7061.001
Adjusted R-squared	0.65	0.69
F-test statistic for no fixed effects (DF)	19.15 (140; 1417)	25.46 (140; 1415)
Hausman test statistic for random effects (DF)	180.22 (2)	140.25 (4)

Figure 1. Plot of per capita income and per capita sulfur emission, all 12 countries.

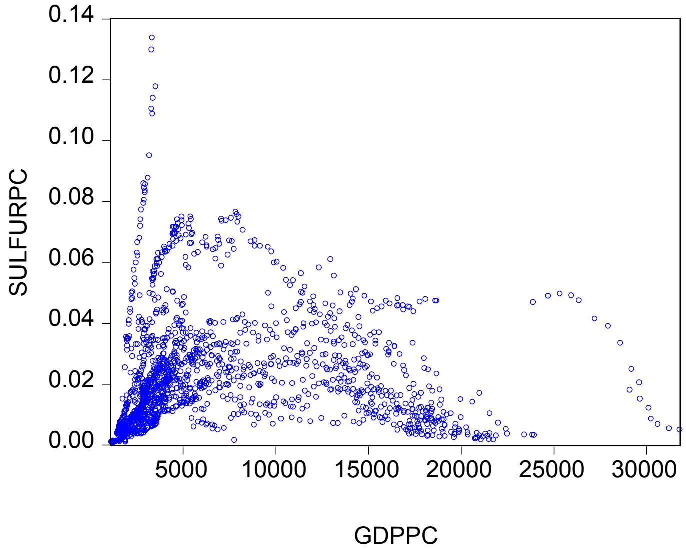

Figure 2. Plot of predicted sulfur emission per capita and income per capita.

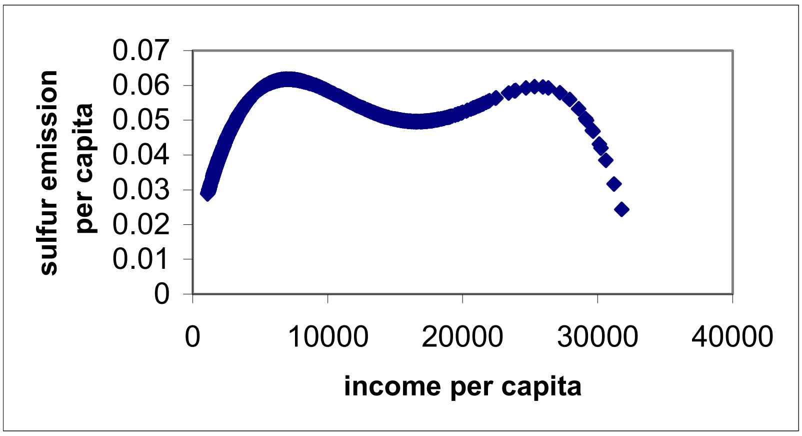

Table 3. Summary of coefficient estimates, country level.

Countries	Coefficient estimates				Maximum
	GDPPC	$GDPPC^2$	$GDPPC^3$	$GDPPC^4$	
Quadratic Model					
Finland	1.10E-05	-5.30E-10	-	-	GK$10,386
Germany	2.81E-06	-9.67E-11	-	-	GK$14,553
Italy	7.31E-06	-3.61E-10	-	-	GK$10,125
Netherlands	5.43E-06	-2.61E-10	-	-	GK$10,418
4^{th} order Model					
Countries	**GDPPC**	**$GDPPC^2$**	**$GDPPC^3$**	**$GDPPC^4$**	**Maximum**
Austria	15.2E-6	-3.5E-9	256.6E-115	-6.2E-18	GK$3,145
Belgium	2.52E-05	-2.96E-09	1.43E-13	-2.68E-18	GK$7,894
Denmark	2.15E-05	-2.94E-09	1.70E-13	-3.54E-18	GK$7,965
France	1.50E-05	-1.76E-09	8.889E-14	-1.80E-18	GK$10,000
Norway	9.08E-06	-1.45E-09	8.44E-14	-1.66E-18	GK$5,075
Sweden	2.39E-05	-4.12E-09	2.86E-13	-6.92E-18	GK$5,439
Switzerland	2.33E-05	-3.47E-09	1.98E-13	-3.91E-18	GK$6,089
UK	3.71E-05	-5.05E-09	2.62E-13	-4.95E-18	GK$6,183

Table 4. Regression results, impact of per capita income and air regulations on sulfur emissions in the United Kingdom.

Variable	UK-Short Term		UK-Long Term	
	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	-4.10E+03	-6.49E+00	-1.87E-02	-1.11E+00
UK_GDPPC	2.76E+00	8.63E+00	3.05E-05	3.15E+00
UK_GDPPC^2	-3.41E-04	-6.24E+00	-2.83E-09	-1.53E+00
UK_GDPPC^3	1.69E-08	4.45E+00	5.98E-14	4.16E-01
UK_GDPPC^4	-3.08E-13	-3.39E+00	7.51E-19	1.99E-01
AR1874	-1.47E+02	-6.02E-01	1.20E-03	4.97E-01
AR1926	-1.30E+03	-5.39E+00	-1.23E-02	-7.34E+00
AR1956	4.08E+02	1.68E+00	3.11E-03	1.27E+00
AR1968	1.80E+02	7.33E-01	-4.76E-03	-1.45E+00
AR1972	-2.13E+02	-8.67E-01	-1.30E-03	-3.26E-01
AR1974	-1.61E+02	-6.58E-01	1.67E-04	4.62E-02
AR1979	4.28E+01	1.73E-01	3.42E-03	6.85E-01
AR1980	7.21E+01	2.92E-01	-4.36E-03	-9.67E-01
AR1985	-1.75E+02	-6.98E-01	4.71E-03	9.27E-01
AR1988	3.49E+02	1.35E+00	3.87E-03	6.05E-01
AR1989	3.57E+02	1.38E+00	-8.42E-04	-1.42E-01
AR1990	3.70E+02	1.43E+00	-1.63E-03	-3.37E-01
AR1993	4.48E+01	1.73E-01	-4.14E-03	-8.62E-01
AR1994	-1.55E+01	-5.92E-02	-3.95E-03	-5.99E-01
AR1995	-6.63E+01	-2.52E-01	-5.57E-03	-8.96E-01
AR1997	-1.35E+02	-4.71E-01	-9.89E-03	-1.11E+00
AR1999	-5.39E+01	-1.54E-01	-8.29E-03	-1.04E+00
R-squared	0.91		0.94	
Adjusted R-squared	0.89		0.93	

Table 5. Regression results, impact of air regulations on per capita income.

Variable	Short Term Effect			Long Term Effect		
	Coefficient	t-Statistic	Prob.	Coefficient	t-Statistic	Prob.
Constant	2987.58	22.89	1.93E-43	3129.16	18.68	9.05E-36
T	66.12	7.52	1.69E-11	74.00	4.20	5.54E-05
T2	-1.13	-7.05	1.69E-10	-1.26	-2.96	0.00
T3	0.01	14.49	3.62E-27	0.01	4.48	1.88E-05
AR1874	94.61	0.27	0.79	-268.38	-1.16	0.25
AR1926	-380.73	-1.10	0.27	31.68	0.18	0.86
AR1956	-240.09	-0.69	0.49	-34.33	-0.17	0.87
AR1968	243.25	0.70	0.48	331.71	1.44	0.15
AR1972	293.56	0.85	0.40	363.07	1.26	0.21
AR1974	413.77	1.19	0.23	-251.06	-0.88	0.38
AR1979	512.36	1.47	0.14	230.76	0.63	0.53
AR1980	17.62	0.05	0.96	-805.51	-2.19	0.03
AR1985	-144.30	-0.41	0.68	472.43	1.73	0.09
AR1988	915.34	2.59	0.01	753.97	1.97	0.05
AR1989	895.91	2.52	0.01	-17.90	-0.04	0.97
AR1990	583.04	1.63	0.11	-864.07	-2.25	0.03
AR1993	-459.92	-1.27	0.21	-486.72	-1.27	0.21
AR1994	-146.27	-0.40	0.69	314.63	0.68	0.50
AR1995	-86.42	-0.24	0.81	78.06	0.19	0.85
AR1997	141.58	0.38	0.71	257.74	0.76	0.45
AR1999	214.50	0.56	0.57	28.01	0.07	0.94
Trend coef. estimate	73.3970			70.76279		
R-squared	0.9947			0.9952		
Adjusted R-squared	0.9937			0.9943		

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ANNEX 1
Raw Data

Annex Table 1. Per capita GDP in 12 European countries, annual estimates 1820-2001 (1990 "international" Geary-Khamis dollars).

	Austria	Belgium	Denmark	Finland	France	Germany	Italy	Netherlds.	Norway	Sweden	Switzerl.	UK
1820	1,287	1,319	1,274	781	1,230	1,077	1,117	1,821	1,104	1,198	1,280	1,707
1850	1,650	1,847	1,767	909	1,685	1,428	1,292	2,373	1,187	1,289	1,710	2,310
1870	1,863	2,692	2,003	1,140	1,876	1,839	1,499	2,758	1,432	1,664	2,202	3,191
1871	1,979	2,682	1,993	1,127	1,899	1,817	1,506	2,734	1,445	1,684	2,176	3,345
1872	1,976	2,824	2,087	1,145	2,078	1,931	1,475	2,771	1,527	1,746	2,312	3,319
1873	1,913	2,820	2,057	1,193	1,922	1,999	1,524	2,853	1,548	1,885	2,394	3,365
1874	1,981	2,890	2,096	1,204	2,157	2,124	1,513	2,727	1,586	1,938	2,543	3,386
1875	1,973	2,861	2,112	1,211	2,219	2,112	1,550	2,880	1,615	1,835	2,529	3,434
1876	2,000	2,875	2,130	1,259	2,028	2,071	1,506	2,890	1,639	1,935	2,480	3,430
1877	2,050	2,884	2,046	1,211	2,127	2,033	1,493	2,927	1,626	1,851	2,434	3,425
1878	2,100	2,942	2,102	1,173	2,091	2,103	1,506	2,991	1,555	1,818	2,518	3,403
1879	2,068	2,945	2,149	1,167	1,953	2,029	1,514	2,778	1,554	1,769	2,430	3,353
1880	2,079	3,065	2,181	1,155	2,120	1,991	1,581	3,046	1,588	1,846	2,384	3,477
1881	2,145	3,070	2,183	1,110	2,194	2,025	1,467	3,074	1,597	1,851	2,425	3,568
1882	2,140	3,136	2,240	1,203	2,288	2,044	1,584	3,117	1,593	1,924	2,447	3,643
1883	2,209	3,145	2,299	1,230	2,288	2,143	1,568	3,305	1,588	1,937	2,566	3,643
1884	2,248	3,136	2,285	1,219	2,253	2,178	1,566	3,328	1,611	1,976	2,608	3,622
1885	2,215	3,138	2,274	1,231	2,207	2,216	1,584	3,362	1,618	1,951	2,653	3,574
1886	2,268	3,153	2,336	1,276	2,237	2,211	1,643	3,374	1,616	1,929	2,647	3,600
1887	2,404	3,250	2,395	1,276	2,249	2,275	1,678	3,467	1,624	1,926	2,724	3,713
1888	2,379	3,247	2,389	1,302	2,269	2,341	1,662	3,544	1,690	1,971	2,803	3,849
1889	2,337	3,379	2,400	1,327	2,322	2,379	1,579	3,502	1,743	2,065	2,849	4,024
1890	2,443	3,428	2,523	1,381	2,376	2,428	1,667	3,323	1,777	2,086	2,907	4,009
1891	2,506	3,395	2,555	1,350	2,432	2,397	1,651	3,224	1,778	2,105	2,870	3,975
1892	2,535	3,442	2,598	1,280	2,493	2,469	1,548	3,240	1,806	2,144	2,956	3,846
1893	2,525	3,455	2,629	1,341	2,535	2,565	1,609	3,236	1,844	2,143	3,071	3,811
1894	2,645	3,468	2,657	1,399	2,626	2,598	1,576	3,273	1,832	2,171	3,111	4,029
1895	2,688	3,512	2,770	1,492	2,569	2,686	1,592	3,334	1,827	2,257	3,216	4,118
1896	2,701	3,551	2,836	1,570	2,685	2,740	1,627	3,166	1,857	2,367	3,281	4,249
1897	2,730	3,586	2,863	1,624	2,639	2,775	1,545	3,436	1,923	2,429	3,326	4,264
1898	2,855	3,615	2,870	1,668	2,760	2,848	1,672	3,460	1,900	2,457	3,410	4,428
1899	2,886	3,656	2,952	1,607	2,911	2,905	1,700	3,465	1,927	2,491	3,511	4,567
1900	2,882	3,731	3,017	1,668	2,876	2,985	1,785	3,424	1,937	2,561	3,580	4,492
1901	2,864	3,719	3,104	1,636	2,826	2,871	1,890	3,440	1,967	2,515	3,644	4,450
1902	2,945	3,739	3,141	1,591	2,775	2,893	1,821	3,543	1,990	2,496	3,704	4,525
1903	2,941	3,772	3,290	1,686	2,831	3,008	1,893	3,562	1,971	2,669	3,761	4,440
1904	2,956	3,821	3,326	1,731	2,847	3,083	1,896	3,535	1,961	2,680	3,817	4,428
1905	3,090	3,882	3,346	1,742	2,894	3,104	1,984	3,594	1,974	2,691	3,932	4,520
1906	3,176	3,917	3,402	1,794	2,943	3,152	2,042	3,669	2,037	2,845	3,924	4,631
1907	3,338	3,932	3,486	1,834	3,070	3,245	2,254	3,622	2,104	2,885	3,976	4,679
1908	3,320	3,933	3,552	1,829	3,045	3,254	2,288	3,577	2,157	2,853	4,027	4,449
1909	3,276	3,971	3,643	1,884	3,167	3,275	2,444	3,660	2,195	2,808	4,077	4,511
1910	3,290	4,064	3,705	1,906	2,965	3,348	2,332	3,789	2,256	2,980	4,125	4,611

Annex Table 1 (continued). Per capita GDP in 12 European countries...

	Austria	Belgium	Denmark	Finland	France	Germany	Italy	Netherlds.	Norway	Sweden	Switzerl.	UK
1911	3,365	4,148	3,857	1,939	3,250	3,408	2,461	3,888	2,309	3,002	4,175	4,709
1912	3,505	4,206	3,812	2,022	3,514	3,524	2,465	3,955	2,392	3,064	4,222	4,762
1913	3,465	4,220	3,912	2,111	3,485	3,646	2,564	4,049	2,501	3,096	4,266	4,921
1914	2,876	3,923	4,110	2,001	3,236	3,059	2,543	3,868	2,530	3,048	4,233	4,927
1915	2,653	3,858	3,778	1,882	3,248	2,899	2,810	3,926	2,611	3,028	4,290	5,288
1916	2,628	4,080	3,891	1,893	3,463	2,935	3,139	3,956	2,669	2,968	4,277	5,384
1917	2,586	3,519	3,617	1,581	2,979	2,952	3,301	3,627	2,399	2,584	3,804	5,421
1918	2,555	2,861	3,459	1,370	2,396	2,983	3,392	3,352	2,286	2,532	3,798	5,459
1919	2,259	3,389	3,860	1,658	2,811	2,586	2,845	4,122	2,647	2,669	4,060	4,870
1920	2,412	3,962	3,992	1,846	3,227	2,796	2,587	4,220	2,780	2,802	4,314	4,548
1921	2,650	4,056	3,826	1,884	3,075	3,078	2,528	4,431	2,518	2,674	4,208	4,439
1922	2,877	4,413	4,166	2,058	3,610	3,331	2,631	4,599	2,784	2,906	4,618	4,637
1923	2,842	4,533	4,559	2,187	3,754	2,750	2,763	4,635	2,826	3,047	4,874	4,760
1924	3,163	4,638	4,528	2,224	4,179	3,199	2,765	4,895	2,796	3,130	5,039	4,921
1925	3,367	4,666	4,378	2,328	4,166	3,532	2,921	5,031	2,949	3,233	5,388	5,144
1926	3,413	4,784	4,598	2,392	4,249	3,605	2,926	5,358	2,996	3,404	5,626	4,936
1927	3,505	4,923	4,658	2,557	4,154	3,941	2,838	5,504	3,098	3,500	5,892	5,315
1928	3,657	5,139	4,785	2,707	4,431	4,090	3,016	5,720	3,188	3,656	6,171	5,357
1929	3,699	5,054	5,075	2,717	4,710	4,051	3,093	5,689	3,472	3,869	6,332	5,503
1930	3,586	4,979	5,341	2,666	4,532	3,973	2,918	5,603	3,712	3,937	6,246	5,441
1931	3,288	4,860	5,359	2,581	4,235	3,652	2,877	5,185	3,404	3,782	5,943	5,138
1932	2,940	4,607	5,169	2,550	3,959	3,362	2,948	5,035	3,609	3,666	5,710	5,148
1933	2,833	4,681	5,291	2,702	4,239	3,556	2,906	4,956	3,674	3,721	5,966	5,277
1934	2,852	4,624	5,402	2,988	4,192	3,858	2,894	4,805	3,771	3,991	5,952	5,608
1935	2,907	4,894	5,480	3,093	4,086	4,120	3,148	4,929	3,912	4,232	5,907	5,799
1936	2,995	4,913	5,575	3,279	4,244	4,451	3,130	5,190	4,130	4,465	5,908	6,035
1937	3,156	4,961	5,668	3,441	4,487	4,685	3,319	5,433	4,255	4,664	6,171	6,218
1938	3,559	4,832	5,762	3,589	4,466	4,994	3,316	5,250	4,337	4,725	6,390	6,266
1939	4,096	5,150	5,993	3,408	4,793	5,406	3,521	5,544	4,516	5,029	6,360	6,262
1940	3,959	4,562	5,116	3,220	4,042	5,403	3,505	4,831	4,088	4,857	6,397	6,856
1941	4,217	4,358	4,574	3,322	3,309	5,711	3,432	4,531	4,163	4,914	6,312	7,482
1942	3,983	3,997	4,629	3,327	2,981	5,740	3,369	4,107	3,976	5,179	6,107	7,639
1943	4,065	3,907	5,080	3,697	2,860	5,890	3,039	3,981	3,867	5,360	6,001	7,744
1944	4,152	4,112	5,543	3,685	2,422	6,084	2,463	2,649	3,631	5,484	6,089	7,405
1945	1,725	4,333	5,066	3,450	2,573	4,514	1,922	2,686	4,029	5,568	7,752	7,056
1946	1,956	4,574	5,777	3,683	3,855	2,217	2,502	4,457	4,409	6,102	8,181	6,745
1947	2,166	4,800	6,035	3,717	4,138	2,436	2,920	5,048	4,855	6,175	9,050	6,604
1948	2,764	5,024	6,133	3,957	4,393	2,834	3,063	5,490	5,182	6,292	9,116	6,746
1949	3,293	5,193	6,494	4,143	4,946	3,282	3,265	5,880	5,230	6,455	8,757	6,956
1950	3,706	5,462	6,946	4,253	5,270	3,881	3,502	5,996	5,463	6,738	9,064	6,907
1951	3,959	5,747	6,936	4,572	5,553	4,207	3,738	6,032	5,663	6,951	9,684	7,083
1952	3,967	5,668	6,955	4,674	5,659	4,550	3,997	6,084	5,809	6,996	9,630	7,048
1953	4,137	5,818	7,292	4,652	5,783	4,900	4,260	6,542	6,016	7,145	9,842	7,304
1954	4,555	6,029	7,371	5,001	6,020	5,242	4,449	6,906	6,253	7,403	10,287	7,574
1955	5,053	6,280	7,395	5,197	6,312	5,788	4,676	7,326	6,311	7,566	10,867	7,826
1956	5,397	6,422	7,440	5,295	6,568	6,164	4,859	7,499	6,577	7,797	11,439	7,891
1957	5,716	6,495	7,965	5,490	6,890	6,482	5,118	7,614	6,706	8,089	11,705	7,982

Annex Table 1 (continued). Per capita GDP in 12 European countries...

	Austria	Belgium	Denmark	Finland	France	Germany	Italy	Netherlds.	Norway	Sweden	Switzerl.	UK
1958	5,907	6,442	8,095	5,474	6,988	6,731	5,360	7,482	6,587	8,076	11,297	7,932
1959	6,051	6,608	8,561	5,753	7,116	7,176	5,653	7,736	6,865	8,279	11,870	8,208
1960	6,518	6,953	8,812	6,230	7,543	7,685	5,916	8,289	7,200	8,688	12,457	8,645
1961	6,826	7,253	9,307	6,658	7,880	7,932	6,372	8,203	7,573	9,137	13,099	8,857
1962	6,950	7,583	9,747	6,820	8,254	8,200	6,822	8,643	7,738	9,468	13,354	8,865
1963	7,187	7,863	9,731	6,994	8,535	8,363	7,255	8,834	7,978	9,917	13,710	9,149
1964	7,567	8,341	10,560	7,306	9,010	8,821	7,476	9,439	8,300	10,514	14,191	9,568
1965	7,734	8,523	10,956	7,669	9,362	9,185	7,580	9,797	8,677	10,815	14,504	9,752
1966	8,112	8,776	11,161	7,824	9,756	9,387	7,914	9,936	8,941	10,937	14,727	9,885
1967	8,297	9,071	11,436	7,946	10,128	9,397	8,416	10,341	9,429	11,218	15,010	10,049
1968	8,621	9,415	11,837	8,094	10,497	9,865	9,063	10,893	9,557	11,562	15,374	10,410
1969	9,131	10,018	12,525	8,877	11,135	10,440	9,527	11,462	9,904	12,055	16,031	10,552
1970	9,748	10,611	12,685	9,578	11,668	10,849	9,689	11,967	10,029	12,716	16,904	10,767
1971	10,199	10,969	12,934	9,765	12,118	11,078	9,827	12,319	10,424	12,749	17,382	10,937
1972	10,771	11,503	13,537	10,447	12,547	11,481	10,057	12,597	10,878	13,002	17,776	11,290
1973	11,235	12,170	13,945	11,085	13,123	11,966	10,643	13,082	11,246	13,493	18,204	12,022
1974	11,658	12,643	13,752	11,360	13,420	12,061	11,069	13,495	11,759	13,886	18,414	11,856
1975	11,646	12,441	13,621	11,440	13,266	12,041	10,767	13,367	12,181	14,184	17,223	11,845
1976	12,200	13,122	14,465	11,358	13,785	12,681	11,410	13,882	12,950	14,282	17,171	12,113
1977	12,767	13,190	14,657	11,354	14,235	13,071	11,690	14,174	13,357	14,005	17,636	12,381
1978	12,731	13,554	14,826	11,558	14,567	13,453	12,083	14,422	13,905	14,209	17,661	12,825
1979	13,449	13,861	15,313	12,331	14,970	13,989	12,731	14,643	14,460	14,721	18,050	13,164
1980	13,760	14,467	15,227	12,948	15,103	14,113	13,153	14,700	15,128	14,936	18,780	12,928
1981	13,710	14,276	15,095	13,134	15,173	14,146	13,198	14,524	15,221	14,917	18,946	12,754
1982	13,959	14,466	15,563	13,485	15,466	14,040	13,242	14,290	15,192	15,058	18,564	12,960
1983	14,367	14,457	15,967	13,766	15,567	14,329	13,392	14,478	15,680	15,315	18,614	13,406
1984	14,407	14,809	16,675	14,106	15,723	14,785	13,730	14,897	16,553	15,919	19,110	13,709
1985	14,717	14,946	17,383	14,521	15,869	15,143	14,110	15,286	17,362	16,201	19,676	14,148
1986	15,085	15,155	17,992	14,818	16,169	15,474	14,511	15,622	17,923	16,533	19,877	14,727
1987	15,319	15,493	18,023	15,381	16,495	15,701	14,960	15,738	18,200	16,996	19,884	15,386
1988	15,762	16,212	18,223	16,090	17,130	16,143	15,552	16,045	18,084	17,300	20,340	16,110
1989	16,368	16,738	18,267	16,940	17,728	16,551	15,988	16,699	18,173	17,593	21,303	16,404
1990	16,905	17,201	18,452	16,868	18,101	15,932	16,315	17,267	18,470	17,695	21,886	16,411
1991	17,250	17,479	18,662	15,677	18,190	16,604	16,535	17,517	18,952	17,380	21,430	16,096
1992	17,346	17,690	18,838	15,117	18,373	16,848	16,632	17,738	19,457	17,032	21,169	16,050
1993	17,197	17,361	18,931	14,873	18,119	16,544	16,606	17,747	19,873	16,556	20,876	16,367
1994	17,551	17,824	19,959	15,394	18,411	16,882	16,919	18,210	20,844	17,116	20,745	17,027
1995	17,876	18,219	20,603	15,918	18,656	17,123	17,376	18,526	21,537	17,655	20,785	17,440
1996	18,206	18,436	20,982	16,500	18,802	17,211	17,542	19,005	22,479	17,821	20,756	17,834
1997	18,462	19,048	21,526	17,496	19,096	17,417	17,853	19,636	23,400	18,181	21,057	18,395
1998	19,107	19,442	21,985	18,383	19,699	17,762	18,150	20,350	23,835	18,822	21,489	18,860
1999	19,608	19,978	22,417	19,058	20,269	18,074	18,432	20,976	23,922	19,652	21,735	19,223
2000	20,159	20,723	23,008	20,183	20,981	18,592	18,914	21,545	24,311	20,323	22,262	19,836
2001	20,287	20,905	23,135	20,269	21,291	18,670	19,205	21,714	24,520	20,514	22,424	20,066

Annex Table 2. Sulfur emissions, 1850 to 1999 (in 1000 metric tons)

Year	Austria	Belgium	Denmark	Finland	France	Germany	Italy	Netherlds.	Norway	Sweden	Switzerl.	UK
1850	13	31	2	0	87	177	3	9	1	1	0	737
1851	16	34	2	0	89	198	3	9	1	2	0	796
1852	20	39	2	0	96	238	4	11	1	2	0	852
1853	24	40	2	0	113	235	5	12	1	2	0	906
1854	24	44	3	0	130	255	6	17	2	2	1	961
1855	27	46	3	0	148	290	6	13	2	3	1	960
1856	32	45	4	0	157	313	7	14	3	4	1	986
1857	37	47	5	1	162	311	8	12	3	5	1	945
1858	40	50	3	1	160	334	9	11	3	5	1	939
1859	43	51	4	1	163	352	10	10	3	6	2	1,041
1860	49	52	4	1	177	389	10	14	3	6	3	1,162
1861	55	56	5	1	190	432	11	13	4	8	4	1,210
1862	62	56	5	1	198	467	17	17	4	8	4	1,173
1863	63	59	5	1	201	481	16	12	4	8	4	1,245
1864	63	62	5	1	213	532	21	10	5	9	5	1,337
1865	70	65	7	1	225	561	18	11	5	9	6	1,414
1866	63	71	6	1	247	579	22	12	6	9	6	1,456
1867	79	78	6	1	250	625	27	12	6	9	6	1,493
1868	93	70	8	1	254	668	78	12	6	10	6	1,467
1869	102	75	7	1	261	711	112	13	6	10	6	1,536
1870	115	86	8	2	227	679	133	14	7	11	7	1,568
1871	143	82	8	2	226	704	89	15	7	12	9	1,658
1872	150	88	8	2	275	852	122	15	7	14	10	1,745
1873	165	99	8	2	295	893	117	15	8	14	10	1,835
1874	163	91	9	2	282	864	105	14	8	15	10	1,783
1875	162	95	10	2	295	900	102	16	10	17	11	1,879
1876	168	93	11	2	297	967	117	18	9	19	12	1,866
1877	169	91	11	2	290	1,024	137	18	11	19	12	1,881
1878	174	96	10	2	296	1,077	109	19	10	17	11	1,854
1879	195	98	12	2	308	1,122	125	21	11	17	12	1,860
1880	203	108	13	2	346	1,274	143	23	12	21	14	2,035
1881	218	109	14	2	356	1,379	138	23	12	21	13	2,134
1882	225	115	15	2	378	1,468	158	24	13	23	14	2,153
1883	243	123	17	2	398	1,539	169	26	13	23	16	2,238
1884	247	121	17	3	385	1,505	177	26	14	25	16	2,182
1885	259	119	18	3	369	1,560	187	28	15	27	17	2,155
1886	263	114	17	2	363	1,423	182	28	15	26	17	2,137
1887	278	121	18	2	381	1,517	188	29	15	27	19	2,191
1888	291	128	20	2	394	1,519	190	32	16	29	19	2,278
1889	308	131	21	3	401	1,621	199	31	18	33	22	2,359
1890	324	144	20	3	444	1,687	215	30	17	33	23	2,414
1891	344	137	22	3	446	1,725	204	35	19	35	30	2,465
1892	343	136	22	3	447	1,672	206	34	20	35	30	2,414

Annex Table 2 (continued). Sulfur emissions, 1850 to 1999…

Year	Austria	Belgium	Denmark	Finland	France	Germany	Italy	Netherlds.	Norway	Sweden	Switzerl.	UK
1893	371	130	22	3	438	1,700	198	34	20	35	24	2,163
1894	383	144	25	3	464	1,713	225	35	22	39	31	2,476
1895	409	146	25	4	466	1,785	203	35	23	39	33	2,500
1896	425	153	33	4	480	1,943	190	37	23	40	36	2,572
1897	449	160	33	6	501	1,968	194	39	25	44	38	2,641
1898	466	164	34	6	514	2,000	198	38	25	46	41	2,646
1899	477	175	37	8	548	2,101	217	40	28	58	45	2,835
1900	505	186	37	7	602	2,198	214	44	29	59	50	2,870
1901	519	174	39	5	583	2,232	208	43	29	55	46	2,809
1902	506	183	40	5	551	2,198	222	43	30	56	46	2,917
1903	515	198	41	6	595	2,294	233	46	31	62	50	2,942
1904	534	203	45	6	583	2,376	241	49	31	66	53	2,956
1905	553	206	44	7	586	2,421	259	50	32	65	55	2,996
1906	605	237	48	7	653	2,568	300	55	33	73	62	3,105
1907	700	241	44	9	699	2,687	325	58	36	83	73	3,245
1908	869	223	54	14	701	2,662	326	59	41	89	73	3,164
1909	724	241	59	13	717	2,738	345	62	41	82	73	3,193
1910	860	257	54	11	719	2,888	349	64	42	84	70	3,220
1911	761	264	58	13	756	2,874	358	69	44	82	79	3,299
1912	793	279	69	15	758	3,122	376	78	48	91	80	3,130
1913	322	292	73	17	840	3,228	407	87	49	104	86	3,429
1914	249	218	73	8	590	2,880	371	82	54	98	79	3,325
1915	337	188	80	3	549	2,931	317	79	59	100	85	3,371
1916	288	202	78	4	587	3,382	323	73	57	107	83	3,496
1917	259	177	47	4	623	3,309	232	58	36	46	61	3,462
1918	223	157	48	4	567	3,091	270	50	41	54	58	3,228
1919	187	184	54	5	641	2,234	264	78	47	53	48	3,160
1920	157	206	67	6	895	2,185	270	79	49	76	78	3,258
1921	187	209	58	5	731	2,362	294	76	37	42	44	2,224
1922	181	223	81	9	878	1,918	336	90	53	69	61	2,977
1923	176	300	91	17	982	1,519	361	90	55	85	77	3,164
1924	195	317	104	19	1,061	1,888	423	100	59	100	72	3,316
1925	181	325	89	18	999	1,921	395	103	58	89	72	3,114
1926	169	308	82	16	983	1,757	426	102	50	79	66	1,734
1927	184	363	102	26	1,025	2,027	488	113	59	113	77	3,235
1928	190	347	94	29	1,005	2,134	438	116	62	100	77	3,023
1929	215	391	112	36	1,134	2,277	504	125	70	123	88	3,185
1930	170	374	105	31	1,150	1,966	450	124	66	119	82	3,048
1931	157	329	106	36	1,028	1,671	370	135	53	117	83	2,847
1932	133	264	102	38	896	1,509	302	125	65	120	85	2,742
1933	127	275	101	40	935	1,580	325	116	70	129	83	2,716
1934	121	282	106	50	938	1,753	425	116	73	139	82	2,930
1935	121	266	108	54	901	1,926	483	109	73	145	80	2,969

Annex Table 2 (continued). Sulfur emissions, 1850 to 1999...

Year	Austria	Belgium	Denmark	Finland	France	Germany	Italy	Netherlds.	Norway	Sweden	Switzerl.	UK
1936	117	279	116	64	915	2,116	331	117	78	159	81	3,136
1937	132	340	118	78	1,029	2,384	461	129	81	180	87	3,235
1938	130	291	109	67	931	2,537	456	126	76	163	83	3,096
1939	139	310	132	66	913	2,777	491	136	88	198	108	3,147
1940	143	280	85	50	620	2,820	520	131	56	130	73	3,304
1941	141	297	85	62	494	2,896	460	143	50	113	57	3,244
1942	143	291	84	60	514	2,955	455	137	48	104	50	3,241
1943	147	288	107	74	537	3,019	396	141	53	122	52	3,144
1944	145	210	105	56	354	2,643	311	108	47	98	37	3,066
1945	103	238	66	33	473	443	272	83	34	40	7	2,899
1946	114	309	123	54	761	1,294	256	114	57	128	51	3,014
1947	165	337	155	77	912	1,489	453	138	77	184	91	3,181
1948	212	327	126	104	965	1,736	405	140	74	215	90	3,236
1949	222	302	136	71	1,100	1,982	424	153	69	186	71	3,324
1950	181	233	80	60	953	2,172	467	187	29	126	41	3,396
1951	208	293	113	85	1,147	2,489	661	212	38	144	61	3,726
1952	195	308	104	89	1,204	2,626	661	220	26	134	48	3,772
1953	189	306	87	78	1,117	2,702	746	222	24	115	34	3,756
1954	210	312	88	81	1,159	2,792	830	239	23	109	42	3,813
1955	237	318	107	96	1,147	3,069	905	255	24	119	45	3,924
1956	250	362	88	105	1,287	3,250	951	276	23	109	60	3,903
1957	257	366	101	122	1,294	3,308	974	269	22	116	66	3,878
1958	219	363	88	121	1,263	3,281	916	250	19	97	43	3,805
1959	202	325	87	135	1,197	3,164	924	240	18	99	41	3,689
1960	208	305	108	146	1,168	3,336	1,019	263	20	105	47	3,503
1961	195	300	110	147	1,159	3,452	1,080	257	32	101	40	3,461
1962	203	309	123	149	1,162	3,551	1,175	270	37	100	41	3,588
1963	225	383	135	150	1,255	3,702	1,290	282	37	98	56	3,507
1964	219	378	134	154	1,299	3,838	1,332	282	39	105	45	3,515
1965	206	375	128	151	1,306	3,708	1,469	269	38	98	42	3,458
1966	200	351	140	140	1,304	3,595	1,611	261	37	98	49	3,280
1967	189	341	145	155	1,364	3,429	1,758	257	40	116	64	3,309
1968	190	376	147	170	1,327	3,487	1,821	258	52	141	67	3,212
1969	180	384	145	185	1,338	3,584	1,854	275	54	153	66	3,008
1970	199	395	147	230	1,432	3,748	2,035	295	60	164	68	2,921
1971	194	358	123	210	1,393	3,711	1,970	266	56	161	61	3,028
1972	204	388	114	203	1,369	3,612	1,925	273	59	149	52	2,589
1973	208	393	125	210	1,451	3,633	2,028	287	62	148	65	2,742
1974	214	392	139	236	1,538	3,620	2,098	280	66	169	71	2,488
1975	197	339	136	236	1,366	3,505	1,731	239	63	175	50	2,650
1976	195	334	129	222	1,415	3,565	1,696	253	73	196	43	2,510
1977	188	381	153	268	1,491	3,542	1,867	255	75	201	48	2,411
1978	191	348	156	248	1,423	3,433	1,789	228	71	205	43	2,365

Annex Table 2 (continued). Sulfur emissions, 1850 to 1999...

Year	Austria	Belgium	Denmark	Finland	France	Germany	Italy	Netherlds.	Norway	Sweden	Switzerl.	UK
1979	208	387	190	278	1,584	3,682	1,933	253	72	219	51	2,343
1980	192	414	226	292	1,606	3,757	1,879	245	69	246	58	2,440
1981	167	356	185	267	1,262	3,721	1,665	232	64	216	54	2,213
1982	158	347	189	242	1,207	3,720	1,425	202	55	186	50	2,107
1983	119	280	161	186	992	3,673	1,232	162	52	153	46	1,937
1984	106	250	153	184	885	3,817	1,057	150	48	148	42	1,856
1985	95	200	172	191	740	3,866	951	129	49	133	38	1,875
1986	86	189	146	166	672	3,821	965	132	46	136	34	1,955
1987	76	184	129	164	665	3,698	1,015	132	37	114	31	1,954
1988	58	177	127	151	610	3,244	982	125	34	112	28	1,920
1989	51	163	99	122	690	3,083	927	102	29	80	25	1,860
1990	46	186	91	130	639	2,661	826	101	26	60	21	1,877
1991	41	167	121	97	695	1,998	770	87	22	48	21	1,784
1992	32	159	94	71	606	1,654	697	86	18	44	19	1,724
1993	30	149	77	62	526	1,473	667	82	18	44	17	1,553
1994	29	127	78	57	495	1,237	636	73	17	41	16	1,333
1995	28	123	74	48	467	997	661	74	17	40	17	1,174
1996	26	120	90	53	457	703	603	68	17	42	15	1,005
1997	25	110	55	50	384	564	538	59	15	26	13	819
1998	23	106	38	45	404	450	520	54	15	25	14	784
1999	21	93	28	44	341	416	462	50	14	32	13	594

Annex Table 3. Key Dates for Sulfur Relevant Legislation in the UK.

Year	Regulation
1821	Smoke prohibition act. *Tried to encourage the prosecution of a public nuisance from smoke.*
1845	Railway Clauses Consolidated Act *Engines to consume their own smoke.*
1847	Improvement Clauses act *Reduce factory smoke.*
1853	London Act. *Penalties against smoke nuisance.*
1863	Alkali Act. *Regulate alkali trade – condense at least 95% hydrochloric acid gas.*
1866	Sanitary Act. *Authorities empowered to take action in cases of smoke nuisances.*
1874	Other noxious gases added to Alkali Act.
1875	Public Health Act
1906	Alkali etc. Works Regulation Act
1926	Smoke Abatement Act
1953	Grit came under control of Alkali inspectors. *Reduce emissions to 0.5 grains per cubic foot and install precipitators.*
1955	Environment Act. *Became law in 1956. 7 years to re-equip, 10 years later, industry had reduced emissions 74%.*
1956	Clean Air Act. *"Subject to the provisions of this Act, dark smoke shall not be emitted from a chimney of any building, and if, on any day, smoke is so emitted the occupier of the building shall be guilty of an offence." Section 1. Dark smoke is one whose color is equal to or darker than shade 2 of the Ringlemann Chart – a subjective measure. (Manning 1993 chap. 3) Smokeless zones allowed – not instituted until 1960.*
1968	Clean Air Act. *Taller chimneys for more dispersement.*
1974	Control of Pollution Act. *Allows for the making of regulations imposing requirements on vehicle fuel regulations could be made for sulfur content of oil in furnaces and engines.*
1979	Convention on Long Range Transboundary Pollution
1980	Directive 80/779 on limit values for sulfur dioxide and suspended particulates: OJ 1980 No. L229/30. *Over a year, the average level of black smoke (or fine particulates) cannot exceed eighty micrograms per cubic meter. The level of sulfur dioxide is dependant on the concentration of smoke. If there are less than or equal to forty micrograms per cubic meter of black smoke, the amount of sulfur dioxide cannot exceed 120 micrograms per cubic meter. When the amount of smoke exceeds forty micrograms per cubic meter, then the top limit of sulfur dioxide is reduced to eighty micrograms per cubic meter. Similar standards are set for wintertime (18) and peak concentrations (19). (Manning chap. 4)*
1985	Helsinki Protocol on Reduction of Sulfur emissions. *Reduce by 30% by 1993 compared to 1980 levels (Europa link)*
1988	Sofia Protocol on Nitrogen Oxide. *Reduce emissions by 1994 compared to 1987 levels. Apply national emissions standards to mobile sources and introduce pollution control measures for major stationary sources. (Europa link)*

Annex Table 3 (continued). Key Dates for Sulfur Relevant Legislation in the UK.

Year	Regulation
1988	EC Directive on large combustion plant. • *Power stations to reduce emissions of Sulfur Dioxide and Nitrogen Oxide.* • *UK to reduce SO_2 by 60% of 1980 levels by 2003.* • *NO by 30% of 1980 levels by 1998.* • *UK Stated target of 30% for Sulfur was an 'aim of policy' Manning 1993 chap. 4*
1989	Air Quality Standards Regulations (S.I. 1989 No. 317). • *One year: limit SO_2 to 120 microg/m^3 if smoke less than 40 microg/m^3 (median of daily values) 80 microg/m^3 if smoke more than 40.* • *Winter: 180 if smoke less than 60 (median of winter values) 130 if smoke more than 60* • *Year, peak 350 if smoke less than 150* • *(98 percentile of daily values) 250 if smoke more than 150* • *From Leeson 1995: 229-230: these figures are the same as for Directive 80/779.* • *Other EC directives to go into effect in the Air Quality Standards Regulations are 82/884/EEC (lead), 85/203/EEC (nitrogen dioxide) and 92/72/EEC (ozone)*
1990	Environmental Protection Act. *Integrated Pollution control. Regulates statutory nuisances i.e. something prejudicial to health or a nuisance at common law. (Handler ed. 58)*
1990	Large Combustion plant national plan. *Reduction targets for SO_2 at 60% of 1980 levels by 2003.*
1992	Directive 91/441/EEC (see SI 1992 No. 2137). *Limits emissions of carbon monoxide, hydrocarbons and oxides of nitrogen from new passenger and light goods vehicles.*
1993	Directive 93/59/EEC. *Limits emissions from new light commercial vehicles and vans (see McEldowney and McEldowney page 269 for further directives limiting vehicular emissions).*
1993	Clean Air Act. *Consolidation of 1955 and 1963 Acts.*
1993	Stubble burning banned.
1994	Second Protocol on Reduction of Suphur Emissions (Oslo Protocol) • *W. Europe to reduce 70-80% if 1980 levels* • *E. Europe to reduce to 40-50%*
1995	Environment Act (came into practice 1997 NAQA)
1997	National Air Quality Strategy. *Standards and Objectives for CO, NO_2, SO_2, particulates, ozone, lead, benzene and 1,3- butadene. Guideline and more serious alert thresholds. Government adopted the standard of 100ppb at 99.9% compliance. (electricity.org)*
1999	Gothenburg Protocol. *Emissions ceilings for sulfur, NOx, VOC, and ammonia. Sulfur should be cut by at least 63%, NOx by 41%, VOC by 40% and ammonia by 17% compared to 1990.*

Annex Table 4. Key European Legislation Relevant to Sulfur Emissions.

Year	Regulation
1972	Environmental Action Programme
1979	Convention on Long Range Transboundary Pollution
1980	Directive 80/779 on limit values for sulfur dioxide and suspended particulates: OJ 1980 No. L229/30. *Over a year, the average level of black smoke (or fine particulates) cannot exceed eighty micrograms per cubic meter. The level of sulfur dioxide is dependant on the concentration of smoke. If there are less than or equal to forty micrograms per cubic meter of black smoke, the amount of sulfur dioxide cannot exceed 120 micrograms per cubic meter. When the amount of smoke exceeds forty micrograms per cubic meter, then the top limit of sulfur dioxide is reduced to eighty micrograms per cubic meter. Similar standards are set for wintertime … and peak concentrations. (Manning chap. 4)*
1985	Helsinki Protocol on Reduction of Sulfur emissions. *Reduce by 30% by 1993 compared to 1980 levels (Europa link)*
1988	Sofia Protocol on Nitrogen Oxide. *Reduce emissions by 1994 compared to 1987 levels. Apply national emissions standards to mobile sources and introduce pollution control measures for major stationary sources. (Europa link)*
1988	EC Directive on large combustion plant. *Power stations required to reduce emissions of sulfur dioxide and nitrogen oxide.*
1989	Air Quality Standards Regulations (S.I. 1989 No. 317)
1992	Directive 91/441/EEC (see SI 1992 No. 2137). *Limits emissions of carbon monoxide, hydrocarbons and oxides of nitrogen from new passenger and light goods vehicles.*
1993	Directive 93/59/EEC. *Limits emissions from new light commercial vehicles and vans (see McEldowney and McEldowney page 269 for further directives limiting vehicular emissions)*
1994	Second Protocol on Reduction of Suphur Emissions (Oslo Protocol) • *W. Europe to reduce 70-80% if 1980 levels* • *E. Europe to reduce to 40-50%*
1999	Gothenburg Protocol. *Emissions ceilings for sulphur, NOx, VOC, and ammonia. Sulfur should be cut by at least 63%, NOx by 41%, VOC by 40% and ammonia by 17% compared to 1990.*
1999	Directive on sulfur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air (1999/30/EC)

Figure E1. United Kingdom: Sulfur emissions (1850-1999) and Real GDP per capita (1870-2001), Annual Growth Rates.

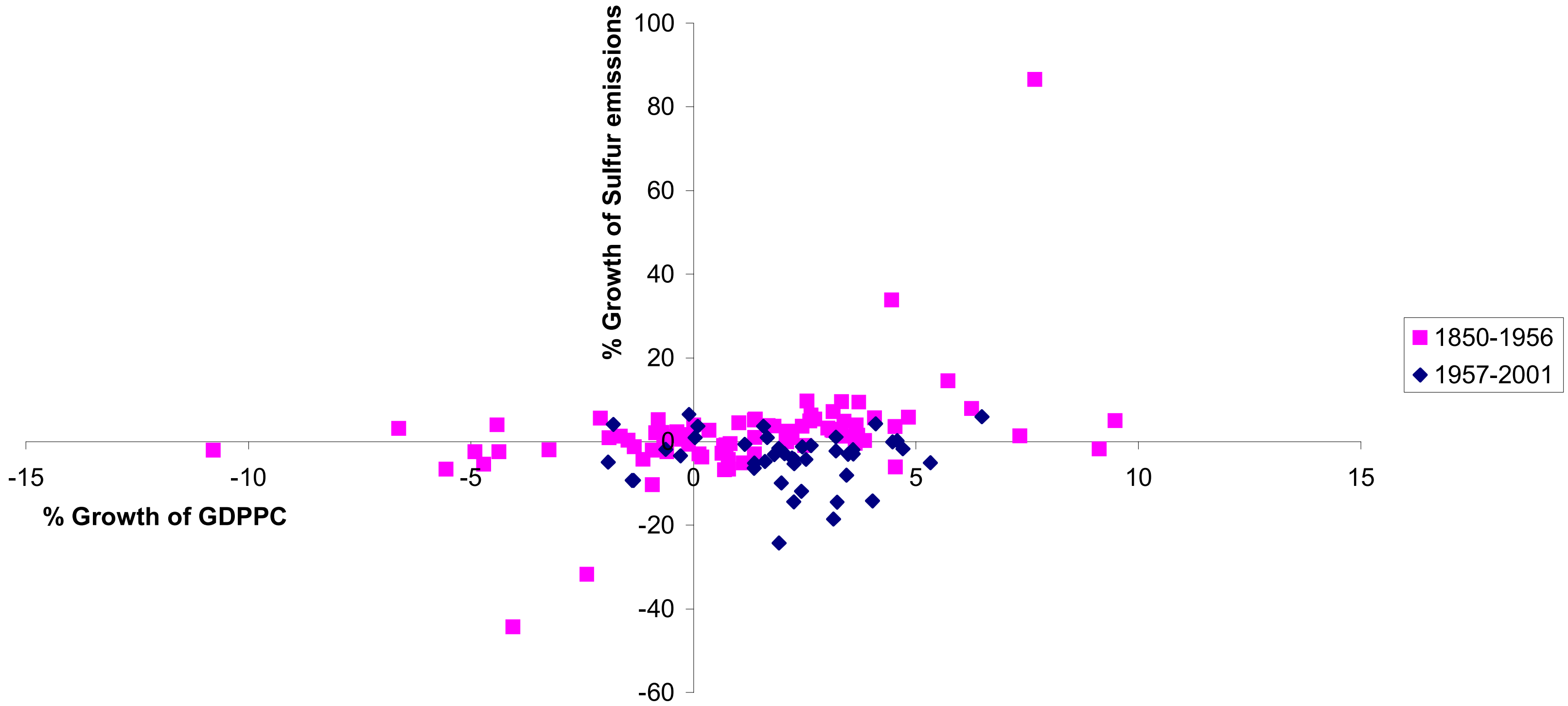
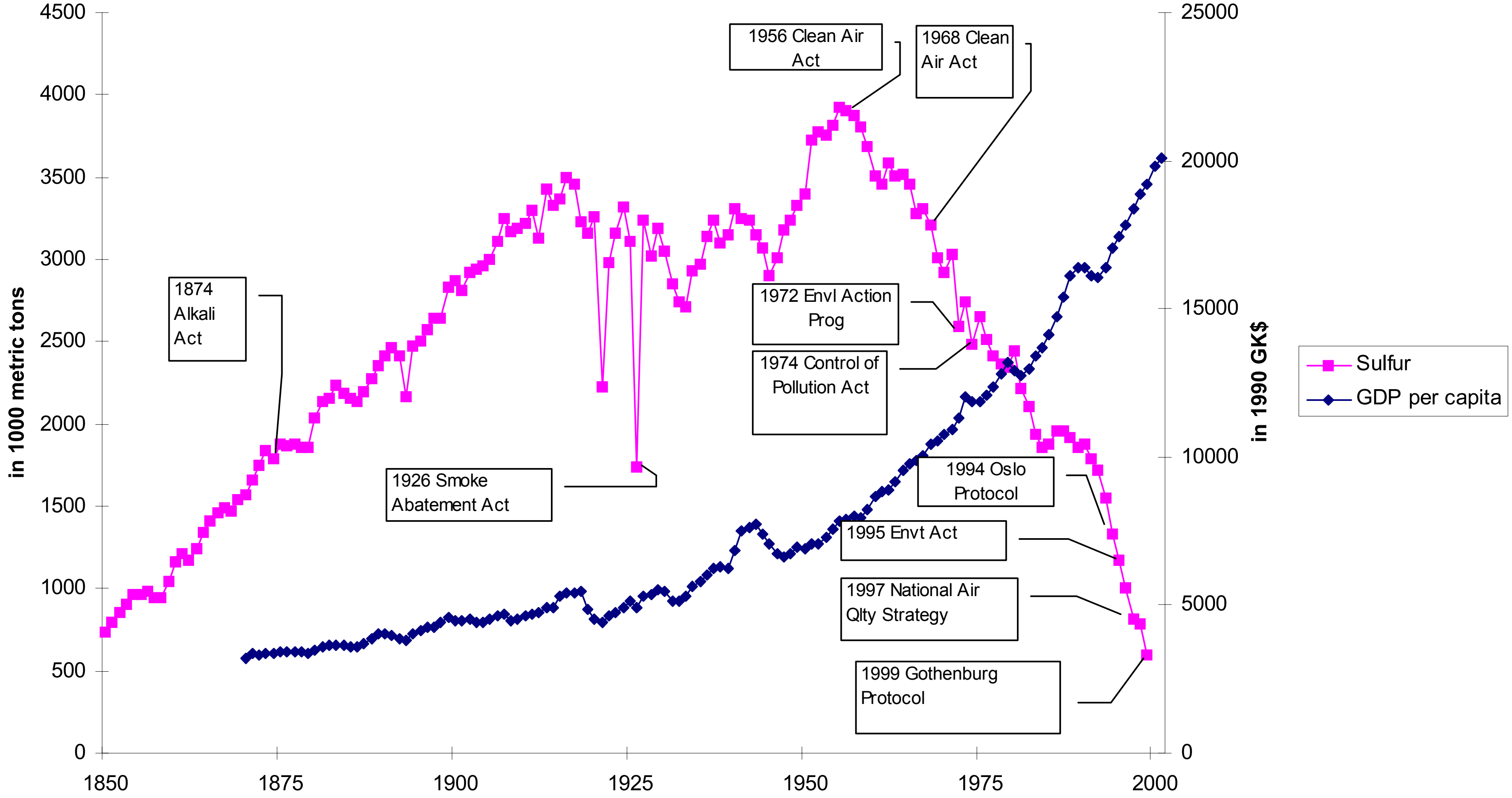


Figure E2. United Kingdom: Sulfur emissions (1850-1999), Real GDP per capita (1870-2001) and Some Air Regulations.



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(lxi) This paper was presented at the Eighth Meeting of the Coalition Theory Network organised by the GREQAM, Aix-en-Provence, France, January 24-25, 2003

(lxii) This paper was presented at the ENGIME Workshop on "Communication across Cultures in Multicultural Cities", The Hague, November 7-8, 2002

(lxiii) This paper was presented at the ENGIME Workshop on "Social dynamics and conflicts in multicultural cities", Milan, March 20-21, 2003

(lxiv) This paper was presented at the International Conference on "Theoretical Topics in Ecological Economics", organised by the Abdus Salam International Centre for Theoretical Physics - ICTP, the Beijer International Institute of Ecological Economics, and Fondazione Eni Enrico Mattei – FEEM Trieste, February 10-21, 2003

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