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DECOIN – Deliverable D3.1 of WP3

Decomposition Analysis of EU Sustainable Development Indicators

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1. Introduction

The objective of WP3 in the DECOIN project is to develop tools and methods which allow (1) elaboration of existing forecasts, (2) identification of the inter-relationships between selected unsustainable trends, and (3) exploration of potential synergies and trade-offs of selected unsustainable trends. This report is deliverable 3.1. of the DECOIN project and it includes decomposition analysis of the EU sustainable development indicators.

The tools and methods to be developed will be based mainly on decomposition analysis of the phenomena under investigation. In decomposition analysis the driving forces of the changes are aspired to divide into meaningful components and their share of the total change is calculated using so called complete decomposition.

The basic hypothesis is that decomposition method provides a suitable technique to analyse the changes in EU sustainable development indicators which are briefly described in section 2 of this deliverable. The decomposition analysis carried out in this deliverable is based on the Advanced Sustainability Analysis (ASA) approach and Sun/Shapley decomposition technique, which are described and explained in section 3. The empirical analysis of selected indicators is presented in section 4. The selected examples include a decomposition analysis for an indicator of each of the 10 themes of EU sustainable development indicators (see section 2). Eurostat has provided data for the whole indicator set – altogether 155 different indicators based on the 2005 indicator set. Empirical examples are selected mostly for the EU15 as a whole due to better data availability than for the EU 25.

This paper aims particularly to introduce the ASA methodology and give detailed preliminary examples of its use. The purpose of the decomposition analysis is to see how different factors affect the change in the phenomena under investigation. In order to do this, the different factors have to be identified/chosen for the analysis. Identification of the driving forces is fully a case-specific issue, and the construction of a relevant identity with a reasonable meaning for each factor in the identity is challenging, especially because the number of explaining factors is high.

Our analysis concentrates mainly on the indicators in the EU Sustainable Development Indictor set, with the exception of decompositions for theme ‘Climate change and energy’, for which the additional indicators were used. The selection of the factors (indicators) affecting the trends of selected indicators under the other themes identified in the EU SDI set is limited to the indicators available within the set, for which the plausibility of different master equations for the decomposition analyses varies from theme to theme. Expanding the research outside the EU SDI set is extremely time consuming and is not done in this context given the resources allocated for DECOIN project. As the aim of WP3 is to study the interlinkages and trade-offs between selected unsustainable trends, we will use the decomposition analyses carried out in this study as a guide for selecting the trends that appear most promising for this type of analysis, giving the limits and restrictions set out by the SDI set and the ASA approach.

2. EU Sustainable Development Indicators

2.1. Background

The renewed EU Sustainable Development Strategy in June 2006, aims to reconcile economic development, social cohesion and protection of the environment. Measuring progress towards sustainable development is an integral part of the renewed strategy, which is based on the EU set of sustainable development indicators (SDIs). A first monitoring report was published in December 2005 (Eurostat 2005). The Commission carried out a review of the 2005 indicator set in cooperation with the working group on SDIs, composed of both statistical and policy representatives at national and EU level. A new monitoring report (Eurostat 2007) updates and adapts the 2005 edition in the context of the renewed strategy, analysing progress in the implementation of the renewed objectives. It uses the reviewed indicator set as far as possible, with the constraint that the final list of indicators had not been adopted at the time of drafting the report.

In this Deliverable 3.1 of the DECOIN project, we have used the set of sustainable development indicators and the publicly available dataset as the situation was in September 2007 at the Eurostat webpage on sustainable development indicators. Thus, the analysis based on the 2005 indicator set and data provided by Eurostat in September 2007. The data used by Eurostat in the new monitoring report (Eurostat 2007) was not yet publicly available when carrying out the empirical examples and writing this Deliverable.

A hierarchical framework based on ten different themes has been developed on the basis of the policy priorities of the Sustainable Development Strategy. The ten themes (which may be further developed in the future) include:

1. Economic development
   - headline indicator: Growth rate of GDP per capita
   - level II and III indicators are arranged in three sub-themes: investment, competitiveness, and employment

2. Poverty and social exclusion
   - headline indicator: At-risk-of-poverty rate after social transfers
   - level II and III indicators are arranged in three sub-themes: monetary poverty, access to labour market, and other aspects of social exclusion

3. Ageing society
   - headline indicator: Old-age-dependency ratio
   - level II and III indicators are arranged in three sub-themes: pensions adequacy, demographic changes, and public finance stability

4. Public health
   - headline indicator: Healthy life years at birth, by gender
   - level II and III indicators are arranged in four sub-themes: human health protection and lifestyles, food safety and quality, chemicals management, and health risks due to environmental conditions

5. Climate change and energy

- two headline indicators: Total greenhouse gas emissions and Gross inland energy consumption, by fuel
- level II and III indicators are arranged in two sub-themes: climate change, and energy

6. Production and consumption patterns
   - headline indicator: Domestic material consumption
   - level II and III indicators are arranged in four sub-themes: eco-efficiency, consumption patterns, agriculture, and corporate responsibility

7. Management of natural resources
   - two headline indicators: Population index of farmland birds, and fish catches taken from stocks outside safe biological limits
   - level II and III indicators are arranged in four sub-themes: biodiversity (no indicators currently available), marine ecosystems, freshwater resources, and land use

8. Transport
   - headline indicator: Total energy consumption of transport
   - level II and III indicators are arranged in three sub-themes: transport growth, transport prices (no indicators currently available), and social and environmental impact of transport

9. Good governance
   - headline indicator: Level of citizens' confidence in EU institutions (European Commission, European Parliament and Council of Ministers)
   - level II and III indicators are arranged in two sub-themes: policy coherence, and public participation

10. Global partnership
    - headline indicator: Official development assistance
    - level II and III indicators are arranged in three sub-themes: globalisation of trade, financing for sustainable development, and resource management.

2.2. Evaluation of the characteristics of EU sustainable development indicators

In the context of the DECOIN project, the most relevant starting point for evaluating the EU sustainable development indicator set provided by the SDI Task Force in 2005, is the possibility to use the indicator set in the DECOIN project, especially in the tasks mentioned in Work Package 3 (Tools and methods for forecasting). The tasks of DECOIN WP3 are the following:

- Elaboration of existing forecasts
- Identification of the inter-relationships between selected unsustainable trends
- Exploration of potential synergies and trade-offs of selected unsustainable trends

Important requirements for the indicator set data from this point of view include

- Availability of forecasts based on the indicator set
- Timeliness of indicator data
- Availability of time series data for a selected time period
- Suitability of the data to be used the ASA framework
- Cause-effect and interlinkage relationships inside the indicator set

- Data reliability.

These requirements are used here as criteria for evaluation. In the following, the EU SD indicator set and related data in the Eurostat database are evaluated in the light of these criteria.

2.2.1. Availability of forecasts based on the SDI set

The analysis of existing forecasts of selected unsustainable trends is one of the tasks in the DECOIN project. The SDI data does not include forecasts for individual indicators at any level in the indicator hierarchy. The only exceptions are:

- Headline indicator of theme “ageing society” (old-age-dependency ratio; as1000), there is a forecast for the years 2005-2050. Data is provided for every fifth year. Levels II and III do not include forecasts.
- Headline indicator of theme “economic development” (growth rate of real GDP per capita; ed1000) includes forecasts for GDP growth rate up to the years 2007 and 2008. For some countries, data for the years 2006 and 2005 are marked as forecasts too.
- Level III indicator of theme “climate change and energy” (share of electricity generated from renewable energy sources in gross electricity consumption; cc2310) includes a forecast for the year 2010. The forecast is the same as the goal defined for each member state in the related RES-E directive.

The EU SDI data set does not include references to other forecasts. The same holds for the EU documents dealing with sustainable development indicators. This means that the empirical analysis of forecasts linked to unsustainable trends cannot be carried out with the EU SDI set and the related Eurostat database.

2.2.2. Timeliness of SDI data

Timeliness of the SDI data varies a lot between different indicators (Table 1), between different indicator themes (Table 2) and between individual indicators inside one theme. The most accurate data can be found for the headline indicators of theme 1 (economic development) and theme 9 (good governance) but for some themes the data is rather old even for the headline indicator. Typical examples are theme 3 (ageing society, newest data from 2000 although there is a forecast), theme 6 (production and consumption patterns; newest data from 2001); theme 4 (public health; newest data from 2003) and theme 7 (management of natural resources, newest data for the first headline indicator is from 2003).

Table 2.1. *The newest year of data among the total number of EU SD indicators in the Eurostat data*

Year of newest data	Number of indicators, all levels (I-III) included	Share (%)	Cumulative percentage
2006	35	24.5	24.5
2005	40	29.5	54.0
2004	25	17.9	71.9
2003	15	10.8	82.7
2002	7	5.1	87.8
2001	9	6.5	94.3
2000	4	2.9	97.2
1999 or older	2	1.4	98.6

Year not available	2	1.4	100.0
Total	139	-	

Table 2.2. *Timeliness of the EU SDI set headline indicators*

Theme	Headline indicator name	Newest data
1 (economic development)	Growth rate of real GDP per capita (ed1000)	2006
2 (poverty and social exclusion)	At-risk-of-poverty rate after social transfers (ps1000)	2005
3 (ageing society)	Old-age-dependency ratio (as1000)	2000
4 (public health)	Healthy life years at birth, by gender (ph1000)	2003
5 (climate change and energy)	Total greenhouse gas emissions (cc1000)	2004
	Gross inland energy consumption, by fuel (cc2000)	2005
6 (production and consumption patterns)	Domestic material consumption (pc1000)	2001
7 (management of natural resources)	Population index of farmland birds (mn1000)	2003
	Fish catches from stocks outside safe biological limits (mn2000)	2004
8 (transport)	Total energy consumption of transport (tr1000)	2004
9 (good governance)	Level of citizens' confidence in EU institutions, by three institutions (gg1000)	2006
10 (global partnership)	Ofiicial development assistance (gp1000)	2005

2.2.3. Availability of time series data for a selected time period

Availability of time series data is perhaps the most serious problem when the data quality is considered from the point of view of applicability to the ASA approach. For a large number of indicators, including several headline indicators, the length of time series data is very short and a lot of data for especially the new 10 member states is lacking. This influences the lack of data for EU aggregates, especially for EU25 but also for EU15. As a conclusion, it is extremely difficult to find yearly data of several indicators for a longer time period than a few (less than five) years.

2.2.4. Suitability of the SDI set to the ASA framework

The ASA framework can be applied to geographical or/and functional entities. The requirement is that all variables and data used in the analysis describe and characterise the same entity at the same level. The EU SDI set includes data mainly on geographical entities, i.e. EU member states. There are few indicators where national data is not available. Several indicators include classifications, but the classification is very different inside different indicators. This means that the national and aggregate EU levels are the only ones that can be used. However, there is a strong need for data also on regional and sub-national level.

From the point of view of indicator use in the ASA approach, some headline indicators are problematic. For example theme 1 (economic development), the headline indicator is the growth of real GDP in percentage while the ASA approach requires absolute values for differences from the selected base year to the studied year. This causes a lot of extra calculation to get the data into a usable form. The headline indicator for theme 9 (good governance) does not have a single value for each country but includes three classes which requires e.g. calculating an arithmetic or a weighted average.

Moreover, the downloadable datasets (for the 2005 SDI set) provided at the Eurostat website are in such a format which requires a lot of work to bring the data in a form ready to be used. These data format related problems include

- Time series are in a reverse order (start from right)
- Subscripts related to individual data values placed in the same cell; the subscripts must be removed manually if the value is used
- Subscripts include codes which are not explained in the datasheets
- Definitions are not provided inside datasheets
- Datasheets do not include full names of variables and their classification need to be obtained from different documents.

These problems make the data use a very time consuming effort. The DECOIN project acknowledges that many of these problems have already been solved in the revised SDI set. Significant improvements have been made to get the data more user-friendly, which is important, if the aim is to enhance to the use of sustainable development indicators, the use of which so far has not been common practice in many organizations.

2.2.5. Cause-effect relationship in the SDI set

Due to the nature of the decomposition analysis applied in the ASA approach, the cause-effect relationship of sustainable development indicators is an issue of major importance. The ASA approach can be used to calculate the relative shares of pre-defined causal factors or driving forces behind a studied phenomenon/indicator. The major problem is where to obtain these pre-defined factors from. There is an existing framework developed inside the EU organization; i.e. the driver-pressure-state-impact-response (DPSIR) closely related this purpose, but the SDI set does not apply this framework, which apparently has been developed to foster the minimal use of sustainable development indicators. The DPSIR framework could be used e.g. inside each of the themes, instead of the three-level hierarchy of lead objectives, SDS priorities and actions (explanatory variables), which totally misses important aspects of sustainable development.

2.2.6. Data reliability in the SDI set

Although Eurostat is the official statistical office in the EU and rests on the data provided by e.g. national statistical authorities, information of the original data sources could be provided in more detail.

2.2.7. Conclusion: the usefulness of the EU SDI set and related database

Above we have evaluated the EU SDI set and related data provided by Eurostat from the perspective of using the data in the DECOIN project, especially in the Advanced Sustainability Analysis (ASA) approach. The SDI set as well as the downloadable datasheets have several characteristics that limit the possibilities to use them in the DECOIN project. (The EU SDI set is also criticised in Europe 2007 monitoring report *Measuring progress towards a more sustainable Europe*. For instance in p. viii it is said that there are limitations to some existing indicators, and some objectives are not adequately (or not at all) monitored due to the lack of appropriate statistics or in p. 9 it is said that the indicators adopted are imperfect, and do not always adequately monitor the issue of concern). The technical difficulties related to the datasheets can be overcome by carrying out the work required, but it is not reasonable that every time the data is used, the same modifications have to be done again and again. The more serious problems are related to the SDI set – the indicators are grouped into ten themes but the relationship between the indicators inside each set remains unclear. Thus the indicator set needs revisions if the usefulness of the SDI set is considered as an important issue. The DECOIN project suggests including the DPSIR approach as a first step to increase the possible use of the set.

In the following, despite of what is said above, a number of decomposition analyses is carried out as preliminary illustration to show what kind on analyses can be carried out with the tool. In addition to the SDI set, some additional data have been used in order to make ad hoc decompositions technically possible. (For instance the theme of climate change and energy is illustrated more profoundly than other themes, which was not feasible in all themes due to lack of resources). In addition to the ASA approach, also within other approaches available in the DECOIN project (i.e. MSIASEM and SUMMA), the lack of relevant data for several indicators at other levels than national level causes a major problem.

As a conclusion, it has to be said that possibilities to utilize the EU SDI set in fulfilling the objectives of the DECOIN project remains very limited. In forthcoming stages of the project, a number of unsustainable trends will be selected for further analysis of inter-linkages between them. Additional data will be searched for empirical analysis.

3. Advanced Sustainability Analysis (ASA)

3.1. Introduction

Advanced Sustainability Analysis (ASA) is a mathematical information system developed by Finland Futures Research Centre. It can be used to analyze economic development from different sustainability points of view. The ASA approach can be used to focus on relationships between changes in environmental, economic and social variables that can be measured with any preferred indicator or index.

ASA applies decomposition analysis in order to divide the observed change in environmental, social or economic variables (indicators) into different effects, called contributing factors. The sum of all identified and decomposed factors is equal to the total change in the studied environmental, social and/or economic indicator. Different decomposition techniques have been developed mainly in the field of energy studies for modelling changes e.g. in energy use or energy intensity (Rose & Casler, 1996; Ang & Zhang, 2000; Ang, 2004). The method applied here is based on a revised Sun/Shapley decomposition technique (see below).

The main features of ASA include applying the decomposition technique into environmental stress (ES) or social welfare (WF) indicators and interpreting the decomposed factors as indicators either advancing or threatening sustainability. One advantage of the ASA approach is that it can be used to interpret and quantify many often used but sometimes poorly defined concepts such as dematerialization of production, eco-efficiency, or rebound effect. ASA can also be used to develop new theoretical concepts such as immaterialization of consumption, welfare productivity (of GDP), sustainable economic growth, or required technological development for sustainability.

ASA can also be applied to scenario construction by setting either a trend (forward) or a target (backward) as drivers of the future development. The drivers can be freely chosen among the identified factors that contribute to the observed change.

3.2. The method of ASA

The ASA approach is always case-specific which sets the important phase of defining the contributing factors and interpretation of results. The following shows a general example of ASA decomposition of variable V. An equation for describing the relationship between the contributing factors (intensive factor and extensive factor X1) to variable V can be expressed in its simplest form as follows (Equation 1):

$$V = \frac{V}{X1} \times X1 \qquad (1)$$

The change of V can be decomposed into the effects of two factors as shown in Figure 1.

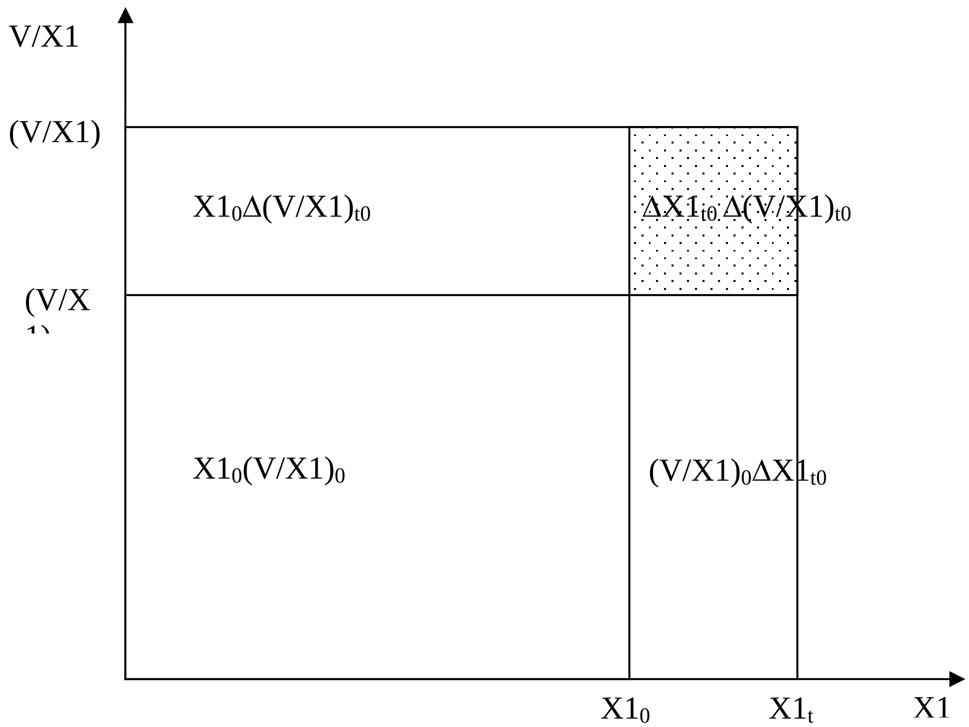


Figure 3.1. *The separate effects of variable X1 and variable V/X1, and their joint effect to the total change of V (modified from Sun 1996, 48).*

The decomposition calculates the effect/contribution of each explaining factor and their “joint effect” (residual term), which in a complete decomposition must be allocated to the two explaining factors. Figure 3.2 defines different alternatives for allocating the joint effect, which may give somewhat different results as the different alternatives presented in Figure 3.2 indicate: The coefficient λ defines the share of the joint effect allocated to the effect of V/X1, and 1-λ defines the share allocated to the effect of X1.

When λ=0 the joint effect is allocated totally to the effect of X1, and λ=1 allocates it totally to the effect of V/X1. A value of λ=0.5 allocates the joint effect “equally” to both effects. Any value between 0 and 1 ($0 \le \lambda \le 1$) can be given to λ. One option is to allocate the joint effect in relation to the relative changes of the contributing effects. In this case, the value for coefficient λ_1 can be calculated as follows:

$$\lambda_1 = \frac{\left|\dfrac{\Delta\left(\dfrac{V}{X1}\right)_{t0}}{\left(\dfrac{V}{X1}\right)_0}\right|}{\left|\dfrac{\Delta X1_{t0}}{X1_0}\right| + \left|\dfrac{\Delta\left(\dfrac{V}{X1}\right)_{t0}}{\left(\dfrac{V}{X1}\right)_0}\right|} \qquad (2)$$

Figure 3.2. *ASA decomposition of change in variable V into the effects of changes in variables V/X1 and X1 during a selected time period.*

This kind of analysis can be applied to multiple explaining factors as well. The two-factor decomposition presented above can be continued by taking a result from the first decomposition as a starting point for further decomposition, and the new results can then be decomposed again. The equation which identifies the contributing variables can be formulated in a general form as follows:

$$V = \frac{X1}{X2} \times \frac{X2}{X3} \times \ldots \times \frac{Xn-1}{Xn} \times Xn \ \text{(n≥2)} \tag{3}$$

The formulas which result the contributions of the chained factors X1, X2, X3 and X4 to the studied variable V are in their simplified form the following (Equations 4a-4e):

$$V/X1 = (X1_0 + \lambda_1 \Delta X1_{t0}) \times \Delta\left(\frac{V}{X1}\right)_{t0} \tag{4a}$$

$$X1/X2 = \left(\left(\frac{V}{X1}\right)_0 + (1-\lambda_1)\Delta\left(\frac{V}{X1}\right)_{t0}\right) \times (X2_0 + \lambda_2 \Delta X2_{t0}) \times \Delta\left(\frac{X1}{X2}\right)_{t0} \tag{4b}$$

$$X2/X3 = \left(\left(\frac{V}{X1}\right)_0 + (1-\lambda_1)\Delta\left(\frac{V}{X1}\right)_{t0}\right) \times \left(\left(\frac{X1}{X2}\right)_0 + (1-\lambda_2)\Delta\left(\frac{X1}{X2}\right)_{t0}\right) \times (X3_0 + \lambda_3 \Delta X3_{t0}) \times \Delta\left(\frac{X2}{X3}\right)_{t0} \tag{4c}$$

$$X3/X4 = \left(\left(\frac{V}{X1}\right)_0 + (1-\lambda_1)\Delta\left(\frac{V}{X1}\right)_{t0}\right) \times \left(\left(\frac{X1}{X2}\right)_0 + (1-\lambda_2)\Delta\left(\frac{X1}{X2}\right)_{t0}\right) \times \left(\left(\frac{X2}{X3}\right)_0 + (1-\lambda_3)\Delta\left(\frac{X2}{X3}\right)_{t0}\right) \times (X4_0 + \lambda_4 \Delta X4_{t0}) \times \Delta\left(\frac{X3}{X4}\right)_{t0} \tag{4d}$$

$$X4 = \left(\left(\frac{V}{X1}\right)_0 + (1-\lambda_1)\Delta\left(\frac{V}{X1}\right)_{t0}\right) \times \left(\left(\frac{X1}{X2}\right)_0 + (1-\lambda_2)\Delta\left(\frac{X1}{X2}\right)_{t0}\right) \times \left(\left(\frac{X2}{X3}\right)_0 + (1-\lambda_3)\Delta\left(\frac{X2}{X3}\right)_{t0}\right) \times \left(\left(\frac{X3}{X4}\right)_0 + (1-\lambda_4)\Delta\left(\frac{X3}{X4}\right)_{t0}\right) \times \Delta X4_{t0} \tag{4e}$$

New factors can be easily added by continuing the chaining. The term $\Delta X4_{t0}$ in Equation 4e will then be replaced with a new term following the same logic as in previous Equations 4a-4d.

3.3. Sun/Shapley complete decomposition

When the aim of the decomposition analysis is to model the changes in input and output also in relation to structural change, the explanatory variables can be divided in the following way: the activity level in the economy, sectoral intensity, and structural shift. It is also possible to combine this kind of analysis and the chained two-factor decomposition introduced above.

Several methods and indexes have been developed for the purposes of decomposition analysis and they have mainly been used to analyse the energy sector. Sun (1996; 1998) has developed a difference method, which has no residual term unlike other methods. Later Ang et al (2003) have shown that this method is the same as a method proposed by Albrecht et al (2002) which is based on the Shapley value. From this complete decomposition model a following dynamic model can be developed (Equations 6a-6d):

$$\Delta X = X^t - X^0 \tag{5a}$$

$$XQ_{effect}{}^t = (Q^t - Q^0)\sum_i I_i^0 s_i^0 + \tfrac{1}{2}(Q^t - Q^0)\sum_i (I_i^0(s_i{}^t - s_i{}^0) + s_i^0(I_i{}^t - I_i{}^0)) + \tfrac{1}{3}(Q^t - Q^0)\sum_i (I_i{}^t - I_i{}^0)(s_i{}^t - s_i{}^0) \tag{5b}$$

$$XI_{effect}{}^t = Q^0\sum_i s_i^0(I_i{}^t - I_i{}^0) + \tfrac{1}{2}\sum_i (I_i{}^t - I_i{}^0)\left[\, s_i^0(Q^t - Q^0) + Q^0(s_i{}^t - s_i{}^0)\ \right] + \tfrac{1}{3}(Q^t - Q^0)\sum_i (I_i{}^t - I_i{}^0)(s_i{}^t - s_i{}^0) \tag{5c}$$

$$XS_{effect}{}^t = Q^0\sum_i I_i^0(s_i{}^t - s_i{}^0) + \tfrac{1}{2}\sum_i (s_i{}^t - s_i{}^0)\left[\, I_i^0(Q^t - Q^0) + Q^0(I_i{}^t - I_i{}^0)\ \right] + \tfrac{1}{3}(Q^t - Q^0)\sum_i (I_i{}^t - I_i{}^0)(s_i{}^t - s_i{}^0) \tag{5d}$$

where X is the input variable under study, Q is the output, I is the intensity (X/Q) and s is the sectoral share of output. Superscript *0* refers to the base year value and *t* refers to the values of the comparison year varying from n_1 to n_n,.

This model produces an exact decomposition so that:

$$\Delta X = XQ_{effect} + XI_{effect} + XS_{effect}\,. \tag{6}$$

The Q_{effect} is the activity effect that describes the effect of total output on sectoral input. Increasing the output increases the activity effect. The I_{effect} is the intensity effect, which reveals the impact of the technological change and the change in production systems on sectoral use of the input. If the increase in the output is larger than the increase in the input the intensity effect decreases. The S_{effect} is the structural effect, which reveals the impact of change in the sectoral share of total output on input use. If the share of one sector in the total output increases its structural effect increases.

4. Selected Empirical Results

4.1. Climate change and energy (CC)

The ASA carried out in this study identifies five different factors behind the change in CO_2 emissions from fuel combustion (see Figure 4.1). The factors are described and interpreted in the following way. The starting points for interpreting the bars presented in Figure 4.1 are that (1) three different time periods with the same base year of 1973 are represented in the same picture. Each time period has a different colour in each bar set. (2) Each factor affecting the change in CO_2 emissions during each time period is presented in a set of bars. (3) The sum of all factors equals the total change in CO_2 emissions from fuel combustion and is presented in the last set of bars labelled “Total”.

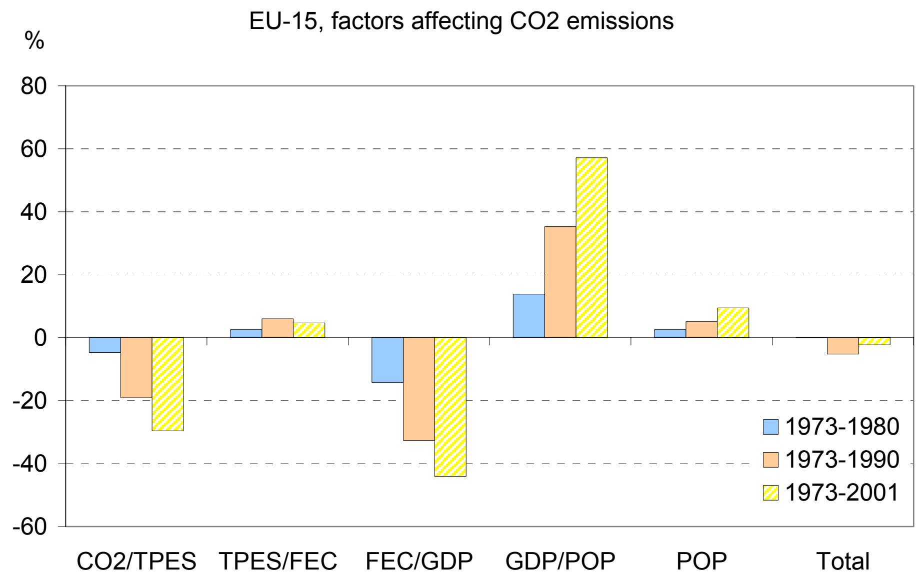


Figure 4.1. *The effects affecting CO_2 emissions in The European Union (EU-15) during the periods 1973-1980, 1973-1990 and 1973-2001.*

Identifying the factors behind change in CO_2 emissions from fuel combustion is based on the partition presented in the following equation:

$$CO_2 = \frac{CO_2}{GDP} \times GDP$$

$$CO_2 = \left(\frac{CO_2}{TPES} \times \frac{TPES}{GDP} \right) \times GDP$$

$$CO_2 = \left(\frac{CO_2}{TPES} \times \left(\frac{TPES}{FEC} \times \frac{FEC}{GDP} \right) \right) \times GDP$$

$$CO_2 = \left(\frac{CO_2}{TPES} \left(\frac{TPES}{FEC} \times \frac{FEC}{GDP} \right) \right) \times \left(\frac{GDP}{POP} \times POP \right) \tag{7}$$

where

- CO_2 is carbon dioxide emissions from fuel combustion;
- GDP is gross domestic product in real prices;
- TPES is total primary energy supply (including all fuels and other forms of primary energy, i.e. before the combustion process and transfer and distribution of electricity or heat;
- FEC is final energy consumption, i.e. the consumption of energy carriers such as district heat and electricity, and fuels used in residential heating and transport;
- POP is the country's population.

As a result, five different factors contributing to the change in CO_2 emissions are identified in a way that their sum is equal to the total change. For the three time periods studied, all factors are calculated as a percentage of the base year (1973) value. Each bar describes the amount of corresponding factor contributing to the change in CO_2 emissions during the studied time period.

The first factor, CO_2/TPES-factor, refers to the contribution of the change in the CO_2 intensity of the entire energy system that has been influenced by a switch from one energy form to another. Negative values for this factor in Figure 4.1 imply a switch from fuels with a high carbon content to energy sources with a lower carbon content, e.g. from coal to natural gas or nuclear power. Positive values would imply an increasing effect on CO_2 emissions due to the opposite type of fuel switch.

The second factor, TPES/FEC-factor refers to the efficiency of the energy transformation system, i.e. efficiency in transforming primary energy into different energy carriers such as electricity or heat. This can be influenced by e.g. a switch from fuel use to electricity or vice versa, or technological changes in fuel combustion. Positive values for this factor in Figure 4.1 imply an increasing use of electricity instead of other energy sources. Negative values would imply an opposite change of direction, i.e. technological changes such as a switch to combined heat and power (CHP) production instead of separate heat and electricity production.

The third factor, FEC/GDP-factor, refers to the energy intensity of the whole economy. This can be influenced by several factors, such as changes in the industrial structure from energy intensive to less energy intensive industrial branches, a shift from industrial production towards services in terms of GDP shares, or technological development inside energy- consuming fields of the economy. Negative values for this factor in Figure 4.1 imply that European countries have decreased their energy intensity due to the reasons provided above. Positive values would imply an increasing CO_2 emissions effect due to changes in the direction of a more energy intensive structure of the economy.

The fourth factor, the GDP/POP-factor refers to the amount of economic activity per capita which can be influenced foremost by economic growth. The positive values for this factor in Figure 3.1 imply that continuous economic growth per capita has increased CO_2 emissions. Negative values would imply a decreasing effect on CO_2 emissions due to a decrease in GDP per capita.

The fifth factor, the POP-factor refers to changes in the population figure brought about by birth and death rates as well as by international migration. The positive values for this factor in Figure 4.1 imply that quite a slow population growth has slightly increased CO_2 emissions from fuel combustion in the European Union. Negative values would imply a decrease in the effect of CO_2 emissions due to a decrease in the population.

The last set of bars in Figure 4.1 shows the total change of CO_2 emissions in the EU-15 countries as a sum of the five factors presented above. Between the years 1973 and 1980 the absolute CO_2 emissions from fuel combustion did not change. During the time periods 1973-1990 and 1973-2001 emissions have slightly decreased as a result of a switch towards energy sources that include less carbon as well as structural changes in the economy, such as the switch towards a less energy intensive industry and an increase in services. These factors have compensated for the factors of population growth, an increase in GDP per capita and the increasing use of electricity, which all tend to increase CO_2 emissions.

4.1.1. Quantitative analysis of emission intensity change and a decomposition analysis for selected countries

The CO_2 emissions of an economy can be defined with the aid of the CO_2 intensity of production and the production volume

$$CO_2 = \frac{CO_2}{GDP} \times GDP \qquad (8)$$

where CO_2 means the amount of carbon dioxide emissions, and GDP is the Gross Domestic Product and the CO_2 intensity of the economy is defined as the CO_2 emissions divided by the Gross Domestic Product, GDP.

$$CO_2 \text{ int} = \frac{CO_2}{GDP} \qquad (9)$$

where CO_2 int means carbon dioxide intensity.

The future development of CO_2 emissions in a country can be defined by the estimated CO_2 intensity of the future and the estimated GDP growth. The changes in CO2 intensity depend on several factors, but the general development path of an industrialising nation has been increasing intensity in the industrialization phase and decreasing intensity when the economy shifts more towards a service sector dominated system. The changes in CO_2 intensity in Italy indicate this general development trend (see Figure 4.2).

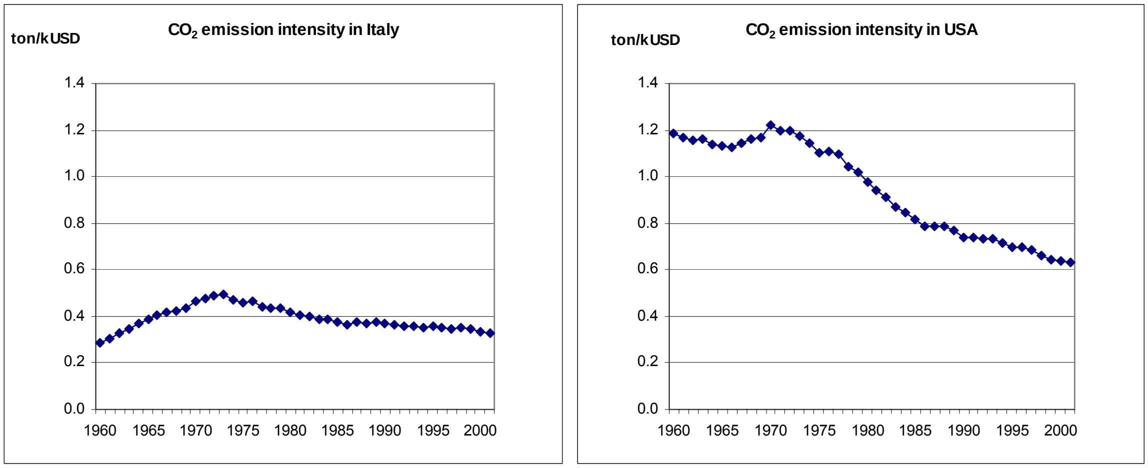


Figure 4.2. *Changes in the CO_2 intensity of the economies of Italy and the USA from 1960-2001 (Source: IEA 2003a).*

A falling trend in CO_2 intensity after the first oil crisis in 1973 can be seen in most industrialized countries. In some countries the trend of decreasing intensity started even before the oil crisis as can be seen in Figure 4.2 for the USA.

The level of the CO_2 intensity of the economy depends strongly on the production structure and the energy sources that are used. The transport sector can have an important effect on the level of the CO_2 intensity in countries, especially those with a high share of private car based passenger traffic and truck dominated freight transport.

In the so called Newly Industrialized Countries (NIC) the trend of growing CO_2 intensity can be clearly seen as is indicated in Figure 4.3 for Thailand and Malaysia. In relation to the Contraction and Convergence model this can be seen as a problem since the model does not take into account responsibility for historical emissions.

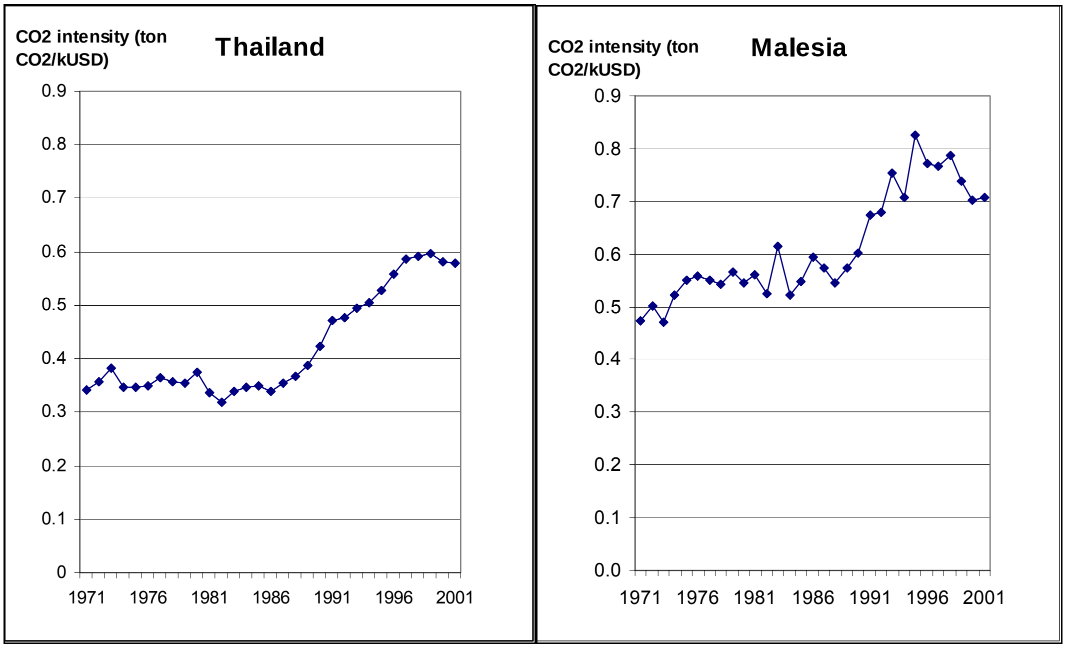


Figure 4.3. *Changes in the CO_2 intensity of the economies of Thailand and Malaysia from 1971-2001 (Source: IEA 2003a).*

We have calculated the future development of the CO_2 intensities of selected economies in order to analyse the likelihood of achieving the target of the so called Contraction and Convergence model (see Global Commons Institute http://www.gci.org.uk/) of 1.8 tons of CO_2 per capita in 2040 and to see what this requires, in terms of action, from different countries. We have downloaded the future emission projections from the C&C web site and calculated the future development of GDP based on the middle scenario of the WEC report “Global Energy Perspectives” (see Nakićenović et al 1998). Based on this data we have calculated the required development paths for the CO_2 intensities in the different economies (Japan, USA and EU, other G7 countries, China and India, Mediterranean countries, Nordic countries and some Transition countries).

In addition we have analysed the past trends of CO_2 emissions and primary energy use for the selected countries. The decomposition analysis thus provides the means to assess the different factors that have contributed to the changes in the emission amounts.

4.1.2. Japan, USA and EU15

The past development and the required future changes in the CO_2 intensity of the economies of the USA, Japan and the EU15 are shown in Figure 4.4.

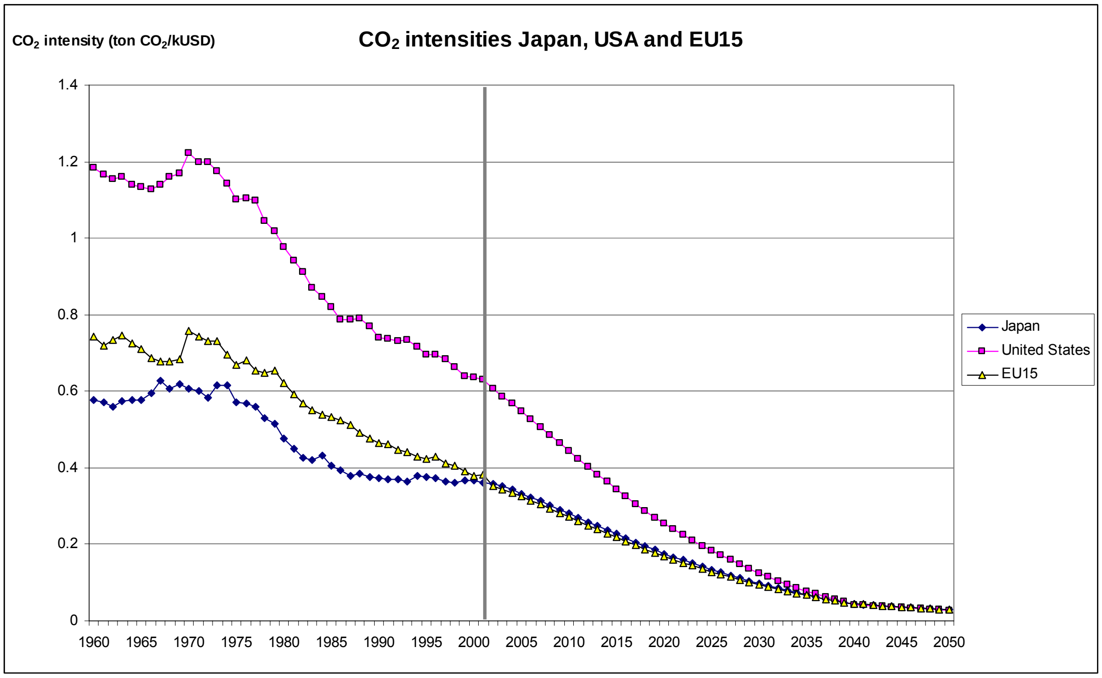


Figure 4.4a. *Changes in the CO_2 intensity of the economies of Japan, the USA and the EU15 from 1960-2001 (Source: IEA 2003a) and the required development from 2002-2050 in order to reach the C&C target.*

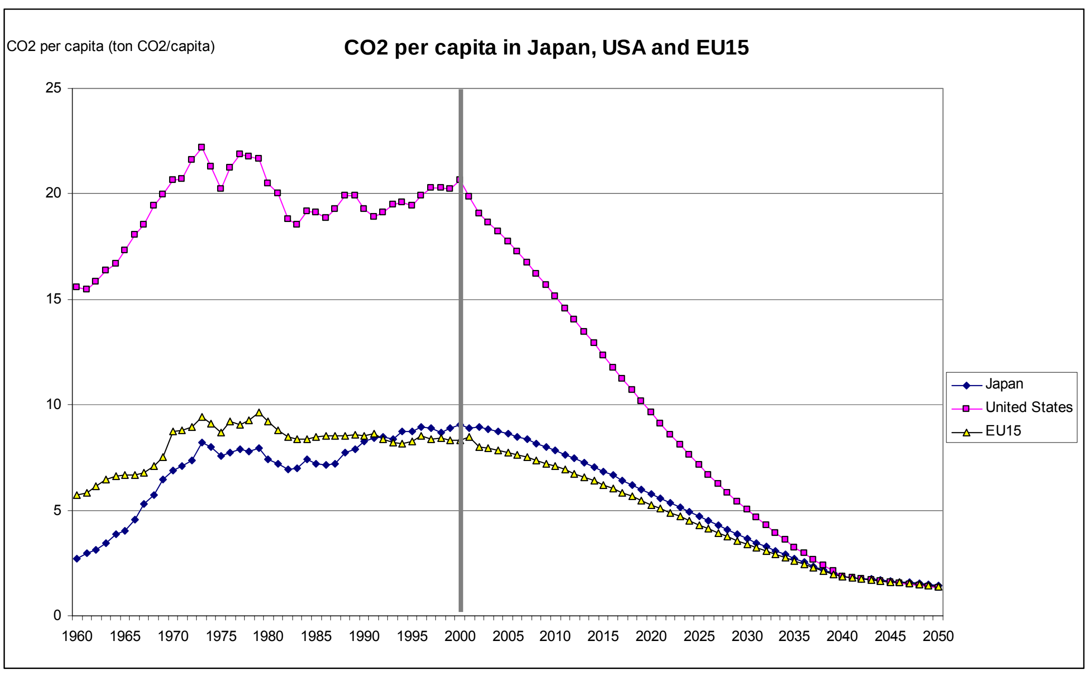


Figure 4.4b. *Changes in the CO_2 emissions per capita of the economies of Japan, the USA and the EU15 from 1960-2001 (Source: IEA 2003a) and the required development from 2002-2050 in order to reach the C&C target.*

The required future development for CO_2 intensities for Japan, the USA and the EU15 seems not to be too unrealistic. The sharp decrease in intensity after the first oil crisis was due to the increased efficiency of their energy use, plus a shift from oil to energy sources of lower carbon content. However, it was mainly due to a structural shift in the production structure, which led to lower energy intensities in their economies. This can be seen in the results of the decomposition analysis shown below.

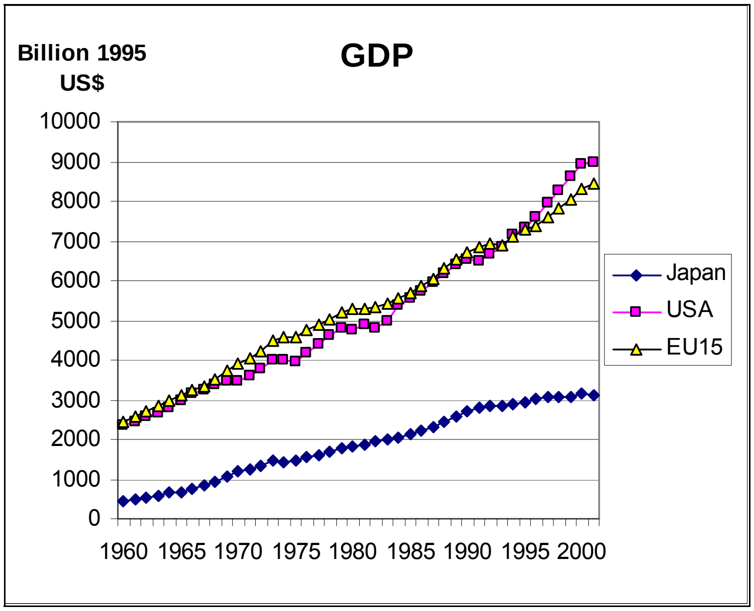
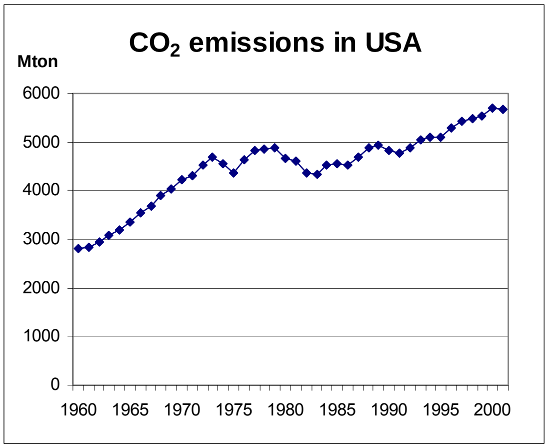


Figure 4.4c. *The growth of Gross Domestic Product (GDP) in Japan, USA and EU15 between 1960 and 2001 (in PPP 1995 US$) (Source: IEA 2003a).*



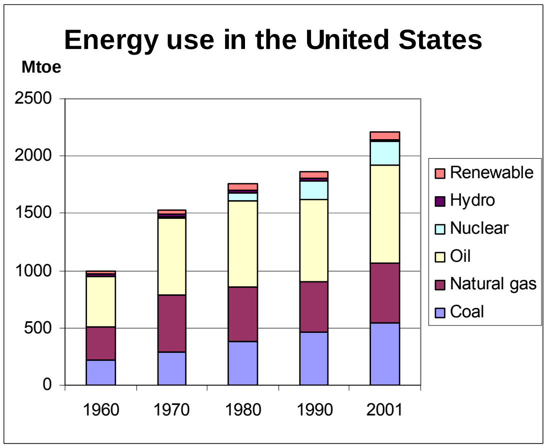


Figure 4.5. *CO_2 emissions and primary energy use in the USA from1960-2001 (Source IEA 2003a, b)*

In the USA the decarbonisation of the economy was quite rapid in the 1970's and 1980's, but development in the nineties has not been as successful. The changes in the fuel mix for energy production can be seen as one factor contributing to intensity change. The levelling off of the use of oil in 70's and 80's together with the increased use of nuclear energy explain the slow growth of CO_2

emissions. In the 1990's the use of oil has rose considerably in the USA increasing CO_2 emissions and lowering the rate of reduction of the CO_2 intensity of the economy.

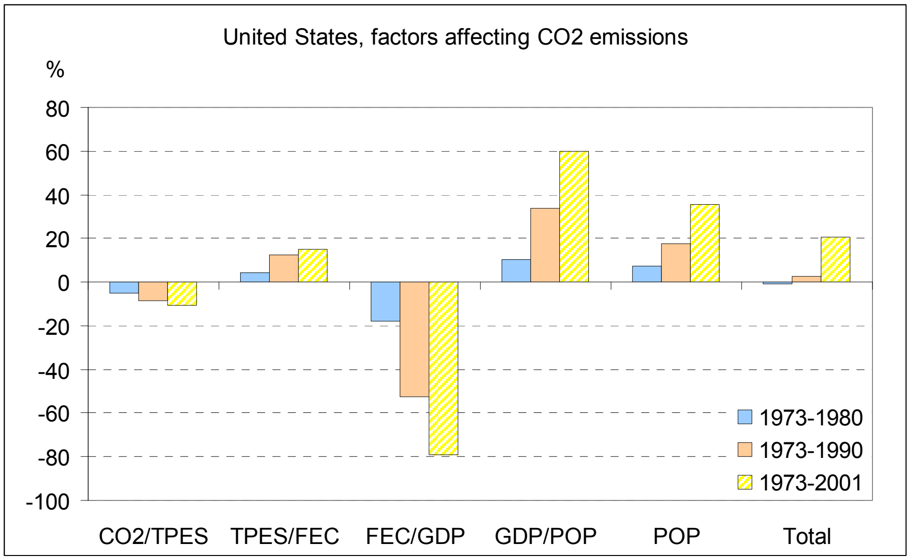


Figure 4.6. *A decomposition analysis for the factors affecting CO_2 emissions in the USA from 1973 to 2001.*

The decomposition of the US's CO_2 emissions according to different factors is shown in Figure 4.6. In this figure the changes in CO_2 emissions are shown in comparison with the year 1973. The first factor CO_2/TPES indicates the fuel shift in the total primary energy supply (TPES). The fuel shift has contributed to about a 10 % decrease in emissions in 2001 compared to the level of 1973. The second factor, TPES/FEC (Final Energy Consumption), indicates the change in the efficiency of the energy transformation chain. In this case efficiency has decreased, due to the increased share of electricity in FEC increasing CO_2 emissions by 17 % in 2001. The third factor, FEC/GDP, indicates the energy intensity of the production system. This has decreased considerably due to the increased share of services and the decreased share of heavy industry in the economy. The structural shift in the economy has decreased CO_2 emissions by 80 %.

The fourth factor, GDP/POP, indicates the effect of the increase in per capita production. This factor has increased emissions by 60 %. The fifth factor, POP, shows the effect of an increasing population on CO_2 emissions. In the USA the population growth effect has been about 35 %.

The total change in the US's CO_2 emissions is the sum of the five effects, which is about a 20 % increase between 1973 and 2001.

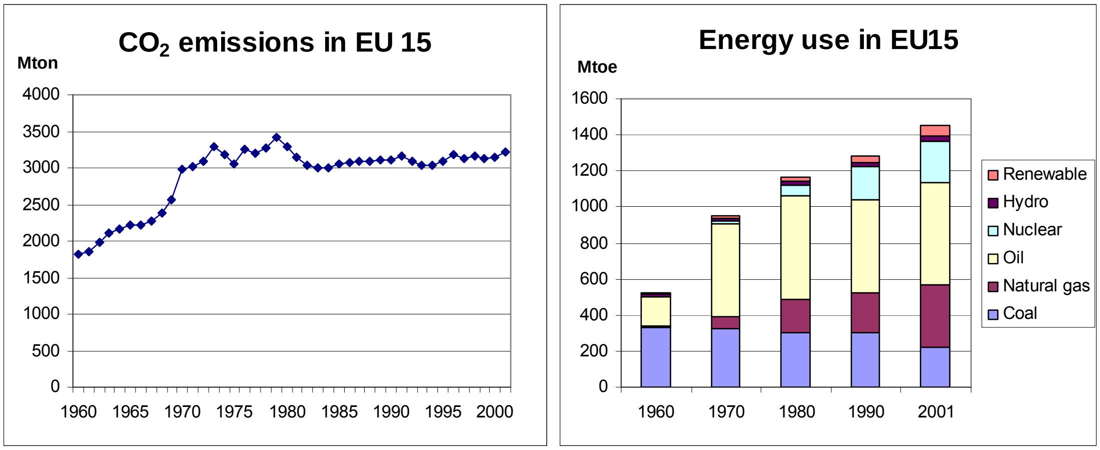


Figure 4.7. *CO_2 emissions and primary energy use in the EU15 from1960-2001 (Source IEA 2003a, b)*

In the EU15 the growth of energy use has been faster than in the USA, but the shift in fuel use has been larger resulting in the stabilisation of CO_2 emissions after 1973. The shift from coal to gas has been remarkable and the increase in nuclear production considerable.

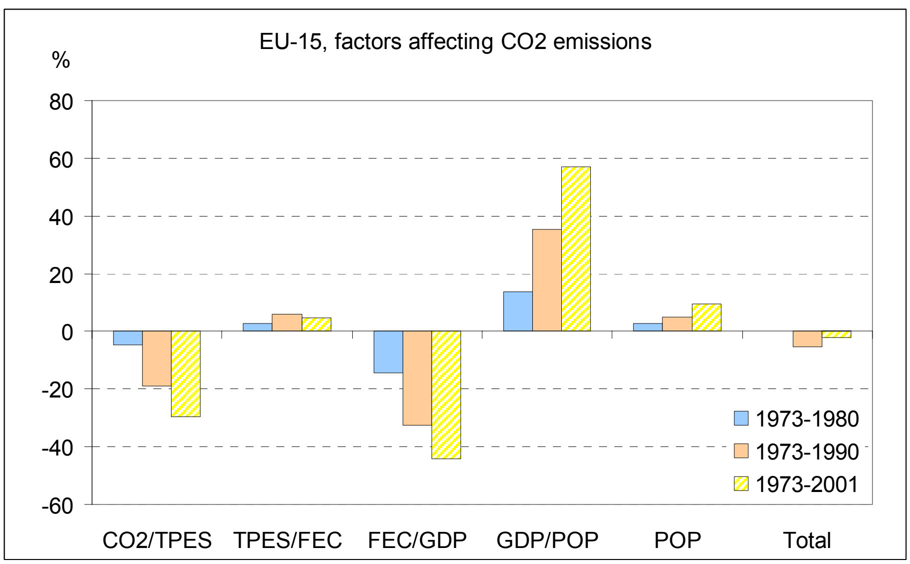


Figure 4.8. *A decomposition analysis for the factors affecting CO_2 emissions in the EU15 from 1973 to 2001.*

The decomposition analysis in Figure 4.8 for the EU15 shows that the fuel shift has been more significant than in the US contributing to a 30 % decrease in emissions. The structural shift in the EU has not been as significant as in the US. The population growth effect and the efficiency loss in the energy transformation system have been smaller leading to a minor decrease in total emissions from 1973 to 2001.

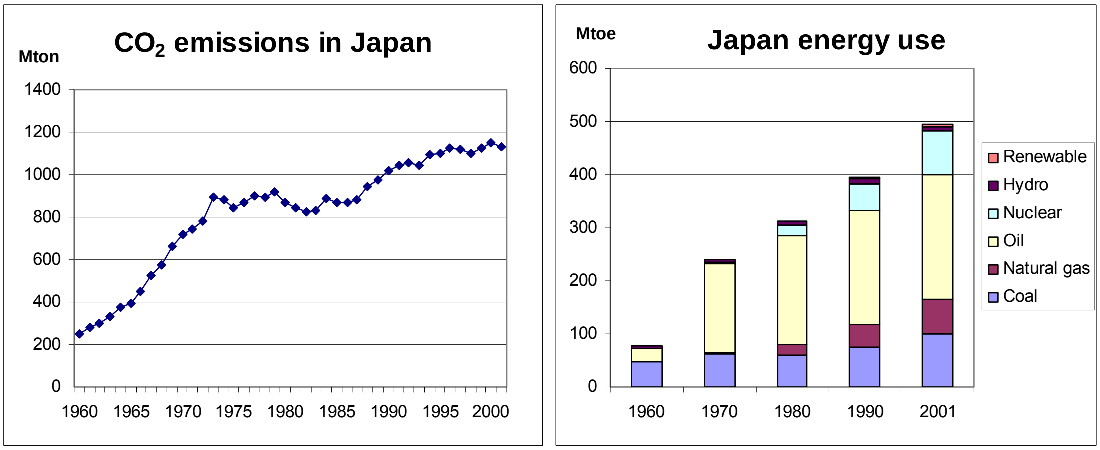


Figure 4.9. *CO_2 emissions and primary energy use in Japan from 1960-2001 (Source IEA 2003a, b)*

In Japan CO_2 emissions stabilized after 1973 but started to increase again in the late 80's. The increased use of oil and coal seems to be the main reason for the emission increase, which was partly triggered by a fast increase in energy demand.

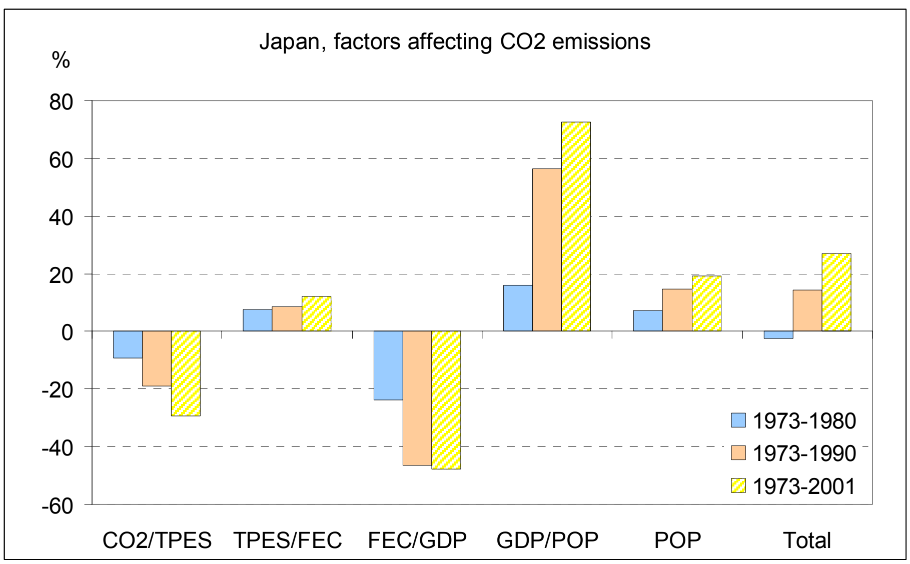


Figure 4.10. *A decomposition analysis for the factors affecting CO_2 emissions in Japan from 1973 to 2001.*

The decomposition analysis in Figure 4.10 for Japan shows that the fuel shift has been quite significant, as has its per capita production growth. The structural shift effect has not decreased emissions after 1990 and that has partly contributed to the total growth of emissions by 25 % from 1973 to 2001.

4.1.3. Other G7 countries

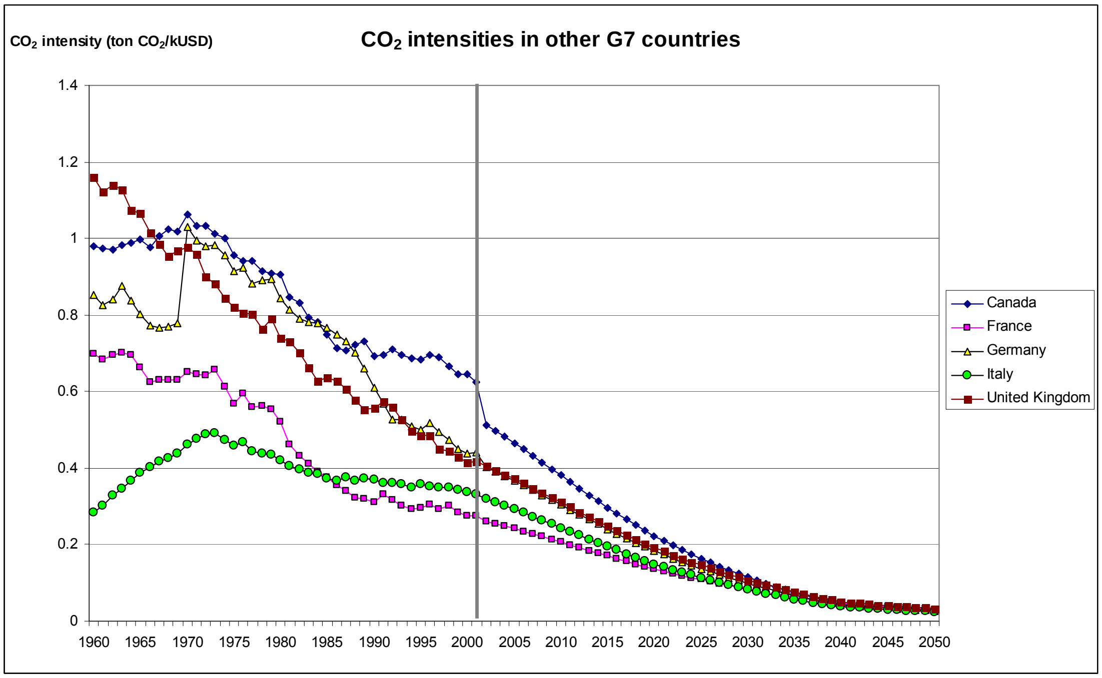


Figure 4.11a. *Changes in the CO_2 intensity of the economies of the other G7 countries from 1960-2001 (Source: IEA 2003a) and the required development from 2002-2050 to reach the C&C target.*

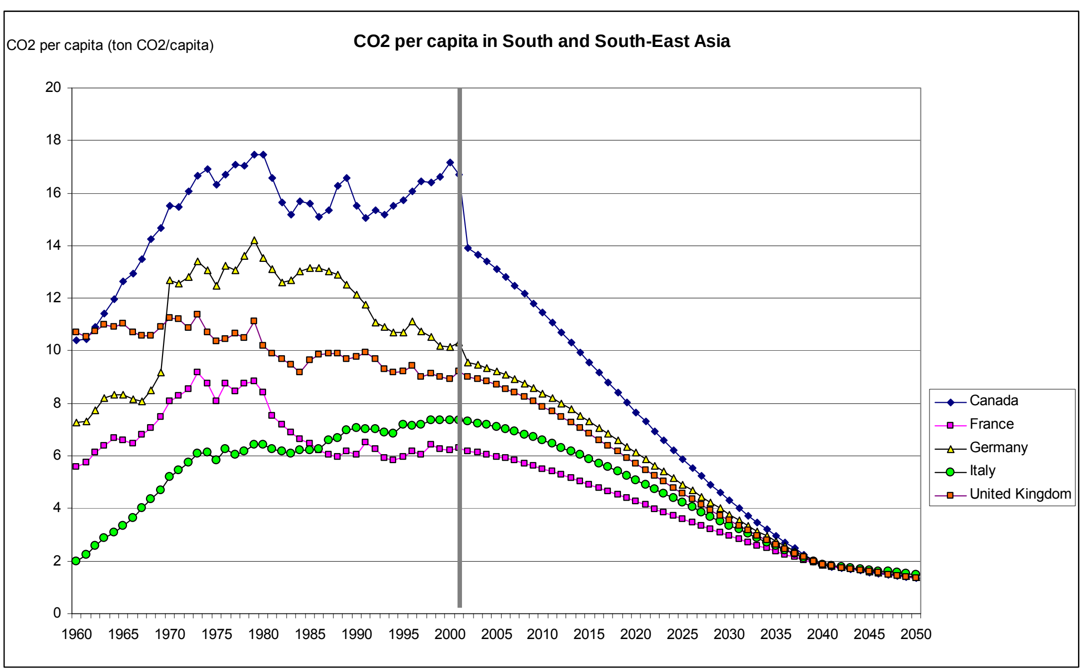


Figure 4.11b. *Changes in the CO_2 emissions per capita of the economies of the other G7 countries from 1960-2001 (Source: IEA 2003a) and the required development from 2002-2050 to reach the C&C target.*

The development with regard to the CO_2 emission intensity changes in the G7 countries of Canada, France, Germany, Italy and the United Kingdom has generally been quite positive.

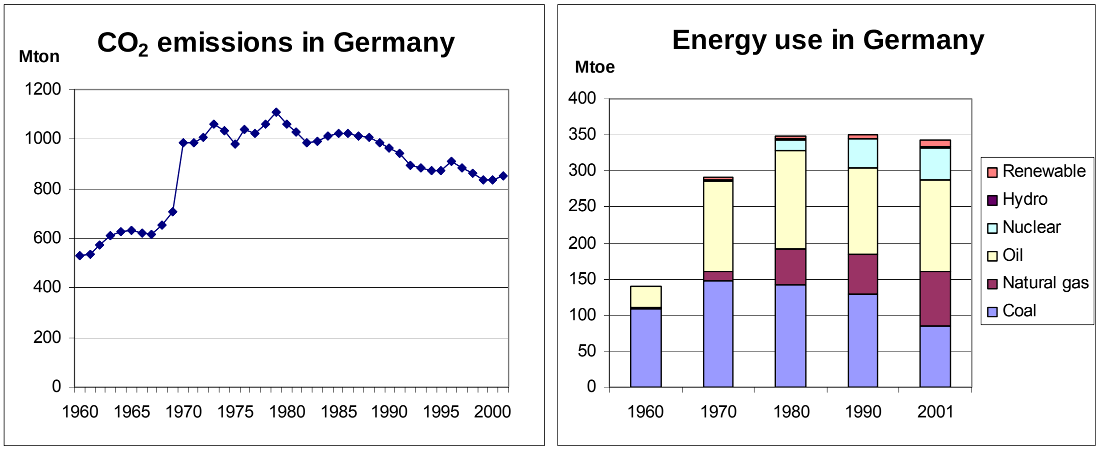


Figure 4.12. *The CO_2 emissions and primary energy use of Germany from 1960-2001 (Source IEA 2003a, b). Note the change caused by the inclusion of former DDR data in 1971 into Germany's data in the IEA database.*

In Germany the shift from coal to gas, an increasing use of nuclear energy and the stabilisation of oil use have been the main reasons, together with the stabilisation of total energy demand, for a decrease in CO_2 emissions.

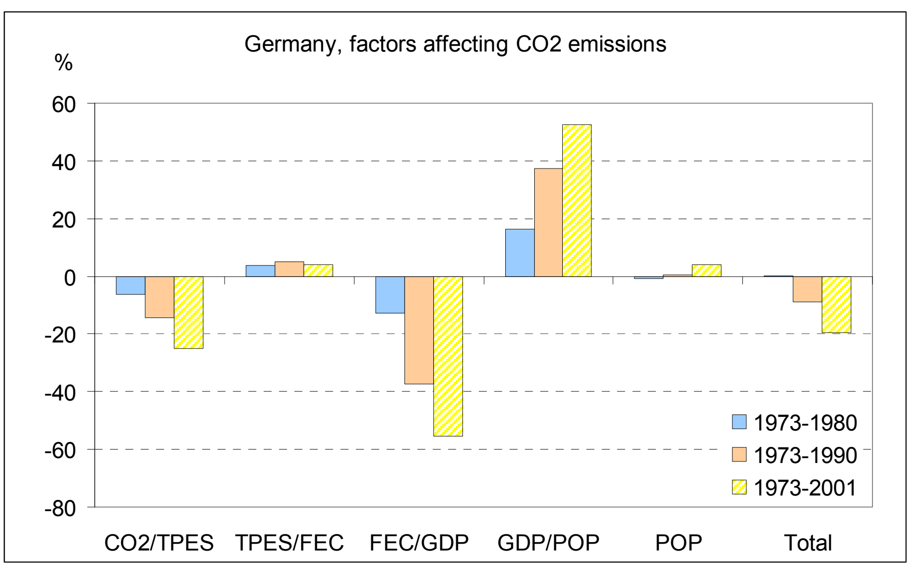
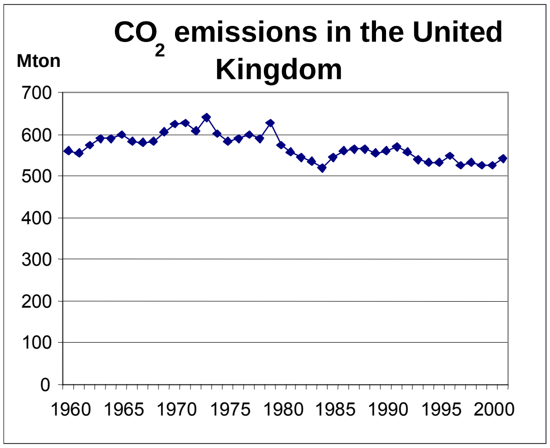


Figure 4.13. *A decomposition analysis for the factors affecting CO_2 emissions in Germany from 1973 to 2001.*

The decomposition analysis indicates that the fuel shift and the structural change in production in Germany have been the main drivers towards lower emissions. The efficiency increase with regard to production (see FEC/GDP) has partly been due to the modernization of the former East German facilities and structures. The economic growth of Germany has been slightly smaller than that experienced by the USA or Japan.



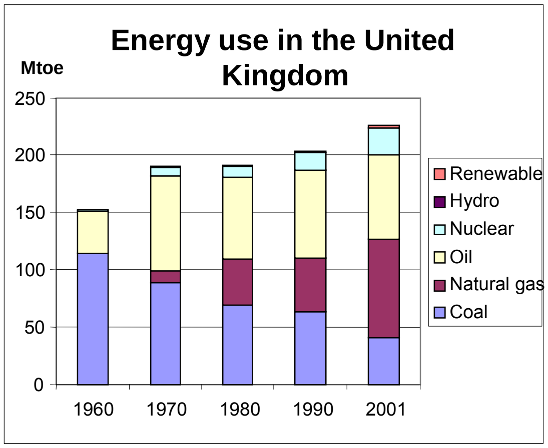


Figure 4.14. *CO_2 emissions and primary energy use in the United Kingdom from1960-2001 (Source IEA 2003a, b)*

In the United Kingdom the decrease of CO_2 emissions has been mainly achieved with the shift from coal to gas and an increase in nuclear energy use. The moderate growth of energy demand has been one reason for the positive development of the emissions.

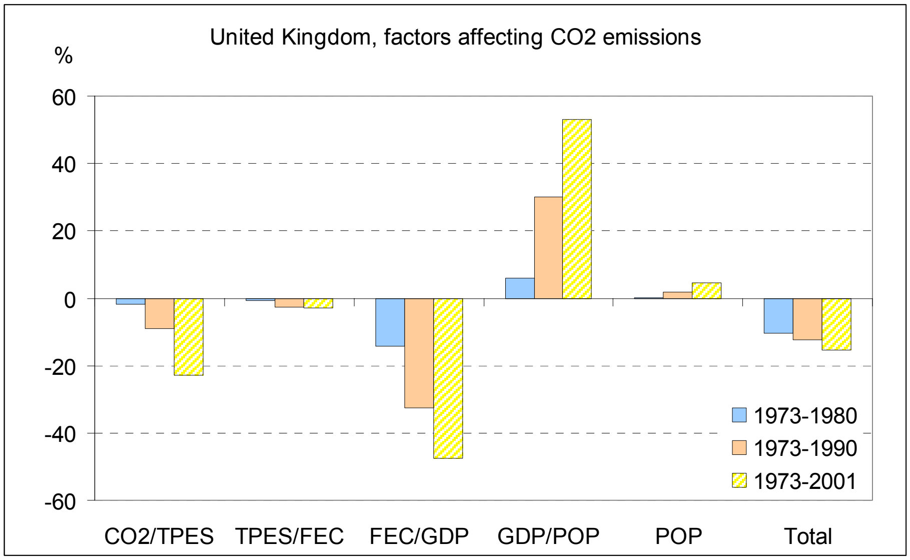
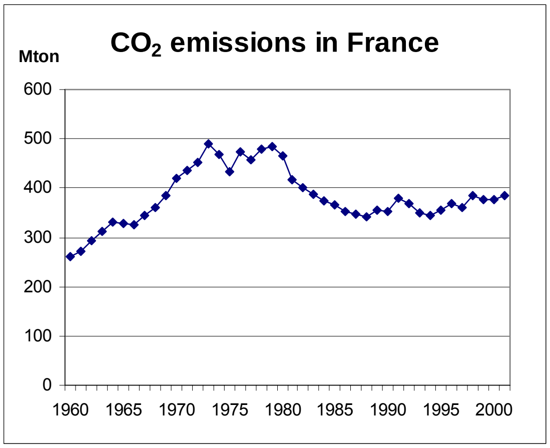


Figure 4.15. *A decomposition analysis for the factors affecting CO_2 emissions in the United Kingdom from 1973 to 2001.*

The decomposition analysis indicates that the structural change in the UK has almost compensated for the per capita growth in the economy. In this case the fuel shift, indicated by CO_2/TPES, has resulted in an absolute decrease of CO_2 emissions.



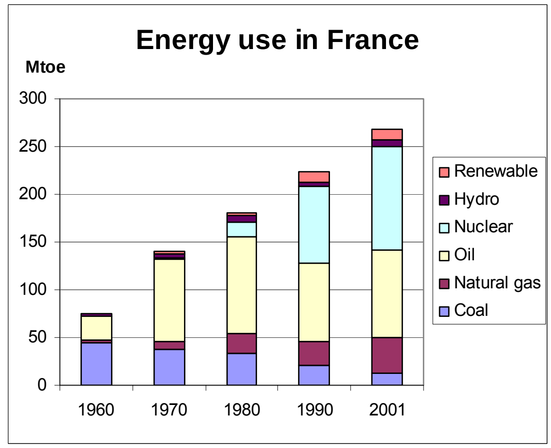


Figure 4.16. *CO_2 emissions and primary energy use in France from 1960-2001 (Source IEA 2003a, b)*

In France CO_2 emissions have decreased considerably in the 1970's and 1980's partly due to the shift from coal to gas but mainly because of a considerable increase in nuclear energy production. The fast growth in energy demand has, however, caused a stabilisation of emissions in the 1990's and the increase in France's nuclear capacity has not been able to further decrease them. The energy intensity of the production structure has not decreased from the 1960's as a consequence of a build up in heavy industry that utilises the increase in nuclear energy.

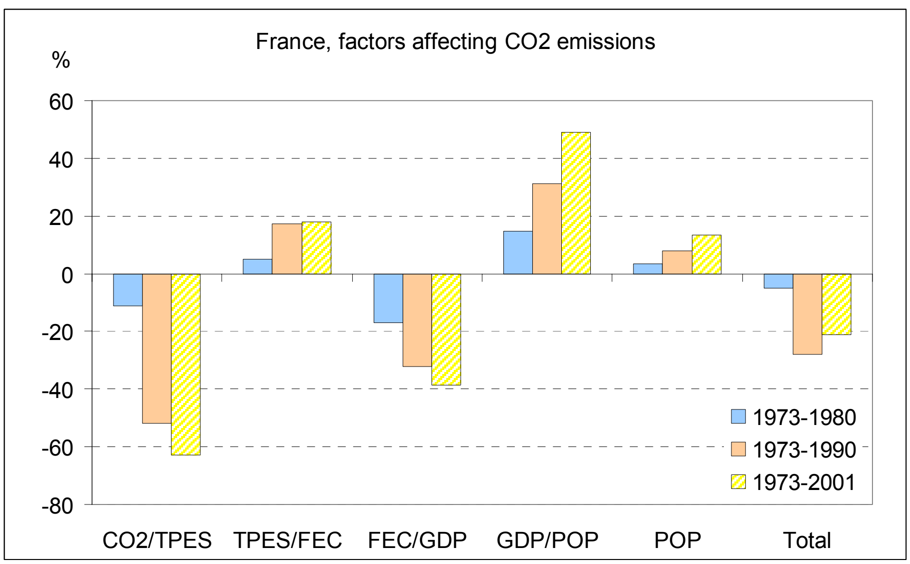


Figure 4.17. *A decomposition analysis for the factors affecting CO_2 emissions in France from 1973 to 2001.*

The decomposition analysis shows the large shift in fuel use that has taken place - mainly in the 1980's. The increased reliance on nuclear power has decreased the efficiency of the energy transformation chain and led to an increase in emissions by 20 %. The structural change in the French economy has not been as significant as e.g. in Germany or the UK as it decreased emissions only by less than 40 %. This was partly due to the reliance on domestic heavy industry, which was possible because of France's large nuclear production.

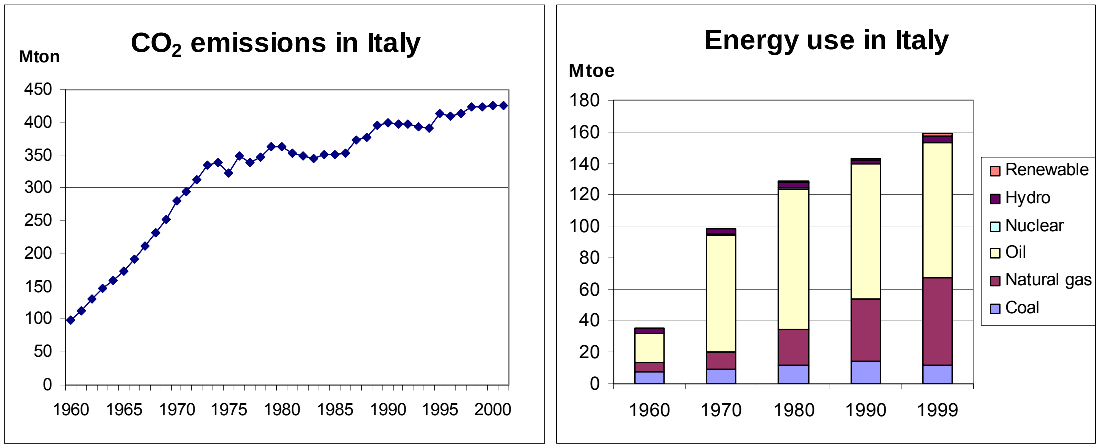


Figure 4.18. *CO_2 emissions and primary energy use in Italy from 1960-2001 (Source IEA 2003a, b)*

In Italy the fast growth of emissions in the 1960's and early 1970's was mainly caused by rapid industrialization and the related growth in oil use. Since the first oil crisis the growth in emissions has been quite slow and the increase has been mainly in gas consumption, which has replaced some oil and coal consumption.

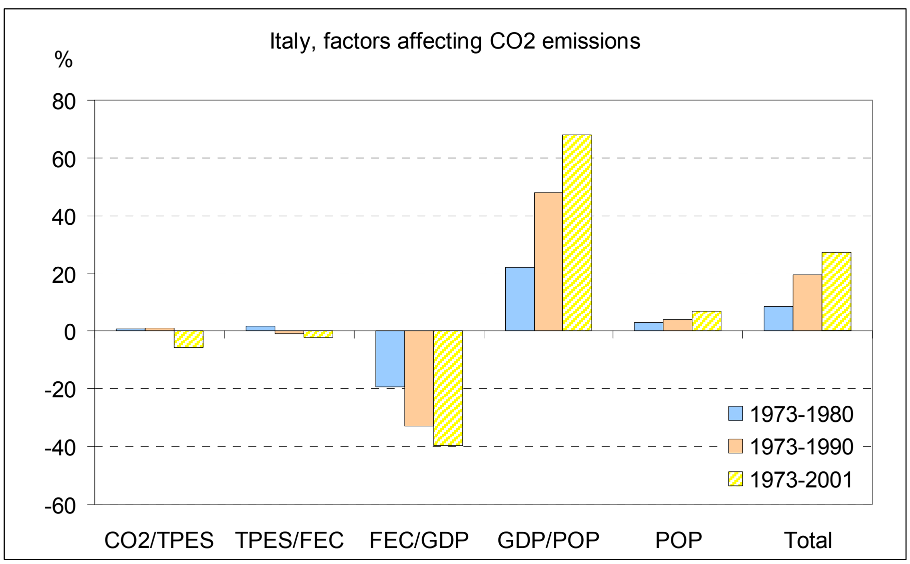
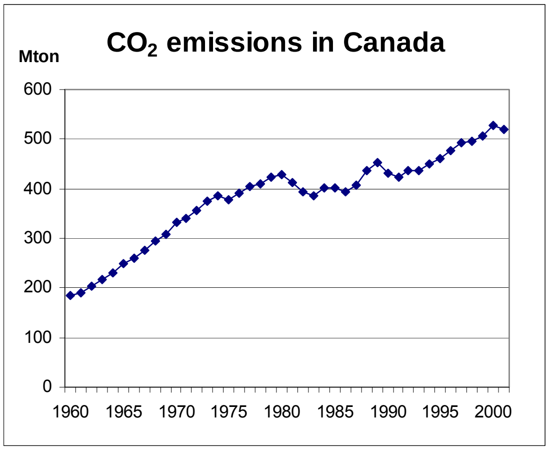


Figure 4.19. *A decomposition analysis for the factors affecting CO_2 emissions in Italy from 1973 to 2001.*

The decomposition analysis shows that there has been almost no fuel shift or efficiency change in the Italian energy sector. The structural shift of the economy has been modest in Italy and significant economic growth has resulted in an increase in emissions.



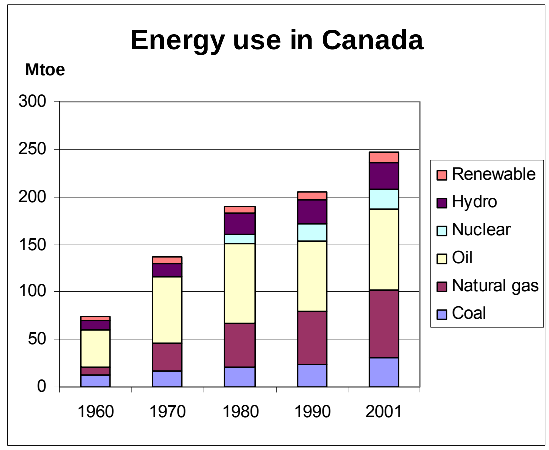


Figure 4.20. *CO_2 emissions and primary energy use in Canada from 1960-2001 (Source IEA 2003a, b)*

In Canada the growth of CO_2 emissions has not been very fast since the first oil crisis. The increased production of hydro and nuclear power together with increased gas use has been able to reduce the growth of oil demand in spite of the general growth in energy demand.

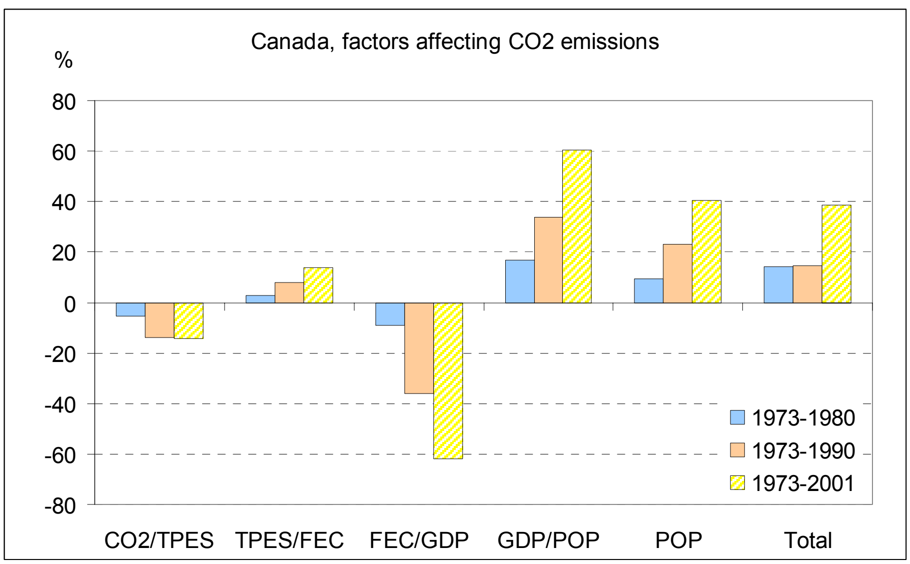


Figure 4.21. *A decomposition analysis for the factors affecting CO_2 emissions in Canada from 1973 to 2001.*

The decomposition analysis indicates that some fuel shifting has taken place in Canada, but at the same time the efficiency of the energy transformation has decreased. The structural shift in the economy has been remarkable and approximately compensated for the effect of the per capita economic growth. The high increase in Canada's population has contributed to the overall emission increase.

4.1.4. China and India

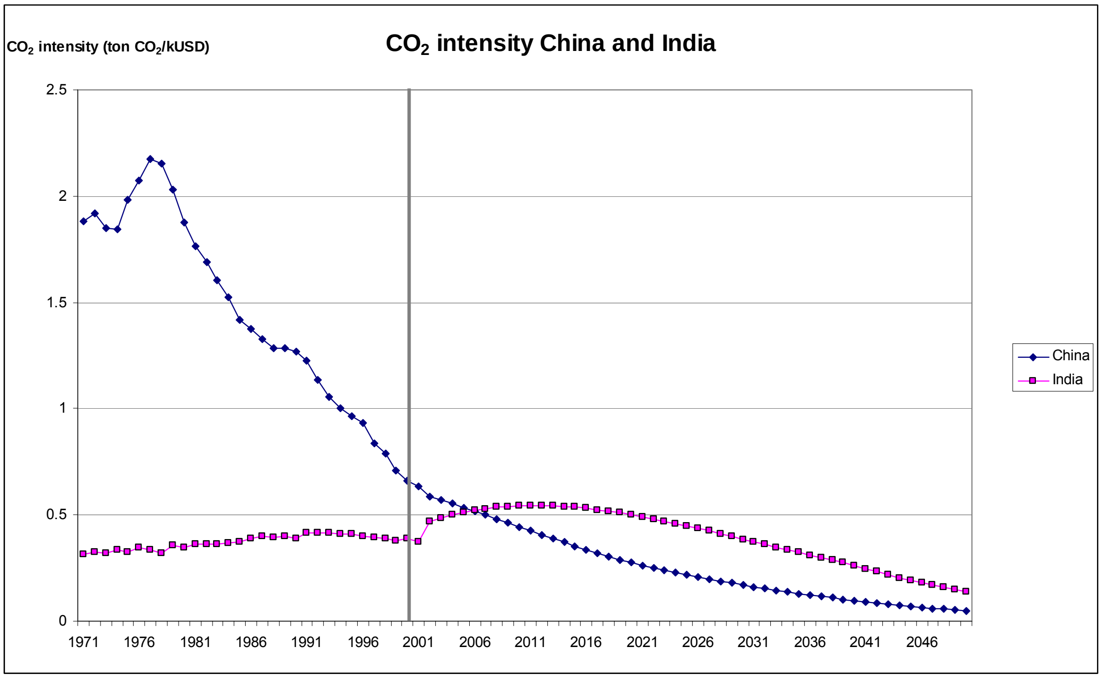


Figure 4.22a. *Changes in the CO_2 intensity of the economies of China and India from 1971-2001 (Source: IEA 2003a) and the required development from 2002-2050 to reach the C&C target.*

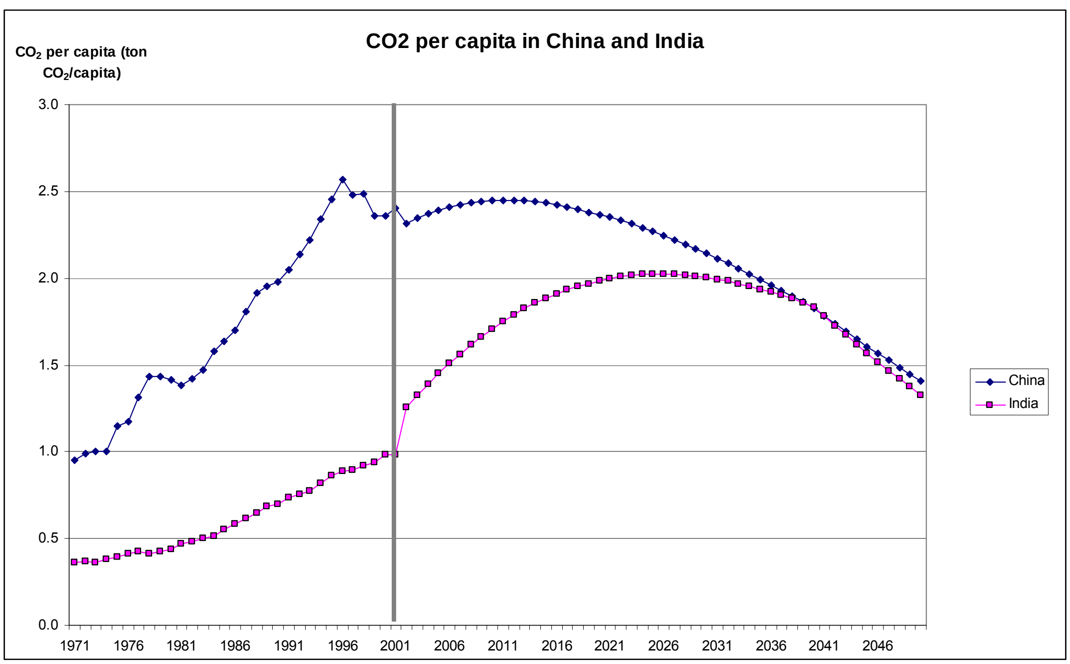


Figure 4.22b. *Changes in the CO_2 emissions per capita of the economies of China and India from 1971-2001 (Source: IEA 2003a) and the required development from 2002-2050 to reach the C&C target.*

In China and India previous changes in the CO_2 intensities of the economies have been quite different from the main industrialized countries. Also the required changes in the future in order to reach the C&C target by 2040 look different. In China emission intensity was considerably high in the 1970's but it rapidly decreased to the US's level by 2001. The fast decrease was mainly caused by fast economic growth. To achieve the C&C target China can considerably reduce its speed of CO_2 intensity reduction. In India the CO_2 intensity level was very low in the beginning of the 1970's and slowly increased up to the mid 1990's after which there has been slow reduction. In order to reach the C&C target India could in fact increase its CO_2 intensity in the near future. This is mainly due to its very low level of CO_2 emissions per capita (about one ton).

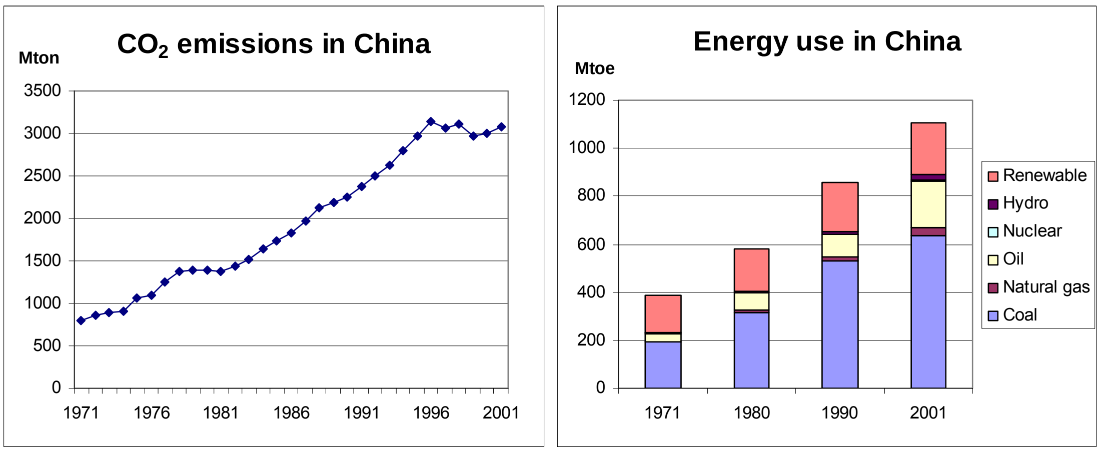


Figure 4.23. *CO_2 emissions and primary energy use in China from 1971-2001 (Source IEA 2003a, c)*

In China emissions grew steadily up to 1996 after which they have levelled off. The fast increase in energy consumption has been met by an increased use of coal and oil. The total use of renewable energy sources has increased by over 50 % from 1973 to 2001, but the share of renewables has diminished due to the very fast overall increase in energy consumption.

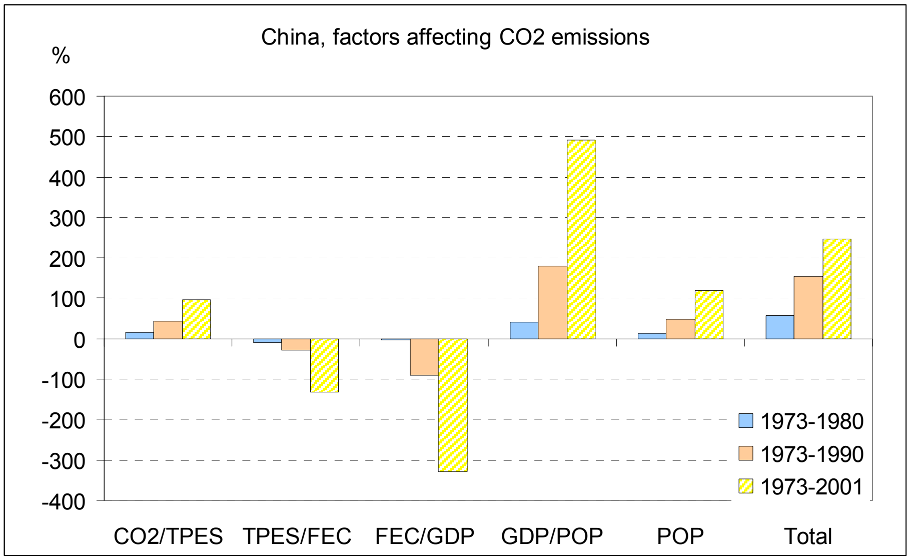
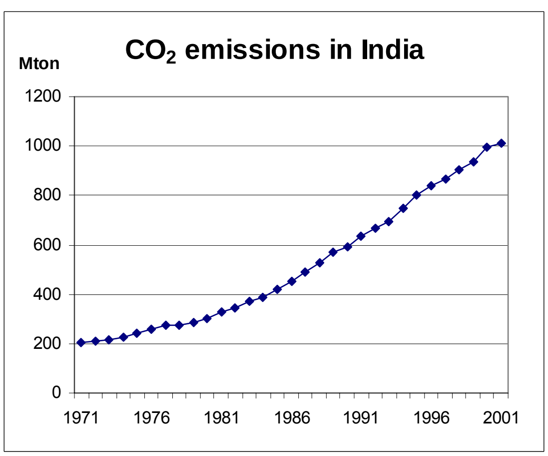


Figure 4.24. *A decomposition analysis for the factors affecting CO_2 emissions in China from 1973 to 2001.*

The decomposition analysis (note the scale) shows a large shift towards fossil fuels. The efficiency increase in the Chinese energy system has been considerable, especially in the 90's. The rapid structural change that lowered the energy intensity of the economy has contributed significantly to emission reduction. However, the per capita economic growth has contributed to an almost 500 % increase in CO_2 emissions compared to the 1973 level and the contribution of the population growth is over 100 %. The total increase in emissions was over 200 % between 1973 and 2001.



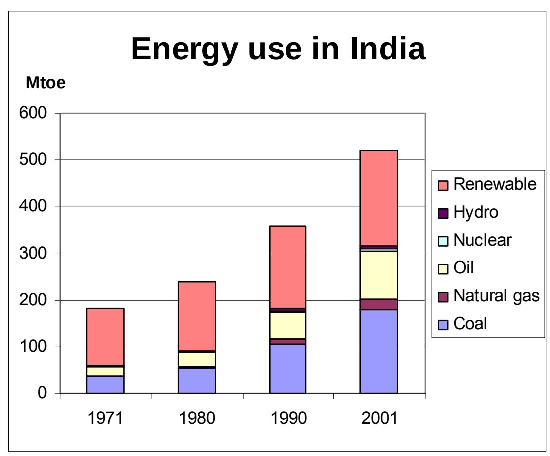


Figure 4.25. *CO_2 emissions and primary energy use in India from 1971-2001 (Source IEA 2003a, c)*

In India the increase in CO_2 emissions was mainly due to the large increase in coal consumption and oil consumption. The use of renewables has increased by over 70 % from 1973 to 2001, but this has not been able to change the trend of emission increase.

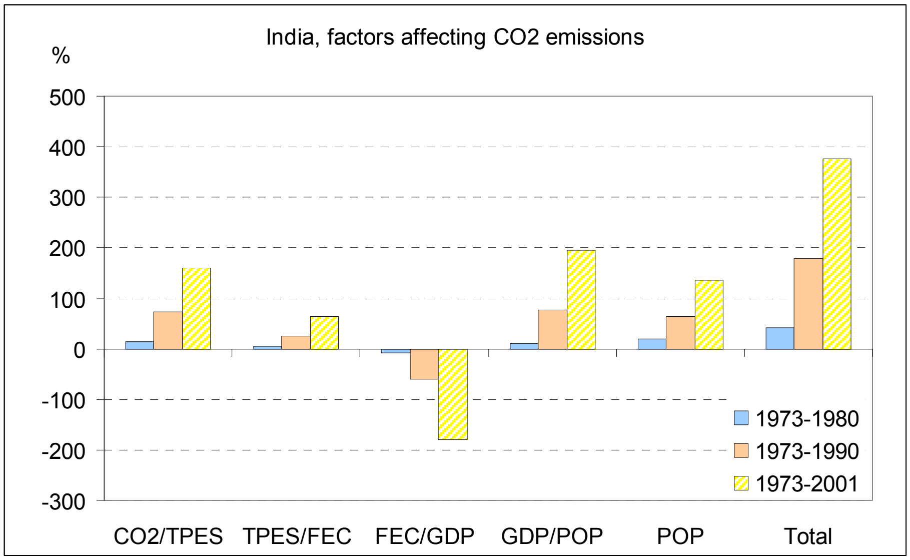


Figure 4.26. *A decomposition analysis for the factors affecting CO_2 emissions in India from 1973 to 2001.*

The decomposition analysis clearly shows a vast shift to a fossil dominated energy system in India. The per capita economic growth has been rapid, but the structural change in the economy has also been remarkable and almost compensates for the growth effect. The population growth in India has been rapid (about a 75 % increase from 1973 to 2001) contributing considerably to the total growth of emissions.

4.1.5. The Mediterranean EU countries

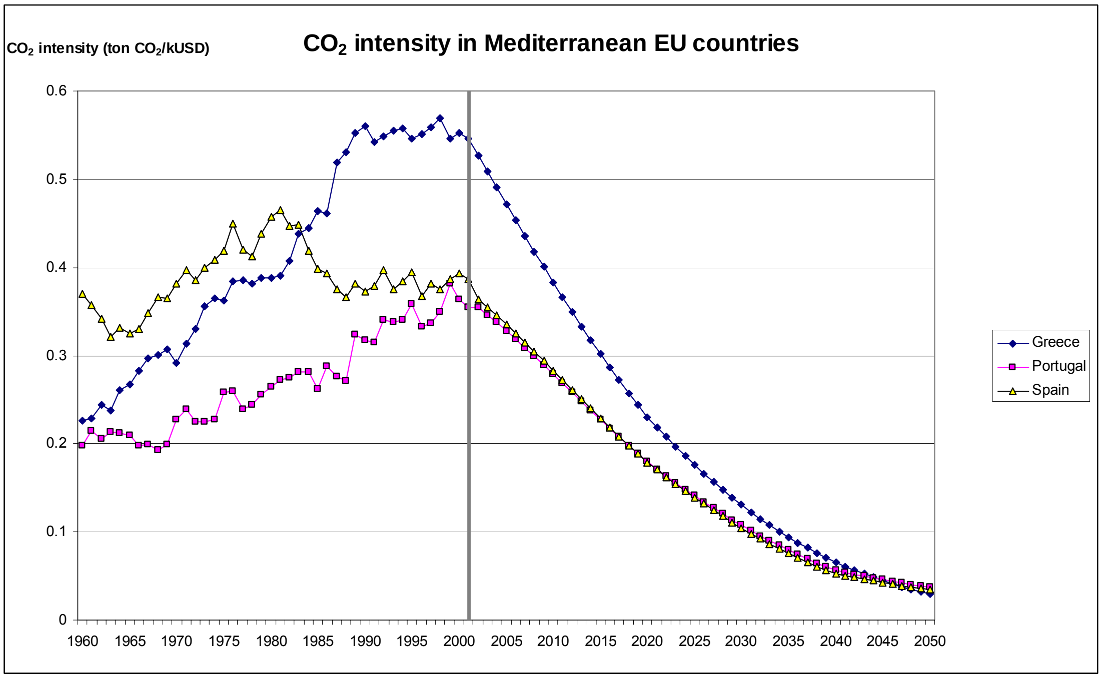


Figure 4.27a. *Changes in the CO_2 intensity of the selected economies of the Mediterranean EU countries; Greece, Portugal and Spain from 1960-2001 (Source: IEA 2003a) and the required development from 2002-2050 in order to reach the C&C target.*

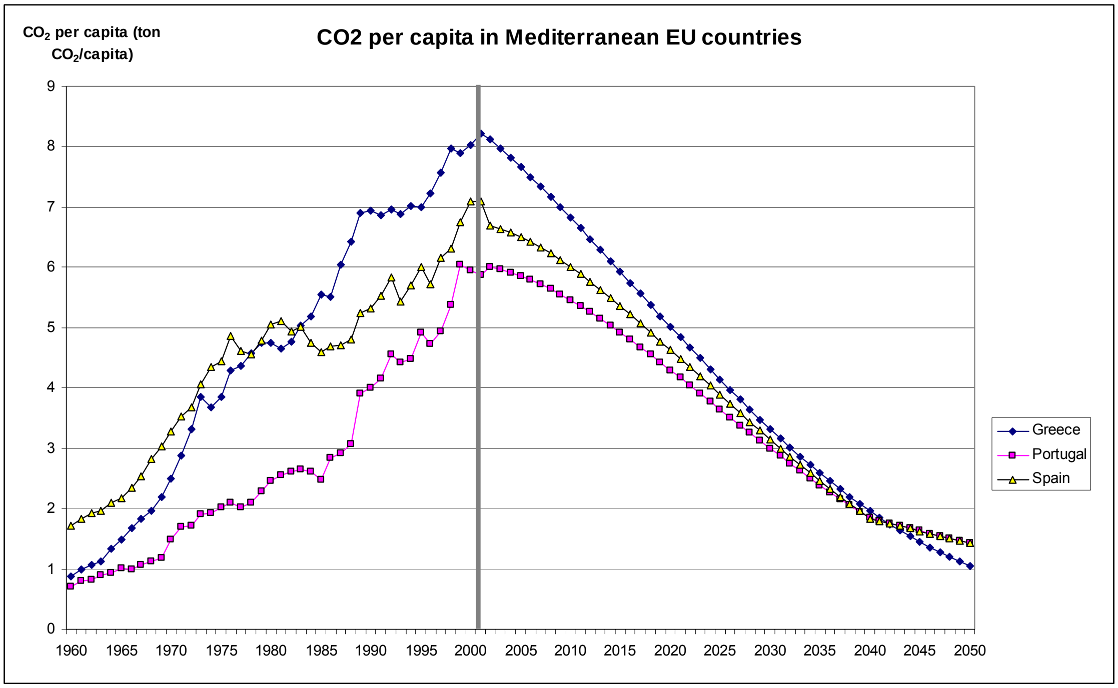


Figure 4.27b. *Changes in the CO_2 emissions per capita of the selected economies of the Mediterranean EU countries; Greece, Portugal and Spain from 1960-2001 (Source: IEA 2003a) and the required development from 2002-2050 in order to reach the C&C target.*

In the Mediterranean EU countries, Greece, Portugal and Spain, CO_2 intensity has grown considerably due to the process of industrialization. To achieve the C&C target the countries must undergo a major change in the direction of their future development.

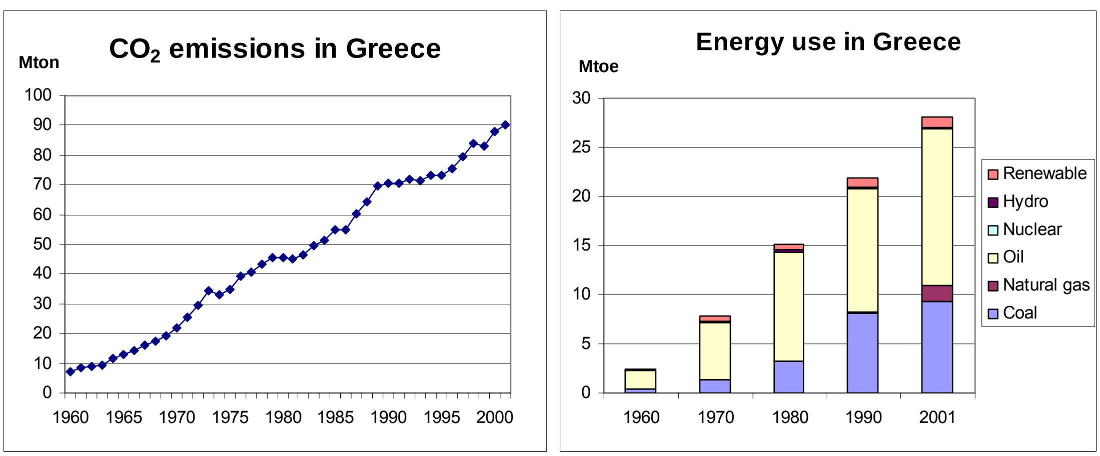


Figure 4.28. *CO_2 emissions and primary energy use in Greece from 1960-2001 (Source IEA 2003a, b)*

In Greece the growth of CO_2 emissions is due to a fast growth in fossil fuel consumption, mainly coal and oil, consumption. This is quite typical for an industrializing economy.

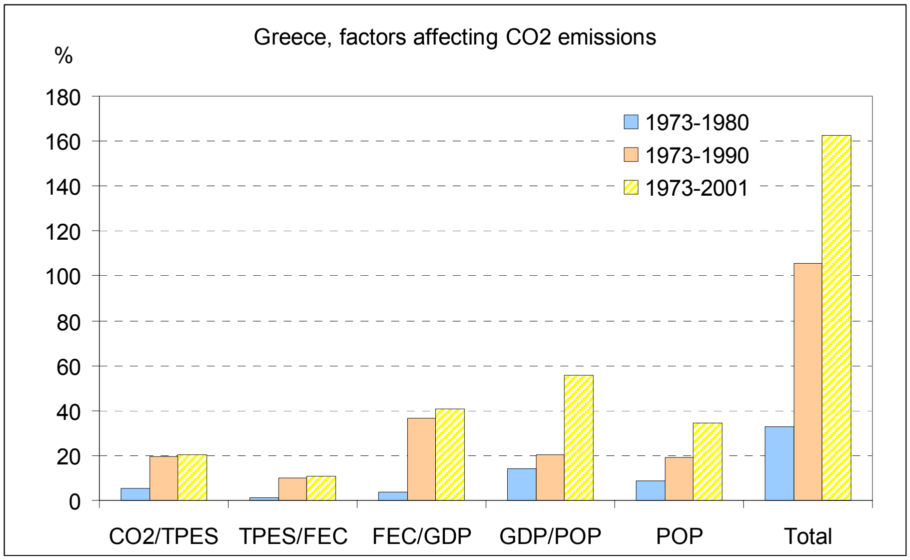


Figure 4.29. *A decomposition analysis for the factors affecting CO_2 emissions in Greece from 1973 to 2001.*

The decomposition analysis shows that all the five factors under study have contributed to an increase in emissions. The fuel shift (CO_2/TPES) has moved Greece towards more carbon intensive fuels and the efficiency of the energy transformation (TPES/FEC) has decreased. Even the energy intensity of the economy (FEC/GDP) has grown considerably contrary to the "old" industrialized economies. The growth of per capita production (GDP/POP) and population growth (POP) have both significantly contributed to the increase in emissions.

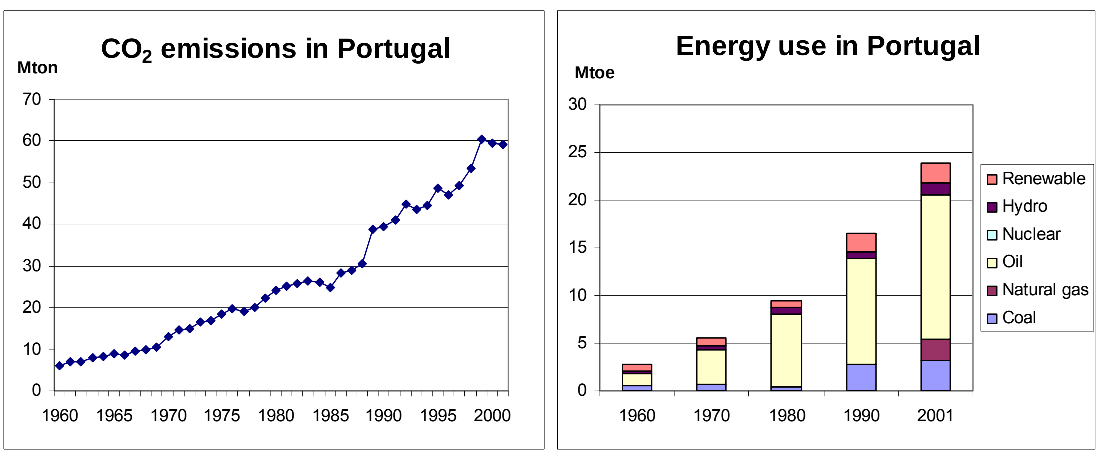


Figure 4.30. *CO_2 emissions and primary energy use in Portugal from 1960-2001 (Source IEA 2003a, b)*

In Portugal the development has been quite similar to that of Greece, an exception is that the share of coal in the primary energy mix is smaller.

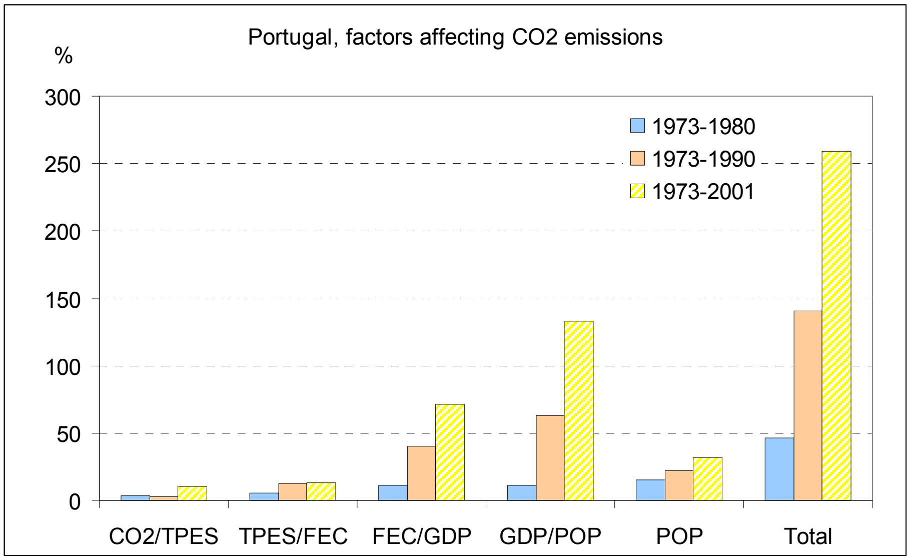


Figure 4.31. *A decomposition analysis for the factors affecting CO_2 emissions in Portugal from 1973 to 2001.*

The shift towards a more energy intensive production structure is even more evident in Portugal and also Portugal's per capita economic growth is higher than in Greece. The total growth of CO_2 emissions was over 250 % in Portugal between 1973 and 2001.

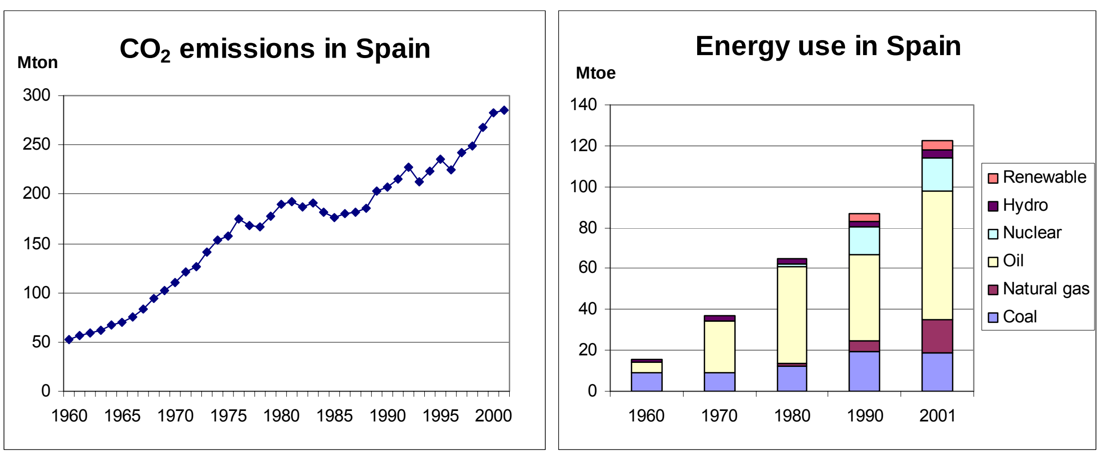


Figure 4.32. *CO_2 emissions and primary energy use in Spain from 1960-2001 (Source IEA 2003a, b)*

In Spain the general trend of emission increase has also been considerable. The introduction of nuclear energy and natural gas has lowered the emission growth rate to some extent.

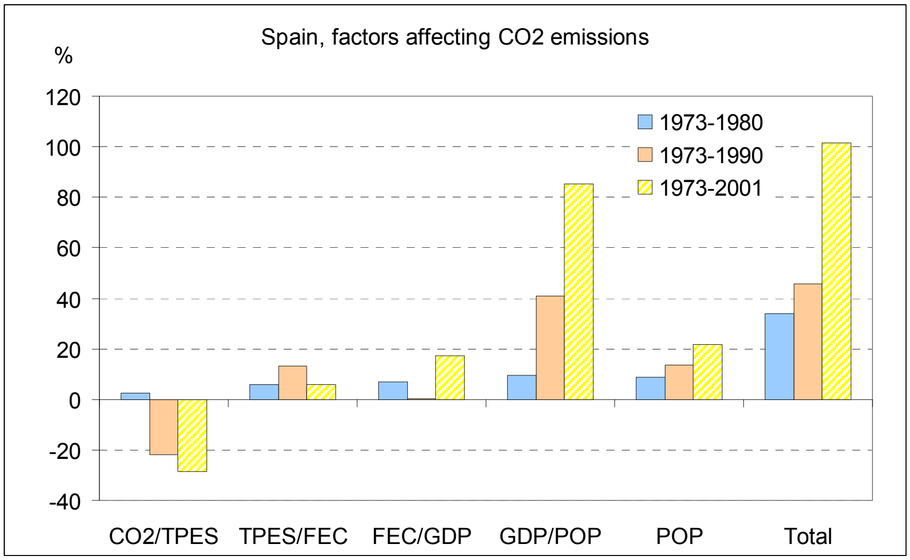


Figure 4.33. *A decomposition analysis for the factors affecting CO_2 emissions in Spain from 1973 to 2001.*

The fuel mix in Spain has shifted towards lower carbon content with the increased use of renewables and nuclear power. The production structure has shifted slightly in the direction of a more energy intensive production. The fast per capita economic growth has also been the main contributor to emission increases in Spain.

4.1.6. The Nordic countries

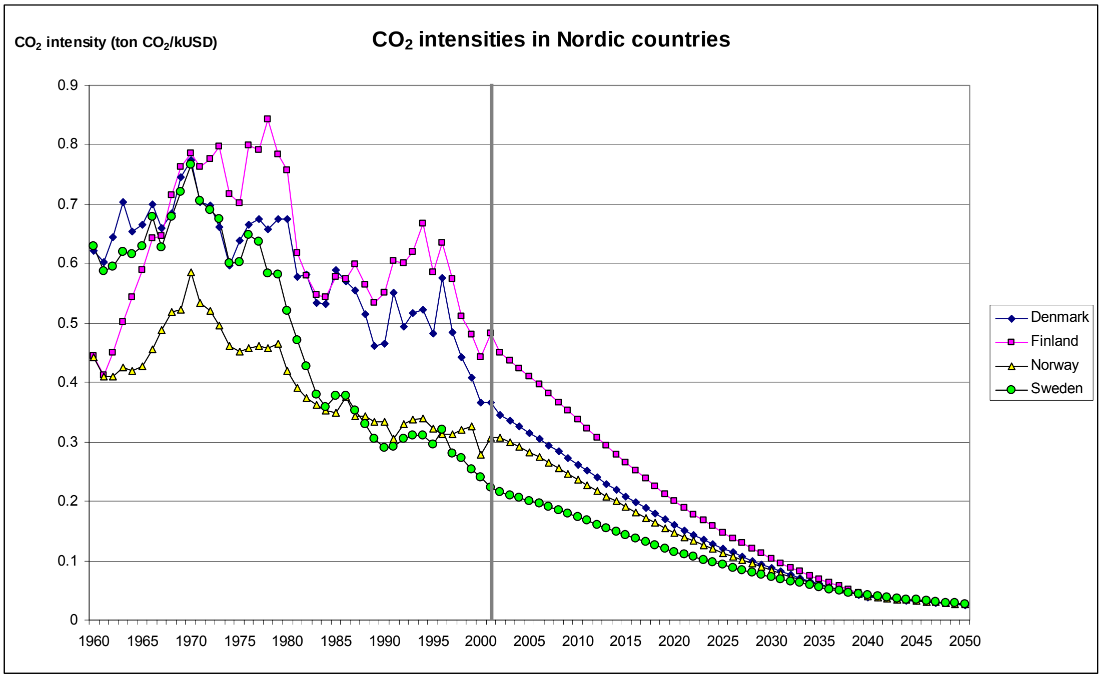


Figure 4.34a. *Changes in the CO_2 intensity of the economies of the Nordic countries from 1960-2001 (Source: IEA 2003a) and their required development from 2002-2050 in order to reach the C&C target.*

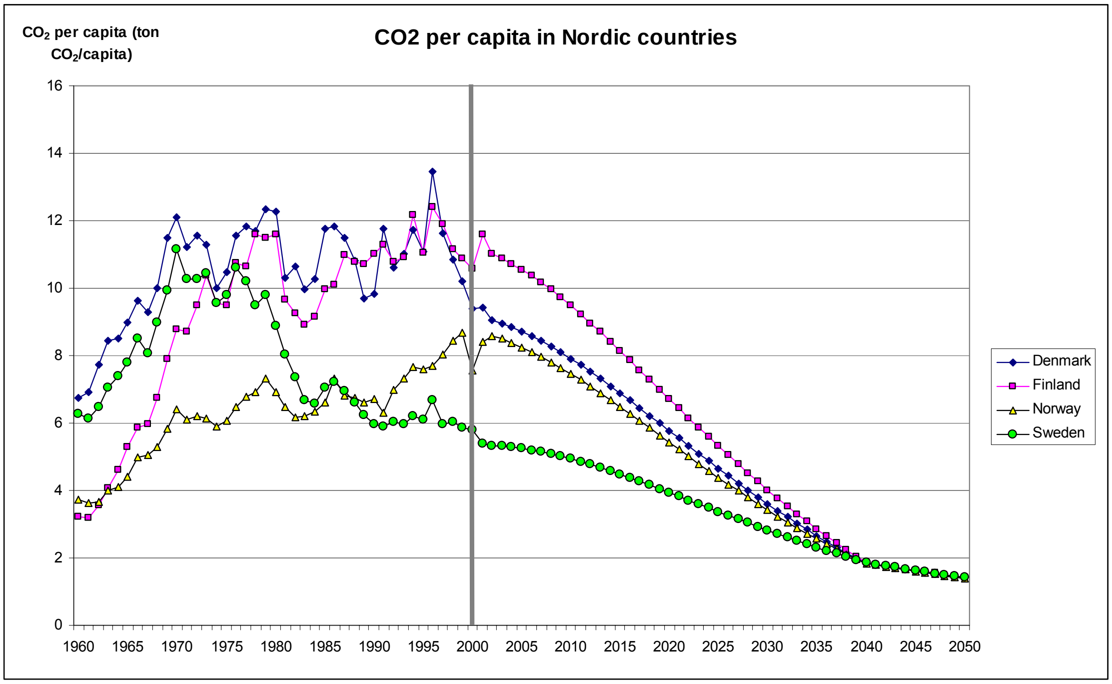
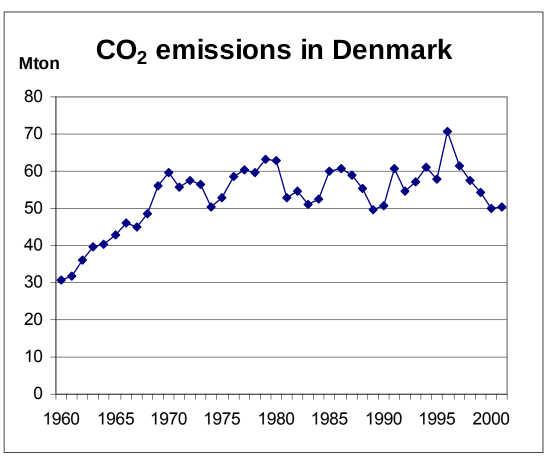


Figure 4.34b. *Changes in the CO_2 emissions per capita of the economies of the Nordic countries from 1960-2001 (Source: IEA 2003a) and their required development from 2002-2050 in order to reach the C&C target.*

The development in the Nordic countries of Denmark, Finland, Norway and Sweden has been quite different from the Mediterranean countries. The CO_2 intensity of the Nordic countries fell considerably in the 1970's and 1980's. However, development in the 90's stagnated, especially in Finland. Amongst the Nordic countries Finland would have to achieve the largest change in the direction of its CO_2 emission intensity trend in order to reach the C&C target.



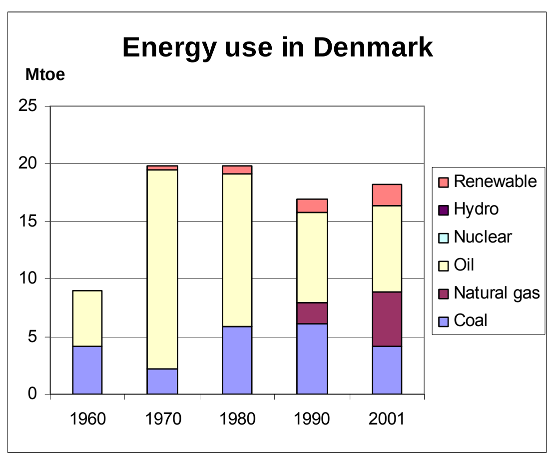


Figure 4.35. *CO_2 emissions and primary energy use in Denmark from 1960-2001 (Source IEA 2003a, b)*

In Denmark the growth of CO_2 emissions slowed after the first oil crisis. The fluctuations in the amount of emissions were mainly caused by changes in hydro power production, caused by changes in precipitation, in the common Nordic electricity market and the related need for domestic coal power production in the absence of cheap hydro based electricity from Norway and Sweden. The fluctuations in the emissions of Finland are mainly of the same cause.

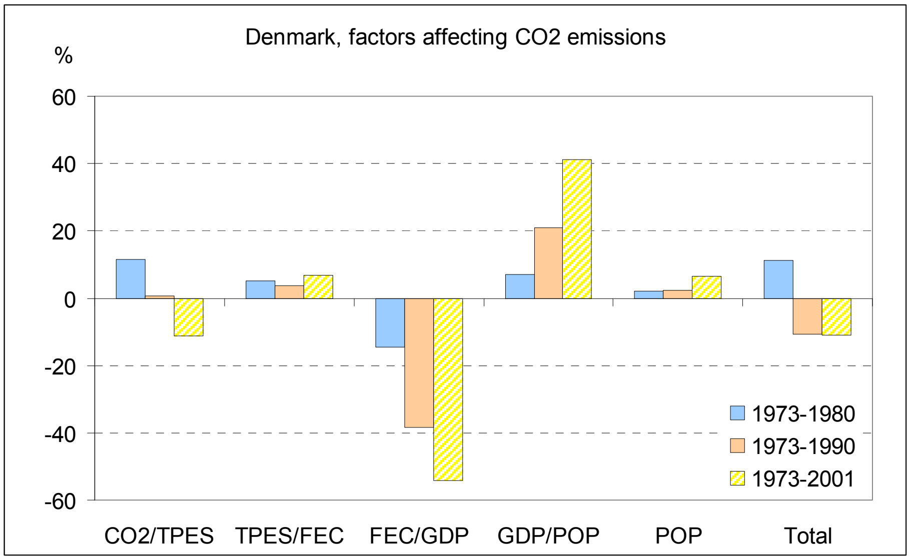


Figure 4.36. *A decomposition analysis for the factors affecting CO_2 emissions in Denmark from 1973 to 2001.*

The shift from oil and coal to natural gas and renewables, especially wind power, has been a significant trend in Denmark especially in the 1990's and is also indicated by the decomposition analysis. The considerable shift in the production structure towards a less energy intensive economy has been able to cut emissions more than the moderate increase in per capita economic growth.

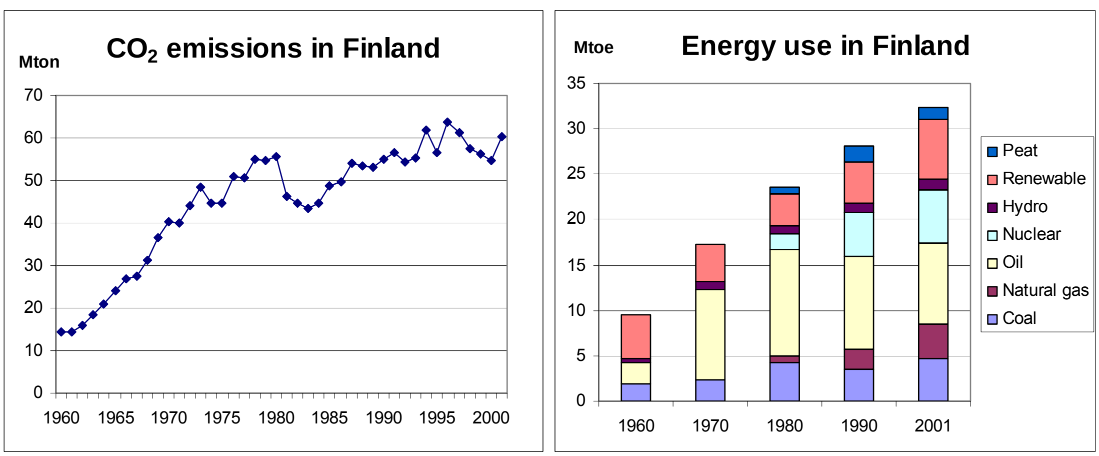


Figure 4.37. *CO_2 emissions and primary energy use in Finland from 1960-2001 (Source IEA 2003a, b)*

In Finland the use of many different primary energy sources is worth noticing. The shift towards fossil based production was the trend especially in the 1960's. The share of renewable energy sources in Finland, especially forest based biomass, is remarkably high, but the rapid increase in energy consumption has led to an increased use of fossil fuels and a related increase in CO_2 emissions. The increase of nuclear production in the 1980's reduced emissions temporarily.

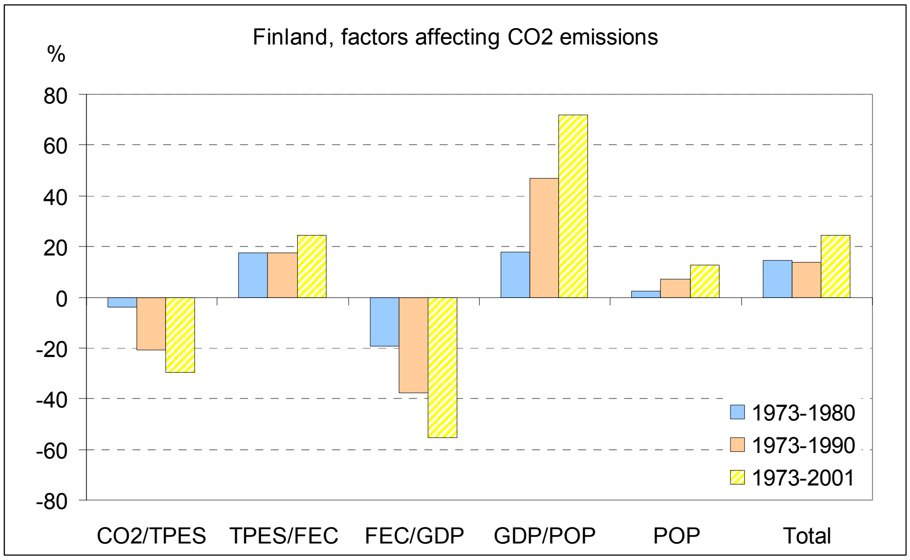
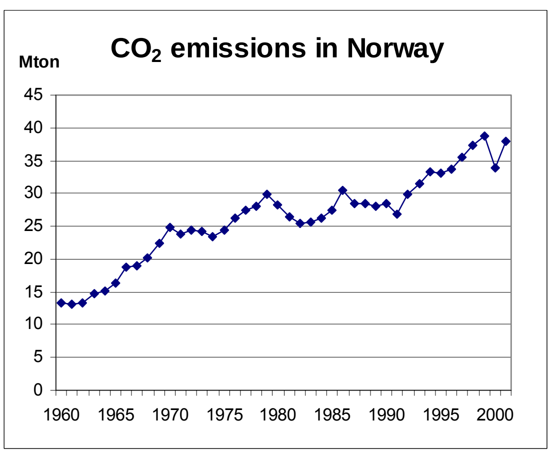


Figure 4.38. *A decomposition analysis of the factors affecting CO_2 emissions in Finland from 1973 to 2001.*

The decomposition analysis shows the fuel shift decreased emissions by 30 % from 1973 to 2001. The shift to a larger share of electricity in final energy consumption however, decreased the transformation's efficiency leading to an increase in emissions. The production structure in Finland has traditionally been quite energy intensive - relying mainly on pulp and paper and basic metal industries, but there seems to be a considerable shift towards the lighter industry and service structures. Finland's fast per capita economic growth has been the main component in increasing emissions.



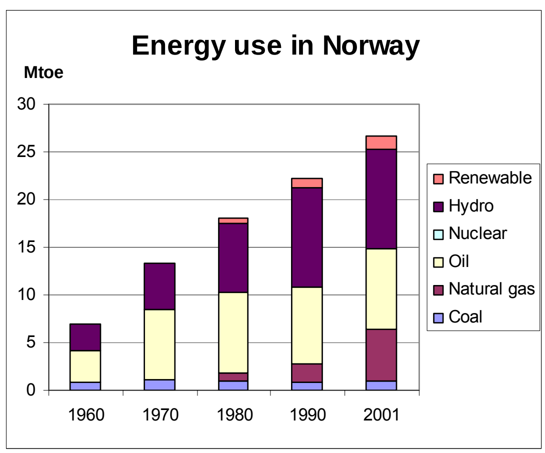


Figure 4.39. *CO_2 emissions and primary energy use in Norway from 1960-2001 (Source IEA 2003a, b)*

Electricity production in Norway is based on hydro production keeping per capita emissions low, but future prospects for increasing the hydro capacity do not exist. With an increasing domestic consumption of electricity Norway will shift either from electricity exporter to importer or will have to build gas based production. The rapid increase of emissions in the 1990's was mainly caused by the increased use of natural gas in gas and oil production and to some extent in industry.

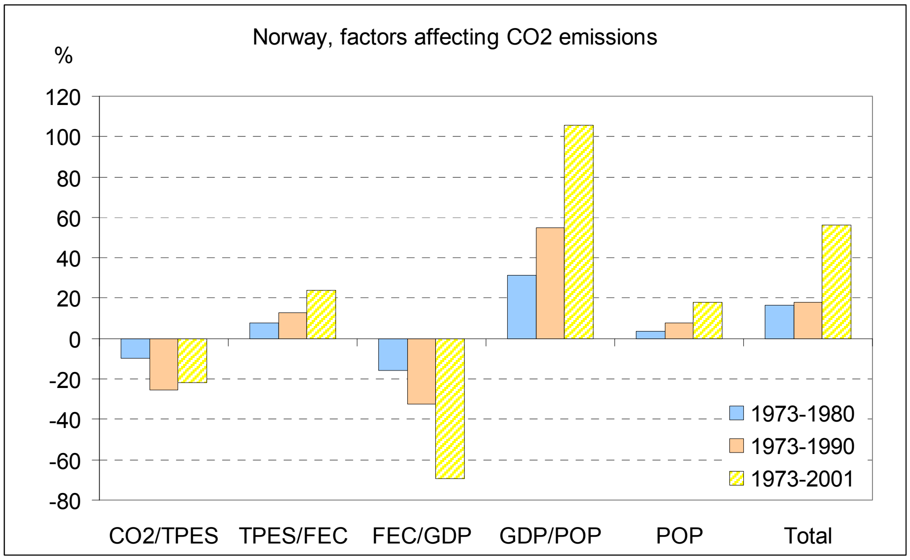


Figure 4.40. *A decomposition analysis for the factors affecting CO_2 emissions in Norway from 1973 to 2001.*

The decomposition analysis shows a small shift towards less carbon intensive primary energy (due to increased hydro-power) and lowered efficiency of the transformation. Structural change in the economy has been quite rapid but very fast economic growth especially in the 1990's has more than counterbalanced the positive changes.

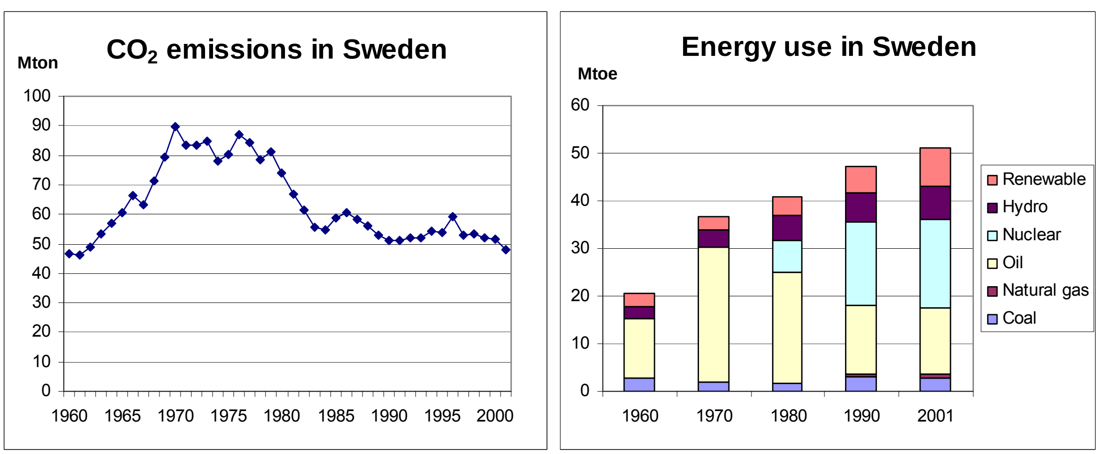


Figure 4.41. *CO_2 emissions and primary energy use in Sweden from 1960-2001 (Source IEA 2003a, b)*

In Sweden the large share of nuclear power (50 % of electricity) and hydro power (also 50 % of electricity) is characteristic of the energy system together with considerable use of renewables (mainly wood based). The rapid increase in nuclear production in the 1970's and 1980's and the related decrease in oil use decreased the total amount of CO_2 emissions significantly.

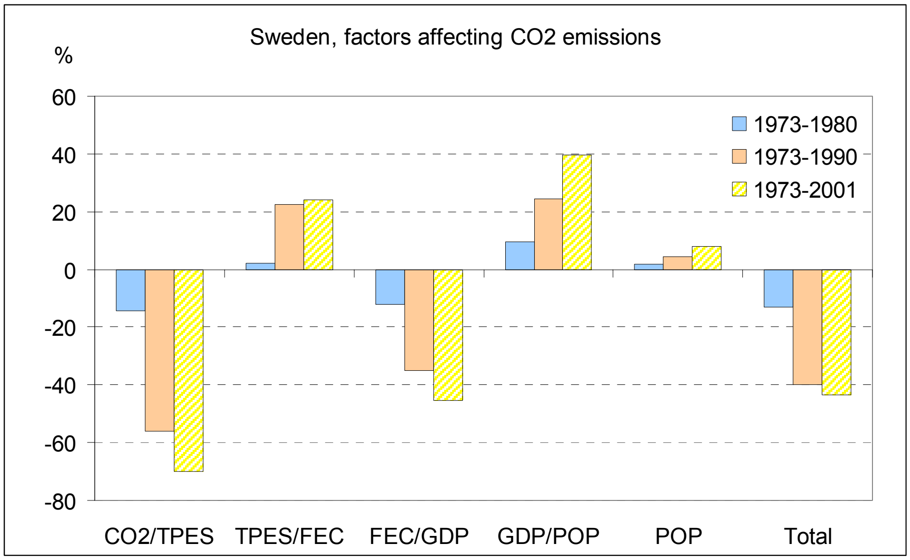


Figure 4.42. *A decomposition analysis for the factors affecting CO_2 emissions in Sweden from 1973 to 2001.*

The decomposition analysis clearly shows the large effect of fuel shifting. At the same time a decreased efficiency of transformation has increased emissions. The structural shift towards a less energy intensive economy has not been very significant, but moderate per capita economic growth has kept the emissions low though.

4.1.7. The transition countries

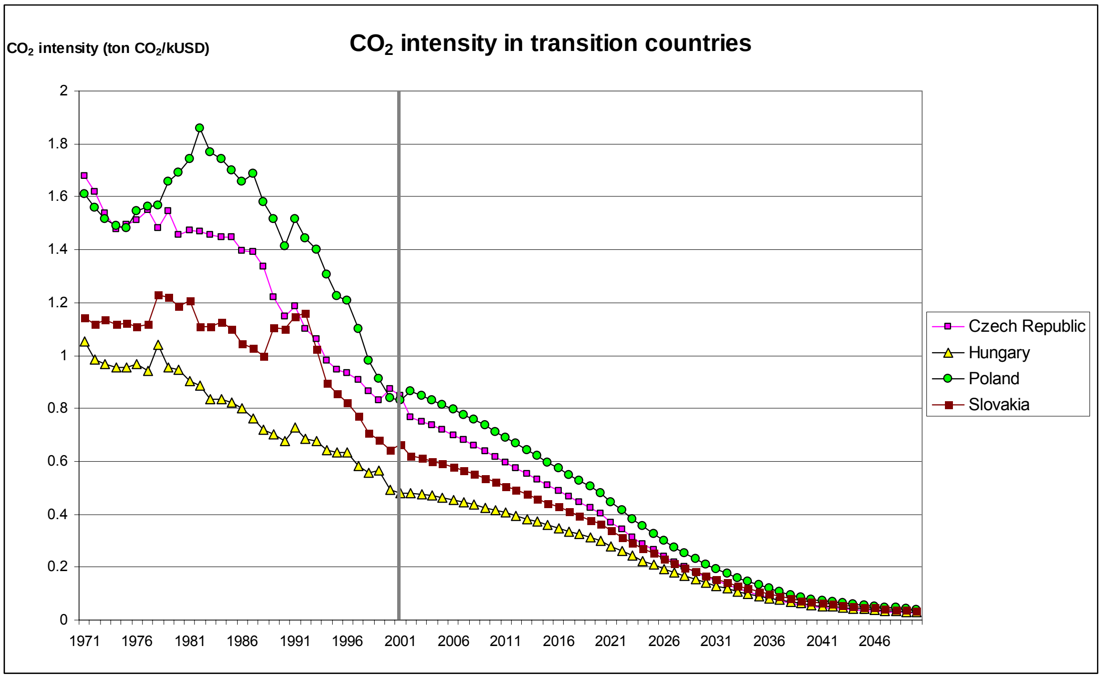


Figure 4.43a. *Changes in CO_2 intensity in selected transition economies from 1971-2001 (Source: IEA 2003a) and the required development from 2002-2050 in order to reach the C&C target.*

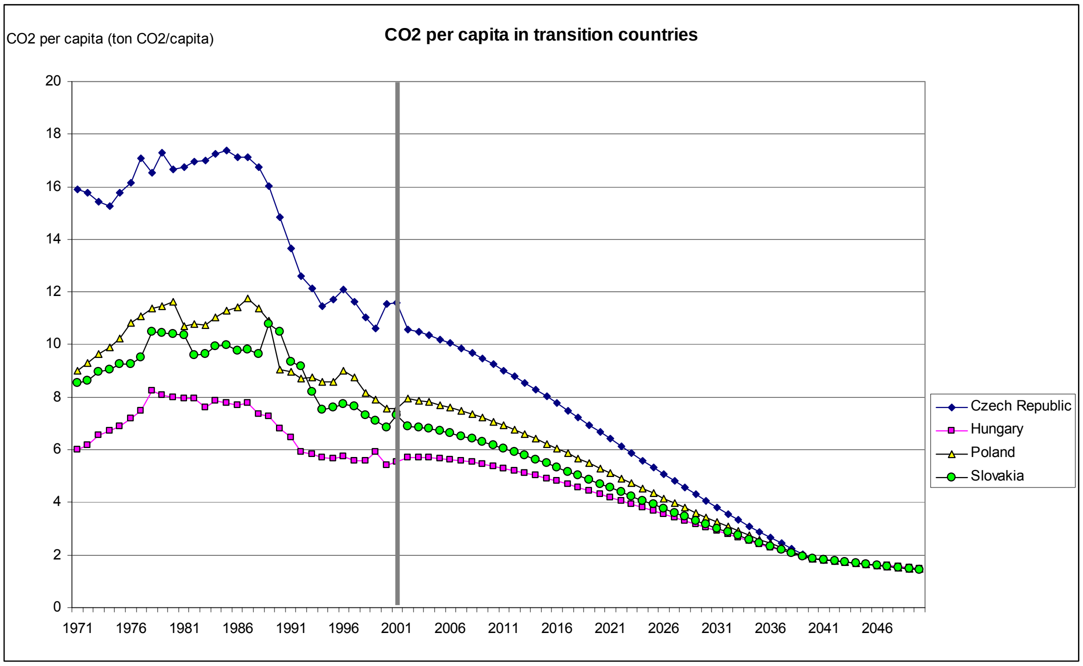


Figure 4.43b. *Changes in CO_2 emissions per capita in selected transition economies from 1971-2001 (Source: IEA 2003a) and the required development from 2002-2050 in order to reach the C&C target.*

The CO_2 intensities in the transition countries analysed have rapidly decreased in the 1990's due to the economic reformations taking place. The inefficient production systems of the Soviet era have been, to some extent, modernised and improved the efficiency of the systems.

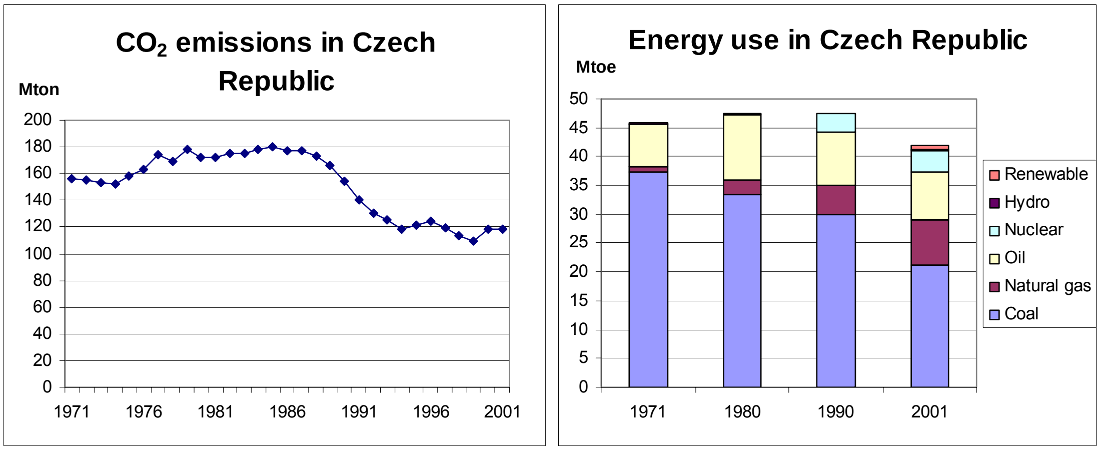


Figure 4.44. *CO_2 emissions and primary energy use in the Czech Republic from 1971-2001 (Source IEA 2003a, b)*

Energy production in the Czech Republic used to be completely coal and oil dominated in the 1970's and 1980's. Nowadays, improved production efficiency has made it possible to decrease energy use and the simultaneous increase of nuclear production and a shift from coal to gas has decreased CO_2 emissions considerably.

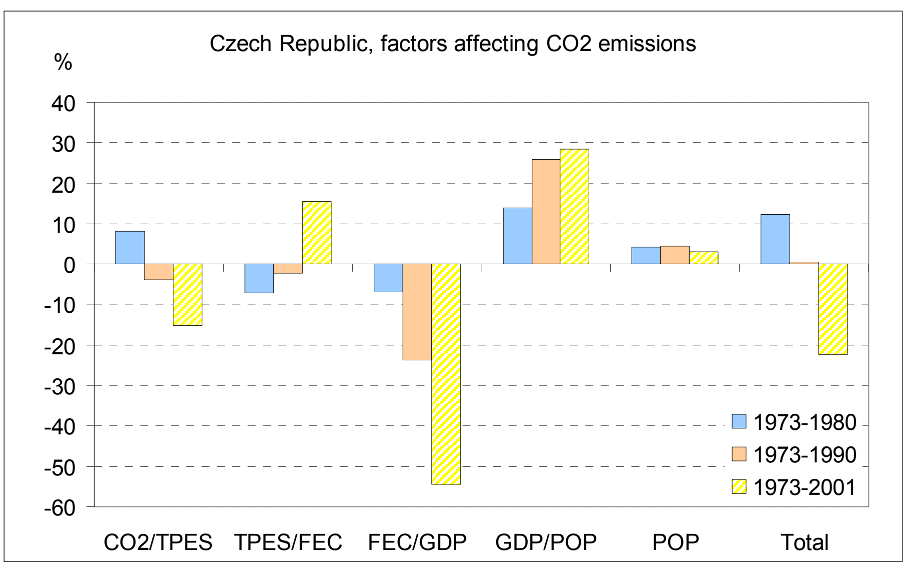


Figure 4.45. *A decomposition analysis for the factors affecting CO_2 emissions in Czech Republic from 1973 to 2001.*

The decomposition analysis indicates a fuel shift, which has, however, been counterbalanced by a decrease of efficiency in the transformation systems caused mainly by an increased share of electricity in final consumption. The significant structural shift to a less energy intensive production system in the 1990's has been the main reason for a decrease in emissions. Moderate per capita economic growth has helped keep emissions low.

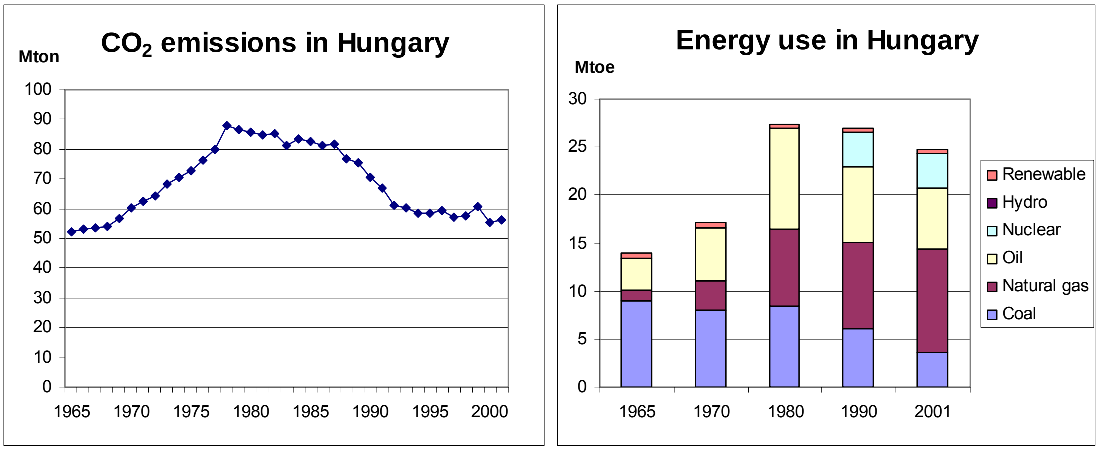


Figure 4.46. *The CO_2 emissions and primary energy use in Hungary in 1965-2001 (Source IEA 2003a, b)*

In Hungary a similar type of development has taken place to that of the Czech Republic. Increased production efficiency has made it possible to decrease energy consumption since 1980. At the same time the increased share of nuclear and natural gas and a decreased use of coal have been main drivers in lowering emissions.

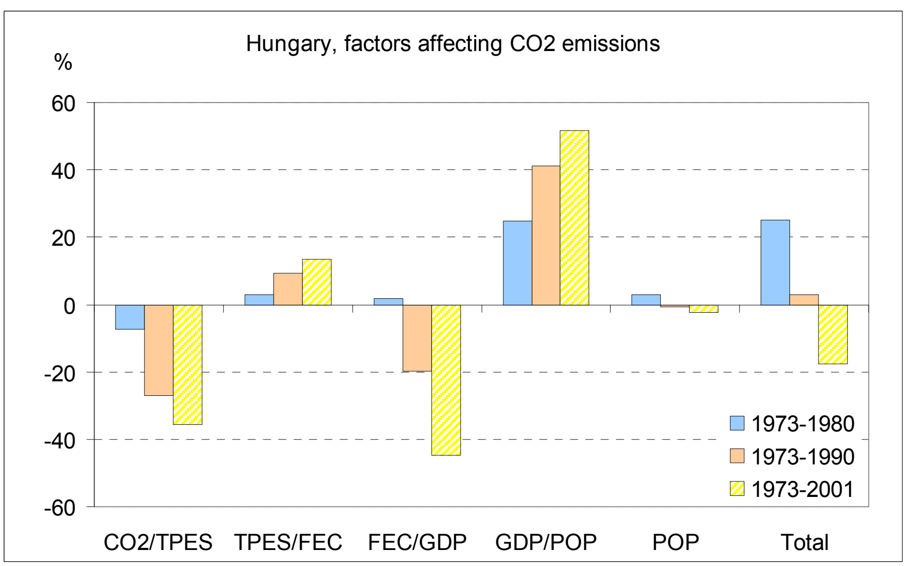


Figure 4.47. *A decomposition analysis for the factors affecting CO_2 emissions in Hungary from 1973 to 2001.*

The decomposition analysis shows the main reasons behind Hungary's decreasing emissions to be a fuel shift and a structural change in the economy.

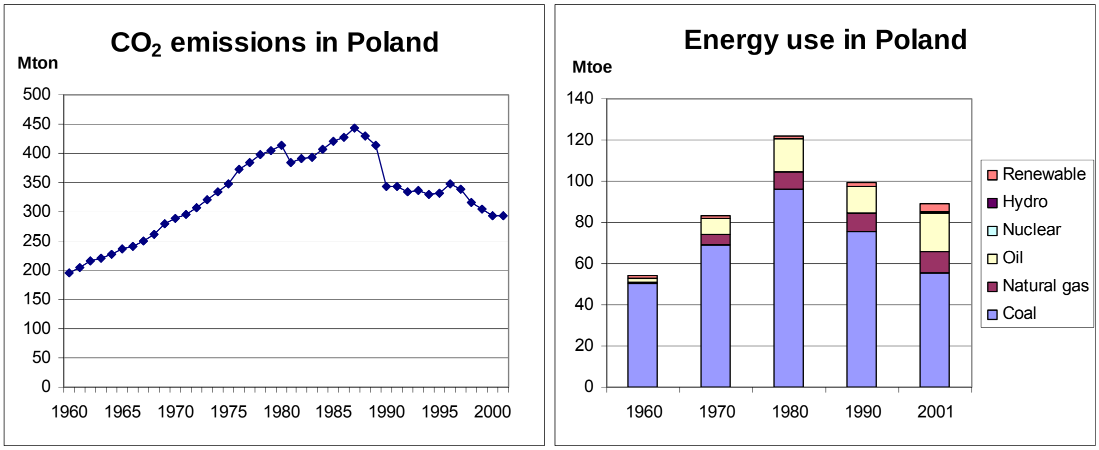


Figure 4.48. *CO_2 emissions and primary energy use in Poland from1960-2001 (Source IEA 2003a, b)*

Poland has been a coal production dominated country due to its large domestic resources. Its rapidly decreasing use of coal and an increasing share of gas and renewables have been the factors behind Poland's decreased emissions.

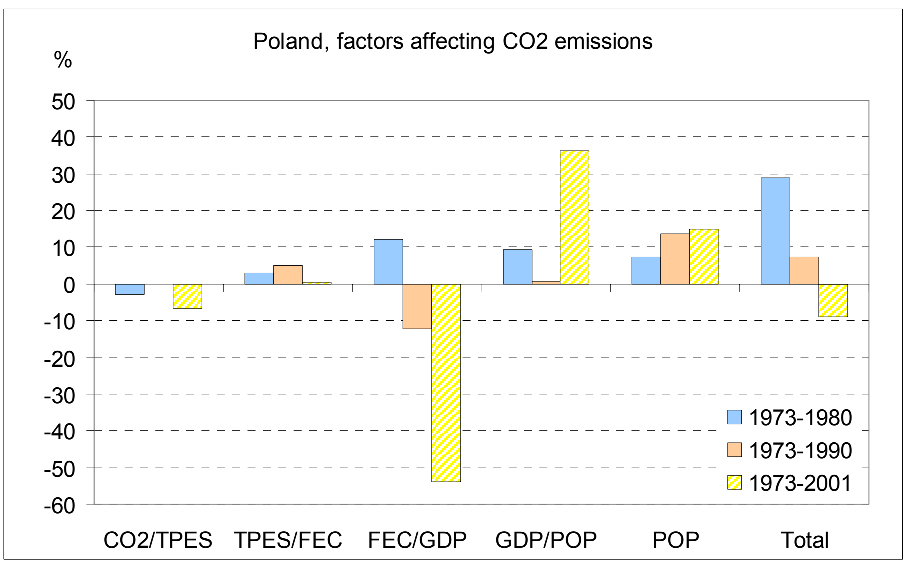
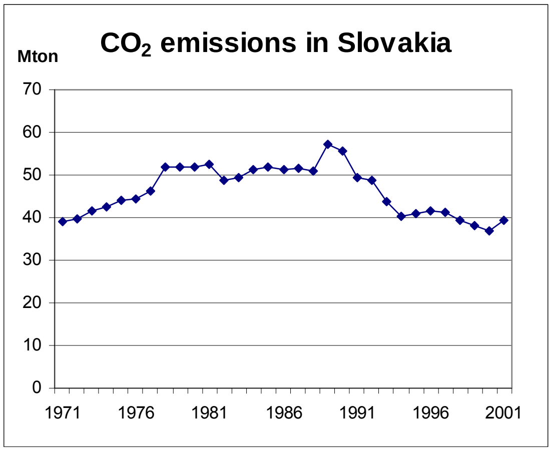


Figure 4.49. *A decomposition analysis for the factors affecting CO_2 emissions in Poland from 1973 to 2001.*

The decomposition analysis reveals the structural change in Poland's economy in the 1990's to be the main driver of change in its emissions.



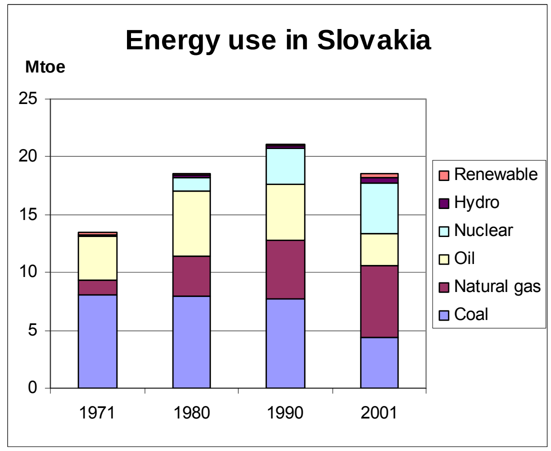


Figure 4.50. *CO_2 emissions and primary energy use in Slovakia from 1971-2001 (Source IEA 2003a, b)*

Slovakia's decreasing emissions in the 1990's seem to be the result of a lowering of energy demand and a fuel shift. The reduced shares of coal and oil and an increased use of gas and nuclear power for power generation were the main reasons for the decrease.

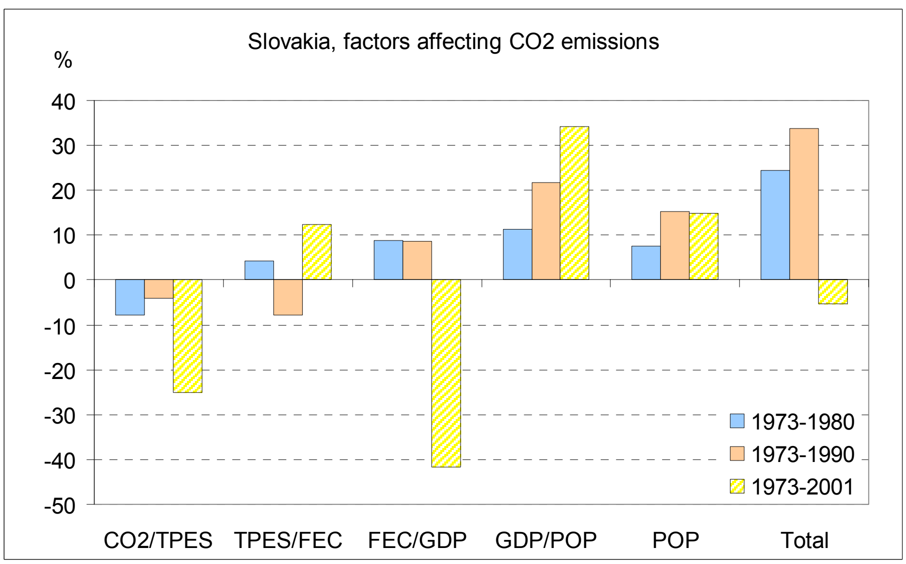


Figure 4.51. *A decomposition analysis for the factors affecting CO_2 emissions in Slovakia from 1973 to 2001.*

The decomposition analysis indicates the fuel shifting and changes in the economic structure to be the main forces driving decreases in the emissions of the Slovak Republic.

4.2. Economic Development (ED)

Decomposition analysis of "Economic development" has been done in relation to factors affecting absolute changes in gross domestic product (GDP). Several decomposition analyses were carried out in order to illustrate factors affecting the change in economic development. In Figure 4.52 the changes in GDP affected by employment and population are presented. The analysis was done for three different time periods, which are from 1990 to 1995, 1990 to 2000 and from 1990 to 2005. Presenting the results this way enables us to determine when the change has been most affected by a particular factor.

Figure 4.53 shows the changes in GDP affected by labour activity and employment from 1995 to 2000 and from 1995 to 2005. The shorter time span is due to data availability. In Figure 4.55 the effect of expenditure on R&D on GDP is presented for time periods from 1995 to 2000 and from 1995 to 2005. The effect of business investments in the change in GDP is shown in Figure 4.56. This decomposition was also carried out for time periods from 1995 to 2000 and from 1995 to 2005. In Figure 4.57 we have chained the effects of business investments and expenditure on R&D on GDP in to same decomposition analysis. The last decomposition for economic development is shown in Figure 4.59, where the effects of employment, ageing society, healthy life years and meat consumption on the change in GDP were calculated. All the decompositions have been done for EU-15.

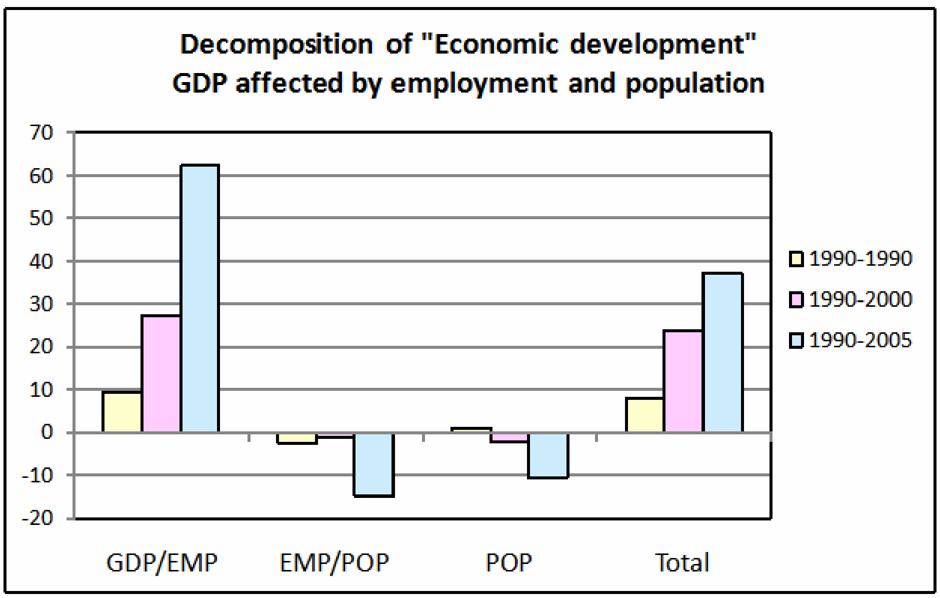


Figure. 4.52. *Decomposition of economic development: GDP affected by employment and population. Percentage changes from the base year 1990.*

In Fig. 4.52 the factors affecting the change in GDP are presented in the following equation:

$$GDP = \frac{GDP}{EMP} \times \frac{EMP}{POP} \times POP \qquad (10)$$

where

- GDP is gross domestic product
- EMP is the amount of employed people
- POP is population
- GDP/EMP is labour productivity (GDP productivity of employment)
- EMP/POP is employment rate of population.

The results in Figure 4.52 show that labour productivity (GDP/EMP) has increasing or positive effect on the growth of GDP. It is worth noticing that the effect of employment has been most significant between 2000 and 2005. Factor EMP/POP, share of employed people in the population, shows slight decreasing affect on GDP, which could be due to ageing society.

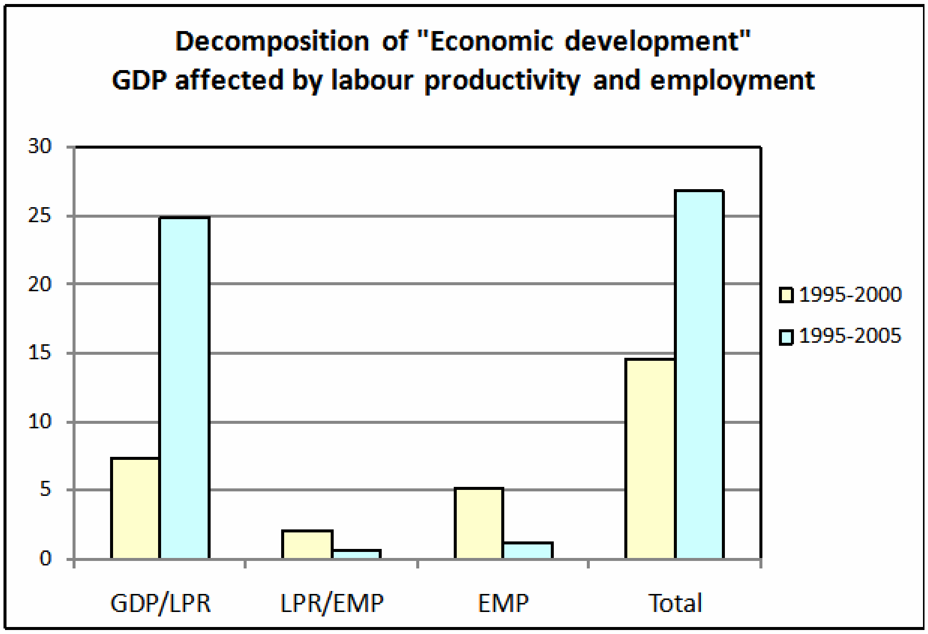


Figure 4.53. *Decomposition of economic development: GDP affected by labour productivity and employment*

The factors affecting the change in GDP are presented in the following equation:

$$GDP = \frac{GDP}{LPR} \times \frac{LPR}{EMP} \times EMP \qquad (11)$$

where

- GDP is gross domestic product
- LPR is labour productivity
- EMP is the amount of employed people
- GDP/LPR is GDP productivity of labour productivity
- LPR/EMP is labour productivity intensity of employment.

The results in Figure 4.53 indicate that both productivity of labour productivity on GDP (LPR/GDP) and the amount of people employed increase the GDP. Figure 4.54 shows the increasing trends of GDP, labour productivity and employment from 1995 to 2005. It is interesting to notice that labour productivity and employment have been growing at almost equal rates (see also LPR/EMP in Figure 4.53).

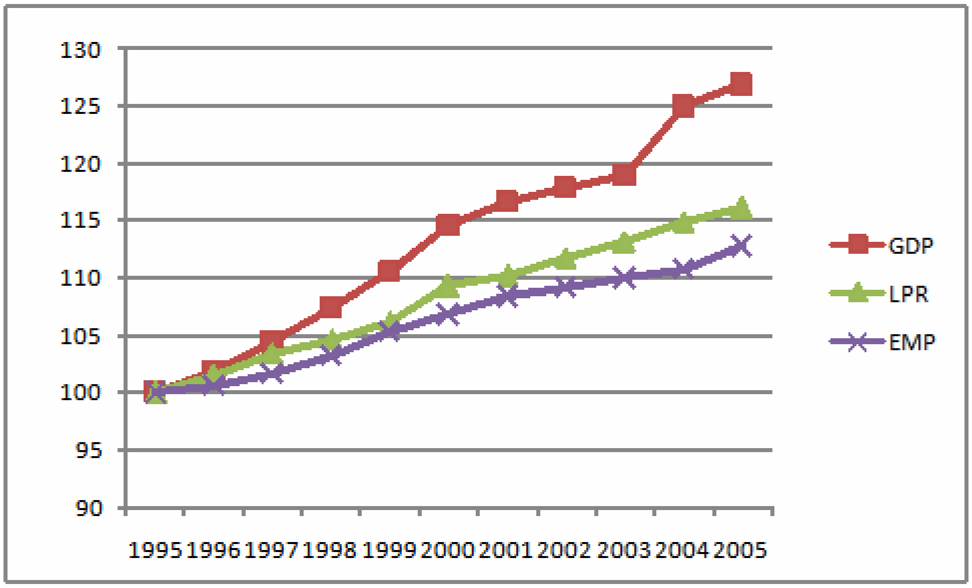


Figure 4.54. *Trends of GDP, labour productivity (LPR) and employment (EMP) between 1995 and 2005*

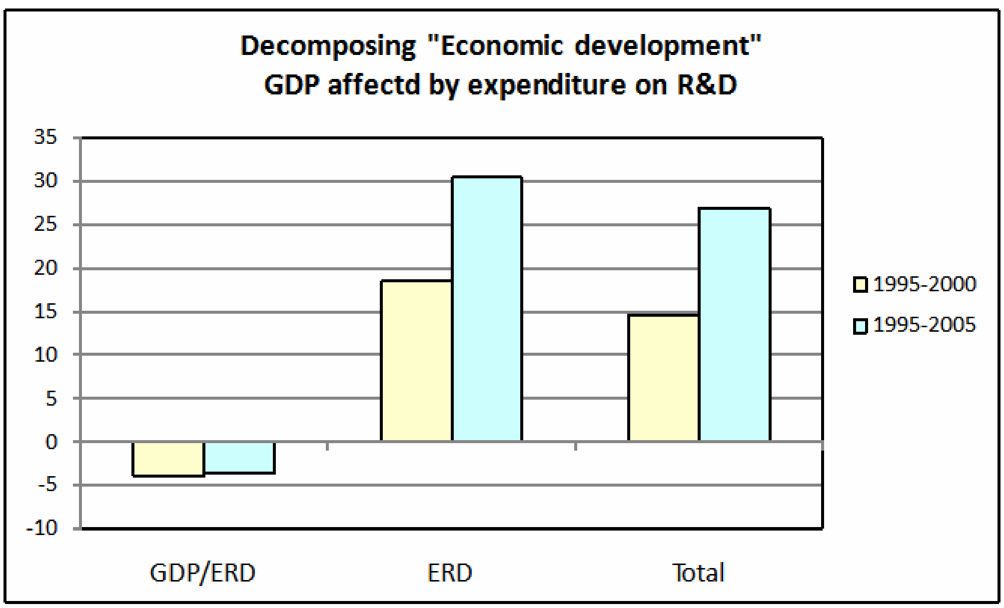


Figure 4.55. *Decomposition of economic development: GDP affected by expenditure on R&D*

GDP affected by expenditure on R&D is presented in the following equation:

$$GDP = \frac{GDP}{ERD} \times ERD \quad (12)$$

where

- GDP is gross domestic product
- ERD is expenditure on R&D

- GDP/ERD is the GDP productivity of expenditure on R & D

The results (Figure 4.55) show that GDP productivity of ERD has had a negative effect on GDP, but ERD has a positive affect on the change in GDP, i.e. when ERD increases also GDP increases. Here we should take into account the dynamics of the process. The increase of expenditure on R&D does not immediately have an impact on GDP, but we should use dynamic analyses and assess the time lag between the variables.

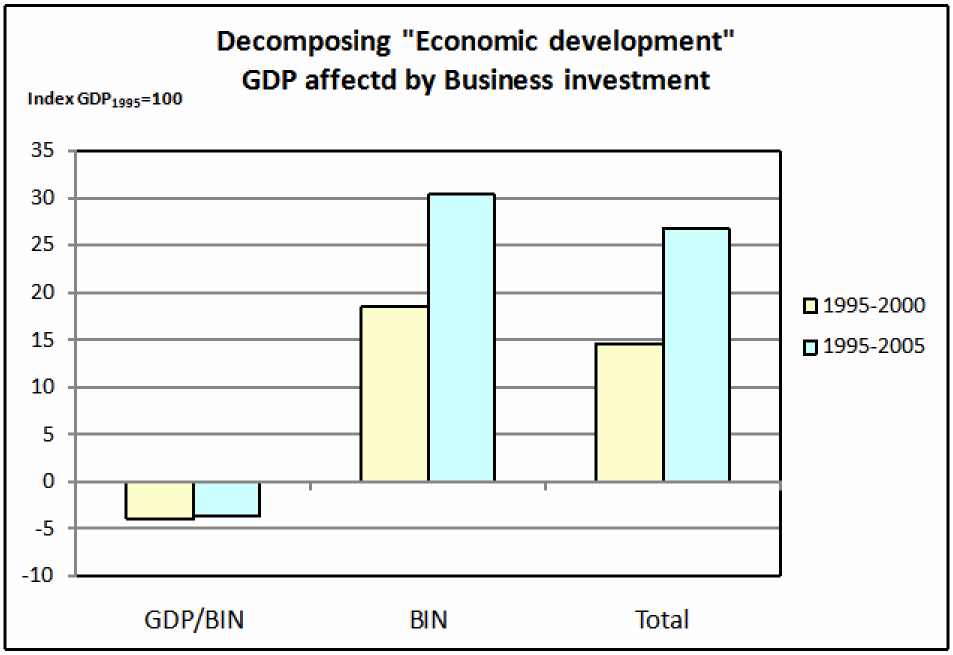


Figure 4.56. *Decomposition of economic development: GDP affected by Business investment*

GDP affected by business investments is presented in the following equation:

$$GDP = \frac{GDP}{BIN} \times BIN \tag{13}$$

where

- GDP is gross domestic product
- BIN is business investment
- GDP/BIN is GDP productivity of business investments.

Similarly to the effects of ERD, the GDP productivity of BIN has decreased GDP, while business investments alone have a positive effect on GDP (Figure 4.56). Here again a dynamic analyses would yield more relevant results.

We have combined the effects of business investment and expenditure on R&D on GDP in Figure 4.57.

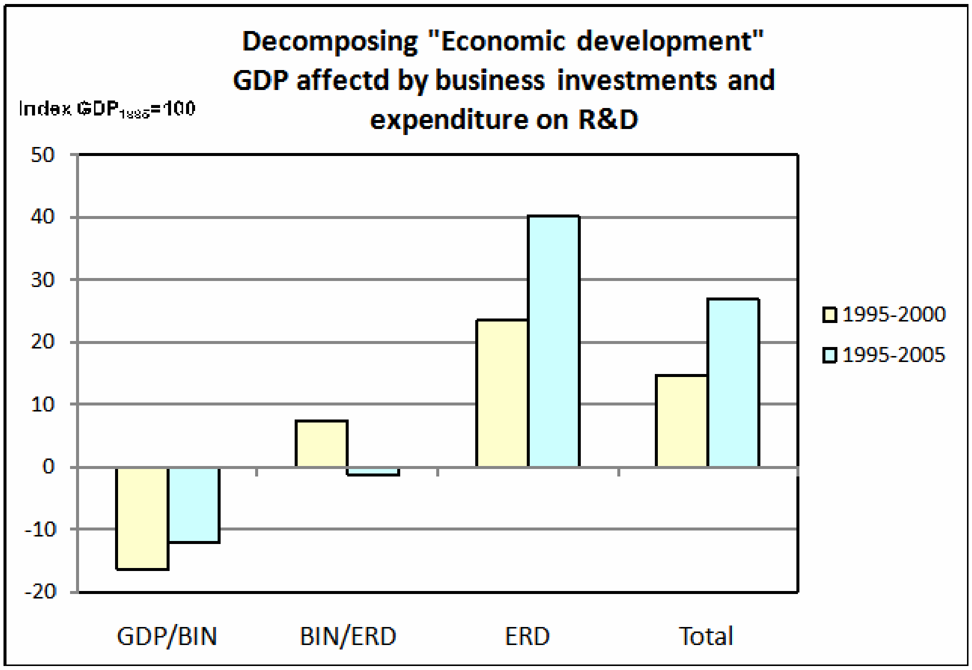


Figure 4.57. *Decomposition of economic development: GDP affected by business investments and expenditure on R&D*

The effects of business investments and expenditure on R&D on GDP are presented in the following equation:

$$GDP = \frac{GDP}{BIN} \times \frac{BIN}{ERD} \times ERD \qquad (14)$$

Where

- GDP is gross domestic product
- BIN is business investment
- ERD is expenditure on R&D
- GDP/BIN is GDP productivity of business investments
- BIN/ERD is business investment productivity of expenditure on R & D.

The first factor, GDP/BIN shows that GDP productivity of business investments has had a decreasing affect on GDP (Figure 4.57). The second factor shows that between years 1995 and 2000 the change in business investments productivity of expenditure on R&D has increased the GDP, but between years 1995 and 2005 the combined effect has been negative. The trends of GDP, BIN and ERD are shown in Figure 4.58.

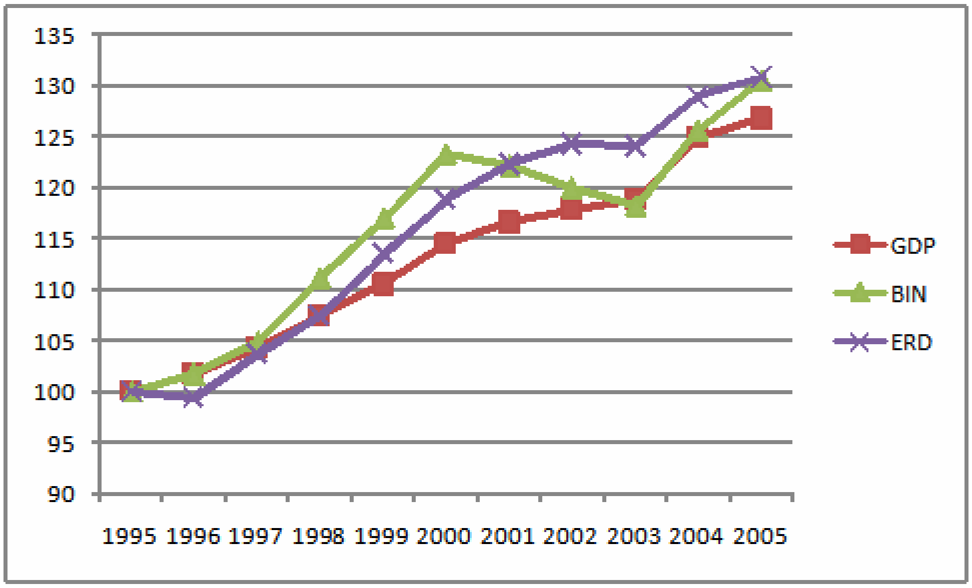


Figure 4.58. *Trends of GDP, business investments and expenditure on R&D between 1995 and 2005*

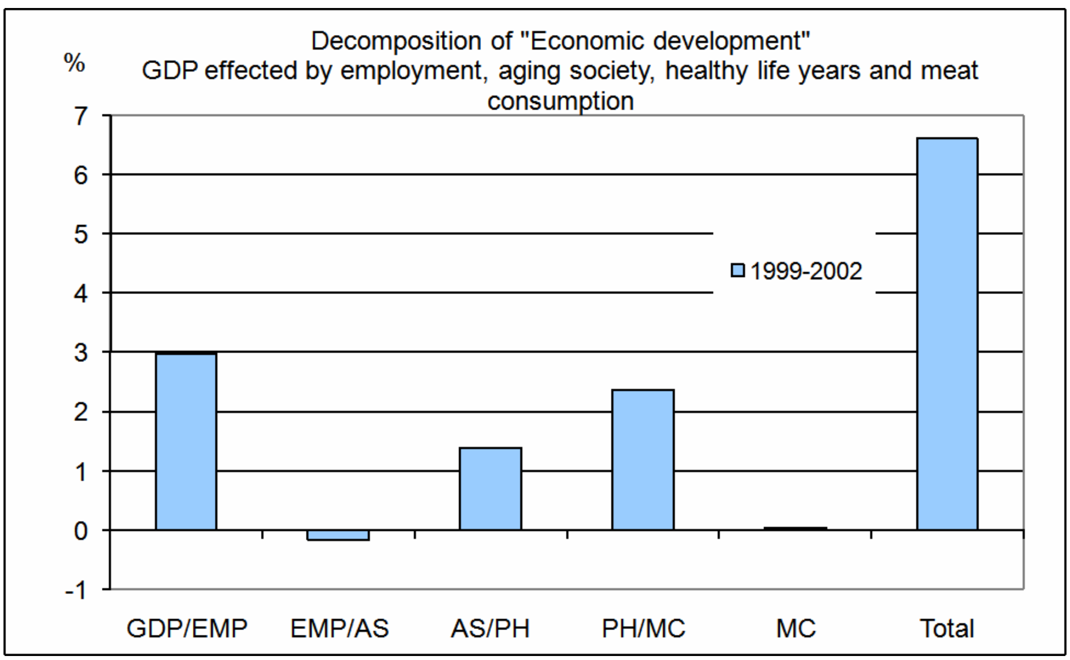


Figure 4.59. *Decomposition of economic development: GDP affected by employment, ageing society, healthy life years and meat consumption*

The factors affecting the change in GDP are presented in the following equation:

$$GDP = \frac{GDP}{EMP} \times \frac{EMP}{AS} \times \frac{AS}{PH} \times \frac{PH}{MC} \times MC \qquad (15)$$

where

- GDP is gross domestic product
- EMP is employment
- AS is ageing society, i.e. old-age-dependency ratio
- PH is public health, i.e. healthy life years at birth
- MC is meat consumption
- GDP/EMP is labour productivity (GDP productivity of employment)
- EMP/AS is employment intensity of ageing society
- AS/PH is ageing society productivity of public health
- PH/MC is public health productivity of meat consumption

The results (Figure 4.59) show that employment intensity of ageing society is the only factor, which has had a negative affect on the change in GDP. Out of the factors increasing GDP, GDP productivity of employment has increased the GDP the most. The meat consumption productivity of public health seems also quite an important factor. This result may come from the fact that both meat consumption and public health have improved although there may not be causal relationship between these factors.

4.3. Poverty and Social Exclusion (PS)

For the decomposition of "Poverty and social exclusion" we have executed three separate analyses. In the first decomposition analysis we have identified factors affecting the change in unemployment (see Figure 4.60). The decomposition of unemployment has been done from 1995 to 2002 and 1995 to 2005. In the second decomposition analysis factors affecting Inequality in income distribution were identified (see Figure 4.61). Due to constraints introduced by data availability, we have used single time series for the decomposition of inequality in income distribution from 1999 to 2003. In the third decomposition analysis, we have identified factors affecting the change in the headline indicator of the poverty and social exclusion theme (see Figure 4.63). All the decomposition analyses were done for EU-15 countries.

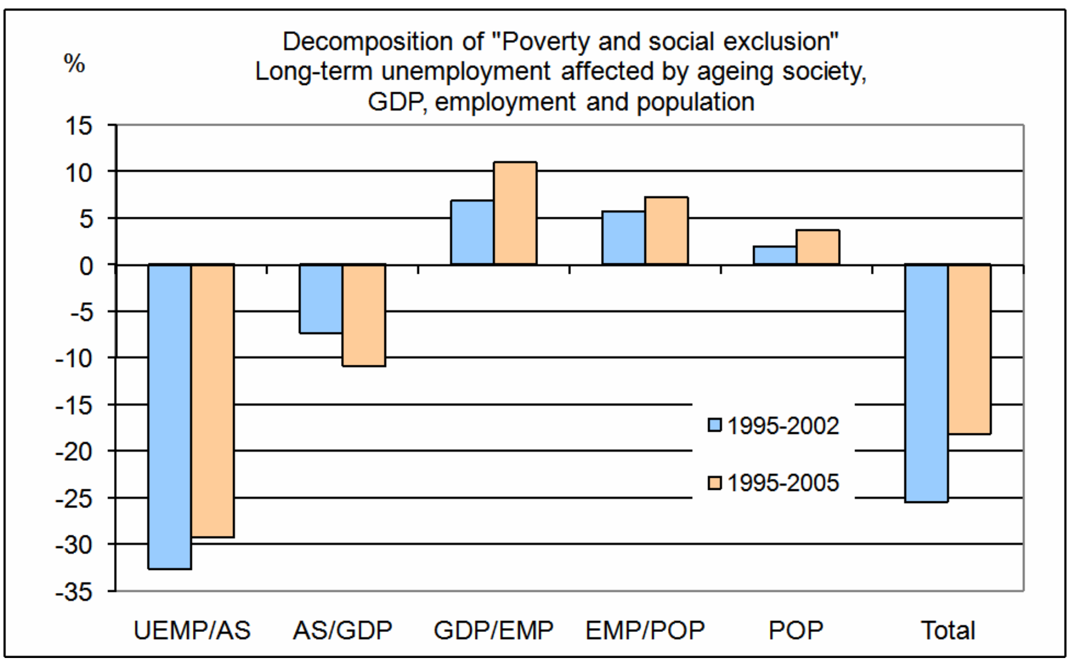


***Figure 4.60**. Decomposition of poverty and social exclusion: long-term unemployment affected by ageing society, GDP, employment and population*

The factors affecting unemployment are presented in the following equation:

$$UEMP = \frac{UEMP}{AS} \times \frac{AS}{GDP} \times \frac{GDP}{EMP} \times \frac{EMP}{POP} \times POP \qquad (16)$$

where

- UEMP is unemployment, i.e. the amount of unemployed people
- AS is ageing society, i.e. old-age-dependency ratio
- GDP is gross domestic product (in ppp)
- EMP is employment, i.e. the amount of employed people
- POP is population
- UEMP/AS is unemployment productivity of ageing society
- AS/GDP is ageing society productivity of GDP
- GDP/EMP is labour productivity (employment intensity of GDP)
- EMP/POP is employment rate in population

The results (Figure 4.60) show that ageing society's unemployment productivity and GDP's ageing society productivity have decreased long-term unemployment, whereas employment's GDP productivity, employment intensity and population growth have had an increasing effect on long-term unemployment. The total change in unemployment has been negative, i.e. it has decreased during the analysed time periods.

The results of the second decomposition can be seen in Figure 4.61, where factors affecting change in inequality in income distribution between 1999-2003 in EU-15 countries have been identified.

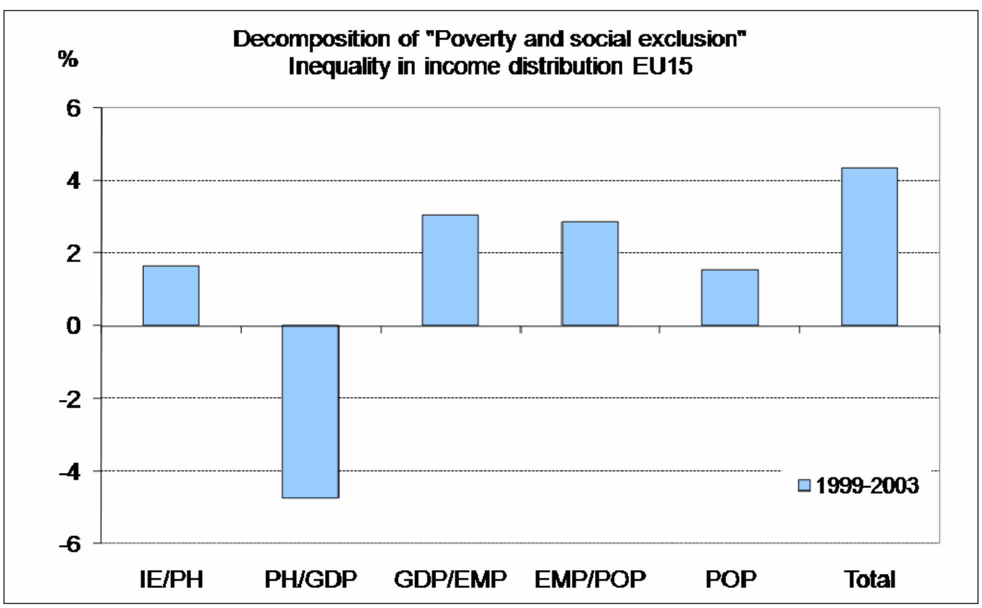


Figure 4.61. *Decomposition of poverty and social exclusion: inequality in income distribution in EU-15 countries*

The factors affecting inequality in income distribution are presented in the following equation:

$$IE = \frac{IE}{PH} \times \frac{PH}{GDP} \times \frac{GDP}{EMP} \times \frac{EMP}{POP} \times POP \qquad (17)$$

where

- IE is inequality in income distribution, i.e. income quintile share ratio
- PH is public health, healty life years at birth
- GDP is gross domestic product (in ppp)
- EMP is employment, i.e. the amount of people employed
- POP is population
- IE/PH is inequality productivity of public health
- PH/GDP is public health productivity of GDP
- GDP/EMP is labour productivity (employment intensity) of GDP
- EMP/POP is employment rate of populatiuon

The results show that inequality in income distribution has increased between 1999 and 2003. This can also be seen from Figure 4.62 below. According to our analysis the inequality in income distribution has been decreased between 1999 and 2003 by GDP's public health productivity, but the other factors have contributed towards increasing inequality.

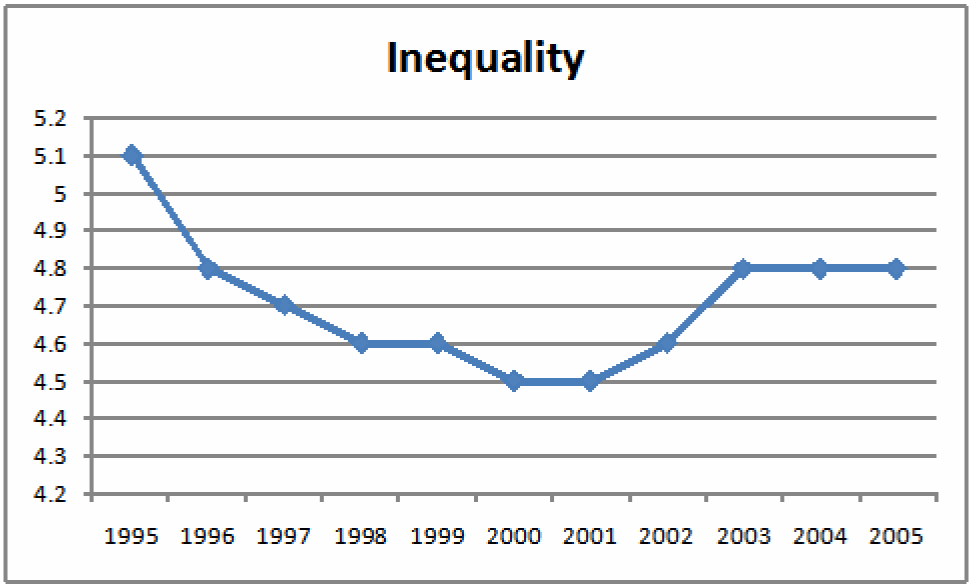


Figure 4.62. *Trend of inequality in income distribution in EU-15 countries between 1995 and 2005*

The last decomposition of poverty and social exclusion can be seen in Figure 4.63. Figure 4.63 shows how at-risk-of-poverty had been affected by ageing society, gross domestic product, population and unemployment between 1995-2000 and 1995-2005 in EU-15 countries.

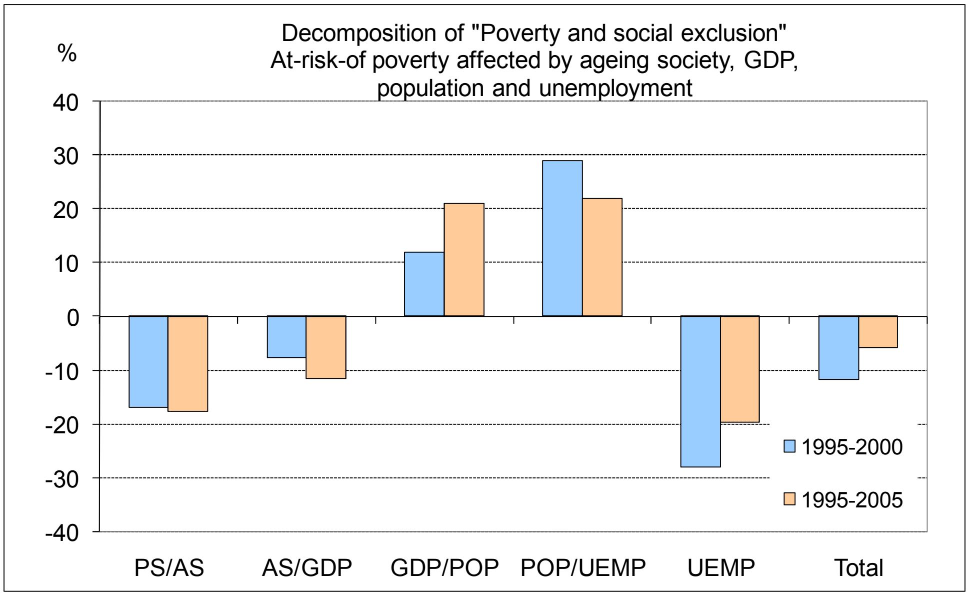


Figure 4.63. *Decomposition of poverty and social exclusion in EU-15 countries: at-risk-of poverty affected by ageing society, GDP, population and unemployment.*

The factors affecting the risk of poverty in Figure 4.63 are presented in the following two equations:

$$PS = \frac{PS}{AS} \times \frac{AS}{GDP} \times \frac{GDP}{POP} \times \frac{POP}{UEMP} \times UEMP \tag{18}$$

where

- PS is poverty and social exclusion, i.e. at-risk-of poverty rate after social transfers
- AS is ageing society, i.e. old-age-dependency ratio
- GDP is gross domestic product
- POP is population
- UEMP is unemployment (amount of unemployed people)
- PS/AS is at-risk-of poverty productivity of ageing society
- AS/GDP is ageing society productivity of GDP
- GDP/POP is Gross domestic production per capita
- POP/UEMP is population intensity of unemployment

The results show that the first two factors, PS/AS and AS/GDP, have had a decreasing effect on the risk of poverty. The decreasing effect of PS/AS is presented in Figure 4.64a. The figure illustrates that the change in the poverty risk is negative when we move from the starting point A (1995) to the end point D (2005) (from level PS1 to PS3). The straight line going from 0 the point A describes the poverty risk productivity of Ageing society in 1995. The poverty risk productivity of the Ageing society has decreased as is indicated by new productivity line from 0 to D and the arrow down from A to a new level B (from PS1 to PS2). While the poverty risk productivity has decreased the change towards more aged society, move from B to C (AS1 to AS2), has resulted in increasing the poverty risk from C to D (from PS2 to PS3). This means that, on the one hand, increasing Ageing society increases the risk of poverty, but on the hand, the decreasing poverty risk productivity has more than compensated the change resulting in lower poverty risk. If, however, the trend of Ageing society exceeds the level AS3 (point E) the poverty risk will increase. This implies that increasing the amount of ageing society might eventually increase the risk-of-poverty. The projected old-age-dependency ratio from 1995 to 2050 (see Figure 4.65,) shows that the old-age-dependency ratio will double from present to 2050.

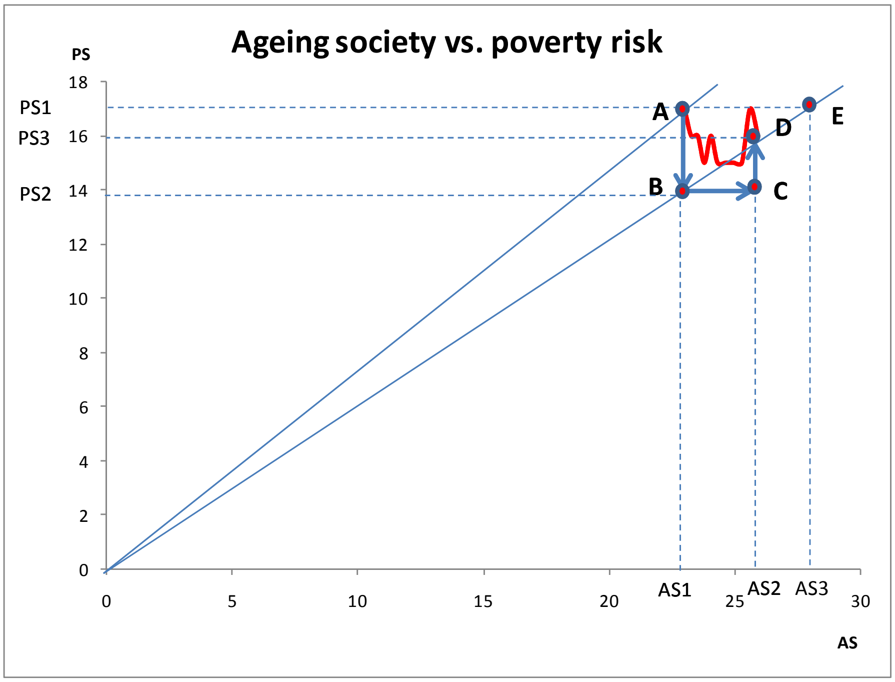


***Figure 4.64a**. Effect of PS/AS from 1995 to 2005.*

Figure 4.64b indicates the need for the change in the poverty productivity of ageing society, if the old-age dependency ratio grows to the level indicated in the Fig. 4.65 for the year 2040. The poverty productivity of ageing society in 1995 is indicated by the line going trough the point A in the figure. To keep the poverty risk at the same level or lover that PS1 the new productivity line for the year 2040 should go through point E (shift from AS1 to AS3 level in the old-age dependency ratio). The required decrease in the productivity to keep the poverty risk at the level PS1 is from 0.77 to 0.34.

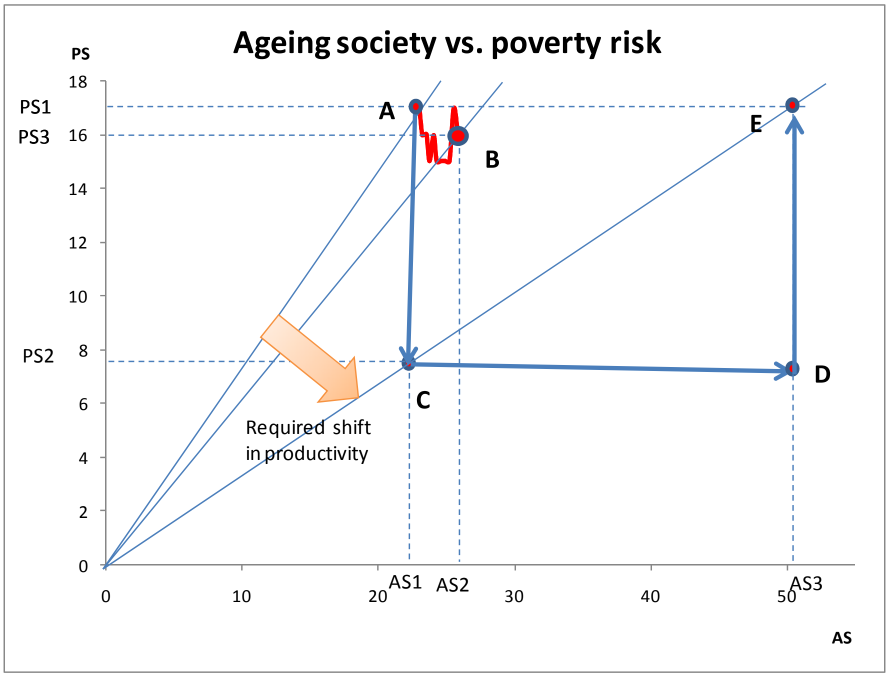


Figure 4.64b. *Effect of PS/AS from 1995 to 2005.*

The second factor in the decomposition (AS/GDP ageing productivity of GDP) shows that GDP has increased faster than the old-age dependency ratio, which has reduced the risk of poverty (see Fig. 4.64c).

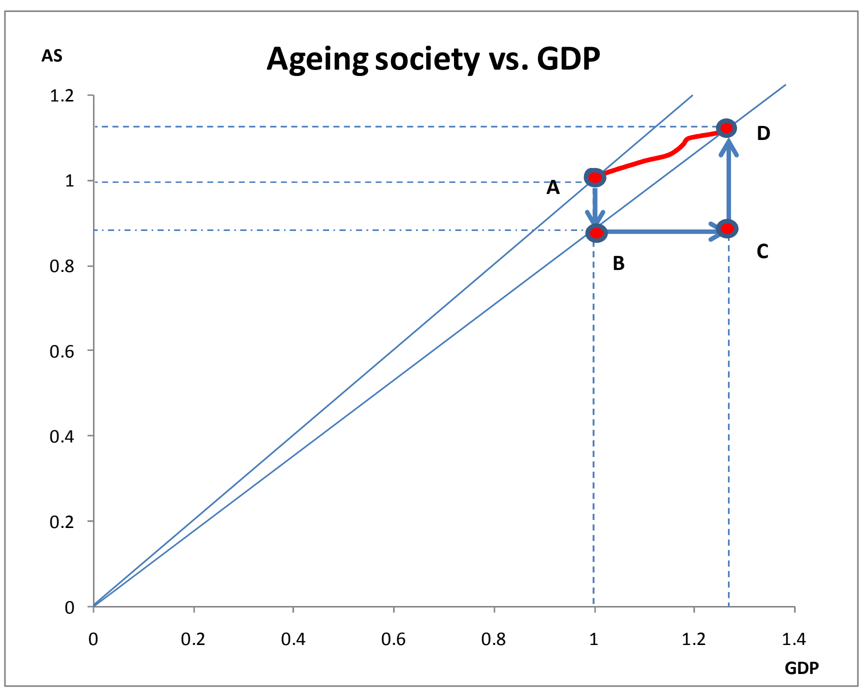


Figure 4.64c. *Effect of AS/GDP from 1995 to 2005.*

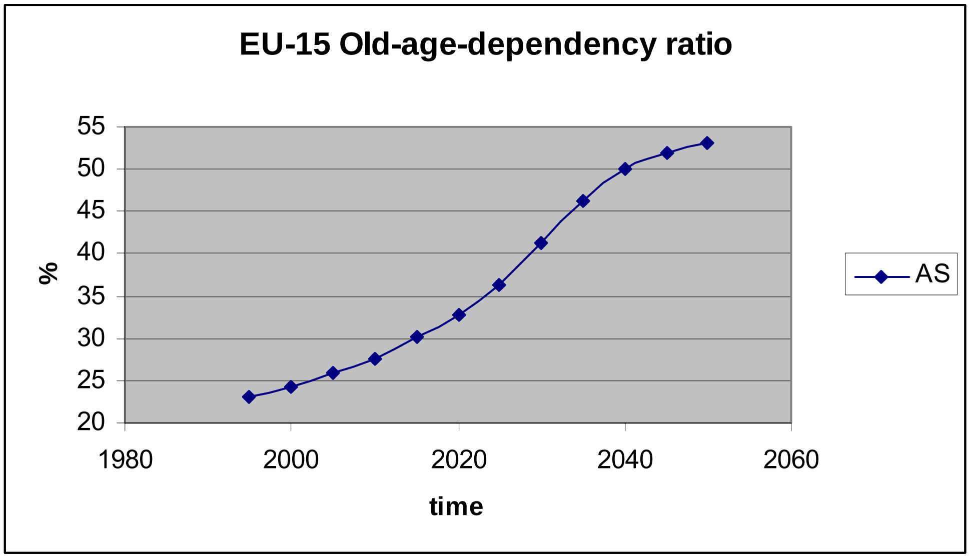


Figure 4.65. Projection of old-age-dependency ratio for EU-15 countries from 1995 to 2050.

The second factor (AS/GDP) in Equation 18 shows that GDP has increased faster than the old-age dependency ratio, which has reduced the risk of poverty. The third factor, gross domestic product per capita has increased the risk of poverty. Similarly the fourth factor, population intensity of unemployment shows an increase in the risk of poverty. This is due to the fact that whilst population is increasing the unemployment has in fact decreased between 1995 and 2005 (see Figure 4.66), thus population intensity of unemployment increases the risk of poverty. According to this decomposition analysis the greatest decrease in the risk of poverty has been achieved by decreasing unemployment.

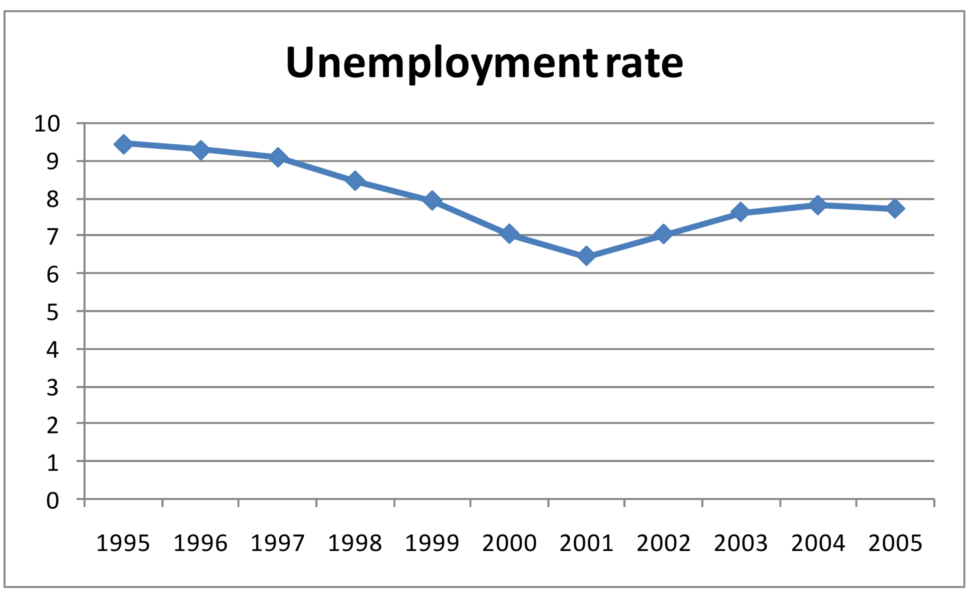


Figure 4.66. *Unemployment rate in EU-15 countries decreased between 1995 and 2005*

4.4. Ageing Society (AS)

Decomposition of ageing society has been done by calculating how old-age-dependency ratio has been affected by healthy life years and gross domestic product (see Figure 4.67).

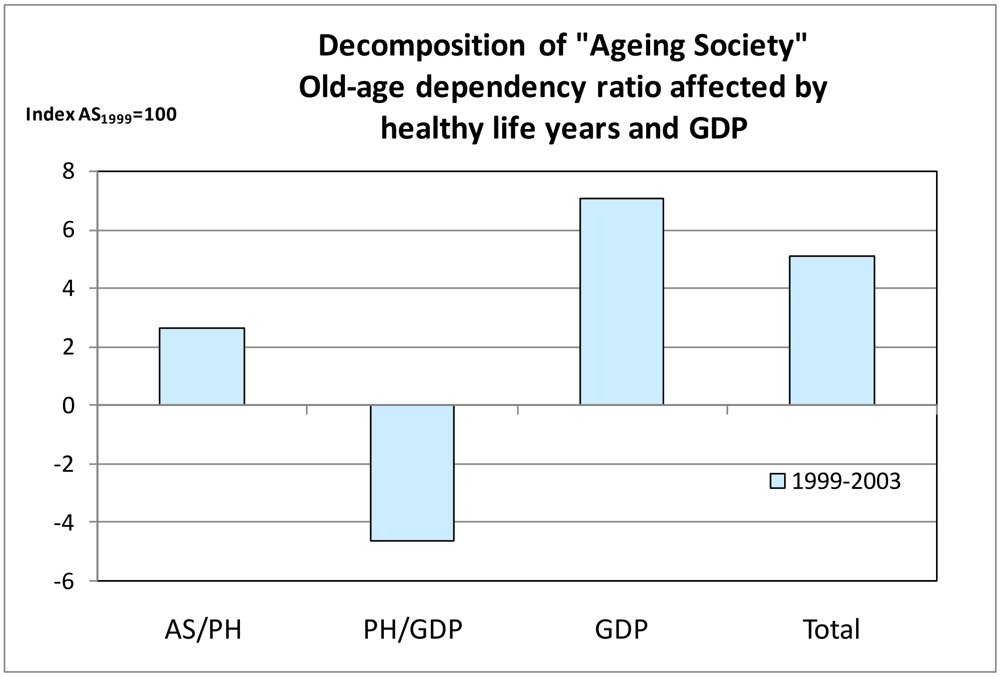


Figure 4.67. *Decomposition of ageing society: old-age-dependency ratio affected by healthy life years and GDP.*

The contributing factors have been identified in Equation 19:

$$AS = \frac{AS}{PH} \times \frac{PH}{GDP} \times GDP \qquad (19)$$

where

- AS is ageing society, i.e. old-age-dependency ratio
- PH is public health, i.e. healthy life years at birth
- GDP is gross domestic production
- AS/PH is ageing society productivity of public health
- PH/GDP is public health productivity of GDP.

The increase of healthy life years (LH) naturally increases the old-age-dependency ratio. The healthy life years productivity of GDP (PH/GDP) has decreased and hence decreases also AS. Also the GDP increase has contributed to the increase of AS.

4.5. Public health (PH)

Two decomposition analyses were done for public health. In the first one (see Figure 4.68) we calculated how ageing society, GDP, employment and population affect the change in healthy life years between 1999 and 2003. In the second decomposition (see Figure 4.69) we explore the affects of overweight, smoking, GDP and population on the change in healthy life years between1998-2001. The first decomposition has been made for EU-15 countries, but the second decomposition includes Belgium, Denmark, Ireland, Greece, Spain, Italy, Austria, Portugal and Finland.

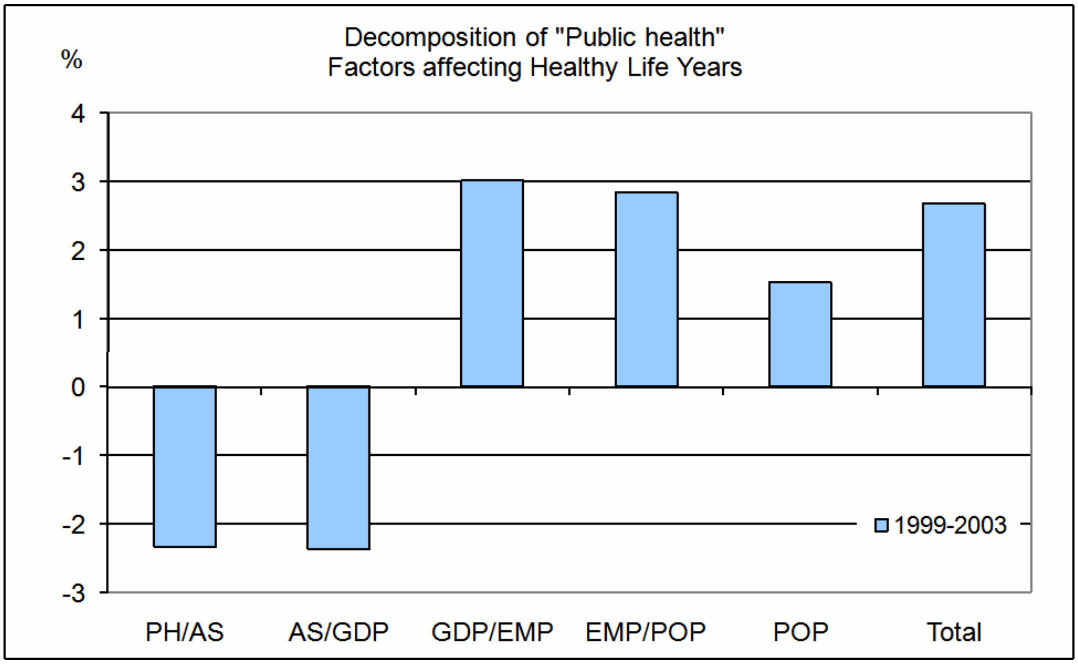


Figure 4.68. *Decomposition of Public Health: factors affecting healthy life years.*

The factors affecting change in public health are presented in the following equation:

$$PH = \frac{PH}{AS} \times \frac{AS}{GDP} \times \frac{GDP}{EMP} \times \frac{EMP}{POP} \times POP \qquad (20)$$

where

- PH is public health, i.e. healthy life years at birth
- AS is ageing society, i.e. old-age-dependency ratio which is defined as the ratio between the total number of elderly persons of an age when they are generally economically inactive (aged 65 and over) and the number of persons of working age (from 15-64)
- GDP is gross domestic product
- EMP is employment
- POP is population
- PH/AS is public health productivity of ageing society
- AS/GDP is ageing society productivity of GDP
- GDP/EMP is GDP productivity of employment
- EMP/POP is employment rate of population

The public health productivity of ageing society (PH/AS) has decreased having decreasing effect on healthy life years. Similarly the ageing society productivity of GDP has decreased lowering the index of PH. On the other hand GDP productivity of employment, employment rate and population growth have increased the healthy life years.

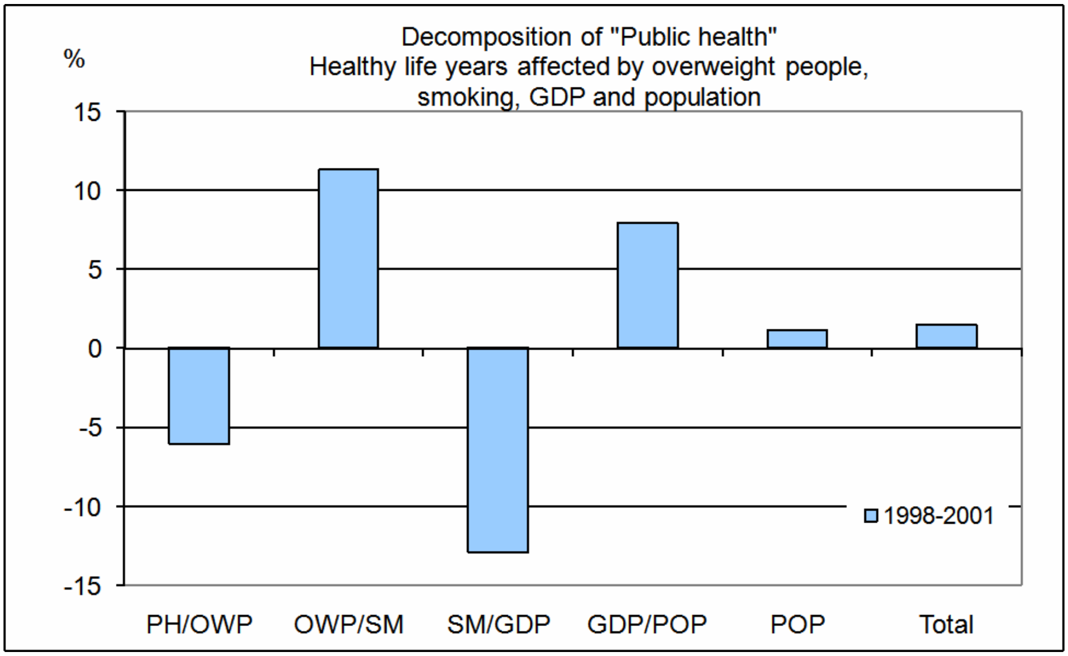


Figure 4.69. *Decomposition of public health: healthy life years affected by overweight people, smoking, GDP and population*

The factors affecting the change in healthy life years are presented in the following equation:

$$PH = \frac{PH}{OWP} \times \frac{OWP}{SM} \times \frac{SM}{GDP} \times \frac{GDP}{POP} \times POP \tag{21}$$

Where

- PH is public health, i.e. healthy life years at birth
- OWP is overweight people
- SM is number of smokers
- GDP is gross domestic product
- POP is population
- PH/OWP is public health productivity of overweight
- OWP/SM is overweight productivity of smoking
- SM/GDP is smoking productivity of GDP
- GDP/POP is GDP per capita

The results show that obesity has decreased healthy life years (decreasing public health productivity of overweight). The second factor OWP/SM (overweight productivity of smoking) is increasing healthy life years. This factor measures the combined effect of obesity and smoking on healthy life years. The effect is positive, because the number of smokers has decreased more than the number of overweight people has increased between 1998 and 2001 (see Figure 4.70). The third factor, SM/GDP has had a decreasing affect on public health, which indicates that smoking productivity of GDP has decreased. Factor four shows that GDP per capita increases healthy life years. The fifth factor, change in population, appears to have an increasing effect on healthy life years.

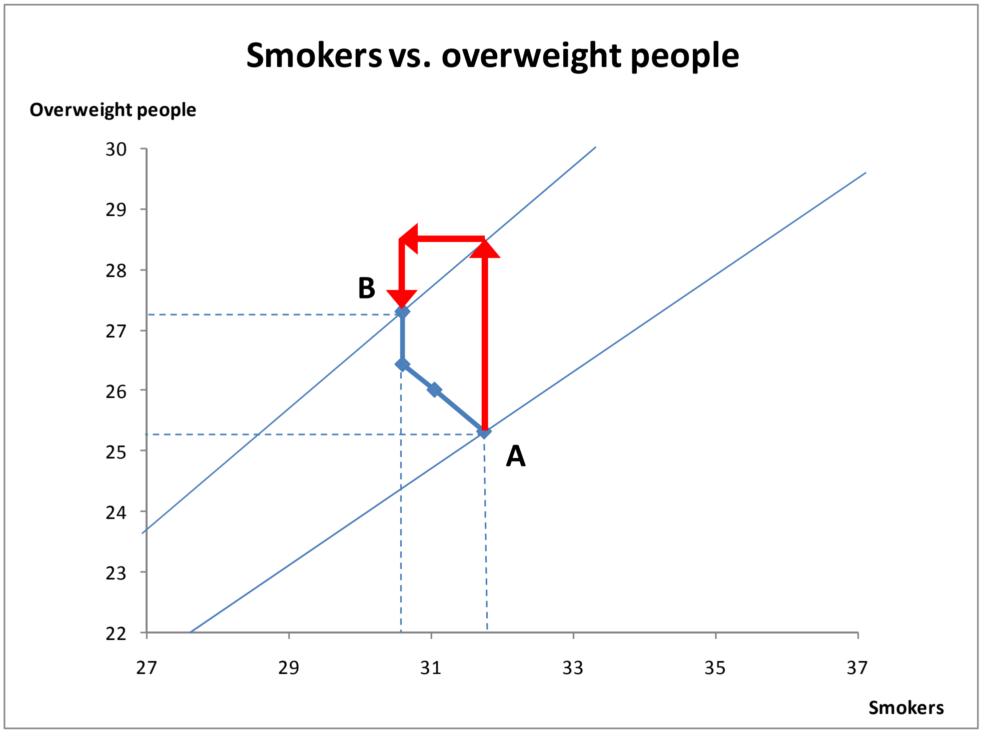


Figure 4.70. *Effect of factor OWP/SM*

The overweight productivity of smoking (OWP/SM) has increased. At the same time the number of smokers has reduced, but still the total effect is increase in overweight people (change A→B).

4.6. Production and Consumption Patterns (PC)

Three separate examples of decomposition analysis were carried out for production and consumption patterns. In the first two decompositions factors affecting meat consumption were examined (see Figures 4.71 and 4.72). Factors affecting meat consumption in this example include livestock density, agricultural budgetary support, GDP and household size. The decomposition is for EU-15 countries between 1995 and 2002. The third decomposition was calculated for domestic material consumption affected by ageing society and GDP between 1995 and 2001(see Figure 4.73).

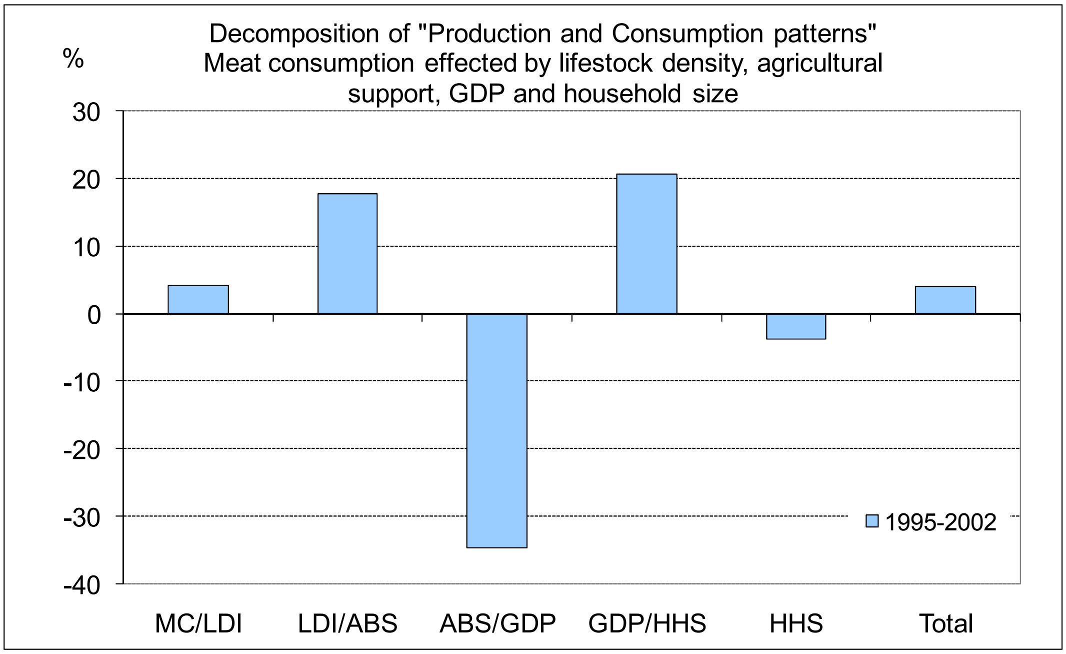


Figure 4.71. *Decomposition of production and consumption patterns: the effects of livestock density, agricultural support, GDP and household size on meat consumption*

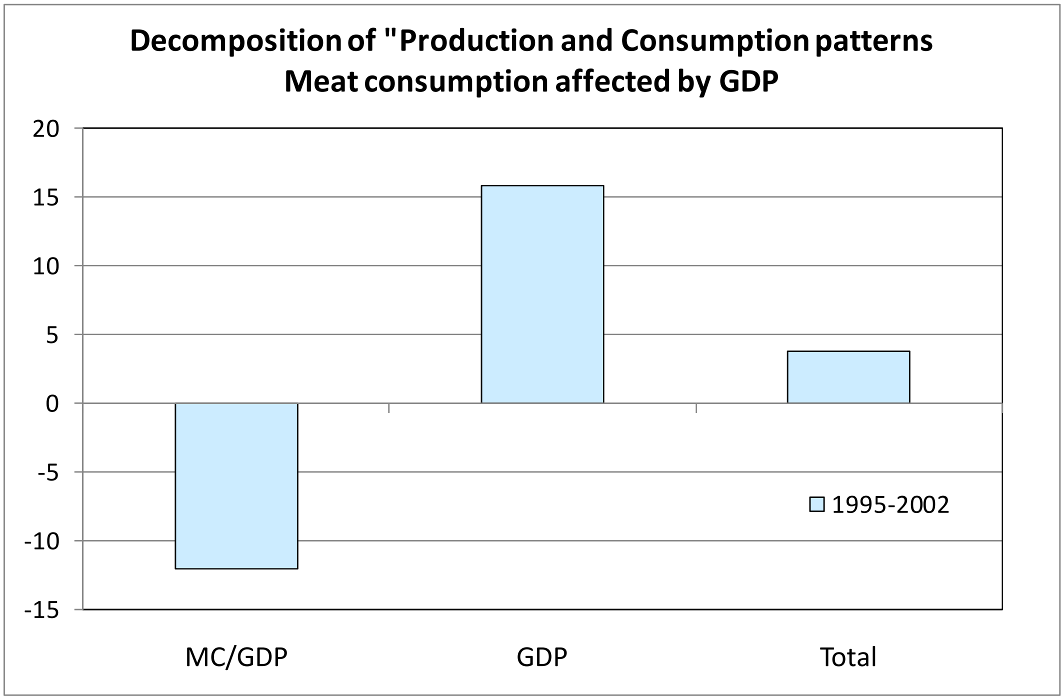
The decomposition of production and consumption patterns in Figure 4.71 is presented in the following equation:

$$MC = \frac{MC}{LDI} \times \frac{LDI}{ABS} \times \frac{ABS}{GDP} \times \frac{GDP}{HHS} \times HHS \quad (22)$$

where

- MC is meat consumption per capita
- LDI is livestock density index
- ABS is agricultural budgetary support
- GDP is gross domestic production
- HHS is household size
- MC/LDI is meat consumption intensity of livestock density indicating the impact of meat production on its consumption
- LDI/ABS is livestock density productivity of agricultural budgetary support indicating the impact of agricultural support on the amount of livestock
- ABS/GDP is share of agricultural support of GDP
- GDP/HHS is a component including the GDP per capita (GDP/POP) and the number of households (POP/HHS)

The first factor MC/LDI shows that the meat consumption intensity of livestock increases meat consumption (increased meat production is related to increasing meat consumption). The second factor LDI/ABS represents meat production's dependency on agricultural support, which has an increasing affect on meat consumption. The third factor ABS/GDP represents the share of Agricultural budgetary support of GDP, which affects very strongly on meat consumption. In this case, the effect has been negative, i.e. the decreasing share of agricultural budgetary support has decreased meat consumption. The fourth factor GDP/HHS represents the effects of GDP per capita and number of households, which in turn have increased meat consumption. The fifth factor HHS represents the change in household size's and how the decreasing household size has decreased meat consumption.



4.72. *Decompositon of production and consumption patterns: meat consumption affected by GDP*

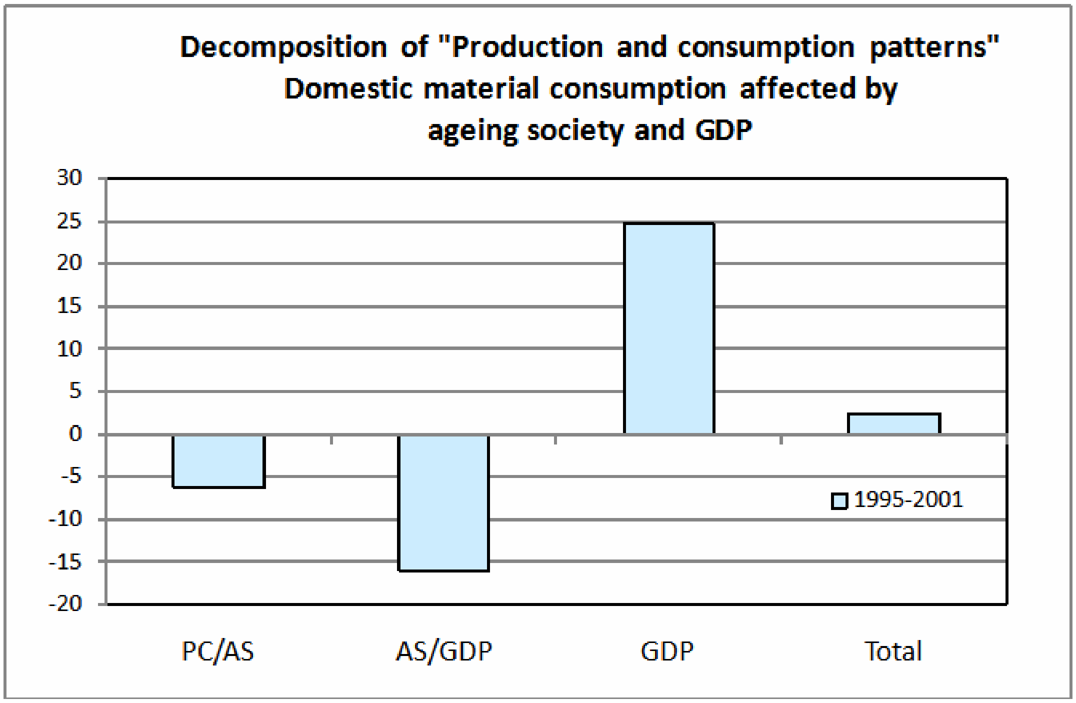
Meat consumption affected by GDP in Figure 4.72 is presented in the following equation:

$$MC = \frac{MC}{GDP} \times GDP \qquad (23)$$

where

- MC is meat consumption
- GDP is gross domestic product
- MC/GDP is the meat consumption productivity of GDP

The meat consumption productivity of GDP has decreased, which decreases the meat consumption. On the other hand GDP growth has increased meat consumption considerably resulting in the growth of total consumption.



***4.73**. Decomposition of production and consumption patterns: domestic material consumption affected by ageing society and GDP*

Factors affecting domestic material consumption in Figure 4.73 are presented in the following equation:

$$PC = \frac{PC}{AS} \times \frac{AS}{GDP} \times GDP \qquad (24)$$

where

- PC is domestic material consumption
- AS is ageing society
- GDP is gross domestic product
- PC/AS is domestic material consumption intensity of ageing society
- AS/GDP is ageing society productivity of GDP

The material consumption intensity of ageing society has been decreasing as well as the ageing society productivity of GDP, both decreasing the domestic material consumption. The fast growth of GDP has, however, resulted in total increase of material consumption.

4.7. Management of Natural Resources (MN)

As examples for decomposition of management of natural resources, we have calculated the effects of GDP, agricultural support and organic farming on the population trends of farmland birds (which is used as an indicator of biodiversity) (see Figures 4.74, 4.75 and 4.76).

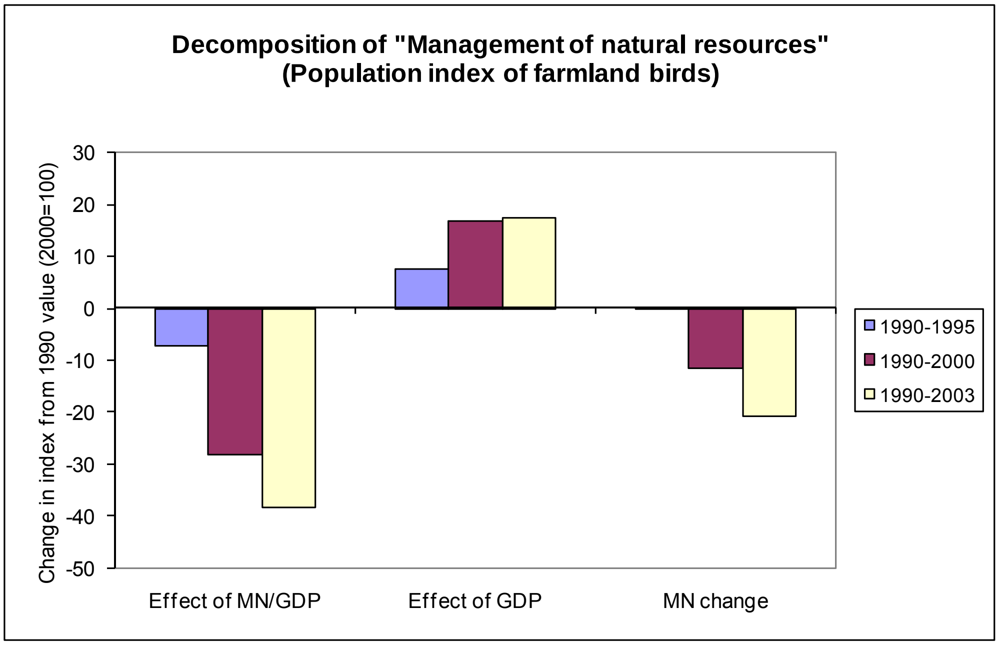


Figure 4.74. *Decomposition of management of natural resources: the effect GDP on population trends of farmland birds.*

The affect of GDP on farmland bird populations trends is presented in the following equation:

$$MN = \frac{MN}{GDP} \times GDP \qquad (25)$$

where

- MN is the population trend of farmland birds
- GDP is gross domestic product
- MN/GDP is biodiversity productivity of GDP

The decomposition was done in three different time periods from 1990 to 1995, 1990 to 2000 and 1990 to 2003. The results show that farmland bird populations have decreased during the studied time period. The effect of GDP on the number of farmland birds has been positive, but the biodiversity productivity of GDP has decreased the population trend.

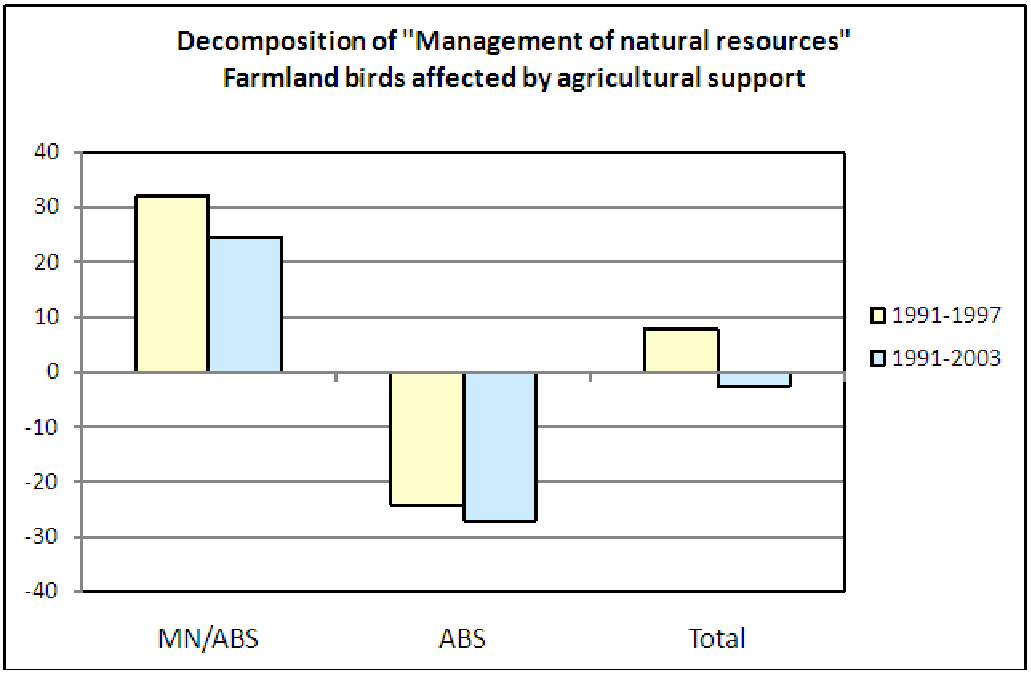


Figure 4.75. *Decomposition of management of natural resources: the effect of agricultural support on the population trends of farmland birds*

Farmland bird population trends affected by agricultural support (Figure 4.75) is presented in the following equation:

$$MN = \frac{MN}{ABS} \times ABS \quad (26)$$

where

- MN is farmland bird population trend
- ABS is agricultural budgetary support
- MN/ABS is biodiversity productivity of agricultural budgetary support

The results show that the biodiversity productivity of agricultural support has affected positively on the change in farmland bird trend, whereas agricultural budgetary support itself has decreased the trend.

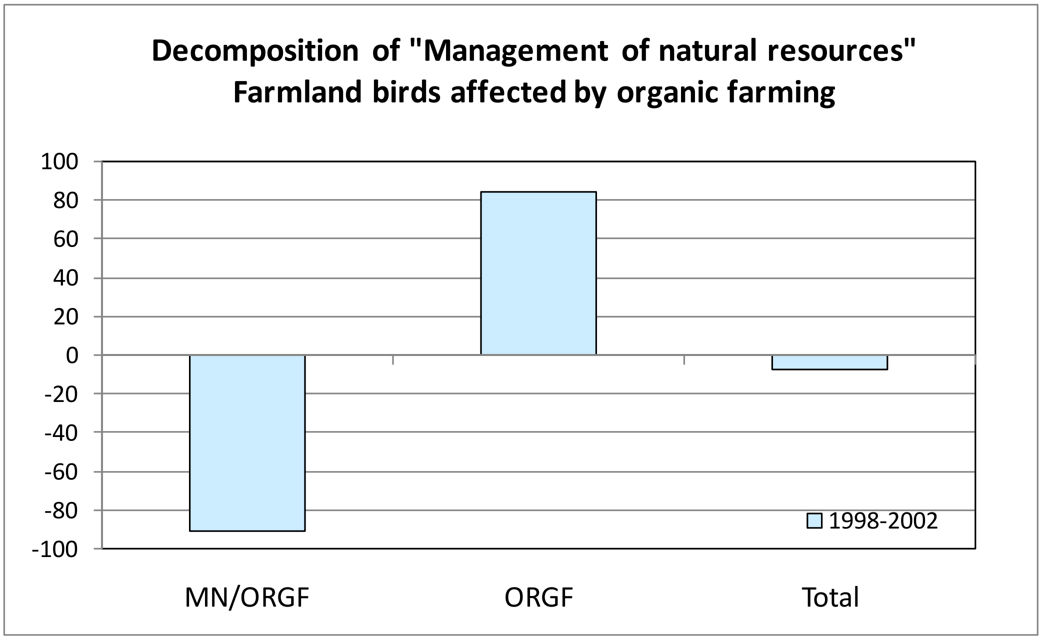


Figure 4.76. *Decomposition of Management of natural resources: the effect of organic farming on the population trends of farmland birds.*

The impact of organic farming on farmland birds in Figure 4.76 is presented in the following equation:

$$MN = \frac{MN}{ORGF} \times ORGF \qquad (27)$$

where

- MN is population trends of farmland birds
- ORGF is organic farming
- MN/ORGF is biodiversity productivity of organic farming

The biodiversity productivity of organic farming has decreased more than the organic farming has increased resulting in decrease of farmland birds.

4.8. Transport (TR)

An example of decomposition of transport is presented in Figure 4.77, where the effect of GDP to transport energy consumption has been calculated from 1990 to 1995, 1990 to 2000 and 1990 to 2004.

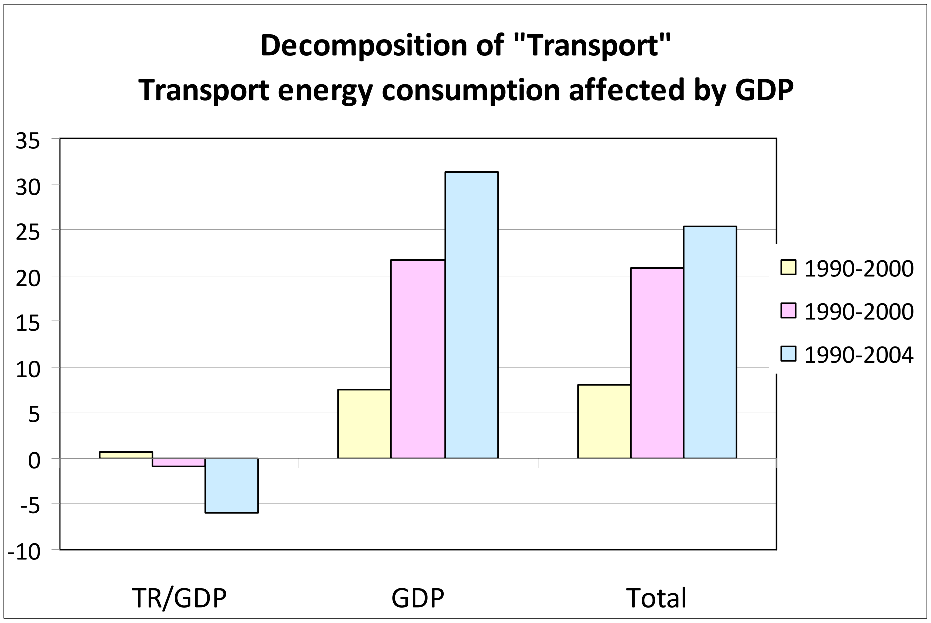


Figure 4.77. *Decomposition of transport: transport energy consumption affected by GDP*

Transport energy consumption affected by GDP is presented in the following equation:

$$TR = \frac{TR}{GDP} \times GDP \tag{28}$$

where

- TR is transport energy consumption
- GDP is gross domestic product
- TR/GDP is the transport intensity of GDP

The transport intensity of GDP has slightly decreased, but the fast growth of GDP has resulted in considerable increase in transport.

4.9. Good Governance (GG)

An example decomposition analysis of good governance was done by identifying factors affecting change in citizen's confidence in EU between 1999 and 2005 (see Figure 4.78).

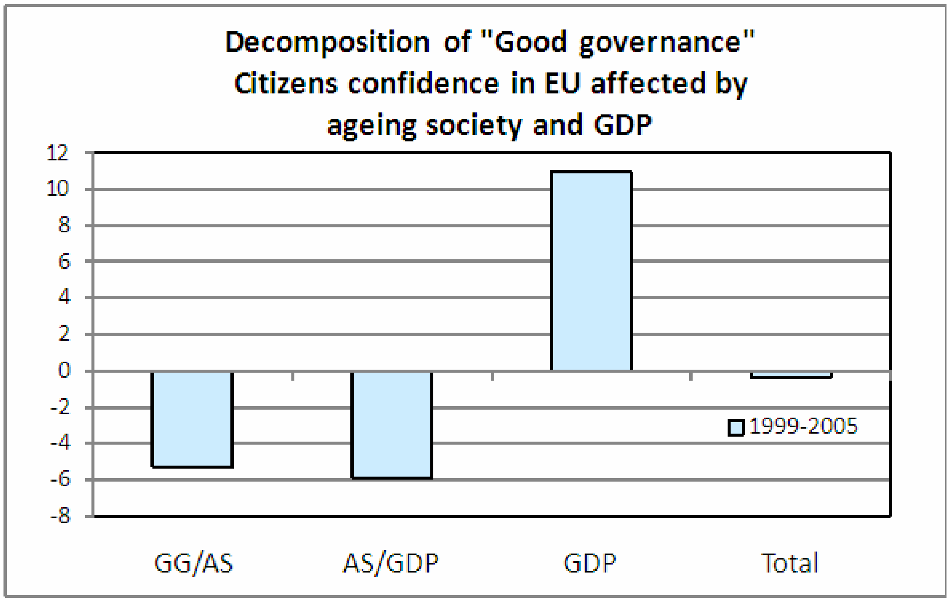


Figure 4.78*. Decomposition of good governance: citizen's confidence in EU affected by ageing society and GDP.*

The factors affecting citizen's confidence in EU (Figure 4.78) are presented in the following equation:

$$GG = \frac{GG}{AS} \times \frac{AS}{GDP} \times GDP \qquad (29)$$

where

- GG is citizen's confidence
- AS is ageing society
- GDP is gross domestic production
- GG/AS is confidence productivity of ageing society
- AS/GDP is ageing productivity of GDP

The results show that citizen's confidence in EU has decreased between 1999 and 2005. GDP has a positive effect on citizen's confidence in EU, but ageing society decreases the overall confidence.

4.10. Global Partnership (GP)

An example of decomposition of global partnership was done by identifying factors affecting the change in development assistance between 1999 and 2005 (see Figure 4.79).

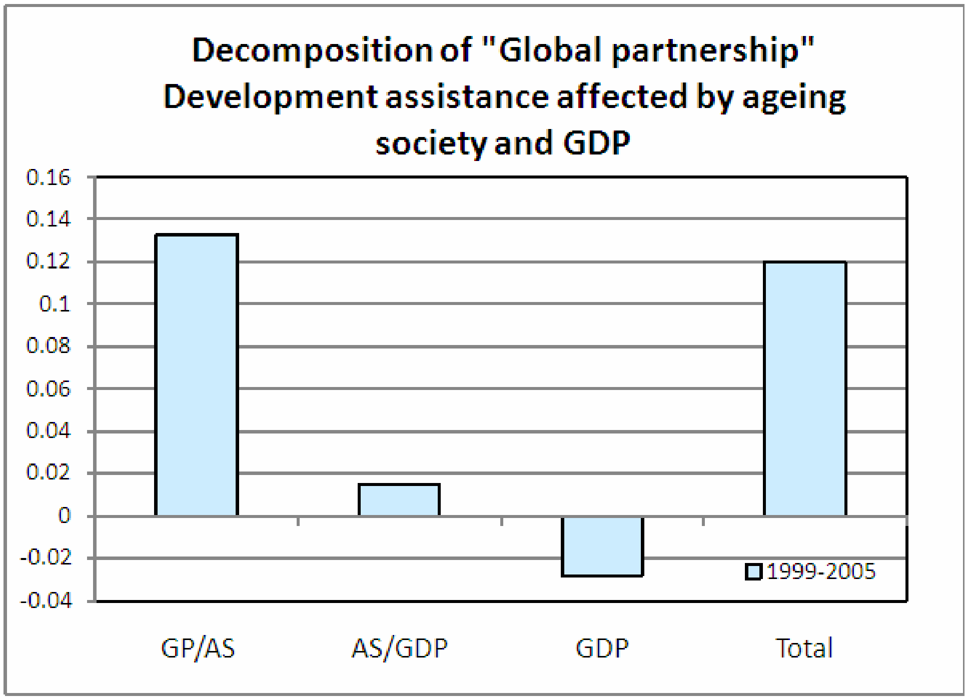


Figure 4.79. *Decomposition of Global partnership: development assistance affected by ageing society and GDP*

The factors affecting development assistance are presented in the following equation:

$$GP = \frac{GP}{AS} \times \frac{AS}{GDP} \times GDP \qquad (30)$$

where

- GP is development assistance
- AS is ageing society
- GDP is gross domestic product
- GP/AS is aid productivity of ageing society
- AS/GDP is ageing productivity of GDP

The results show that the overall development assistance has increased between 1999 and 2005, which has been positively affected by ageing society, whilst GDP appears to have a negative effect on the change.

5. Conclusions

In this study we have tested the suitability of Advanced Sustainability Analysis (ASA) for the analysis of the different dimensions of sustainable development. The aim of this study was to tentatively calculate examples of driving forces of the changes in unsustainable trends identified in EU. The idea was to divide Sustainable Development Indicator set into meaningful components and to calculate their share of the total change using the so-called complete decomposition. In the calculations we used the EU Sustainable Development indicators to the extent possible, but as mentioned above in Evaluation of the characteristics of EU sustainable development indicators section (2.2) possibilities to utilize the EU SDI set in fulfilling the objectives of the DECOIN project remains limited.

The purpose of this paper was to introduce the ASA methodology and give a detailed example of its use. Therefore the decomposition analyses were done for all the 10 themes of the EU Sustainable Development Indicator set. In this paper, we have showed how decomposition analysis can be used for analysing different dimensions of sustainable development. We were able to elaborate on the results of decomposition analysis for CO_2 emissions, which was possible due to existing quantity of relevant researches. The traditional decomposition of the energy system and CO_2 emissions has provided new insight in the changes of the systems. Apart from the ‘Climate change and energy’ theme, identifying factors affecting the changes in the trend in EU, turned out to be very challenging. This is mainly because the previous work done with the decomposition analysis, in the field of sustainable development, has concentrated only on factors affecting climate change (CO_2) and energy, thereby providing us reasonable amount of empirical results for that particular theme.

For the other themes, acquiring sufficient amount of empirical results to back up the selection of affecting factors is not as easy due to lack of previous research. Therefore, it should be acknowledged that there is not an empirical causal basis behind the selection of certain indicators for the examples. For instance the selection of indicators for the decomposition analysis of population trends of farmland birds (or biodiversity/management of natural resources) was not straightforward. This due to the fact that the SDI set does not include indicators that would directly affect the farmland bird population. In addition, the selection of indicators that do affect the farmland bird population trends, even outside the SDI set, can be difficult to identify without sufficient ecological knowledge on what affects the changes in population trends. Since one of the objectives of Work Package 3 is to find trade-offs and interlinkages between the different dimension of sustainable development, we have chosen for the analyses indicators, which represent the other dimensions of sustainable development (i.e. the affects of GDP, agricultural support and organic farming on the population trends of farmland birds). These indicators do not affect the trends of farmland bird populations directly, but one can argue that there is an indirect effect. Similar logic has been carried out throughout the study for other themes (i.e. for indicators under sections 4.2 – 4.10). For that reason, it needs to be stressed that these decompositions are highly experimental and should be treated as such. The development of coherent set of chained decomposition requires lot of work input and expertise, therefore further research would be needed in order to elaborate on these results. Ergo the results for the other decomposed indicators should be treated only as indicative.

The monitoring reports Measuring progress towards a more sustainable Europe: Sustainable Development Indicators for the European Union 2005 and 2007 include tentative inter-linkage sections which are meant to provide an illustration of the linkages between the different issues relevant to sustainable development. However, those sections have not been aimed at being comprehensive at this stage due to the fact that those links are complex issues, and knowledge is often limited. The monitoring reports also emphasise that there is not necessarily an empirical basis behind the links suggested, but they could be seen as hypotheses that could be further tested – this is also the case with the results of this study.

The results of this study serve as a basis and will be elaborated on in future work to be done in this work package (WP3), which includes elaboration of existing forecasts, identification of the inter-relationships between selected unsustainable trends (identified in EU) and exploring potential synergies and trade-offs between selected unsustainable trends. However, given the limitations encountered in this study (i.e. limitations set by the SDI set, ASA approach and lack of previous research targeting abovementioned aspects of sustainable development), the DECOIN project should proceed in analysing the global megatrends in more detail in order to produce more solid basis for dealing with the unsustainable trends and to meet the objectives of work package 3. In addition to the megatrend analysis an elaboration of most promising results of this study will be performed in order to identify inter-relationships and explore synergies and trade-offs between those selected trends. In the absence of existing forecasts, it could be an option to create forecasts for selected unsustainable trends using either back-casting or forecasting methods.

6. References

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