Economic Analysis of Driving Forces of Environmental Burden during the Transition Process: EKC hypothesis testing in the Czech Republic.

Jan Brůha
Charles University Environment Center in Prague, Czech Republic

Milan Ščasný
Charles University Environment Center in Prague, Czech Republic

Paper presented at the 6th International Conference of the European Society for Ecological Economics (ESEE-2005), Lisbon, 14-17 June 2005.

Abstract
This paper aims at a quantitative assessment of main possible driving forces of the changes in the environmental burden in the Czech Republic during the transition. We focus on a relation between economic performance and main air quality indicators – SO2, NOx, CxHy, CO, particulates, and GHG emissions – at macro and sectoral level during 1992-2003 in the Czech Republic. Firstly, we provide a brief qualitative assessment of air pollution caused by entire economy, sectors and households, of the Czech economy performance including its structural change, of energy consumption and main regulative changes possible affected the emission level. Secondly, we do quantitative exercise in order to explain changes in emission levels. We decompose the change on three effects: effect of change in the <u>scale</u> of economic performance, of change in economic <u>structure</u>, and of environmental <u>intensity</u>. Non-GHG emission reduction was mainly due to a change in the economic structure, this was followed by the fall in emissions per unit of value added (the intensity effect). SOx and particulate matter emissions enjoyed the most significant intensity effect during the years 1997-2000. The likely explanation is that power plants had to fulfil the legislative requirements in air quality protection up to 1998. The change in the composition of economic activity led to an emission reduction in almost all years, except of the years 1996 and 2002. Using economic and environmental data, we then perform an econometric exercise to infer impacts of economic variables such as environmental investment, factor productivity and autonomous technology diffusion on the intensity effect in the manufacturing sector. We find that environmental investments in this sector mattered only for a part of emissions, and for those with a limited impact only. The fall in emission intensities was associated with an increase in capital or labour productivity (or both). The influence of the technological change due to rapid restructuring of the economy is steadily diminishing. Discussion on our further possible research steps needed to improve our exercise here provided concludes.

Keywords:
Environmental Kuznets Curve; air pollution; driving forces; structural changes; transition

1. Introduction

The Central European economies have passed a long way from centrally-planned systems towards the market system since 1990. Although the transition economies are still material and energy intensive, huge structural economic changes have occurred and the quality of the environment in many areas has been significantly improved.

There are several explanations why the environmental quality has improved, among the most popular ones are:

- structural changes of the economy, particularly relative increase in the share of market services,

- increase in public environmental concern leading to adoption of stricter environmental regulation,
- technology diffusion from abroad,
- external pressures from international bodies (e.g. from the European Union) to adopt stricter environmental standards and regulation.

These explanations are surely not mutually inconsistent, and thus it is not easy to assess the exact role of each of them. Moreover, other important factors can have an unclear (or even ambiguous) impact as well: a prominent example is Foreign Direct Investments. These investments may diminish relative environmental burden by technology diffusion, or they can intensify the burden by a 'composition effect'.

To understand the nature and extend of these factors is crucial not only for 'historical' reasons, but also for future regulatory policy. Certain policy action may be expected due to the fact that the material and energy intensity of new EU Member States, and the Czech Republic particularly, has being still remained high in comparison to the former EU-15. For this policy purposes, it is worth to *ex post* analyse the change in certain environmental burden due to economic activity, particularly, if this change was caused mainly by (firm, public or foreign) environmental investment, direct and indirect regulation, or by technological change in the past.

This paper aims at quantitative assessment of main driving forces, which possibly involved the change in certain environmental burden in the Czech Republic during the transition, namely during 1993 to 2002. We focus on macro level – entire economy and selected sectors. Using these data, we perform an econometric exercise to infer impacts of economic factors on the environmental indicators.

The paper tries to answer particularly the following set of question:

- To test, for which ecologic phenomena, the EKC hypothesis holds in the Czech Republic.
- To what extend, the structural change in the Czech economy has led to decrease in the environmental burden and what is the role of technological progress and factor utilization.
- To assess quantitatively efficiency of environmental investment on the main ecological indicators.

2. Data description

In this chapter, firstly, we describe source of data we used. Then, we provide a brief overview of Czech economy during the transition, covering the period 1990-2003 including qualitative assessment of changes in energy consumption, material intensity and important environmental regulation that - all of them - have likely played the most important role as driving forces for the change in air emission levels. Lastly, we summarize development in airborne emissions, that we pay attention in our analysis for.

2.1. Data sources

Economic variables - considered in our analysis - compose data on production, gross value added (GVA), gross fixed capital formation and consumption, labour costs and number of employees, operational surplus, and the capital-labour intensity ratio. Source of data is Czech Statistical Office (CSO 2005). The data span covers the period of 1995-2003 for that consistent time series can be found for 30 sectors, data on GVA for overall 60 sectors of the Czech economy (according to NACE classification; at digit-3 level, or digit-2 level resp.). A more comprehensive exercise may be done at the end of 2006 when consistent time series of economic data for the period of 1990-1994 will be provided by the Czech Statistical Office (CSO). Similarly, consumption of households including data on energy expenditures and expenditures on durables are provided by CSO and cover time span of 1995-2003. Environmental investments, total and related to air-protection, are provided by CSO as well and are taken from the official statistical yearbooks of Ministry of the Environment and CSO. This data are disaggregated for 60 economic sectors (at NACE digit-2 level) and covers span of 1994-2003. Investment is deflated at 1995 price level by using officially reported data on investment in current prices and prices of previous year (deflator for GVA is used for missing years). Economic data are deflated by GVA deflator. Prices of energies are taken from IEA/OECD energy statistics (IEA/OECD 2004).

Data on energy consumption are provided by CSO and got from the yearly statistics of the Czech Ministry of the Environment (MoE 2004). Consumption of main energies including electricity and heat by sectors (NACE classification) covers only the period 1998-2003 and therefore cannot be used in our analysis. Data on energy consumption provided by IEA/OECD energy statistics different classification then NACE does. Data on material flows were compiled by using various official statistical sources following relevant methodological guide by Eurostat (see Ščasný et al. 2003).

Emission data for main classical pollutants such as SOx, NOx, CxHy (VOC), CO, and particulates are based on the Register on sources of air emission (REZZO database) compiled by the Czech Hydrometeorological Institute. Emission data are allocated for 60 economic sectors (NACE digit-2 level) and households covering period 1990-2003. Household non-GHG emissions are taken from REZZO 3 (non-point sources) and a part of REZZO 4 (mobile sources) by using relevant emission and transport data provided by the Transport Research Center (CDV 2004). The rest of emissions reported in REZZO-4 category (mobile sources) are recalculated into i) NACE 60, 61, 62 (mobile sources in transport), ii) NACE 01, 02, 03 (mobile sources in agriculture and forestry further divided according generated GVA), and iii) NACE F (45) and L (75) (emission from construction and army divided equally to them).

GHG data are taken from the National Greenhouse Gas Emission Inventory Report of the Czech Republic (Fott et al. 2004) prepared in accordance with the UN Framework Convention on Climate Change. GHG emission data reported in particular NIR Sectors are re-allocated into the relevant NACE sectors and covers the time span of 1990-2003. GHG household emission are based on Sector 1 – category 4.b Residential. So far, we have not been able to calculate GHG emission from combustion of motor fuels used in individual transport by households.

2.2 Economy and environmental regulation

GDP significantly felt down during 1990-1992 by 12%. Mild economic growth in 1993-1996 ceased during the 1997-1999 recession, and after then, GDP has grown by 3% yearly in average. Changes in the economy scale were accompanied by significant changes in the economic structure; a fall in industry and mining sectors was switched to growth in services, public sector and transport (see figure 1). The composition change occurred not only from industry to services, but also within particular manufacturing sectors.

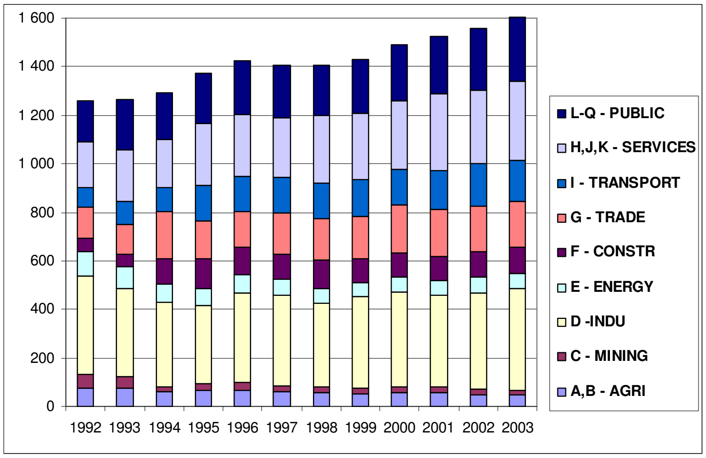


Figure 1: Gross value added per sectors, in billion of CZK (constant prices 1995).

Environmental regulation or intervention with the most important impact on air emission counts:

- (i) emission limits set out for the large power plants required to be fulfilled up to the year of 1998,
- (ii) subsidy for gasification provided from the State Environmental Fund to municipalities as well as households preferentially in heavily-polluted regions during the period 1993-1997,
- (iii) subsidy from the State Environmental Fund for installation of electric heating systems in households and small private and public bodies within the Air Quality Program during 1993-1997,
- (iv) change in taxation regime (a shift energies and electricity from 5% VAT rate to 22% VAT rate),
- (v) change in energy market regulation regime when cross-subsidy for electricity from industry to households were gradually abolished; with the effect of a continual decrease in electricity price for industry;
- (vi) a real decrease in motor fuel prices due to absence of price indexation for relevant excise tax rates.

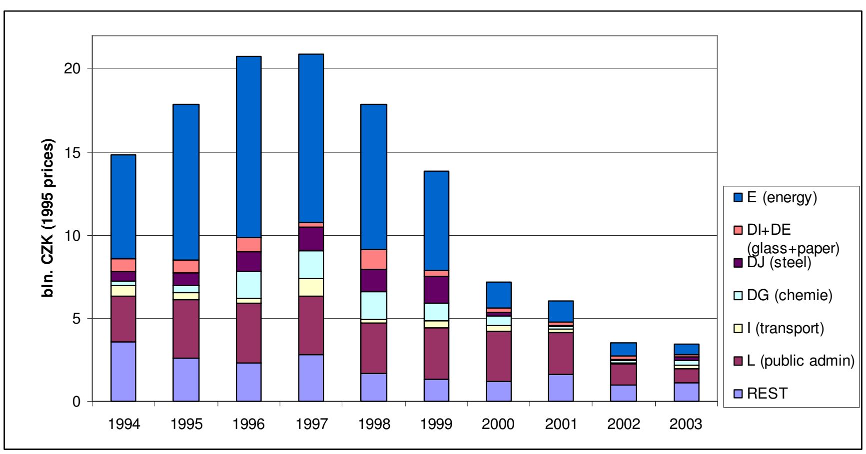


Figure 2: Environmental investment in air protection.

We should deal with both direct and indirect effects of environmental regulation. Emission limits (i) had direct effect on emissions emitted by energy sector (NACE E). Subsidy (ii and iii) had obviously direct effect on emissions by households and public sector (NACE L, M, N, O, or NACE 75-93) but also indirect effect on energy generation (NACE E). Energy prices (iv and vi) through the effect on demand for energy has affected emissions particularly in transport sector (I) and households, but also in fuel-intensive sectors (e.g. NACE G); the intensity effect may be counter-balanced by the fall in real price of electricity used in industry, particularly in manufacturing sector (v).

The impact of regulation on the air emission level can be also assessed by looking at involved environmental investment in air quality shown in figure 2 (absolute investment) and figure 18 (its relative share on total capital formation). Almost 50% of all environmental investment in air protection during 1994-1999 was spent by energy sector (NACE E); its share felt down up to 20% of all these investment when the deadline for the fulfilment of legislative requirement ended. A high share of air protection investment- 25% in average - was spent by sector of public administration (NACE L).

2.3 Energy consumption and material intensity

Energy consumption felt down between 1990-1994 likely due to structural economic changes and then during economic recession in 1997-1999. Economic growth has enhanced the primary energy consumption by 2% yearly since 2000.

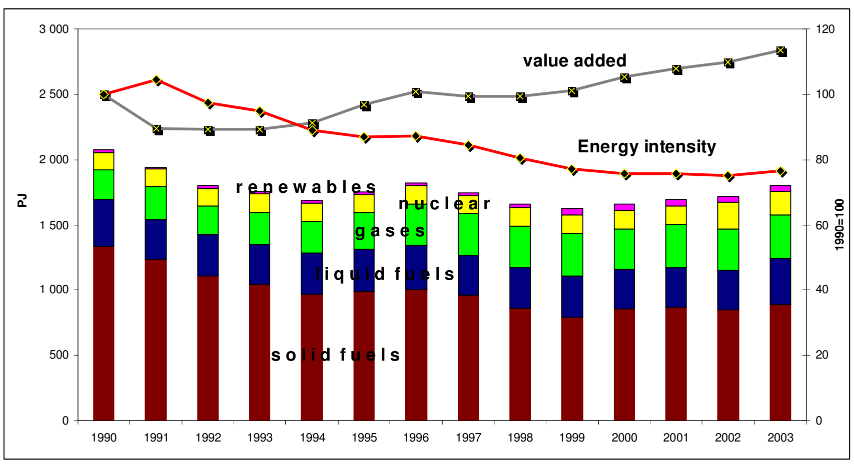
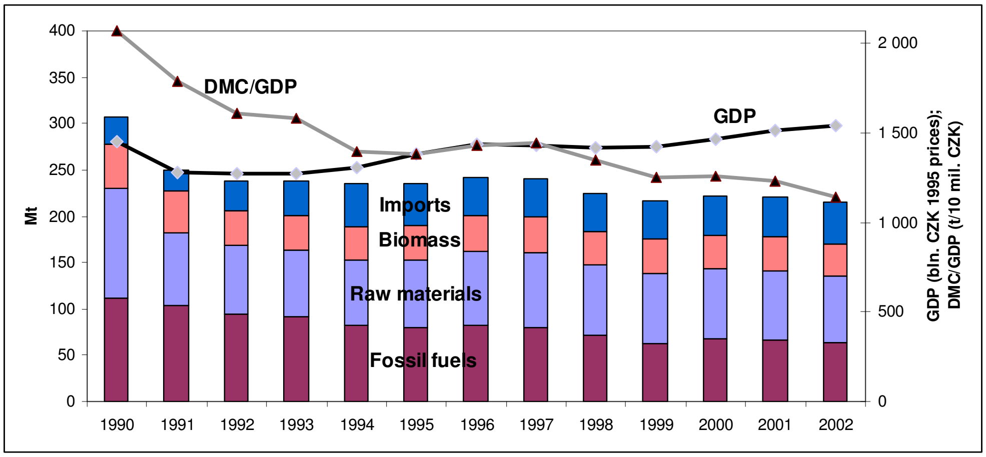


Figure 3: Energy intensity in the Czech Republic

Despite of high energy intensity of the Czech economy, the energy intensity – measured by consumption of primary energy resources in PJ per unit of gross value added – felt down by 25% during 1990-2000. Since the year 2000, this positive trend has stopped.

Material intensity of Czech economy felt down by 33% during 1990-1994 due to radical decline of GDP in 1991 followed by structural economic changes in later years. During the economic recession 1998-1999, material intensity again rapidly declined by 7% yearly. Recently, the Czech economy is almost two times more materially effective then it was in 1990. This dramatic change was mainly caused by fall in domestic extraction of fossil fuels (by 30% in 1994, then by next 10%; compared with 1990 level) and other raw materials (by 40%), while extraction of biomass felt down by 25%. On the contrary to extraction, imports have been growing since 1992, and recently they are 1.5-times higher then in 1990.



Note: DMC – Direct Material Consumption (DMC=DMI – Exports)
DMI – Direct Material Inputs (DMI = Extraction of fossil fuels and raw materials + Extraction of biomass + Imports)

Source: Ščasný, Kovanda, Hák (2004); Kovanda (2005).

Figure 4: Material intensity by DMC/GDP and Direct Material Inputs.

2.4 Air pollution

Before 1990, the Czech environment suffered mostly from air pollution. During the period 1990-2003, a significant reduction in emission occurred: SOx and particulates fell by 83%, CO and CxHy by more than 50%, and NOx by about 40%.

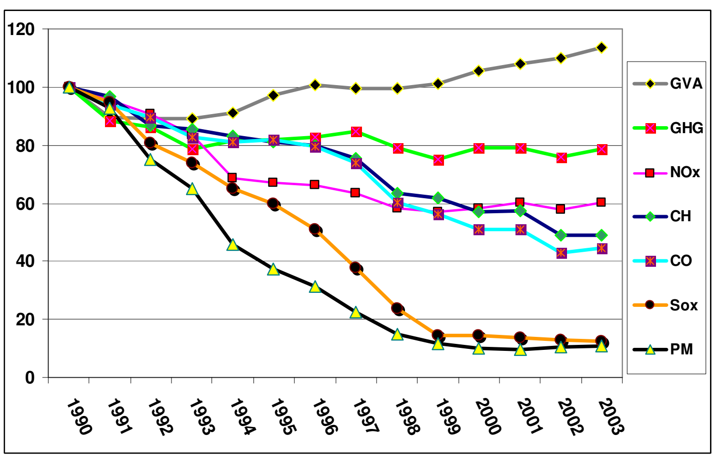


Figure 5: Indicators of air pollution and GVA for 1990-2003 in the Czech Republic.

Contribution of economic sectors to the emission reduction has varied. All non-GHG emission was reduced mainly by the energy sector; this was caused by command-and-control regulation introduced in 1991. This regulation required a large emission reduction from energy power plants up to 1998 (see Figure 6 for the effect). On the contrary, emission from the transport sector has been growing since 1995; we can expect contribution of the scale effect and the effect of the transport modal shift from rail to road transport to the emission level growth. Emission from manufacturing industry (NACE D) was continuously falling during the entire period, except SOx emission that can be characterized by a U-curve.

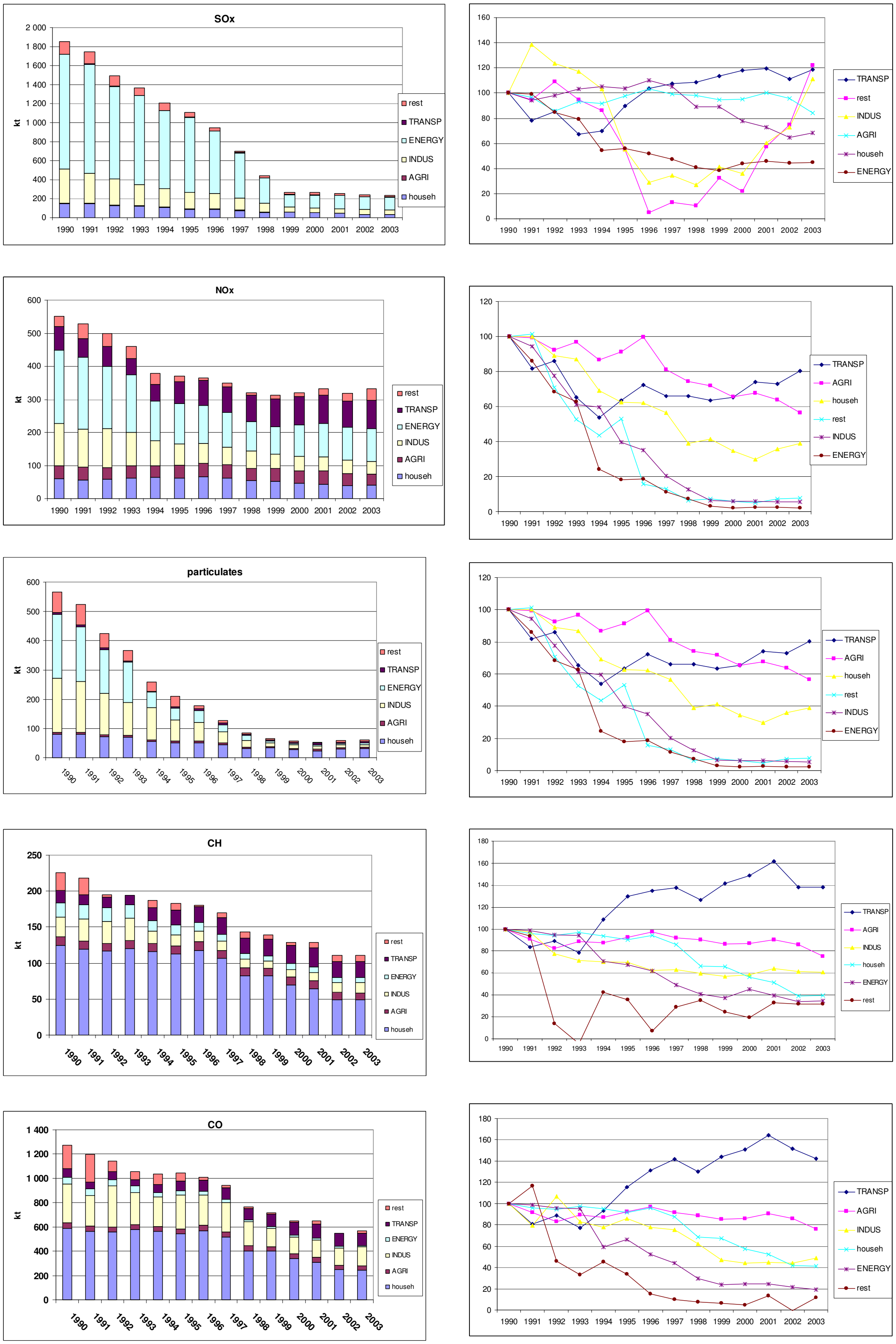


Figure 6: Sectoral decomposition for air pollution.

2.5 Greenhouse gasses emission

Greenhouse gasses (GHG) emission felt down by 20% during 1990-1993, after then it was growing up to the recession during 1998-1999, after that GHG emission was stabilized at 79% of 1990-level during 2000-2003. GHG emission felt down mostly in the manufacturing industry sector, likely due to structure and intensity changes. GHG emission from the energy sector has had an upwarding trend since 1993, GHG emission from transport – similarly to non-GHG emission – exhibited a more rapid growth. Also similarly to non-GHG emission, a small fall in emission occurred in the year 2002.

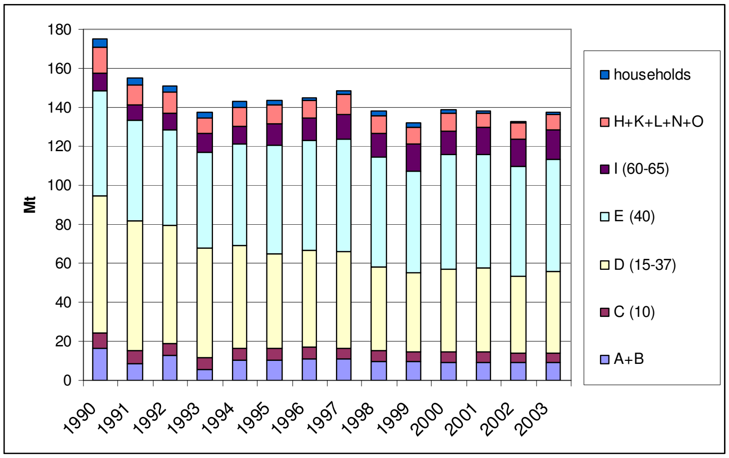


Figure 7: Sectoral decomposition of GHG emission in the Czech Republic, in Mt.

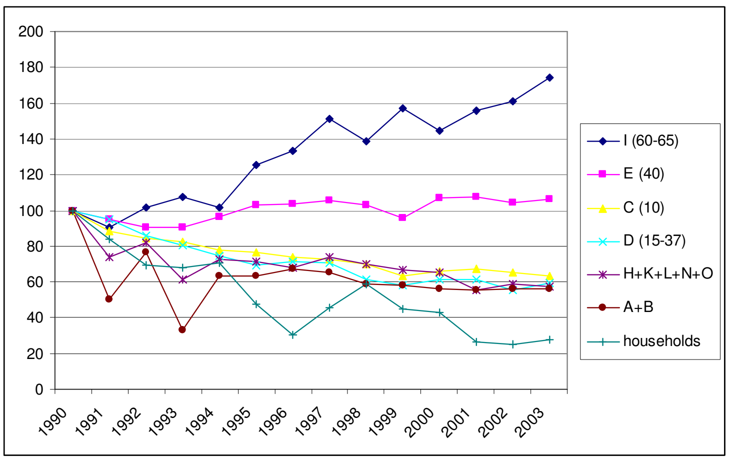


Figure 8: Development of GHG emissions by sectors of Czech economy, 1990=100.

2.6 Households

Households contribute with a minor part to GHG emission (1-2%), on the contrary they contribute with a major part to CO and VOC (CxHy) emission (about 50-60%). The share of their SOx, NOx, and particulates emission on total emission was continuously growing - from 10% up to 15-20% for NOx and SOx, and even up to 50% in the case of particulate matters.

Household emission felt down during the entire period. Emission reduction was mainly caused by the heating fuel switch that was supported by the gasification public program in 1993-1996. Solid fuels were replaced by gas, liquid fuels used for heating have not almost been used at all since mid of the 1990s (see Figure 8).

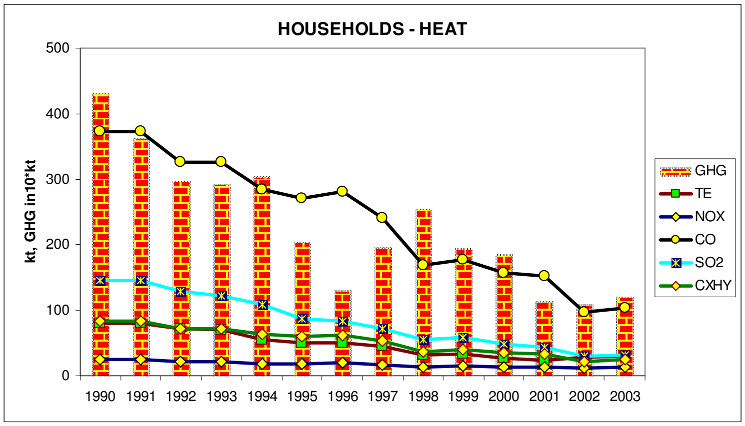


Figure 9: Household airborne emissions.

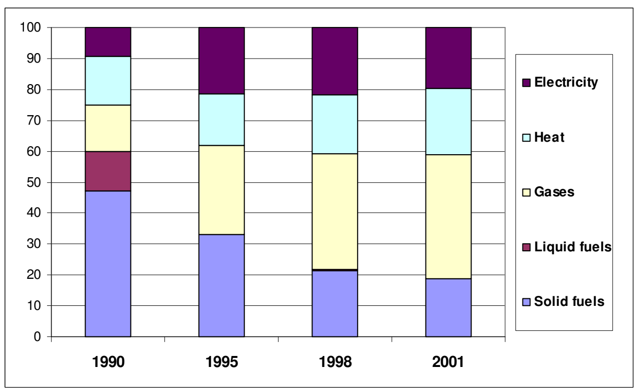


Figure 10: Composition of household primary energy consumption.

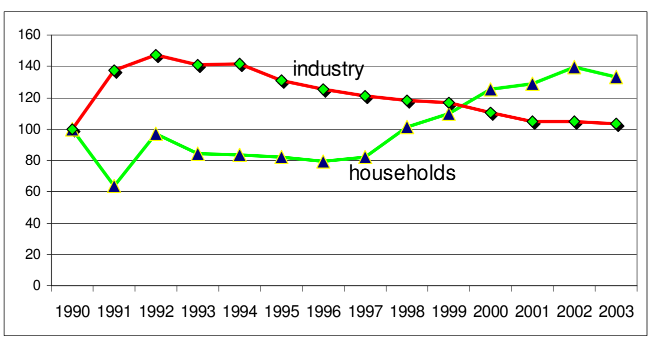


Figure 11: Real prices of electricity for households and industry, 1990=100.

There are, however, two exemptions: firstly, GHG emission grown in 1997 and 1998, we conjecture that this was due to switch from electric heating facilities previously granted by public sources back to coal; the reason was changes in VAT rates on energies introduced in January 1998. Secondly, all emissions have been started to grow after longer period of economic growth in the end of examined period since 2002.

3. Decomposition of Environmental Burden

This section is organised as follows: first we define the quantitative exercise and then we apply it to data.

3.1 Methodology

Let W_t be an environmental indicator (such as air emissions) at time t in the national economy. The national economy is composed of a set I of various sectors; a generic element of I is denoted as i. Let W_{it} be the indicator associated with the ith sector.

Let Y_t be the output of an economy at time t and Y_{it} be the output of the ith sector. Define shares of sectors as follows:

$$s_{it} = \frac{Y_{it}}{Y_t},$$

clearly $Y_t = \sum_{i\in I} Y_{it}$ and $\sum_{i\in I} s_{it} = 1$. Environmental intensity of the sector i is defined as:

$$\alpha_{it} = \frac{W_{it}}{Y_{it}}.$$

Then the following identity holds:

$$W_t = \sum_i \alpha_{it} s_{it} Y_t .$$

This identity suggests that a change of the indicator between years t and $t+1$ can be decomposed in the following terms:

$$\frac{W_{t+\tau}}{W_t} = \frac{Y_{t+\tau}}{Y_t}\left(1 + \frac{\sum_{i\in I}\alpha_{it}s_{it}\left(\Delta_t^{t+\tau}\alpha_i\right)}{\sum_{i\in I}\alpha_{it}s_{it}} + \frac{\sum_{i\in I}\alpha_{it}s_{it}\left(\Delta_t^{t+\tau}s_i\right)}{\sum_{i\in I}\alpha_{it}s_{it}} + R_{it}\right), \qquad (1)$$

where we have introduced the following operator: $\Delta_t^{t+s}x \equiv (x_{t+s} - x_t)/x_t$, i.e., this is the operator of the percentage change between dates t and $t + s$. The first term (before the brackets) is called the **level effect**, the first term in the brackets is called the **intensity effect**, the next term is the **composition effect** and the last term R_{it} arises due to interaction between last two effects (and for reasonable figures, this term shall be small). More specifically, the term is given as follows:

$$R_{it} = \frac{\sum_{i\in I}\alpha_{it}s_{it}\left(\Delta_t^{t+\tau}\alpha_i\right)\left(\Delta_t^{t+\tau}s_i\right)}{\sum_{i\in I}\alpha_{it}s_{it}}.$$

Formula (1) can be further simplified, if the following approximation is used[1]: $\log(1+x) \approx x$; this approximation is safe for $|x| \leq 0.1$. The simplified approximate formula is given by:

$$\Delta_t^{t+\tau}\frac{W_{t+\tau}}{W_t} \cong \Delta_t^{t+\tau}\frac{Y_{t+\tau}}{Y_t} + \frac{\sum_{i\in I}\alpha_{it}s_{it}\left(\Delta_t^{t+\tau}\alpha_i\right)}{\sum_{i\in I}\alpha_{it}s_{it}} + \frac{\sum_{i\in I}\alpha_{it}s_{it}\left(\Delta_t^{t+\tau}s_i\right)}{\sum_{i\in I}\alpha_{it}s_{it}}. \qquad (2)$$

[1] More specifically, we apply $\log(x_{t+1}/x\tau) = \log(1+\Delta x) \approx \Delta x$.

Thus, the percentage change of an environmental indicator between two specific dates can be decomposed among:

- **the level effect**: ceteris paribus the percentage change of the indicator is equal to the percentage change of economic activity,
- **the composition effect**: environmental pressures change if the composition of economic activity is changed, e.g., air emissions can fall if economic activity is reallocated from heavy industry to services,
- **the intensity effect:** if intensity coefficients α_j fall, then the indicator will fall as well.

3.2 Results for the Czech Republic

We apply the methodology described in the previous subsection to Czech data. We report results of two quantitative analyses: firstly we decompose Czech economy to 9 broadly defined sectors (agriculture and fishery, mining, energy, manufacturing industry, construction, transport, trade, other market services, public services) from 1993 to 2003; secondly, we use sixty sectors (in the digit 2 NACE nomenclature) from 1995 to 2003. The reason, why we did not perform the more detailed analysis from the beginning of the transition in the year 1990, is the lack of consistent economic data (see Part 2.1 for the description). Therefore, the reader is urged to realise that any results before 1995 should be taken with caution. We report results for the first analysis.

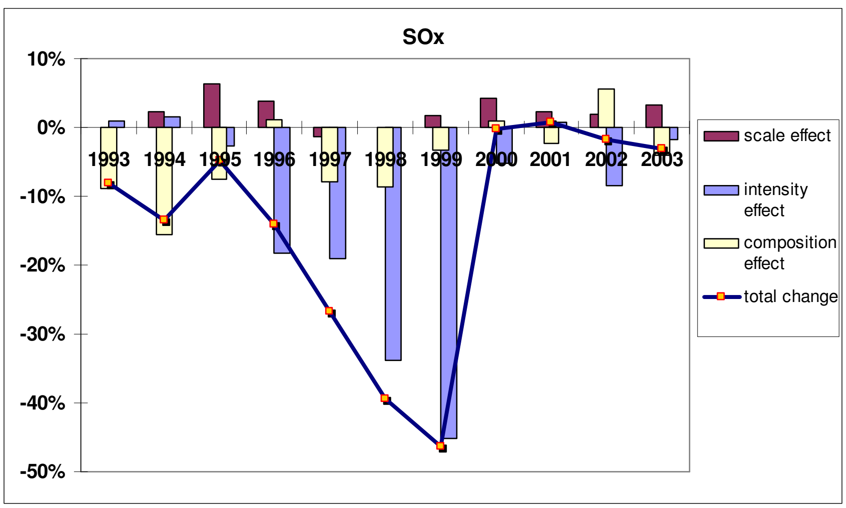


Figure 12: Graphical representation of scale, composition and intensity effects for **SOx**.

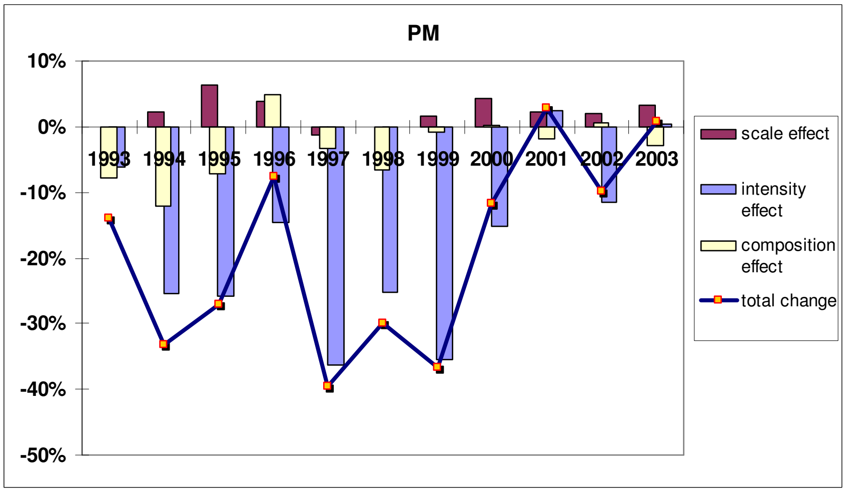


Figure 13: Graphical representation of scale, composition and intensity effects for **particulate matter**.

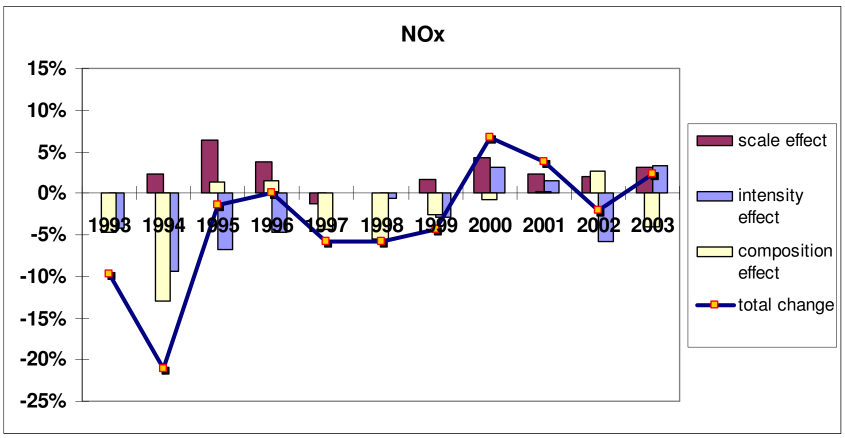


Figure 14: Graphical representation of scale, composition and intensity effects for **NOx**.

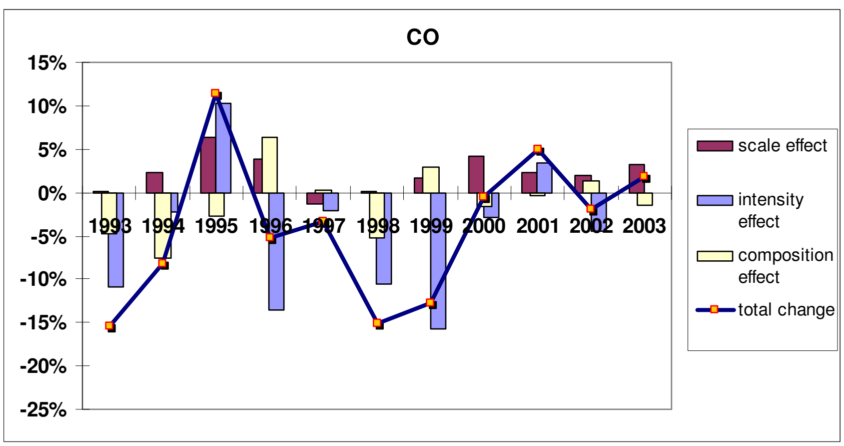


Figure 15: Graphical representation of scale, composition and intensity effects for **CO**.

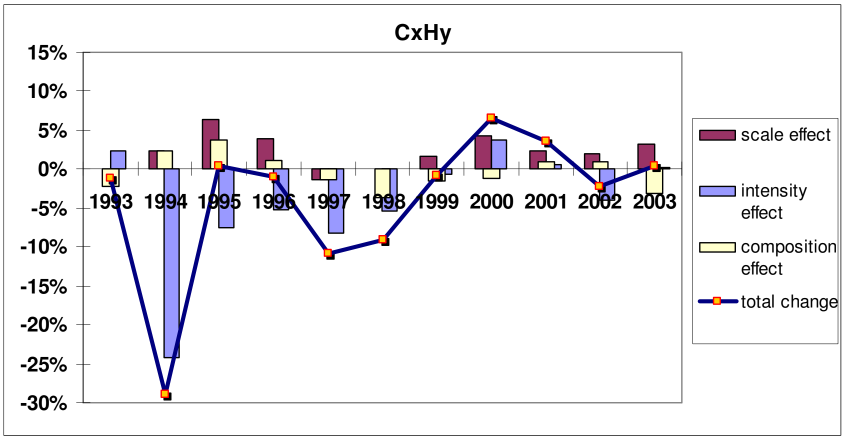


Figure 16: Graphical representation of scale, composition and intensity effects for **CH**.

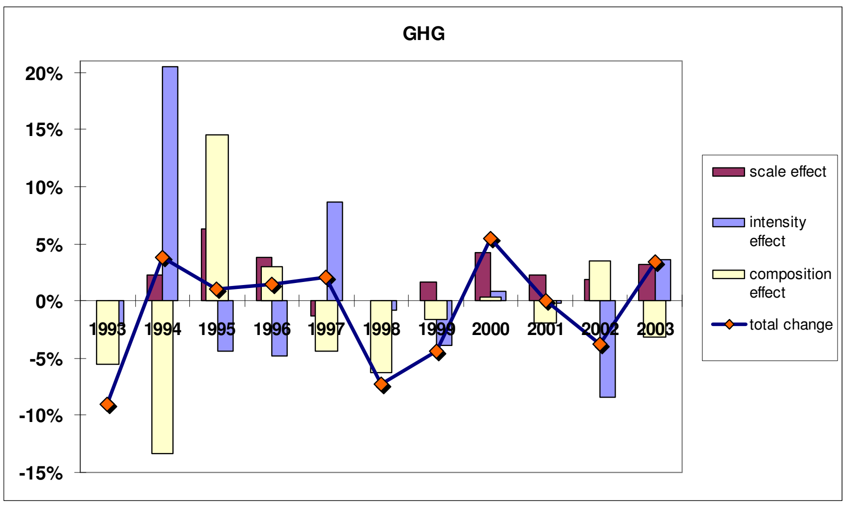


Figure 17: Graphical representation of scale, composition and intensity effects for **GHG**.

Except GHG emission, the intensity effect is negative and caused emission intensity to fall. SOx emission and particulate matter emissions enjoyed the most significant intensity effect during the years 1997-2000. There were likely acting two forces: firstly, power plants had to fulfil the legislative requirements in air quality protection up to 1998; secondly, we conjecture that there were stronger incentives on cost savings during the economic recession in 1997-1999.

Changes in composition led to an emission reduction in almost all years, except of the years 1996 and 2002 when the composition effect was positive. In the year 2002, the positive composition effect even supported by the positive scale effect (meaning that both effect would *ceteris paribus* lead to emission increase) did not counter-balanced the negative intensity effect.

The decomposition based on Formula (2) can explain the change in emission by 97% (in the case of SOx and particulates), by 95% (CO and NOx) and by 91% (CxHy and GHG). The rest is the approximation error, which is clearly not substantial.

4 Econometric analysis of the emission intensity

The quantitative exercises of Section 3 identify the relative importance of the level, composition and intensity effects. While important, this analysis may be more appreciated if extended with the analysis of driving forces of these effects.

Moreover, it is evident that the composition effect alone is not a long-run solution to the environmental menace: either the level or the intensity effects are needed, if economic activity pressures exceed assimilating capacities of the nature. Thus it is a legitimate agenda to try to identify driving forces behind these effects. Therefore we shall concentrate especially on the intensity effect.

4.1 Methodology

To do that, we perform a set of econometric exercises. The main aim is to identify important variables, which contribute to changes in emission intensities in twelve sectors of the Czech manufacturing industries. These sectors are manufacturing of:

- food products, beverages and tobacco,
- textiles and textile products,
- wood and wood products,
- pulp, paper and paper products; publishing and printing,
- chemicals, chemical products and man-made fibres,
- rubber and plastic products,
- other non-metallic mineral products,
- basic metals and fabricated metal products,
- machinery and equipment
- electrical and optical equipment
- transport equipment
- other manufacturing.

We excluded the following two sectors of manufacture of leather and leather products, and manufacture of coke, refined petroleum products. The reason is that these two sectors had zero (or even negative) value added and capital investment in some years during the sample period.

Especially, we concentrate on the following driving forces:

- investment on the environment protection,
- factor productivity,
- autonomous technology diffusion.

The general form of regression equations is as follows:

$$\Delta_t^{t+1} \frac{W_{it}}{Y_{it}} = \beta_{\mathrm{air}} \frac{I_{it}^{\mathrm{air}}}{I_{it}} + \beta_{\mathrm{eco}}^{\mathrm{T}} \mathrm{Productivity\ measures}_{it} + \beta_{\mathrm{trend}} t + \varepsilon_{it}, \qquad (3)$$

where β is the vector of unknown parameters, W_{jt} are emissions of the sector j at year t, Y_{jt} is the corresponding value added, I_{jt} are total investment, while I^{air} are environmental investment in air and climate protection. The vector of productivity measures includes percentage changes of various measures of factor productivity in manufacturing sectors. We experiment with several productivity measures, which include labour productivity, capital endowment (measured as value added over capital consumption), and so on.

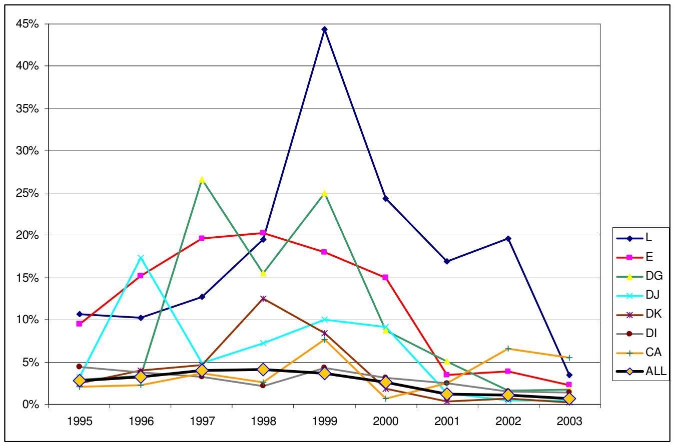


Figure 18: Share of environmental investment on air protection on total investment (gross capital formation) of the sectors.

If environmental investments have a non-negligible effect, then we expect the negative and significant coefficient of the parameter β_{air}. We conjecture that an autonomous technological diffusion played an important role in the beginning of the transition, therefore we expect the positive value of the parameter β_{trend}: this means that the *ceteris paribus* fall in emission is diminishing during the sample period. The reason, why one can expect this to happen, is the rapid restructuring of the Czech economy during the transition. As the restructuring – and replacement of the old capital stock by the new one – is finishing, the source of 'autonomous' technological improvement is exhausted. This has a serious policy implication: it would be misleading to base emission forecasts on past trends in the emission intensities. Especially, it would be unwise to rely on 'autonomous' forces of technology improvement if policymakers wished to reduce emission intensities in future.

4.2 Estimation Results

The span of data for the econometric exercise is from 1995 to 2003. As already noted above, the used dataset consists of the panel of manufacturing subsectors. From the technical point of view, the estimation strategy is to apply the ordinary least-squares method to the fixed-effect panel data model; Green (2003), chap. 13. Therefore, Equation (3) is extended by dummies, specific to each subsector. The estimation results for the specific pollutants are the following (standard errors are in parentheses below point estimations):

SO_2

$$\Delta_t^{t+1}\frac{W_{it}}{Y_{it}} = -\underset{(1.318)}{1.232}\frac{I_{it}^{\text{air}}}{I_{it}} - \underset{(0.327)}{0.846}\Delta_t^{t+1}\frac{Y_{it}}{K_{it}} + \underset{(0.022)}{0.033}t$$

NOx

$$\Delta_t^{t+1}\frac{W_{it}}{Y_{it}} = -\underset{(0.441)}{1.078}\Delta_t^{t+1}\frac{Y_{it}}{K_{it}} - \underset{0.157}{0.262}\left(\Delta_t^{t+1}\frac{Y_{it}}{K_{it}}\right)\left(\Delta_t^{t+1}\frac{Y_{it}}{L_{it}}\right) + \underset{(0.024)}{0.011}t$$

CO

$$\Delta_t^{t+1}\frac{W_{it}}{Y_{it}} = -\underset{1.118}{0.380}\frac{I_{it}^{\text{air}}}{I_{it}} - \underset{(0.346)}{0.698}\Delta_t^{t+1}\frac{Y_{it}}{K_{it}} - \underset{1.238}{0.601}\left(\Delta_t^{t+1}\frac{Y_{it}}{K_{it}}\right)\left(\Delta_t^{t+1}\frac{Y_{it}}{L_{it}}\right) + \underset{(0.020)}{0.031}t$$

CxHy

$$\Delta_t^{t+1}\frac{W_{it}}{Y_{it}} = -\underset{(0.317)}{0.840}\Delta_t^{t+1}\frac{Y_{it}}{K_{it}} - \underset{1.130}{0.473}\left(\Delta_t^{t+1}\frac{Y_{it}}{L_{it}}\right) + \underset{(0.017)}{0.052}t$$

Particulate Matters

$$\Delta_t^{t+1}\frac{W_{it}}{Y_{it}} = -\underset{(1.490)}{2.600}\frac{I_{it}^{\text{air}}}{I_{it}} - \underset{(1.185)}{2.292}\left(\Delta_t^{t+1}\frac{\mathrm{Y_{it}}}{\mathrm{L_{it}}}\right) + \underset{(0.030)}{0.034}t$$

Symbols not used so far are following: K_{jt} is the fixed capital consumption, and L_{jt} is the number of employee in the sector *j* in year *t*.

The interpretation of the estimation results is the following:

- Environmental investments have a significant impact for reduction of particular matters emissions, some effect can be also found for SO_2 emissions, while for NOx and CxHy emissions the impact is insignificant. Note that this result holds only for manufactures during the estimation period.
- The fall in emission intensities is associated with an increase in capital or labour productivity (or both). This finding implies that the factor productivity progress in the Czech Republic has been resource-saving rather than resource-using during the transition process. One may not be surprised because of spectacular inefficiency of the central planned economies, but this effect continues to hold even when the 'autonomous' technology progress is controlled for. The reader may want to consult the sensitivity analysis in Appendix 2, to get sense of changes of the relevant coefficients under controlling and non-controlling for the trend.
- The positive coefficient β_{trend} implies that the influence of the technological change due to rapid restructuring of the economy is steadily diminishing as the transition economy has replaced old inefficient capital structures.

5. Conclusion

This paper discusses the evolution of certain types of the environmental burden in the Czech Republic, with the emphasis on air pollution. Firstly, we overviewed data and trends and then we used a quantitative exercise to assess relative importance of the level, composition and intensity effects in air pollution emissions during the transition. We find that – although the composition effect was important – a reduction of certain pollutants (mainly SO2 and particulate matters) was caused by a significant drop in emission intensities. This drop was – at least in the energy sector – influenced by environmental regulation.

Then, we use an econometric exercise to explain the intensity effect. This exercise reveals that environmental investments had in the manufacturing sector a limited impact only, and on selected emissions only. On the other hand, the most significant impact is caused by factor productivity, suggesting that the productivity increase in the Czech Republic has been resource-saving rather than resource-using. Lastly, we find that the potential of a technology diffusion, or of an 'autonomous' technology progress in diminishing environmental burden is almost exhausted in the Czech Republic.

This analysis presents the first exercise of Environmental Kuznets Curve testing for the Czech Republic. We would like to point out that the exercise is far to be comprehensive and perfect. More research is however planned to improve our exercise here presented. First of all, more comprehensive analysis may be done at the end of 2006 when the consistent time series of economic data covering the period of 1990-1994 will be provided by Czech Statistical Office. Secondly, GHG emission re-allocated into the NACE digit-2 level economic sectors may be done if data on energy consumption by sectors are prolonged (so far, we allocate GHG emission reported in NIR by using the key in Appendix 1). Data on energy consumption type-by-type by sector – according our best knowledge - is in disposal for the Czech Republic only for year 1998-2003. We also plan to do estimation of energy consumption data for 1995-1997 in order using them in our further econometric examination of changes in emission levels, this applies especially to GHG emissions. Thirdly, explanatory model can be improved or widened, e.g. we plan to test the impact of i) foreign direct investment inflows on emission levels in order to test pollution heaven or pollution hallo hypothesis in the case of the Czech Republic, ii) sectoral energy consumption, and iii) environmental investment by particularly public sector. No doubt, there is also constraint of our paper related with using environmental investment rather then services provided by the investment. We may like - rather then to use environmental capital formation in our regressions - to model consumption of environmental fixed capital formation or respectively service flow provided by environmental investment accumulation. Fourthly, the model for intensity effect testing presented in Section 4, can be applied for further sectors such as energy, transport, and trade sectors and sector of services. We may like to test various variables and models independently for each of them. Fifthly, our exercise may be widened in terms of new environmental problems covered. We may like to do statistical and econometric exercise in order to explain changes in material flows such as indicators of direct material inputs, direct material consumption or total material requirements, or track the changes in the area of water or waste management. Results of the presented statistical and econometric exercise can be used in further assessment of possible environmental impacts involved by either regulation, business cycle or whatever exogenous changes, not necessarily related to the transition.

Acknowledgements

The research was done thanks to grant no. 402/04/1376 "Environmental Kuznets Curve: testing hypothesis and evidence for the Czech Republic" supported by the National Science Foundation of the Czech Republic. The support is gratefully acknowledged. We are also grateful to Pavel Machálek from Czech Hydro-meteorological Institute, Marek Rojíček from Czech Statistical Office and Miroslav Havránek from Charles University Environmental Center, Prague for data provision and consultations. All possible mistakes are of course just ours.

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Appendix 1. Allocation of GHG emission reported in NIR into NACE economic sectors.

	NACE (digit – 2)	NACE (digit - 3&4)
1. Energy		
1. Energy Industries		
a. Public Electricity and Heat Production	40	E
b. Petroleum Refining	23	DF
c. Manufacture of Solid Fuels and Other Energy Ind	23	DF
2. Manufacturing Industries and Construction		
f. Other *(please specify)*	15-37 + 45	D+F
3. Transport		
a. Civil Aviation	62	I
b. Road Transportation	60	I
c. Railways	60	I
d. Navigation	62	I
e. Other Transportation	60	I
4. Other Sectors		
a. Commercial/Institutional	55+(70-74) +75+85+(90-93)	H+K+L+N+O
b. Residential	HOUSEH	---
c. Agriculture/Forestry/Fisheries	01+02+05	A+B
5. Other		
a. Stationary	---	---
b. Mobile (Mobile sources from Agri/For/Fish)	01+02+05	A+B
Fugitive: 1. Solid Fuels		
a. Coal Mining	10	CA
b. Solid Fuel Transformation	---	---
c. SO2 reduction from combustion by using limestone	40	E
Fugitive: 2. Oil and Natural Gas	60	I
2. Industrial Processes		
A. Mineral Products	26	DI
B. Chemical Industry	24	DG
C. Metal Production	27-28	DJ
3. Solvent and Other Product Use	55+(70-74) +75+85+(90-93)	H+K+L+N+O
4. Agriculture	01	A
5. Land-Use Change and Forestry	02	A
6. Waste	90	O
Bunkers	62	I

Appendix 2. Sensitivity analysis of regression results

This appendix presents sensitivity analysis of the regression estimation (3) from Section 4 for the relevant pollutant. Standard-font figures are point estimates, while small-font figures are corresponding standard errors.

Pollutant: SO_2										
Model										
X1 = Envi Invest / Total Investment	-1,887	-1,232	-1,880	-1,201	-1,594	-1,092	-1,594	-1,043		
	-1,236	1,318	1,262	1,331	1,269	1,325	1,277	1,339		
X2 = Value Added / Capital Consumption	-0,944	-0,847	-0,887	-0,913	-0,194	-0,265	-0,192	-0,336	-0,033	-0,269
	-0,323	0,327	0,415	0,412	0,663	0,663	0,688	0,693	0,678	0,686
X3 = Labor Productivity					-0,838	-0,666	-0,836	-0,691	-0,981	-0,750
					0,648	0,660	0,660	0,667	0,652	0,661
X2*X3			-0,311	0,398			-0,024	0,553	-0,020	0,662
			1,407	1,474			1,420	1,480	1,425	1,470
Trend		0,033		0,035		0,029		0,031		0,037
		0,022		0,023		0,023		0,024		0,023

Pollutant: NOx										
Model										
X1 = Envi Invest / Total Investment	-0,294	-0,062	-0,283	-0,083	-0,292	-0,076	-0,293	-0,101		
	1,336	1,422	1,344	1,436	1,366	1,439	1,374	1,454		
X2 = Value Added / Capital Consumption	-1,159	-1,125	-1,072	-1,079	-1,153	-1,183	-1,096	-1,147	-1,078	-1,140
	0,345	0,353	0,442	0,445	0,714	0,720	0,740	0,753	0,441	0,743
X3 = Labor Productivity					-0,007	0,067	0,030	0,080		0,075
					0,698	0,716	0,711	0,724		0,715
X2*X3			-0,478	-0,269			-0,488	-0,029	-0,262	-0,277
			1,499	1,590			1,528	1,608	0,157	1,591
Trend		0,012		0,010		0,012		0,011	0,011	0,011
		0,024		0,025		0,025		0,026	0,024	0,024

Pollutant: CxHy										
Model										
X1 = Envi Invest / Total Investment	-1,784	-0,802	-1,748	-0,844	-1,594	0,075	-1,596	-0,791		
	1,004	1,018	0,999	1,026	1,020	1,028	1,017	1,038		
X2 = Value Added / Capital Consumption	-1,093	-0,947	-0,819	-0,854	-0,606	-0,724	-0,449	-0,660	-0,840	-0,609
	0,259	0,253	0,329	0,318	0,533	0,514	0,548	0,538	0,317	0,532
X3 = Labor Productivity					-0,544	-0,255	-0,445	-0,232	-0,473	-0,277
					0,521	0,512	0,526	0,517	1,130	0,512
X2*X3			-1,496	-0,552			-1,343	-0,500		-0,417
			1,115	1,137			1,131	1,148		1,140
Trend		0,047		0,047		0,048		0,046	0,052	0,050
		0,017		0,018		0,018		0,018	0,017	0,017

Pollutant: PM										
Model										
X1 = Envi Invest / Total Investment	-3,399	-2,571	-3,348	-2,677	-3,062	-2,415	-3,065	-2,520	-2,556	-2,600
	1,588	1,670	1,585	1,681	1,611	1,682	1,611	1,696	1,672	1,490
X2 = Value Added / Capital Consumption	-0,779	-0,657	-0,398	-0,425	0,083	-0,007	0,293	0,150		
	0,410	0,415	0,521	0,521	0,842	0,841	0,867	0,878		
X3 = Labor Productivity					-0,964	-0,743	-0,831	-0,688	-0,571	
					0,822	0,837	0,833	0,844	0,499	
X2*X3			-2,081	-1,379			-1,796	-1,225	-1,137	-2,292
			1,768	1,862			1,791	1,875	1,179	1,185
Trend		0,042		0,035		0,037		0,031	0,032	0,034
		0,028		0,030		0,029		0,030	0,030	0,030