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Factoring the environmental Kuznets curve
Evidence from Norway

Abstract:
The environmental Kuznets curve theory suggests that economic growth may reduce environmental problems. In this article, we analyze the changes in environmentally damaging emissions to air in Norway from 1980 to 1996. In order to reveal the factors which decrease the emissions per produced unit, these changes are subdivided into 8 components.

Our analysis shows that, holding emissions per produced unit constant, economic growth alone contributed to an increase in all emissions by about 60 percent. In contrast, decreased energy intensity, the substitution of cleaner for polluting energy types and other technological progressions have reduced the growth. Consequently, the growth in all emissions has been significantly lower than economic growth, and negative for some pollutants.

The emissions of sulfur dioxide and lead had the largest reductions over the period. The main cause was technological changes, which have generated lead substitutes in gasoline and abatement technologies for sulfur. For most other emissions, the effect of technological changes was not sufficient to weigh up for economic growth. Then the emissions of carbon dioxide and nitrogen oxides grew over the period, but far less than the growth in GDP.

The emission reducing factors may be explained by the general technological progress that follows economic growth. The correlation between economic growth and the emission reducing energy intensity component is for instance significant.

Keywords: Economic growth, energy intensity, environmental Kuznets curve, pollution

JEL classification: Q13, Q25

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1 Introduction

Does economic growth lead to environmental improvement or degradation? This is the main question in the literature concerning the "Environmental Kuznets Curve" (EKC). In 1955, Simon Kuznets postulated that economic growth and income inequalities follow an inverted U-curve. As the economy grows, it first enters a period with increased income inequality and then decreasing inequality (Kuznets 1955). In other words, first worse, then better.

The same relation to income has been claimed for environmental quality. In the 1990's, a long series of studies investigated the inverted U-relationship between income and environment. Initial papers by Grossman and Krueger (1993, 1995), Shafik and Bandyopadhyay (1992) and Selden and Song (1994) presented evidence that some pollutants historically followed an inverted U-curve with respect to income. Evidence for inverted U-curves is strongest for PM (particulates), SO_2 (sulfur dioxides), NO_x (nitrogen oxides), Pb (lead) and CO (carbon monoxides). The turning points for the different pollutants vary, but in most cases they come before a country reaches a per capita income of $8000 Grossman and Krueger (1995).

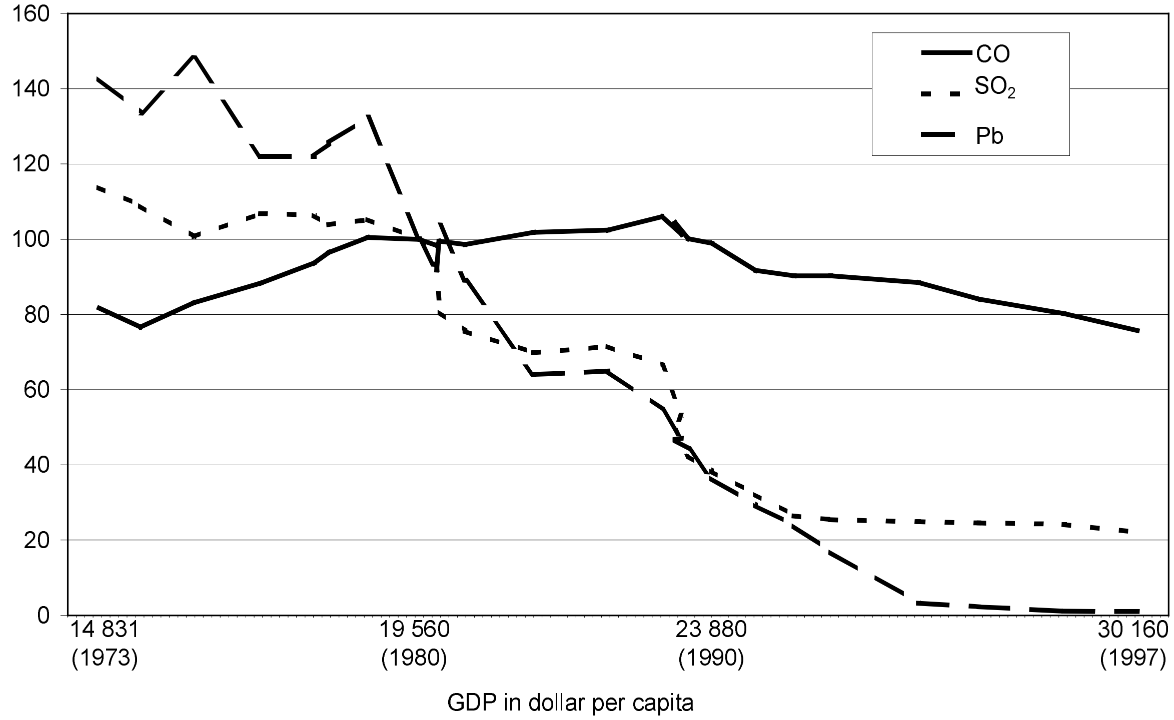
The idea of a positive relationship between economic growth and environmental quality may not correspond with common sense. The usual picture of economic growth is that it leads to more use of natural resources and environmentally damaging materials. Environmental organizations warn that, sooner or later, nature reaches its capacity for receiving pollutants to air, soil and water, and some environmentalists advocate reductions in growth and consumption (see e.g. Worldwatch Institute, 2000 or FIVH, 2000).

On the other side of the debate, the proponents of technology claim that human capability to create technological solutions is more or less unlimited. A hundred years ago, citizens worried that as traffic increased, horse manure would eventually bury the streets of London. But before the problem took over, solutions were created. With all the problems that human minds have solved, from prehistoric times to modern life, advocates of technology argue there are good reasons to believe that solutions for the future treatment of hazardous substances and other environmental problems as well will be found.

A survey of the EKC literature reveals that the relationship between income and environmental quality varies according to the type of pollution involved. Generally, local problems, like water quality and sanitary conditions, are among the first to be solved (Shafik and Bandyopadhyay, 1992). The costs-benefit ratio is normally low. Compared to regional and global environmental problems, the contributor or the local society harvests the benefits of the input to reduce the environmental stress.

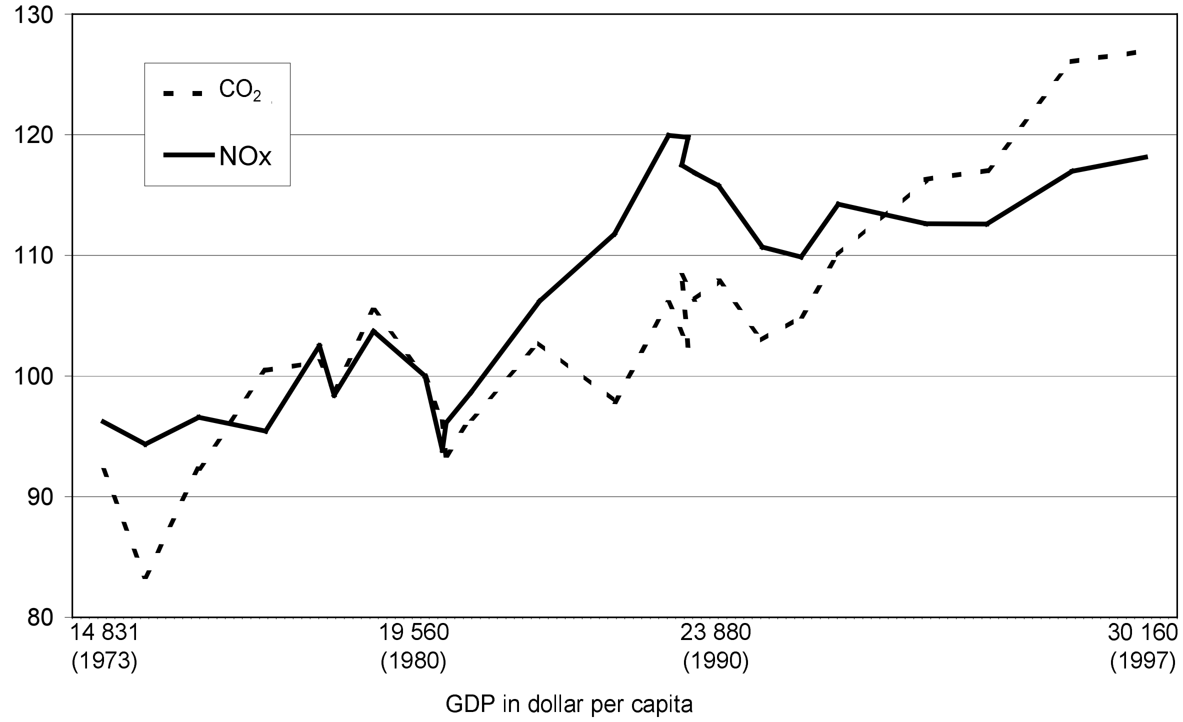
Thus, local and regional environmental problems illustrate the inverted U-curve. In their cross-country panel data, both Grossman and Krueger (1993), and Selden and Song (1994), reveal inverted U-curves for SO_2, CO, NO_x and PM. Also Norwegian time series show that total emissions of Pb, SO_2 and CO have decreased significantly as income increased over the last decades (see Figure 1). Based on the data regarding the use of fossil fuels, Mylona (1996) estimates that the emissions of sulfur have increased steadily from the turn of the century and peaked in 1970. For Pb, the statistics only cover the descending part of the curve[1]. CO emissions seem to peak at a per capita GDP of $US 23000.

Figure 1. Norwegian Pb, SO2 and CO emissions to the atmosphere 1973 - 1997, 1980=100, in relation to GDP in $US per capita ($1 ≈ NOK 8)



However, it is important to note that the writers strongly caution against assuming that there will be an automatic link between economic growth and environmental improvements in the future. The emissions of climate gases, which many consider to create the most threatening environmental problems we will face, serve as an example. In contrast to the emissions which have caused local environmental problems, the emissions of CO_2 (carbon dioxide) have increased steadily with income, in Norway (see Figure 2) as well as worldwide (OECD, 1997). Holz-Eakin and Selden (1995) point out that estimates of the peak for CO_2 emissions by far exceeds current income levels. Regarding the issue of environmental problems crossing national borders, the benefits may be small or negligible compared to the costs. Only a share of the benefits of reducing one's own emissions falls to the controlling country. Thus, international negotiations and binding agreements between countries are needed to restrict these emissions.

Figure 2. Norwegian CO2 and NOx emissions to the atmosphere 1973 - 1997, 1980=100, in relation to GDP in $US ($1 ≈ NOK 8)



As acid rain crosses national borders, SO_2 and NO_x cause both local and regional environmental problems. Contrary to SO_2, but similar with CO_2, NO_x emission abatement costs are relatively high. This difference in marginal abatement costs may in part explain the discrepancies regarding the abatement of SO_2 and NO_x emissions. While SO_2 emissions have fallen with rising income, there has

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[1] As these emissions are mainly related to human exploitation of fossil fuels, we know that earlier emissions must have been significantly lower. Most Pb emissions origin from leaded gasoline.

been a positive correlation between income and NO_x emissions up to 1987. The NO_x curve may also indicate that we have reached a peak in regards to NO_x emissions, given that the emissions were at about the same level in 1997 as in 1987. The Norwegian Pollution Agency (1999) finds a reduction potential of 40 percent from 1990 to 2010, as an effect of regulations on emissions control and fuel quality.

One of the ideas behind the environmental Kuznets-curve is that environmental goods are normal goods; higher income increases the demand for a cleaner environment[2]. An increased willingness to pay for the environment is demonstrated by the desire to embrace a lower economic growth in order to improve environmental quality. This forms the basis for politically acceptable environmental regulations and taxes. These political steps may trigger structural changes that result in less polluting production processes and more efficient use of resources. Furthermore, technological progress and income go hand in hand; as we will see, technological changes generally promote decrease in the use of resources and less pollution per unit produced. However, the implementation of environmentally friendly technologies and political regulations can also be a result of foreign innovation; of for example cars with catalytic converters and not correlated to domestic income.

Improved understanding of the mechanisms between economic growth and the pollution over the past can provide valuable information in the prediction of the environmental quality and the consequences of policy alternatives in the future. In this analysis, we apply a decomposition method to isolate eight driving forces behind the changes in Norwegian emissions to air over the period 1980 to 1996. Grossman and Krueger (1993) used a similar method, as they decomposed the changes in emissions into effects from total GDP, production structure and the remaining effects. Selden et al. (1999) isolated the driving forces in US air emission changes from 1970 to 1990 into the same categories, adding changes in energy intensity and energy mix.

We take a further step by also including the effects of changes in combustion methods. Our analysis also offers a specific model for road traffic-related emissions, which contribute to a significant share of the total emissions. Furthermore, we analyze factors influencing the computed energy intensity component in a regression analysis.

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[2] Some of the EKC studies focus on the role of political rights and the level of education, see e.g. Torras and Boyce (1998), who claim that an equal distribution of power is important to attain environmental improvements, as implementing the polluter pays principle.

Compared to Selden et al. (1999), we have included four additional types of emissions, including CO_2. Even though CO_2 clearly does not follow an inverted U-curve, the growth in CO_2 emissions has been far lower than the economic growth, which raises the question of what forces have worked in the opposite direction. Our data cover the years up to 1996. Thus the study covers the recent effects from new technology and political actions, for instance the effect of the policies against the use of leaded gasoline, the sulfur tax and the introduction of catalysts in vehicles.

We have also performed sensitivity analyses to investigate whether the components have been stable over the period and whether the results are influenced by changes in the aggregation levels of sectors and energy types.

The rest of the paper is organized as follows: In Section 2 we present the method and in Section 3 the data. In Section 4 we discuss the results for each of the components, followed by the sensitivity analyses in Section 5. Finally, we summarize and discuss the results in Section 6.

2 Method

2.1 The main model

The emissions in a given year decomposed into the individual components can be written as:

$$(1) \qquad P^{SM} \equiv \sum_w \sum_i \sum_j \frac{P_{wij}}{E_{wij}} \frac{E_{wij}}{E_{ij}} \frac{E_{ij}}{E_j} \frac{E_j}{Y_j} \frac{Y_j}{Y} \frac{Y}{B} B$$

Symbols: P^{SM}: emissions from combustion of energy, E: energy use, Y: production, B: population, w: combustion method , i: energy type and j: sector

The last two factors on the right hand side of the equation correspond to the effect of economic growth on emissions, $Y \equiv Y/B \cdot B$. Given constant emissions per unit produced, P/Y[3], emissions will increase at the same rate as production Y; $P \equiv P/Y \cdot Y$. Economic growth will exclusively increase pollution and degrade the environment, holding all other factors constant. We further decompose economic growth into a component computing the effect of population growth, the *population component B*, and a component of the growth in production per capita, the *scale component Y/B*.

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[3] Note that the sum total of the first five factors on the right hand side of equation (1) equals P/Y.

As we saw in figures 1 and 2, the growth in emissions has varied between the pollutants, and generally the growth in pollution was lower than economic growth. The reason is that emissions to air per produced unit, P/Y, have decreased for all pollutants. New technologies have both led to a more efficient utilization of energy (reduced E_j/Y_j) and to changes in the composition of the use of energy types (E_{ij}/E_j). Furthermore, changes in the production structure (Y_j/Y), the combustion method (E_{wij}/E_{ij}), political actions and technologies increasing emissions abatement have influenced the relationship P/Y. We will now explain these factors further.

In the developed countries, we have observed a transition from agriculture and other primary activities to the main weight on manufacturing and eventually increasing service sectors. This corresponds to a transition from relatively low polluting to more polluting and finally less polluting activities. These stages seem to be natural steps in the development of the economies. The shift to more environmentally friendly production may also be influenced by environmental pressure, and consequently implementation of taxes and regulations which increase the costs of polluting sectors. In the next instance, these means reduce the growth in the most polluting sectors, and may even lead to shutdown of dirty industries. The *composition component*, Y_j/Y, reflects these structural changes' impact on emissions.

The first four terms in Equation (1) represent emissions per unit produced within an individual sector. The energy consumed is important to the changes in emissions per produced unit. Energy consumption is also the main source for pollution to air in Norway. The emissions of NO_x, CO and PM from combustion amount to over 90 percent of the total emissions of these gases, while the remaining originate from processes[4].

The factor E_j/Y_j corresponds to the effect on pollution from changes in the *energy intensity* within each sector. Economic considerations motivate development and use of more energy efficient technologies. Energy taxes in particular, but also policy measures directed towards pollutants, influence the cost of energy per produced unit, and pull in the direction of reduced energy intensity. Thus the energy policy influences the environment, and some of the political measures are obviously motivated by environmental concerns, which in the EKC perspective correlate positively to income. Also, the general technological progress over time works in the direction of more efficient utilization of resources. In a regression analysis, we find a strong and negative relationship between our calculated energy intensity component and income, see Appendix 2.

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[4] Non-combustion emissions; emissions from industrial processes, evaporation, biological processes etc.

The development and use of new types of energy and other changes in the composition of energy commodities affect the environment. While the use of coal and oil leads to acid rain, SO_2 emissions from the use of natural gas are low. CH_4 emissions however, are higher for gas than for coal and oil. The use of electricity, on the other hand, does not generate emissions[5]. Changes in the use of energy types can be motivated by means directed towards the reduction of environmental degradation, as for instance the sulfur tax, which particularly increases the cost of heavy oil. Both the sulfur tax and taxes on CO_2 emissions influence the relative costs, particularly between electricity and fossil fuels. Furthermore, the discovery and extraction of new energy resources, as for instance oil and coal, and the policies towards supporting the development and use of hydro-power, bio-energy and windmills influence the composition of energy. The *energy mix component*, E_{ij}/E_j, reflects the impact on pollution from changes in the energy type composition.

The emissions per energy unit vary between stationary and mobile combustion. We also compute this effect of using different combustion methods, in the *combustion method component,* E_{wij}/E_{ij}.

We have now discussed several influences of technological progress. The corresponding components in Equation (1) capture the effect of technological changes on economic growth, the production structure, energy intensity, energy mix and combustion methods. But there are also other effects of technological changes which affect pollution, beyond those influencing these components. These technological changes may originate from taxes and regulations, as e.g. the taxes on leaded gasoline or regulations on the use of abatement technologies, or from the implementation of new technologies other than affecting the components above, as catalytic converters in cars. The effects of these changes are included in the *other technique component* (P_{wij}/E_{wij}).

When we investigate the *changes* in emissions from 1980 to 1996, we compute the contribution from *changes* in the factors defined in (1); changes in population, economic growth etc. The principles for computing each of the components are described in equation (3) to (10) in Appendix 1.

The identity (1) holds for energy related emissions only. Process related emissions are part of the population-, scale- and composition components, see Appendix 1. In addition, a technique component for process related emissions captures changes in process emissions per produced unit in a given sector (P^{PR}_j/Y_j).

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[5] Electricity production is almost 100% hydro-based in Norway, so there are also few emissions related to the production of electricity.

2.2 The road traffic model

The main model covers the emissions from all sectors in the economy. Most of the car and van traffic takes place in the private households and private services sectors, while the heavy traffic takes place in other industries. The road traffic model thus explains the changes in emissions in these sectors in more detail.

Also, the growth in traffic has been significant in Norway during the several last decades, and traffic stands for a significant share of the polluting emissions to air. Road traffic contributed almost 90 percent of the total Pb emissions in the 1980's and about 70 percent of the total CO emissions and 30 percent of the NO_x emissions over the period from 1980 to 1996, while the shares of CO_2 and PM were about 15-20 percent. For these pollutants, a decomposition of the traffic-related emissions offers important information on the driving forces behind the changes in emissions, see Equation (2).

$$(2) \qquad P^V \equiv \sum_k \sum_l \frac{P^V{}_{kl}}{E_{kl}} \frac{E_{kl}}{E_l} \frac{E_l}{T_l} \frac{T_l}{T} T$$

Symbols: P^V: emissions from road traffic, E: energy use, T: traffic volume, k: fuel type and l: vehicle type

The traffic volume, T, in this model corresponds to the *scale component* given by the production, Y, in Equation (1). The traffic volume measured in kilometers was 1.6 times higher in 1996 as compared to 1980. Despite this growth in traffic, the reductions in the traffic-related Pb and CO emissions were significant. The emissions of PM, NO_x and CO_2 increased, but far less than the traffic volume. Thus, there have been changes in the composition of vehicles, use of fuel per kilometer, fuel types and other technological factors of great importance to the level of polluting emissions. The *composition component*, T_l/T, corresponds to the changes in the use of vehicle type. The energy use per kilometer, E_l/T_l, corresponds to the *energy intensity component*. The *energy mix component* is represented by E_{kl}/E_l and finally the *other technique component* by $P^V{}_{kl}/E_{kl}$.

3 Data

The main model covers emissions from all sources and sectors in the Norwegian economy, except from foreign ocean transport, for the years 1980, 1987 and 1989-1996, with 1980 as base year. The economy is divided into 8 sectors and the energy use into 18 energy types. In a sensitivity analysis over the period 1991 to 1996, with 1991 as base year, we use a sector classification of 125.

The detailed data on emissions to air, energy use and production are documented in the Emissions accounts and the National accounts in Statistics Norway. Energy use is measured in PJ, and the total energy used in a sector is the sum over the use of each energy type, $E_j = \Sigma_i E_{ij}$[6]. Production is measured in NOK. Income (Y) is equal to GDP in fixed 1990 prices, while Y_j is gross production in fixed 1990 prices in sector j except for in the household sector, where Y_j is total household consumption[7].

The total data set consists of 25698 variables, see Bruvoll and Medin (2000) for further documentation of the database. There are a few minor consistency problems in the data set disaggregated to 125 sectors. However, these problems are not of significance for the results.

The stationary and mobile emissions are, to a large extent, computed on the basis of coefficients in the energy accounts. The emissions from the combustion of energy originate from the *use*, and not the *production* of the energy type in question. For the most part, the production of electricity in Norway is not related to combustion of energy. However, since energy constitutes an important part of total energy use, electricity is part of our analysis. Although there are no emissions related to the use of electricity, the changes in electricity use affect the energy mix and energy intensity components.

The emissions accounts are documented in Rypdal (1993, 1995) and Norwegian Pollution Agency and Statistics Norway (1999). The National accounts are documented in Statistics Norway (1997).

4 Results

The main results are presented in Table 1. This table displays the contribution from the different components, computed by equation (3) to (10) in Appendix 1. The factoring is complete, thus the components add up to the total changes in emissions.

In reviewing the results, we emphasize the Pb, SO_2, NO_x and CO_2 emissions. Additional to NMVOC, these emissions are considered the most environmentally damaging emissions to air in Norway.

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[6] Hence, energy use in a given sector is defined as a function of different energy types: $E_j = f(E_{ij})$, where E_{ij} is a vector of the i different energy types used in sector j. It is not obvious, however, that the function should be the sum over all the energy types, as different energy types may provide services of different efficiency, even though the same amount of PJ is used. See Longva and Olsen (1983). The method we have used here is consistent with the method used in Selden et al. (1999).

[7] Hence $\Sigma_j Y_j \neq Y$.

Table 1. The contribution from each component to the changes in emissions, 1980 - 1996. Emissions in percent of 1980 emission level

Components	Pb	SO_2	NO_x	CO_2	CO	PM	NMVOC	N_2O	CH_4	NH_3
Population (N)	7	7	7	7	7	7	7	7	7	7
Scale (S)	52	52	52	52	52	52	52	52	52	52
Composition (C)	-13	-9	2	8	-13	-14	3	-5	8	-6
Energy intensity (H)	-16	-13	-21	-22	-16	-15	-9	-1	-1	0
Energy mix (M)	-8	-29	-3	-17	-5	8	-1	1	0	0
Combustion method (K)	0	0	3	0	0	1	0	0	0	0
Other technique, energy (T^{SM})	-112	-31	-19	0	-42	-13	-16	3	0	4
Other technique, process (T^{PR})	-9	-52	-4	-2	-3	-3	69	-40	-37	-40
Total change	-99	-76	17	26	-20	24	105	18	29	17

See Appendix 1 for the calculations of the components.

4.1 The population and scale components

The pure growth in population (N) of 7 percent also contributes to a growth in all emissions of 7 percent, keeping all the other components, i.e. emissions per capita, constant. The scale component (S, the growth in GDP per capita) is 52 percent. These two components add up to a total GDP growth of 59 percent. This means that given constant energy intensity, energy mix, production structure, and all the other factors influencing the relationship between production and emissions kept constant, the growth in GDP would lead to a growth in all emissions of 59 percent.

4.2 The composition component

Changes in the production structure (C) have also affected the emissions (see Figure 3).

The composition component contributes to reductions particularly in the PM, Pb and SO_2 emissions (see Table 1 and figures 4 and 5). Also Selden et al. (1999) find that the sector composition is an important emission reducing component for PM and SO_x. Most of the Pb emissions stem from car traffic in the household sector. A lower growth in private households' consumption compared to production gives an emission reducing composition component. Another important factor is the shutdown of heavily polluting coal extraction and metal producing firms.

Figure 3. Production and percent growth in production, 1980 and 1996

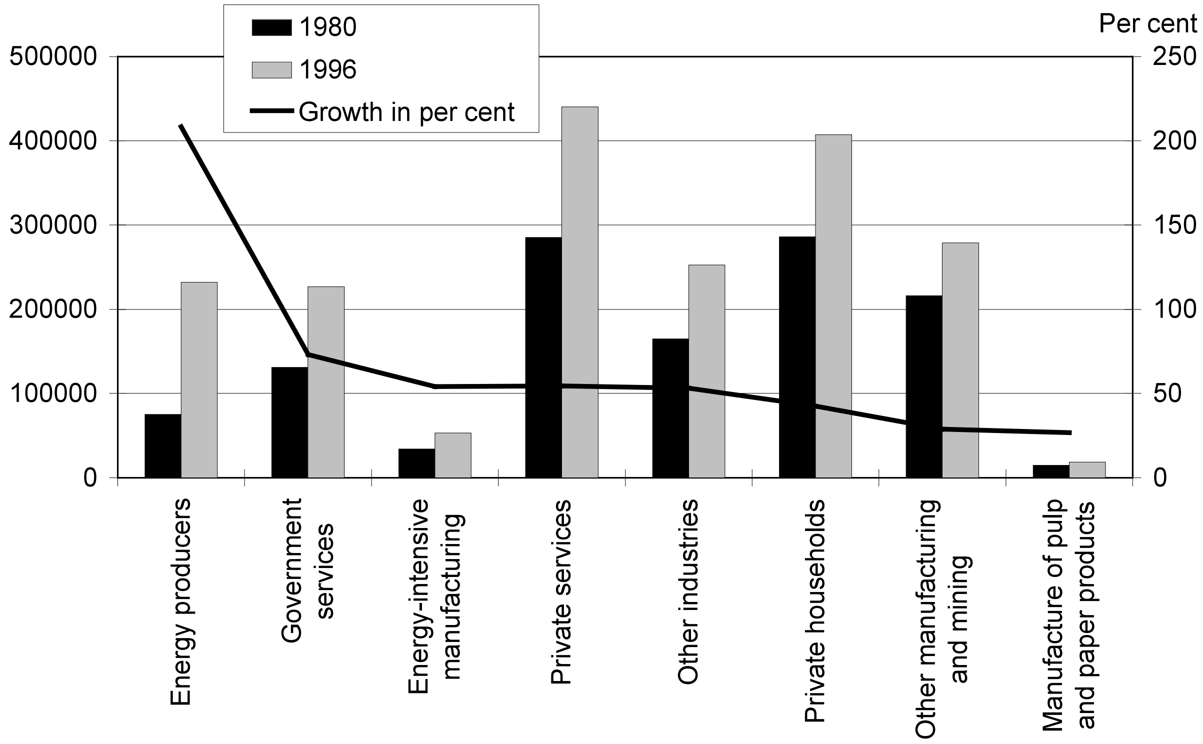


Figure 4. Contribution to emission changes from 1980 to 1996, Pb. Percent

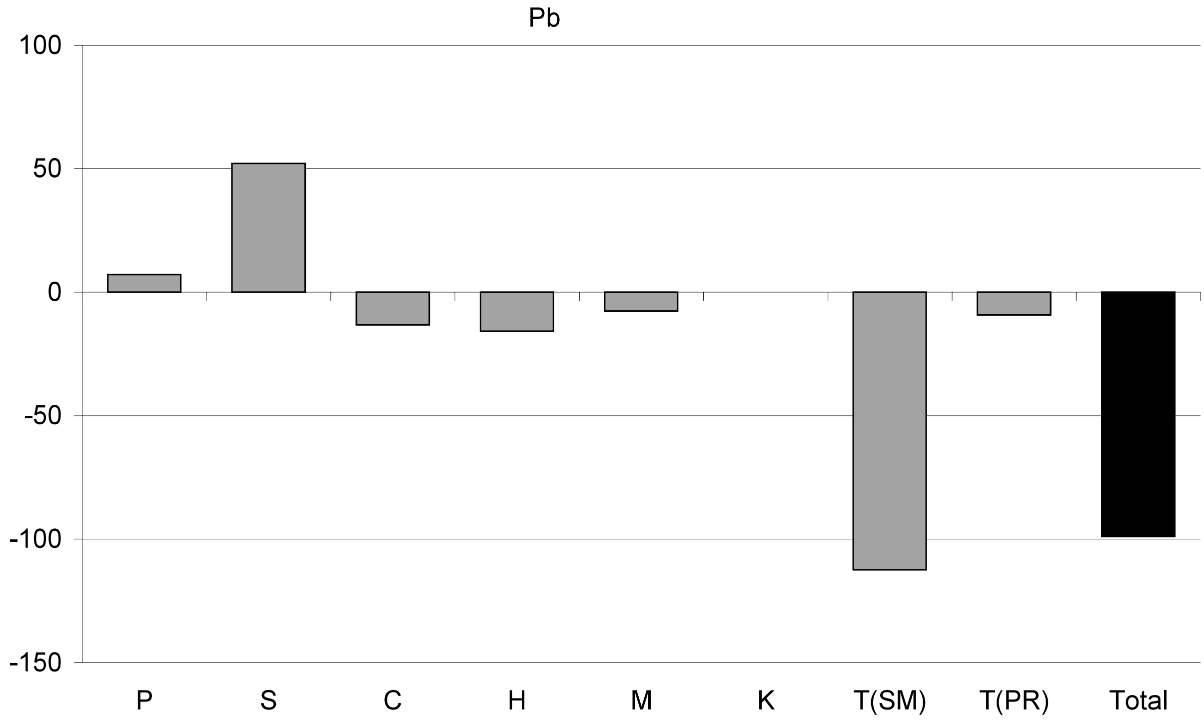
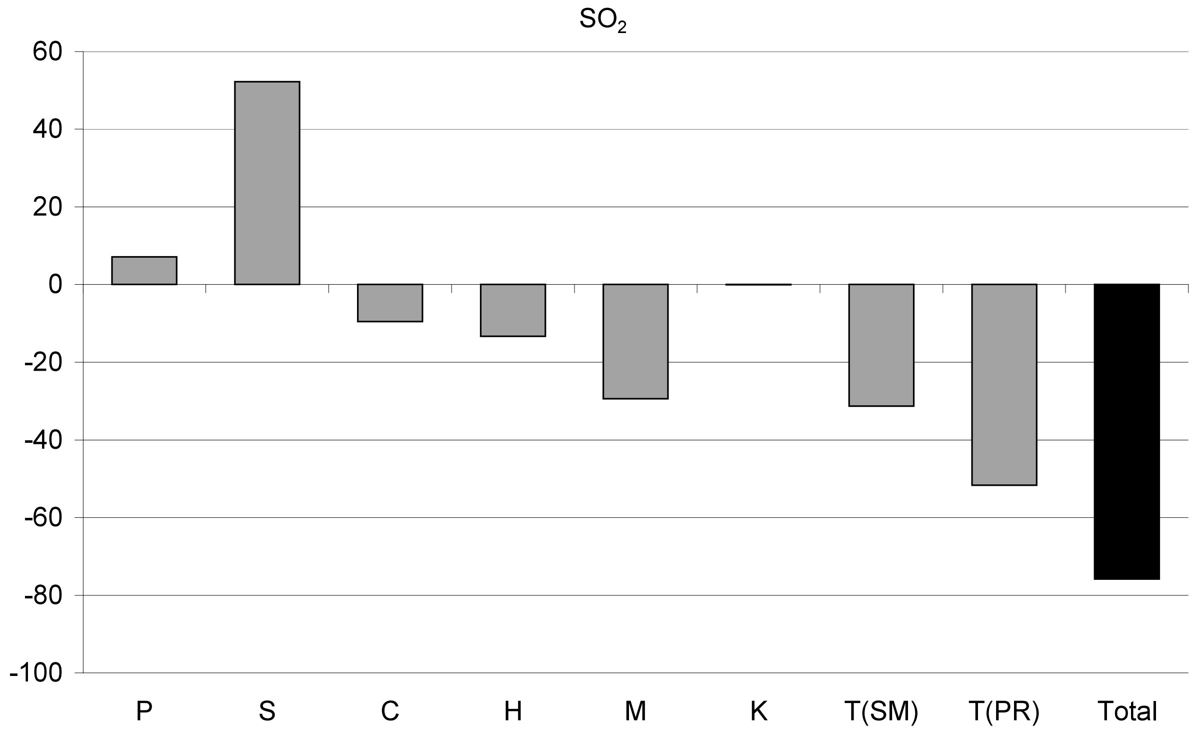


Figure 5. Contribution to emission changes from 1980 to 1996, SO_2. Percent



For SO_2, the sector of other manufacturing and mining contributes to an emission reducing composition component. This sector was the main emitting source in the base year, and the production growth in the sector was lower than average. The relatively low growth in manufacture of paper is also an important contributor to reduced SO_2 emissions. At the same time, the growth in the energy producing sector of 210 percent contributes to higher emissions, and, in total, to dampening the emission reducing effect for SO_2.

For CO_2 and NO_x, the same factors are important (see figures 6 and 7). However, for these emissions, the effect of the growth in oil extraction, which is a part of the energy producing sectors, was stronger than the effect of a lower growth in consumption and in other manufacturing and mining.

Figure 6. **Contribution to emission changes from 1980 to 1996, CO_2. Percent**

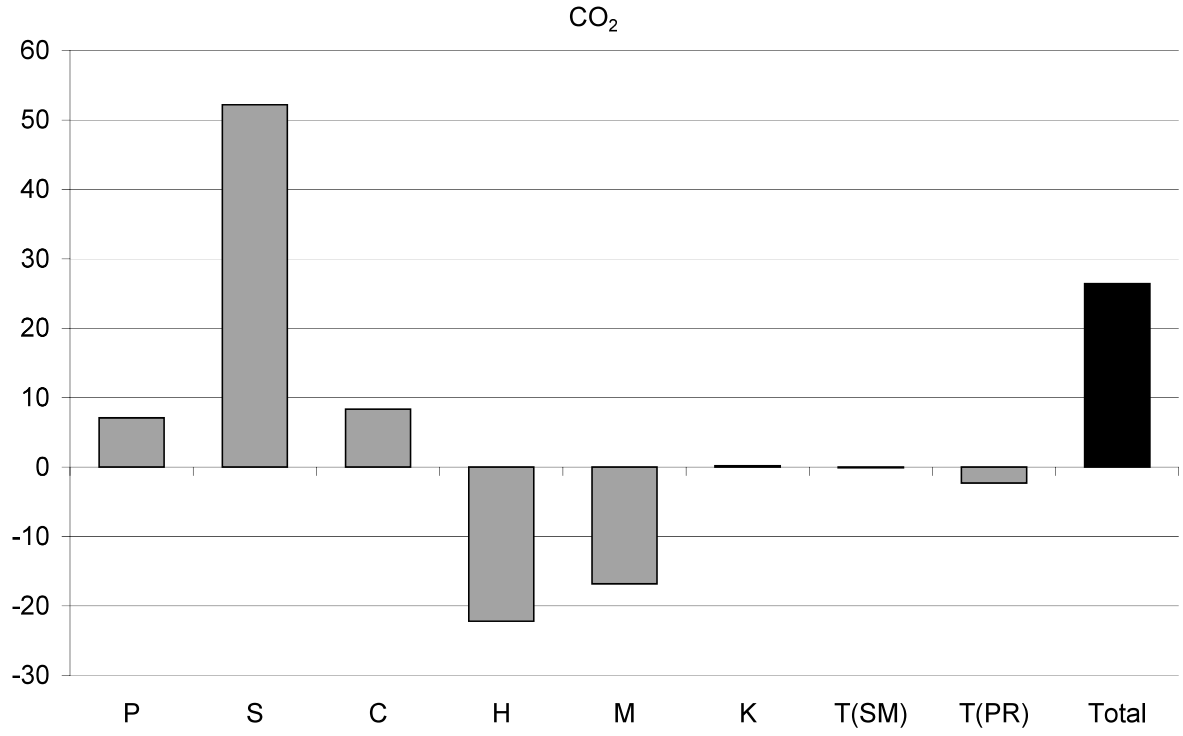
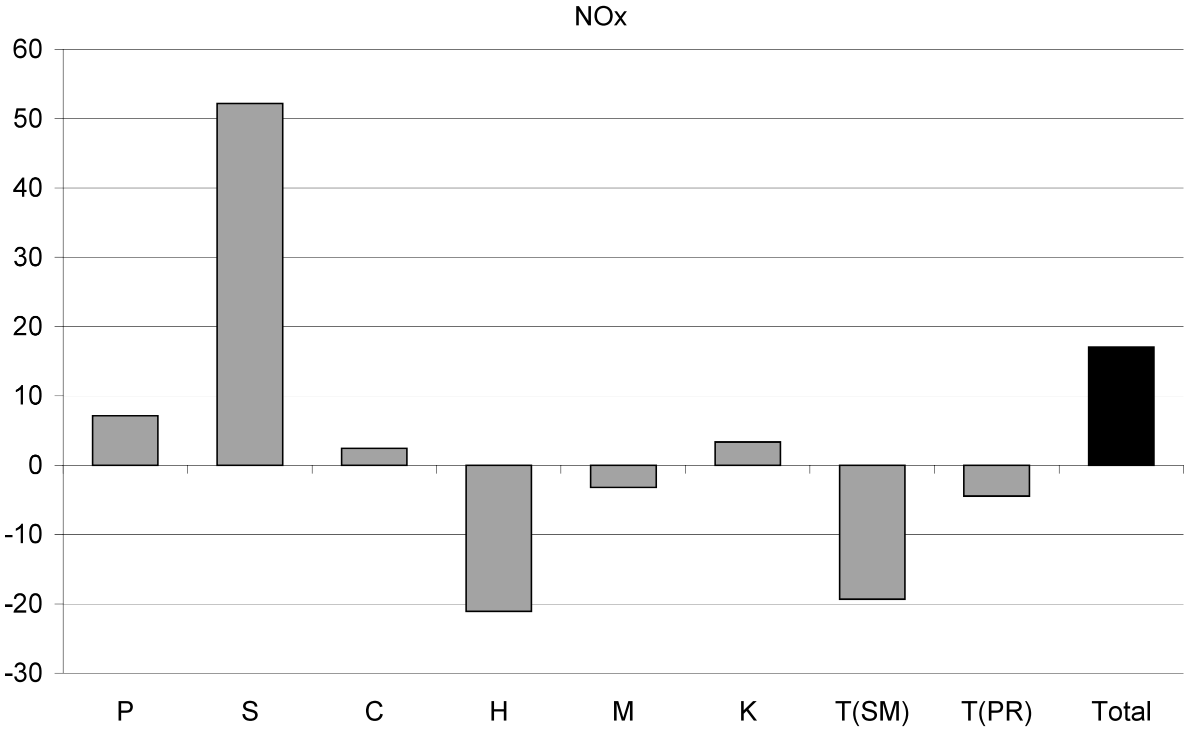


Figure 7. **Contribution to emission changes from 1980 to 1996, NO_x. Percent**

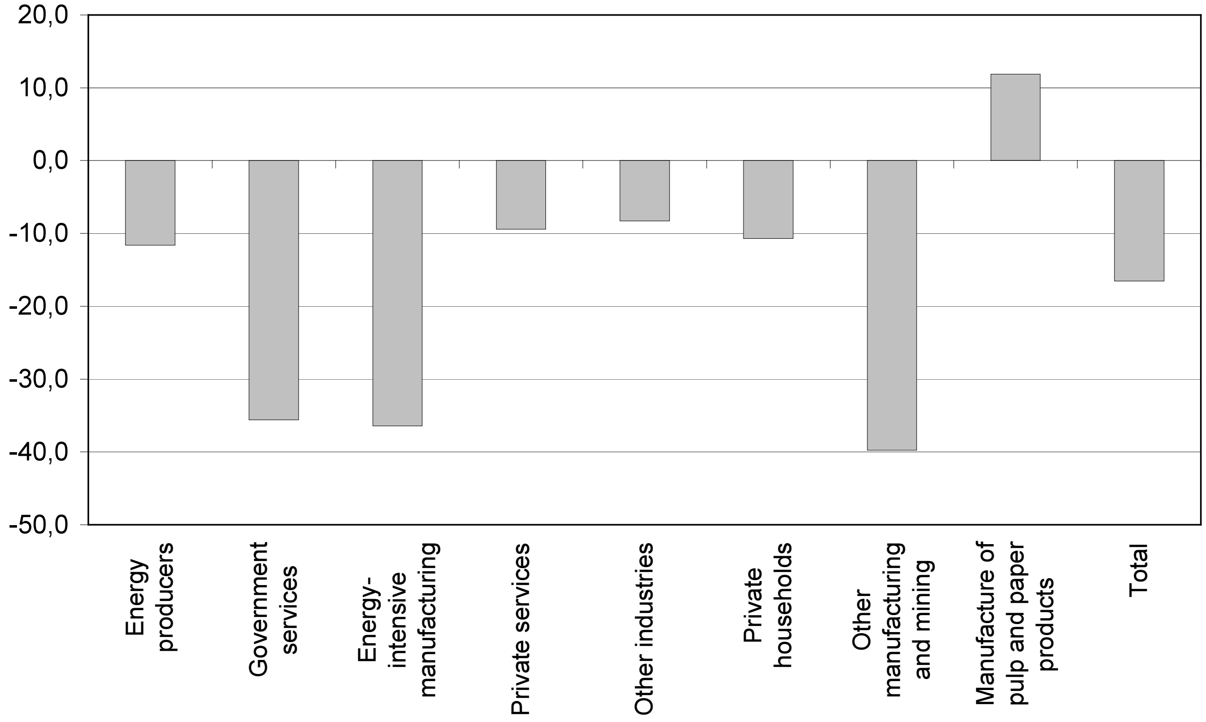


Despite the relatively fast growth in less polluting service industries over the period, the total effect of changes in the composition of sectors was relatively weak, since there was a strong growth in the energy producing industries. A removal of the energy sectors from the analysis results in an emission reducing composition effects for all pollutants except CH_4. Then the composition effect turns out to be an important contributor to the reduction in the emissions particularly for SO_2.

4.3 The energy intensity (H) component

After the other technique components, the reduced energy intensity is most important in explaining the emissions' slowdown or reduction for almost all emissions. Total energy use in relation to total production was reduced in all sectors, except for manufacture of paper and paper products (see Figure 8). On average, the intensity was reduced by 17 percent from 1980 to 1996. The effect on the typically energy-related emissions is in the range 13 to 22 percent (see Table 1). The insignificant effect on N_2O, CH_4 and NH_3 is not surprising, as over 90 percent of these emissions originate from processes. Also in Selden et al. (1999), the energy intensity effect is negative for all emissions.

Figure 8. Percent change in energy intensity from 1980 to 1996



For CO_2, decreased energy intensity was the most important cause for the de-linking between economic growth and the emissions. Our results are in accordance with Torvanger (1991), who find that decreased energy intensity has been the main reason for reduced CO_2-emissions per unit produced. Also, Sun (1999) argues that EKC for CO_2 merely reflects an inverted U-relationship between income and energy intensity. Most important to CO_2 is the effect of the decreased energy intensity in other manufacturing and mining. Also the reduced energy intensity in energy-intensive manufacturing and energy producers contributes to the emission reduction. But the CO_2-emissions are relatively evenly spread over the sectors, and the negative component is a result of the general reduction in energy intensity for most sectors.

The energy intensity is the most important factor counteracting the scale component also for NO_x. Again, the reduced energy intensity in other manufacturing and mining is most important. Even though the energy intensity reduction is relatively small in other industries, this sector is the second-most important contributer, since almost half the NO_x emissions stem from this sector in the base year 1980.

Next to the other technique component, reduced energy intensity is the main reducing component for Pb, CO and PM. In the base year, about two thirds of the emissions stem from households for all three pollutants, and the reduced energy intensity in households of 11 percent contributes to a corresponding reduction in the emissions.

For SO_2, the base year 1980 emissions were highest in other manufacturing and mining, and these industries contribute most to the emission reductions.

4.4 The energy mix (M) component

The energy mix component is less important than the energy intensity for most gases, except for SO_2 and CO_2. Also in Selden et al. (1999), this component is less important than the energy intensity component[8]. In our study, the growth in the use of oil and gas dominate changes in the energy mix (see Figure 9). While gas amounted to 18 percent of the energy use in 1980, this share increased to 34 percent in 1996. At the same time, oil's share was reduced from 74 to 56 percent.

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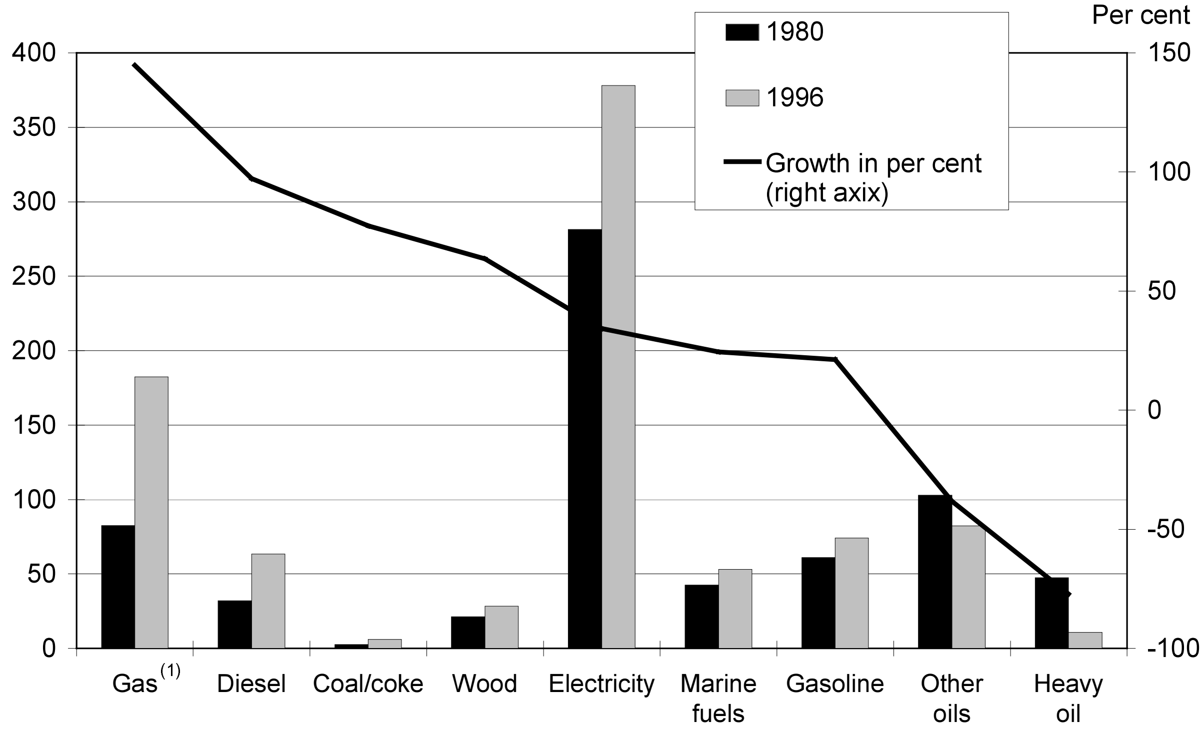
[8] However, note that the energy type aggregation level in Selden et al. (1999) was higher than in this study. This may affect the magnitude of the energy mix component (see Section 5).

Figure 9. Energy use in PJ and percent growth in energy use, 1980 and 1996



(1): Natural gas, LPG and other energy gases.

Changes in the energy mix were particularly important to the reductions of SO_2 emissions, and the reason is the reduced use of heavy fuel oils. For CO_2, the reduced use of heavy oil and other oils has been most important to the reduction. The emission reducing components are somewhat dampened by an increased use of diesel for CO_2. For Pb, this component is dominated by reduced use of gasoline in the private services and other industries, while the increased use in private households have somewhat dampened the effect. For PM, the effect is positive, and the reason is increased use of diesel, particularly in the other industries, and increased use of wood.

4.5 The combustion method (K) component

The share of oil used in mobile combustion increased from 54 percent in 1980 to 76 percent in 1996. The emissions are usually higher in mobile than in stationary combustion, and as a result, changes in the combustion methods of marine oil resulted in higher emissions of NO_x. For the other emissions, this component did not contribute significantly to emission changes.

4.6 The other technique components (T^{SM} and T^{PR})

The other technique components capture the effect of political actions and the effect of technological changes not captured by the other components. For instance, the use of catalytic converters and restrictions of sulfurous content in oil have been important for the reductions in pollution in the period from 1980 to 1996. But the effect of these measures will not, or only to a minor extent, influence the energy mix, energy intensity or the other components already discussed. In our model, the effect will be captured by the other technique component.

The other technique component is also the most important emission reducing component for all emissions except for NMVOC and CO_2. In Selden et al. (1999), the other technique component is the most important component in reducing emissions for VOC, PM, CO and Pb.

For Pb and SO_2, the negative contribution from this component more than outweighs the positive contribution from economic growth. The other technique component alone is strong enough to reduce these emissions. For SO_2, the use of less sulfurous oil (T^{SM}) and the treatment of sulfur emissions (T^{PR}) dominate the component. The Norwegian sulfur tax has been an important economic incentive to reduce the use of heavy fuels and the general acid content in oils.

For Pb, the contributions to increased emissions from the growth in population, GDP per capita and gasoline are stronger than the emission reducing effects from the relatively low growth in consumption and the reduced energy intensity. Still, the total reduction in the Pb emissions is nearly 100 percent. This is a result of the introduction of unleaded gasoline and subsequently the reduction in lead emissions from vehicles. The substitution of unleaded for leaded gasoline has been strongly stimulated by regulations and taxes on leaded gasoline. Also the treatment of process related dust emissions in the metal producing industries has contributed to reductions (T^{PR}).

Since methods have not been developed for treating the CO_2 emissions arising from fossil fuel use, the component is very small for these emissions. For NO_x, this component is dominated by abatement technologies, particularly the use of catalytic converters in motor vehicles. The other technique component also contributes to reductions in the process related emissions. This is due to measures against emissions related to the fertilizer production.

The other technique effect decreased the energy combustion related emissions (see T^{SM}) for all gases except CH_4 and NH_3. This is due to a negative side effect of the use of catalytic converters in vehicular traffic. Evaporation associated with oil loading have increased process related NMVOC emissions

(T^{PR}). The other technique components decreased all other process related emissions. The large negative T^{PR} for CH_4, NH_3 and N_2O is probably an error due to a too aggregated sector classification in the model (see Section 5 for details).

4.7 The road traffic model

The growth in the traffic volume alone contributes to a growth in pollution due to road traffic of over 60 percent, see figures 10 and 11.

Figure 10. Contribution to emission changes from 1980 to 1996, Pb. Road traffic only. Percent

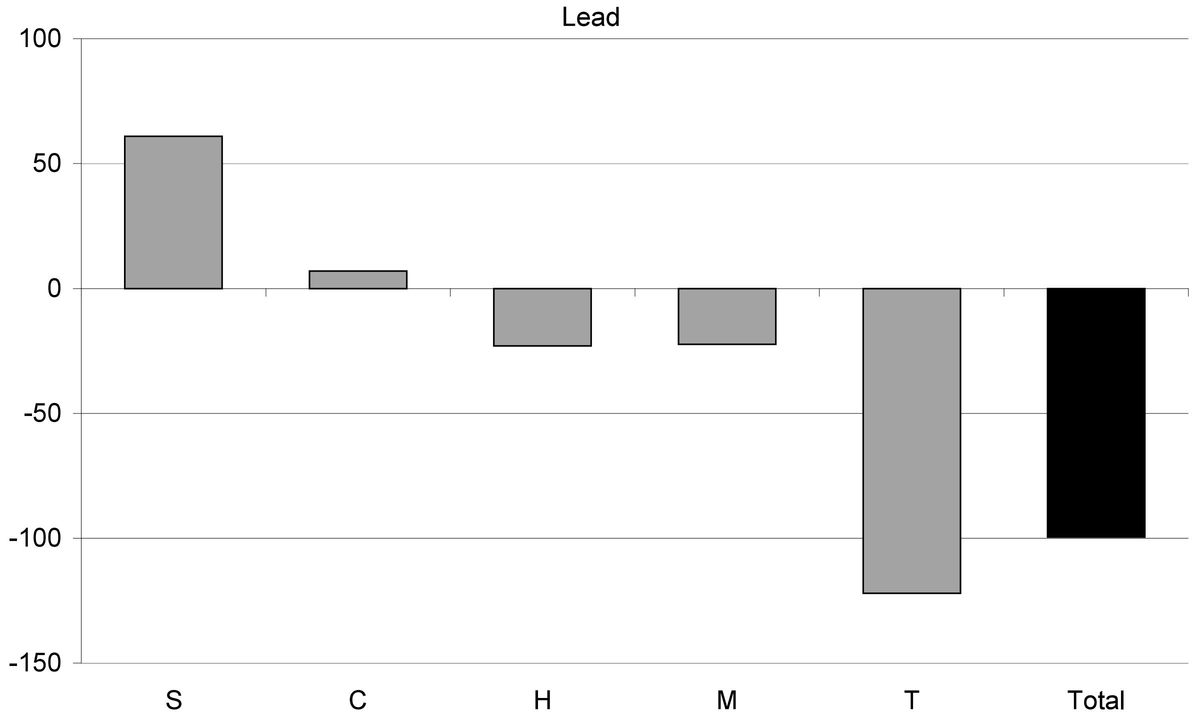
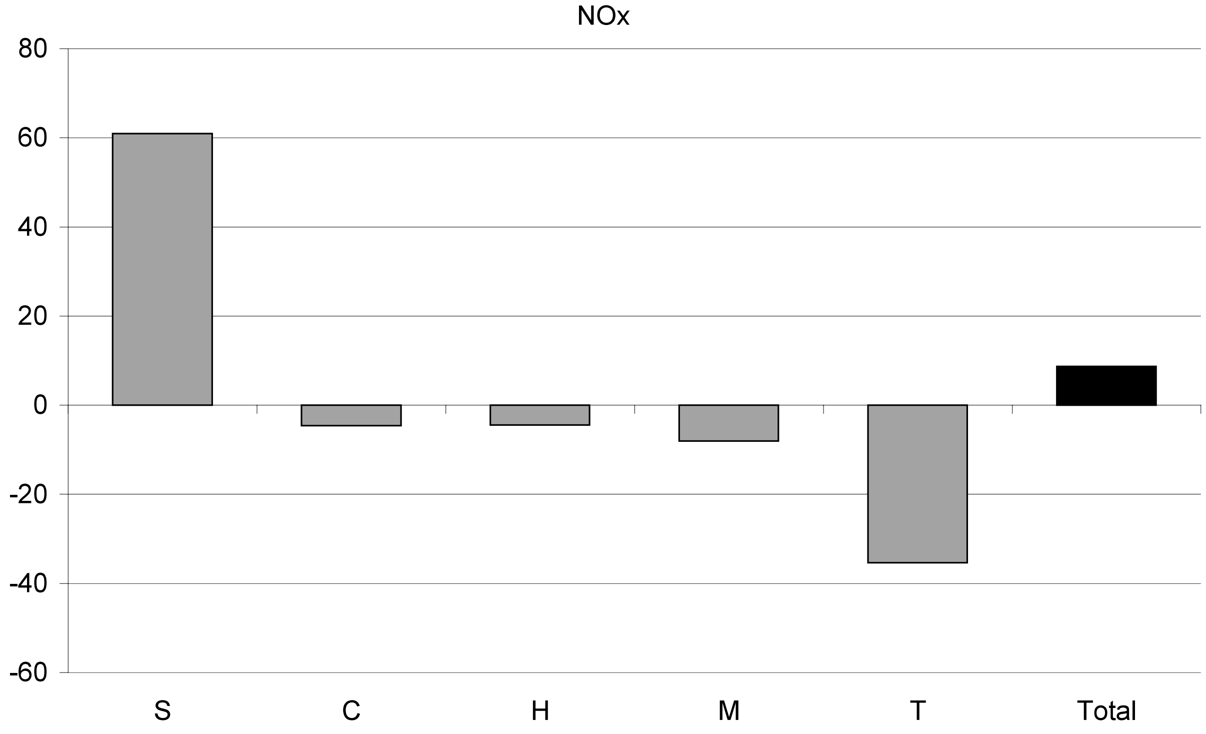


Figure 11. Contribution to emission changes from 1980 to 1996, NO_x. Road traffic only. Percent



The composition component also contributes to higher emissions of Pb. This is due to a change from heavy vans and private cars to low-weight vans. Low-weight vans use more gasoline, while heavy vans use more diesel. In the base year, the Pb content of gasoline was much higher than in diesel. A substitution of diesel for gasoline dominates the energy mix component. Thus, for Pb the effect of the energy mix in the road model is the opposite effect of the composition component, and contributes to lower emissions.

However, the reductions in Pb emissions would not have taken place without the change from leaded to unleaded gasoline, which in our model operates through the other technique effect (T). In a cross sectional study, Hilton and Levinson (1998) decomposed the changes in the amount of automotive lead pollution into factors of pollution intensity (Pb per gallon of gasoline) and pollution activity (consumption of gasoline). They found that Pb follows an EKC, and that the declining portion of the curve depends critically on the reduction in gasoline Pb content, i.e. the factor corresponding to the most important effect in our other technique component.

The introduction of catalytic converters works through the other technique component, and is the most important emission reducing factor for NO_x. These emissions are higher from gasoline than from diesel for smaller cars and vans, but higher for diesel than from gasoline for trucks. The emission reducing composition component is due to the increase in the use of low weight vans (using relatively more gasoline) and the reduced use of heavy vans (using relatively more diesel). Also, the energy mix component reduces emissions, due to a higher substitution of diesel for gasoline in light cars compared to in heavy cars.

5 Sensitivity analyses

We have so far concluded that the energy intensity and the other technique components are most important to the emission reductions over the period 1980-1996. Except for SO_2, the composition, energy mix or combustion method components seem to be of less importance. However, the relative importance of the components might change from year to year. To further investigate the generality and stability of our conclusions, we have looked into the time series of the components and compared the results using 1980 and 1991 as base years.

This comparison offers some interesting results concerning the energy mix and energy intensity components. From 1980 to 1991, the energy intensity is a more important emission reducing component than the energy mix for all emissions except SO_2 and CO_2. In fact, the energy mix component contributes to increased emissions of Pb, NO_x, CO and NMVOC. However, the energy mix becomes negative for these emissions in the period 1991 to 1996. Here, also the energy mix becomes more important than the energy intensity to the emission reductions of Pb, NO_x, and SO_2. For CO_2 and PM the development is different: while the energy mix contributes to reduced emissions in the first period, it increases them in the last period. For N_2O, CH_4 and NH_3 the components related to energy use are insignificant in both periods because almost 100 percent of these emissions are process emissions. See Appendix 3, table 4 and 5 for the results from the analysis.

Another interesting question is whether the aggregation level of sectors and energy types are of significant importance to the results. Selden et al. (1999) used data with a highly disaggregated sector classification of 94 sectors, while we use only 8 sectors. Our aggregated sector classification may give inaccurate results for components calculated on the basis of sector specific data (all components except the population and scale components). For instance, the emissions from the oil-producing sector were large in the base year, and this sector also grew relatively fast. The composition component may become more important if the energy-producing sector is disaggregated into an oil producing sector and other energy producing sectors[9]. '

We used a sector aggregation level of 125 instead of 8 to examine the impact of the aggregation level. This sensitivity analysis was conducted with the base year 1991 instead of 1980, the first year with available data on 125 sector level. For all emissions except CH_4, N_2O and NH_3, there are only small differences in the components using different sector aggregation levels. For the latter emissions, a significant emission-reducing part of the composition component is incorrectly regarded as an other technique component for process emissions, when we use an aggregated sector classification. In general, process emissions seem to be more sensitive to the sector aggregation level than the energy use realted emissions[10]. This is probably due to the fact that the process emissions are only decomposed into 4 components in the model, as opposed to the combustion emissions, which are decomposed into 7 components. The energy use related emissions' share of total emissions is much higher for the rest of the emissions; hence we conclude that the results from the main model are robust to changes in the sector classification except for emissions from CH_4, N_2O and NH_3[11]. Compare the tables 5 and 6 in Appendix 3 for the results from the analysis.

Finally, the energy type classification may influence the energy mix, combustion method and other technique (T^{SM}) components. The energy classification of Selden et al. (1999) was more aggregated than our data[12]. In order to investigate the importance of the energy type aggregation level, we merged our 18 energy types into 5 aggregates in a sensitivity analysis and calculated the model over the same period as the main calculation (1980-1996). In the more aggregated data, the combustion method component is generally strongly overestimated at the expense of the energy mix and the other technique component (T^{SM}) for Pb, NO_x, CO and NMVOC. For SO_2 and PM, the energy mix components are incorrectly regarded as part of the other technique components for energy. The sources of error are mainly due to a strongly aggregated petroleum commodity. Our sensitivity analysis demonstrates the importance of distinguishing between energy types as gasoline, diesel, heavy fuel oils, fuel oil and

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[9] The sectors "Extraction of crude petroleum and natural gas" and "Gas terminal" grew with 57 percent from 1991 to 1996, while the average growth of the energy producer sectors was 43 percent.

[10] With 125 sectors, the main contributors to the large negative composition component for the emissions in question, are sectors with a high share of process emissions compared to combustion emissions.(Manufacture of cement, lime and plaster, Manufacture of fertilisers, nitrogen compounds and pesticides, Extraction of crude petroleum and natural gas, Gas terminal and Agriculture).

[11] There may also be a slight underestimation of the emission increasing composition component for CO_2 and NMVOC in the main model. The prosess emissions' share of total emissions for these gases is 20 and 67 % respectively.

[12] The energy types in Selden et al. (1999) was electricity, coal, natural gas, distillates, residual fuel oil, and wood (for residential heating) for stationary sources and diesel oil, gasoline, residual oil and coal for mobile sources (personal correspondence).

marine oils, and in future analyses on similar data this should be taken into account. However, a distinction between different gases or coal and coke types seems to be of minor importance.

This last sensitivity analysis may suggest that our results can be improved by a further disaggregation of energy. Dividing gasoline in leaded and unleaded gasoline would indeed transfer some of the other technique component to the energy mix component for e.g. Pb and CO. Also, dividing heavy fuel oil into high sulfur and low sulfur heavy fuel oil could increase the importance of the energy mix component for SO_2. But, apart from the two examples mentioned here, a further disaggregation of energy types would probably not change the results significantly. Compare Table 7 in Appendix 3 and Table 1 in Section 4 for the results from the analysis.

6 Discussion

What can we learn about the relationship between economic growth and the environment from this analysis? First of all, the air pollution has not followed the pace of the economic growth. Even for CO_2 emissions, where there exist no abatement technologies, emissions have grown at a rate less than half of the growth in production.

This is mainly due to new technologies. Economic growth follows technological progress, which has improved the utilization of energy. In general, reduced energy intensity contributes to lower emissions of all pollutants related to the energy use. In addition, environmentally motivated political actions, in combination with other technological changes, have been decisive factors in the cases where the emissions have actually been reduced. Even though the Norwegian economy has experienced large structural changes, as well as changes in the use of various types of energy, the effect of these changes has been relatively small compared to the more technologically related influences. However, our sensitivity analysis indicates that for process related emissions, changes in the sector composition seem to be important. Further, the composition of energy types seems to become more important at the end of the analyzed period.

An interesting question arises regarding factors that reduced emissions, and whether or not they were influenced by economic growth. The relation between economic growth and technological progress is like the chicken and the egg debate, a question of which came first? Our regression analysis shows that there is a strong and negative relationship between production and one of the components, namely energy intensity (see Appendix 2). This, of course, demonstrates only a partial effect on emissions. Even though general technological progress may affect the environment positively, rebound effects can increase the overall environmental pressure through the scale component.

Some studies find that energy prices are more significant explanatory factors than economic growth, (see Agras and Chapman, 1999). In the regression analysis, we also tested whether energy prices influence emissions through the energy intensity component. For all emissions except SO_2, we find a significant and negative effect of energy prices, when controlling for economic growth. In Norway, taxes on SO_2 have probably been important in bringing about reductions in emissions. But the effect of the sulfur tax has been more significant for other technologies (such as emission treatment) than the technologies reducing the energy intensity.

Our results do not imply that economic growth is an environmental cure. Even though it seems like growth so far has reduced the emissions of Pb, SO_2 and CO, and can also reduce other emissions, there is no reason to assume that this is a natural process that will continue in the future. The EKC writers also emphasize this. Some researchers argue that the reduced emissions might increase again in the future; instead of an upside down U-curve, the emissions may follow an N-curve (see Torras and Boyce, 1998 or Suri and Chapman, 1998). When the capability level for technological improvements is reached, the scale effect takes over.

For some emissions, such as CO_2, there is no tendency to reach a peak of a possibly inverted U-curve within a reachable income level per capita. Holz-Eakin and Selden (1995) estimate a top of CO_2 emissions at about $ 8 mill. per capita. According to Holz-Eakin and Selden, although emissions in some countries were reduced due to a decrease in subsidization of heavy industries and changes in the sector composition, the underlying economic growth will actually increase the emissions over time. Their study is a clear warning that economic growth alone is not sufficient in reducing emissions.

This analysis is a step towards understanding the forces behind changes in air pollution. A possible further step will be to investigate the impact of economic growth, and of prices and regulations on each of the components, in accordance with our above analysis of the energy intensity component. Particularly, it would be interesting to look into the factors influencing the other technique component and the general technological progress.

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Appendix 1

Computing the emission components

The population component, N_t:

$$(3)\qquad \overline{N}_t = P_0\frac{1}{B_0}\left[B_t - B_0\right] = P_0\left[\frac{B_t}{B_0} - 1\right], \qquad N_t = \frac{\overline{N}_t}{P_0}100$$

The scale component, S_t:

$$(4)\qquad \overline{S}_t = P_0\frac{B_t}{Y_0}\left[\frac{Y_t}{B_t} - \frac{Y_0}{B_0}\right] = P_0\left[\frac{Y_t}{Y_0} - \frac{B_t}{B_0}\right], \qquad S_t = \frac{\overline{S}_t}{P_0}100$$

The composition component, C_t:

$$(5)\qquad \overline{C}_t = \sum_j P_{j0}\frac{Y_t}{Y_{j0}}\left[\frac{Y_{jt}}{Y_t} - \frac{Y_{j0}}{Y_0}\right] = \sum_j P_{j0}\left[\frac{Y_{jt}}{Y_{j0}} - \frac{Y_t}{Y_0}\right], \qquad C_t = \frac{\overline{C}_t}{P_0}100$$

The energy intensity component, H_t:

$$(6)\qquad \overline{H}_t = \sum_j P_{j0}{}^{SM}\frac{Y_{jt}}{E_{j0}}\left[\frac{E_{jt}}{Y_{jt}} - \frac{E_{j0}}{Y_{j0}}\right] = \sum_j P_{j0}{}^{SM}\left[\frac{E_{jt}}{E_{j0}} - \frac{Y_{jt}}{Y_{j0}}\right], \qquad H_t = \frac{\overline{H}_t}{P_0}100$$

The energy mix component, M_t:

$$(7)\qquad \overline{M}_t = \sum_j\sum_i P_{ij0}{}^{SM}\frac{E_{jt}}{E_{ij0}}\left[\frac{E_{ijt}}{E_{jt}} - \frac{E_{ij0}}{E_{j0}}\right] = \sum_j\sum_i P_{ij0}{}^{SM}\left[\frac{E_{ijt}}{E_{ij0}} - \frac{E_{jt}}{E_{j0}}\right], \qquad M_t = \frac{\overline{M}_t}{P_0}100$$

The combustion method component, K_t:

$$(8)\qquad \overline{K}_t = \sum_j\sum_i\sum_w P_{wij0}{}^{SM}\frac{E_{ijt}}{E_{wij0}}\left[\frac{E_{wijt}}{E_{ijt}} - \frac{E_{wij0}}{E_{ij0}}\right] = \sum_j\sum_i\sum_w P_{wij0}{}^{SM}\left[\frac{E_{wijt}}{E_{wij0}} - \frac{E_{ijt}}{E_{ij0}}\right], \qquad K_t = \frac{\overline{K}_t}{P_0}100$$

The other technique component for combustion related emissions, $T^{SM}{}_t$:

$$(9)\qquad \overline{T}_t{}^{SM} = \sum_j\sum_i\sum_w\left[P_{wijt}{}^{SM} - P_{wij0}{}^{SM}\frac{E_{wijt}}{E_{wij0}}\right], \qquad T^{SM}{}_t = \frac{\overline{T^{SM}{}_t}}{P_0}100$$

The other technique component for process related emissions, $T^{PR}{}_t$:

$$(10)\qquad \overline{T}_t{}^{PR} = \sum_j\sum_i\left[P_{jt}{}^{PR} - P_{j0}{}^{PR}\frac{Y_{jt}}{Y_{j0}}\right], \qquad T^{PR}{}_t = \frac{\overline{T^{PR}{}_t}}{P_0}100$$

Symbols:

P: emissions
Y: production
E: energy use
B: inhabitants
SM: stationary and mobile combustion
PR: process
j: sectors
i: energy commodities
w: energy use process (stationary or mobile)
t: time

Process emissions include all non-combustion emissions. Thus, it is not relevant to link these emissions to energy use, and the emissions and energy use in equations (6) to (8) include stationary and mobile combustion only (SM). The process emissions are included in population, scale, composition and other technique components (10).

Equation (1) expresses an identity, i.e. the decomposition is complete. All components in (3) to (10) summarize to the total emissions, $\overline{N}_t + \overline{S}_t + \overline{C}_t + \overline{H}_t + \overline{M}_t + \overline{K}_t + \overline{T}^{SM}_t + \overline{T}^{PR}_t = P_t$.

Factors behind the energy intensity component

Although we have calculated the scale component, i.e. the effect of economic growth holding all other factors constant, this component does not reveal the *total* effect of economic growth on the environment. Economic growth influences most, or all, of the other calculated components. For instance, economic growth and technological progress are likely to be important factors behind the reduced energy intensity. A likely response to price increases is decline in the use of energy per unit produced. Furthermore, the adjustment to more energy efficient technologies might depend on the historical adjustment.

To investigate the relationship between the impact of energy intensity changes and income and energy prices, we study the computed energy intensity component. We use panel data including the energy intensity component, energy prices and production over 8 years[13] and 7 production sectors[14], see Equation (12). The energy intensity component in each sector, $\overline{H}_{jt}$, is calculated according to the non-summarized data in Equation (8) in Appendix 1. This component measures the change in emissions from the base year 1980. The energy price data, p_{jt}, and GDP per capita, y_t, are computed in the national accounts in Statistics Norway. We use a fixed effect model to execute a regression analysis on Equation (12):

$$(12) \qquad \overline{H}_{jt} = a_0 + a_1 Y_t + a_2 p_{jt} + a_3 \overline{H}_{j,t-1} + \varepsilon_t \qquad \text{t} = 1987,...,1995$$

$$\varepsilon_{11} ....\varepsilon_{JT} \sim IID\left(0, \sigma^2\right)$$

The basic results are displayed in Table 2. See Table 3 for an overview over the complete regression results.

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[13] 1987 - 1995. Emission data do not exist for 1988. Thus the energy intensity value is calculated as the average value of 1987 and 1989.

[14] Government services, private services, private households, energy-intensive manufacturing, manufacture of paper and paper products, other manufacturing and mining, other industries. Our sources include no price data for the energy sector.

Table 2. Regression analysis, factors determining the energy intensity component

	PB	SO_2	NO_x	CO_2	CO	PM	NMVOC
R^2-adj	0,84	0,98	0,93	0,95	0,83	0,83	0,82
Y							
coefficient	-0,1	-16,7	-51,0	-8076,4	-194,2	-3,7	-21,8
p-value	0,008	0,001	0,000	0,000	0,009	0,011	0,009
mean: 201							
standard error: 1.6							
p							
coefficient	-0,2	-8,8	-48,1	-8184,2	-328,4	-5,6	-36,0
p-value	0,005	0,203	0,027	0,001	0,006	0,018	0,007
mean: 91							
standard error: 6.4							
lag							
cofficient	0,9	0,6	0,2	0,5	1,0	1,0	1,0
p-value	0,000	0,000	0,127	0,000	0,000	0,000	0,000
Standard error	4,2	346	1043	107336	5755	114	637

Number of observations: 56.

As we see from Table 2, the increase in GDP per capita has been significant in explaining the pollution changes from the energy intensity component. The energy price is also significant for all emissions, except for SO_2. Furthermore, there is a significant lag effect in the energy intensity component for all emissions except NO_x.

We then find a significant correlation between production and one of the components contributing to reduce or slow down the direct effect of economic growth specified as the scale component. Also Agras and Chapman (1999) find that energy prices are important in explaining changes in CO_2 emissions, as energy prices are important indicators of energy demand. They argue that an energy price increase possibly shifts the inverted U-curve downwards, hence reducing the total future environmental load.

We have not investigated the impact of energy prices on the *total* use of energy in our material. A further step would be to investigate the effect of sector- and energy specific prices on the energy mix and other technique components. However, such analyses would require more detailed data than what is available at the present time.

Table 3. Sector dummies from the fixed effect model

Emission		Coeffecient	P-value
Pb	Other industries	11,1	0,016
	Other manufacturing and mining	7,3	0,033
	Energy-intensive manufacturing	-0,5	0,807
	Government services	19,6	0,011
	Private households	26,4	0,020
	Private services	21,8	0,011
SO_2	Other industries	-323,3	0,423
	Other manufacturing and mining	-2704,4	0,006
	Energy-intensive manufacturing	-1003,2	0,004
	Government services	350,3	0,565
	Private households	1106,1	0,232
	Private services	717,7	0,296
NO_x	Other industries	-6077,8	0,000
	Other manufacturing and mining	-5025,5	0,000
	Energy-intensive manufacturing	-980,4	0,079
	Government services	2437,2	0,192
	Private households	5201,9	0,069
	Private services	2842,3	0,174
CO_2	Other industries	-567,1	0,996
	Other manufacturing and mining	-530827,1	0,002
	Energy-intensive manufacturing	-368079,1	0,000
	Government services	387286,4	0,047
	Private households	920788,1	0,003
	Private services	597728,8	0,008
CO	Other industries	14935,8	0,018
	Other manufacturing and mining	9925,4	0,034
	Energy-intensive manufacturing	-654,0	0,822
	Government services	26802,1	0,012
	Private households	35833,4	0,021
	Private services	30823,2	0,009
PM	Other industries	241,7	0,054
	Other manufacturing and mining	168,7	0,075
	Energy-intensive manufacturing	-16,2	0,782
	Government services	473,0	0,024
	Private households	605,2	0,048
	Private services	546,3	0,020
NMVOC	Other industries	1597,5	0,021
	Other manufacturing and mining	1068,7	0,039
	Energy-intensive manufacturing	-74,2	0,817
	Government services	2934,3	0,013
	Private households	3917,4	0,023
	Private services	3396,2	0,009

Appendix 3

Sensitivity analyses

Table 4-7 show the results from the sensitivity analysis referred to in Section 5.

Stability over time

Table 4. The contribution from each component to the changes in emissions, 1980 - 1991. Emissions in percent of 1980 emission level

Components	Pb	SO_2	NO_x	CO_2	CO	PM	NMVOC	N_2O	CH_4	NH_3
Population (N)	4	4	4	4	4	4	4	4	4	4
Scale (S)	26	26	26	26	26	26	26	26	26	26
Composition (C)	-7	-5	0	5	-7	-9	1	-4	8	-6
Energy intensity (H)	-5	-10	-15	-13	-5	-5	-3	-1	0	0
Energy mix (M)	6	-25	1	-16	4	-5	4	0	0	0
Combustion method (K)	0	-1	2	0	0	1	0	0	0	0
Other technique, energy (T^{SM})	-88	-21	-6	-1	-30	-1	-8	1	0	1
Other technique, process ($T^{PR.}$)	-7	-37	-3	-3	-1	0	48	-6	-18	-19
Total change	-71	-68	11	3	-8	11	72	21	21	6

Table 5. The contribution from each component to the changes in emissions, 1991 - 1996. Emissions in percent of 1991 emission level

Components	Pb	SO_2	NO_x	CO_2	CO	PM	NMVOC	N_2O	CH_4	NH_3
Population (N)	3	3	3	3	3	3	3	3	3	3
Scale (S)	19	19	19	19	19	19	19	19	19	19
Composition (C)	-3	-2	2	4	-3	-2	9	-1	-2	1
Energy intensity (H)	-9	-1	-3	-6	-9	-7	-3	0	0	0
Energy mix (M)	-12	-7	-4	1	-6	11	-3	0	0	0
Combustion method (K)	0	0	0	0	0	0	0	0	0	0
Other technique, energy (T^{SM})	-93	-15	-11	1	-14	-10	-5	2	0	3
Other technique, process ($T^{PR.}$)	-2	-22	0	1	-2	-2	-1	-26	-13	-15
Total change	-96	-25	6	22	-13	12	19	-3	7	10

The aggregation of sectors

Table 6. The contribution from each component to the changes in emissions, 1991 - 1996. Emissions in percent of 1991 emission level. 125 sectors

Components	Pb	SO_2	NO_x	CO_2	CO	PM	NMVOC	N_2O	CH_4	NH_3
Population (N)	3	3	3	3	3	3	3	3	3	3
Scale (S)	19	19	19	19	19	19	19	19	19	19
Composition (C)	-2	-4	3	7	-2	-2	15	-23	-21	-23
Energy intensity (H)	-12	1	-4	-5	-11	-5	-4	0	0	0
Energy mix (M)	-9	-6	-4	0	-5	8	-2	0	0	0
Combustion method (K)	0	0	0	0	0	0	0	0	0	0
Other technique, energy (T^{SM})	-92	-15	-10	1	-14	-9	-4	3	0	3
Other technique, process ($T^{PR.}$)	-1	-24	-1	-3	-2	-3	-8	-4	7	9
Total change	-95	-26	5	21	-13	12	18	-3	7	10

The aggregation of energy types

Table 7. The contribution from each component to the changes in emissions, 1980 - 1996. Emissions in percent of 1980 emission level. 5 energy types

Components	Pb	SO_2	NO_x	CO_2	CO	PM	NMVOC	N_2O	CH_4	NH_3
Population (N)	7	7	7	7	7	7	7	7	7	7
Scale (S)	52	52	52	52	52	52	52	52	52	52
Composition (C)	-13	-9	2	8	-13	-14	3	-5	8	-6
Energy intensity (H)	-16	-13	-21	-22	-16	-15	-9	-1	-1	0
Energy mix (M)	-30	-13	-13	-16	-25	-3	-14	0	0	0
Combustion method (K)	39	-6	13	0	32	3	18	0	0	0
Other technique, energy (T^{SM})	-128	-42	-19	-1	-54	-4	-21	4	0	4
Other technique, process ($T^{PR.}$)	-9	-52	-4	-2	-3	-3	69	-40	-37	-40
Total change	-99	-76	17	26	-20	24	105	18	29	17

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