Institut für Raumplanung

Fakultät Raumplanung · Universität Dortmund

Berichte aus dem Institut für Raumplanung

49

Franz Fürst, Roland Hackl, Adelheid Holl, Hans Kramar,
Carsten Schürmann, Klaus Spiekermann, Michael Wegener

The SASI Model: Model Implementation

Deliverable D11 of the EU Project
Socio-Economic and Spatial Impacts of
Transport Infrastructure Investments
and Transport System Improvements
(SASI)

Dortmund, December 1999

Institut für Raumplanung
Fakultät Raumplanung, Universität Dortmund

D-44221 Dortmund
Tel. 0231-7552291, Fax 0231-7554788

IRPUD

Table of Contents

1. Summary

The Trans-European Transportation Networks (TETN) programme is one of the most ambitious initiatives of the European Union since its foundation. However, the impacts of this programme on the social and economic development of the European regions are uncertain. In the face of conflicting policy goals of the European Union, the consistent prediction and transparent evaluation of likely socio-economic impacts of major infrastructure investments will therefore become of great political importance for European decision makers.

The relationship between transport infrastructure and economic development has become more complex than ever. There are successful regions in the European core confirming the theoretical expectation that location matters. However, there are also centrally located regions suffering from industrial decline and high unemployment. On the other side of the spectrum the poorest regions, as theory would predict, are at the periphery, but there are also prosperous peripheral regions such as the Scandinavian countries. To make things even more difficult, some of the economically fastest growing regions are among the most peripheral ones.

The central task of the SASI project is to identify the way transport infrastructure contributes to regional economic development in different regional contexts. The main goal of the project is to design an interactive and transparent modelling system for forecasting the impacts of transport infrastructure investments and transport system improvements, in particular of the TETN, on socio-economic activities and developments in Europe. For that purpose the impacts have to be measured by means of indicators that can be related to the policy goals of the European Union.

This report, which is the eleventh deliverable of the EUNET project and the fifth of the SASI sub-project, describes the implementation of the SASI model based on the previous SASI Deliverables D4 (Bökemann et al., 1997), D5 (Schürmann et al., 1997), D7 (Masser et al., 1997) and D8 (Wegener and Bökemann, 1998).

The SASI model is a recursive simulation model of socio-economic development of 201 regions in Europe subject to exogenous assumptions about the economic and demographic development of the European Union as a whole and transport infrastructure investments and transport system improvements, in particular of the TETN. The model has six forecasting submodels: *European Developments*, *Regional Accessibility*, *Regional GDP*, *Regional Employment*, *Regional Population* and *Regional Labour Force*. A seventh submodel calculates *Socio-Economic Indicators* with respect to efficiency and equity. For each region the model forecasts the development of accessibility, GDP per capita and unemployment in one-year increments until the forecasting horizon 2016. In addition cohesion indicators expressing the impact of transport infrastructure investments and transport system improvements on the convergence (or divergence) of socio-economic development in the regions of the European Union are calculated.

The SASI model differs from other approaches to model the impacts of transport on regional development by modelling not only production (the demand side of regional labour markets) but also population (the supply side of regional labour markets), which makes it possible to model regional unemployment. The impacts of transport infrastructure investments and transport system improvements on regional production is modelled by regional production func-

tions in which, besides non-transport regional endowment factors, sophisticated spatially disaggregate accessibility indicators are included.

The study area of the model are the regions of the European Union with the other European countries, including the European part of Russia, considered as external regions. This makes the model suited to model spatial redistribution effects of the TETN within the European Union. However, it is not presently intended to model the aggregate macroeconomic multiplier effects of transport investments on the European economy as a whole. As the model does not contain a full transport submodel, it does not take network congestion or intermodality of transport networks into account.

This deliverable describes the implementation of the SASI model i.e. the application of empirical data to the model and the estimation and calibration of its parameters. Where modifications in the model specification had to be made since the completion of Deliverable D8, this is pointed out.

The remaining work of SASI will be presented in the forthcoming Deliverables D13 and D15. Deliverable D13 will present the model software and sample output. Deliverable D15 will present the results of the demonstration scenario simulations. A joint final report will summarise the work of both EUNET and SASI.

2. Introduction

2.1 Problem Statement

Article 2 of the Maastricht Treaty states as the goals of the European Union the promotion of harmonious and balanced economic development, stable, non-inflationary and sustainable growth, convergence of economic performance, high levels of employment and social security, improvement of the quality of life and economic and social coherence and solidarity between the member states. A prominent role for the achievement of these goals play the envisaged trans-European networks in the fields of transport, communications and energy (TEN). Article 129b of the Treaty links the trans-European networks to the objectives of Article 7a (free traffic of goods, persons, services and capital in the Single European Market) and Article 130a (promotion of economic and social cohesion). In particular, the trans-European transport networks (TETN) are to link landlocked and peripheral areas with the central areas of the Community.

More recently Decision No. 1692/96/CE of the European Parliament and of the Council (European Communities, 1996) states that "the establishment and development of TEN contribute to important objectives of the Community such as the good functioning of the internal market and the strengthening of the economic and social cohesion" and underlines that TETN have "to ensure a sustainable mobility for persons and goods, in the best social, environment and safety conditions, and to integrate all transport modes".

In physical and monetary terms the trans-European transport networks are one of the most ambitious initiatives of the European Community since its foundation. The masterplans for rail, road, waterways, ports and airports together require public and private investment between 400 and 500 billion ECU until the year 2010, nearly a quarter of which are needed for fourteen priority projects proposed at the 1995 EU summit in Essen.

However, the programme is not undisputed. Critics argue that many of the new connections do not link peripheral countries to the core but strengthen the ties between central countries and so reinforce their accessibility advantage. Only forty percent of the new motorways in the road masterplan are in peripheral countries, whereas sixty percent are in countries with an already highly developed road infrastructure. Some analysts argue that regional development policies based on the creation of infrastructure in lagging regions have not succeeded in reducing regional disparities in Europe, whereas others point out that it has yet to be ascertained that the reduction of barriers between regions has disadvantaged peripheral regions. From a theoretical point of view, both effects can occur. A new motorway or high-speed rail connection between a peripheral and a central region, for instance, makes it easier for producers in the peripheral region to market their products in large cities, however, it may also expose the region to the competition of more advanced products from the centre and so endanger formerly secure regional monopolies.

In addition there are environmental concerns. High-speed rail corridors or multi-lane motorways consume environmentally valuable open space in high-density metropolitan areas and cut through ecologically sensitive habitats and natural regions outside of cities and in addition contribute to the general trend of inducing more and higher-speed travel and goods transport.

In the face of these conflicting goals the consistent prediction and the rational and transparent evaluation of likely socio-economic impacts of major transport infrastructure investments become of great political importance both for the European Union and for its member states. This is also underlined by the European Commission's *Cohesion Report* (1997a) which emphasises that "regions should ensure that policy success is measurable, that results are regularly monitored, and that the public and political authorities are regularly informed of progress."

2.2 Objectives of the SASI Project

The SASI project aims at the development of a comprehensive and transferable methodology for forecasting the socio-economic and spatial impacts of large transport investments in Europe, in particular of different scenarios of the development of the trans-European transport networks (TETN) planned by the European Union. With respect to the cohesion objective of the European Union the model is to answer the question whether the TETN will lead to a reduction of regional disparities and which regions of the European Union are likely to benefit from the TETN and which regions are likely to be disadvantaged.

To achieve this objective the project focuses on

- developing a comprehensive, consistent and transferable methodology for the prediction of the impacts of transport infrastructure investments and transport system improvements (road, rail and air) on socio-economic activities and development, including spatial and temporal distribution of impacts;

- designing an interactive, transparent modelling system for forecasting of socio-economic impacts of transport investment decisions and policies;

- demonstrating the usability of the modelling system by applying it to a number of scenarios of transport infrastructure investments and transport system improvements.

The proposed methodology and modelling system is innovative in that it is based on measurable indicators derived from advanced location-theory approaches to explain and predict the locational behaviour of investment capital, manufacturing and service activities and population. It is pragmatic and feasible in that it does not require massive and repeated collection of data on socio-economic distributions or trade flows and travel patterns. It is designed to facilitate political discussion and negotiation by being transparent, understandable and open for new indicators and issues that may become relevant in the future.

2.3 The Position of D11 within SASI

The first deliverable of SASI, or D4 in the count of EUNET deliverables, (Bökemann et al., 1997) linked the policy objectives of the European Union, in particular of its Common Transport Policy, to the model to be developed in SASI. For this purpose the main political goals of the European Union were systematically structured. Then a set of socio-economic indicators was derived taking account of (i) the state of the art in social indicator research, (ii) the indicators most frequently used in other studies and their strengths and weaknesses, (iii) their relevance for the policy goals of the European Union, (iv) their ability to express socio-economic impacts of transport policies and (v) their interpretability by decision makers, as well as technical constraints such as (vi) their computability by the model to be developed and (vii) the availability of data. Finally, empirical illustrations of selected indicators were presented. In the conclusions the limitations of the proposed methodology were discussed.

The second deliverable of SASI, or D5 of EUNET (Schürmann et al., 1997), defined, discussed and tested accessibility indicators to be generated and used in the SASI model. Accessibility is the main 'product' of a transport system. It determines the locational advantage of a region relative to all other regions and so is a major factor for the social and economic development of a region. At the same time accessibility has a value by itself as an element of quality of life. Accessibility indicators therefore are a central sub-group of the socio-economic indicators discussed in D4 (Bökemann et al., 1997). D5 identified basic types of accessibility frequently appearing in the literature. Based on their weaknesses, new disaggregate measures of accessibility were proposed and demonstrated with pan-European data. For these new accessibility indicators also 'cohesion' indicators measuring the distribution of accessibility across regions were developed. The preliminary empirical findings indicated that the trans-European networks, in particular the European high-speed rail networks, are likely to stabilise if not increase the differences in accessibility between central and peripheral regions in Europe. However, it also became apparent that accessibility is no longer the most important factor determining location choice of firms but rather one of many transport and non-transport location factors (Linneker, 1997). The conclusion was that accessibility has to be seen as an enabling condition necessary to facilitate economic development but which, if present, does not guarantee that development will occur.

The third deliverable of SASI, or D7 of EUNET (Masser et al., 1997) examined the data available for SASI. The Eurostat database Regio was identified as the primary data input to the project as a whole, as it is the main official source of regional data that is provided on a regular basis and in a harmonised framework. Data problems identified were large differences in the size of regions, changes in region boundaries and the creation of new regions all resulting in outliers and gaps in the data. Data coverage was found to be very poor for the new member states Austria, Finland and Sweden and the new German Länder. Missing data, in particular for the base year 1981, had to be estimated or derived from other data sources such as national statistical offices. It was concluded that, although Regio covers a considerable amount of the data required, the collection of the information needed for the *European Developments* submodel (see Section 4.1) as well as the calculation of regional endowment factors for the *Regional GDP* submodel (see Section 4.3) require a variety of other data sources.

The fourth deliverable of SASI, or D8 of EUNET (Wegener and Bökemann, 1998) described the structure of the SASI model based on the results of the previous three SASI deliverables. Starting from a review of the state of the art of modelling regional economic development, it introduced and explained the major design considerations that led to the construction of the model. It presented a detailed description of each submodel including their interactions and summarised the data requirements, output and operation of the model.

D11 has a similar structure to the previous three SASI reports. Therefore topics that have been dealt with in depth in Deliverables D4, D5, D7 and D8, such as the discussion of policy goals of the European Union (D4), the specification of accessibility indicators (D5), the detailed discussion of the data issues (D7) or the model design (D8) are not repeated.

This report starts, in Section 3, with a brief outline (and update) of the SASI model structure which has been described in detail in Deliverable D8. Section 4 is the central part of this report. It presents the data input and calibration of the submodels in detail. Section 5 draws conclusions for the implementation and testing of the model.

The calibration of the model, i.e. the statistical analyses to test different hypotheses about factors to be included in the regional production and migration functions and their exact numerical specification, are therefore the main contribution of D11. It may therefore be useful to recapitulate the four guidelines set up in Deliverable D8 (Wegener and Bökemann, 1998) for the calibration:

(1) All factors (explanatory variables) included in both functions should be based on theory-based hypotheses about direction and intensity of causal relationships; statistical correlations that cannot be clearly interpreted or proxies, i.e. variables that are only indicators for unobserved or unobservable factors are to be avoided.

(2) Preference should be given to positive (pull) factors; negative (push) factors ("lack of ...") are to be avoided wherever possible.

(3) Except where factors can reasonably be considered to be time-invariant over the whole forecasting horizon (e.g. climate), factors should be either exogenous policy variables or endogenous variables updated in each simulation period by the model.

(4) Factors that may lead to unreasonable policy conclusions should be avoided. For instance the fact that accessibility correlates negatively with agricultural GDP per capita (which merely indicates that agriculture is more important for peripheral than for central regions) should not lead to the conclusion that transport infrastructure investments in peripheral regions are counterproductive for agriculture.

These principles will be referred to in the report when discussing the selection or exclusion of variables during the calibration process.

The model software and the results of the scenario simulations results will be presented in the final sixth and seventh deliverables of SASI, or Deliverables D13 and D15 of EUNET.

3. Model Overview

This section gives a brief overview of the structure of the SASI model. It repeats and partially updates the tentative outline of the SASI model accompanying the four previous SASI deliverables, especially Deliverable D8 (Wegener and Bökemann, 1998). The overview is to make the reader familiar with the basic structure of the SASI model and the interactions between the seven submodels, which will be presented in more detail in Section 4.

The SASI model consists of six forecasting submodels: *European Developments*, *Regional Accessibility*, *Regional GDP*, *Regional Employment*, *Regional Population* and *Regional Labour Force*. A seventh submodel calculates *Socio-Economic Indicators* with respect to efficiency and equity.

This structure defines the minimum scope of the SASI model necessary to achieve the objectives outlined in Section 2.2. More submodels may be added later in order to improve the model and extend its area of application.

3.1 Submodels

In this section the seven submodels of the SASI model and the interrelationships between them are briefly described. Figure 3.1 visualises the interactions between the submodels.

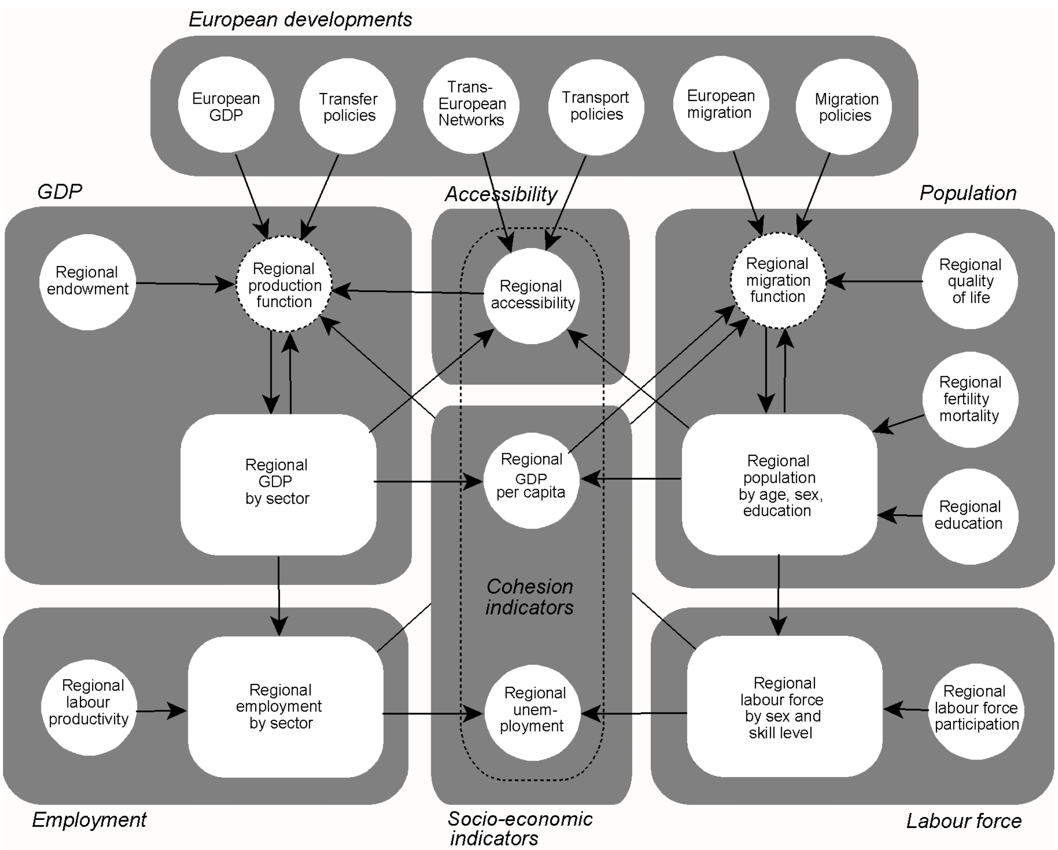


Figure 3.1. The SASI model

European Developments
The *European* Developments submodel is not a 'submodel' as it contains no forecasting equations. It simply prepares the exogenous assumptions about the wider economic and policy framework of the simulation for subsequent processing by the other submodels. European developments include assumptions about the future performance of the European economy as a whole and the level of immigration and outmigration across Europe's borders. They serve as constraints to ensure that the regional forecasts of economic development and population are consistent with external developments not modelled. Given the expected rapid population growth and lack of economic opportunity in many origin countries, total European immigration will be largely a function of immigration policies by national governments of the countries of the European Union. Another relevant European policy field are transfer payments by the European Union or by national governments, which are responsible for a sizeable part of their economic growth in some regions. The last group of assumptions concern policy decisions on the trans-European networks. As these are of focal interest in SASI, they are modelled with considerable detail. Besides a 'baseline' scenario several TETN scenarios reflecting different investment programmes for the road, rail or air networks will be specified.

Regional Accessibility
This submodel calculates regional accessibility indicators expressing the locational advantage of each region with respect to relevant destinations as a function of travel time or travel cost (or both) to reach these destinations by the strategic road, rail and air networks.

Regional GDP
This is the core submodel of the SASI model. It calculates a forecast of gross domestic product (GDP) by industrial sector (agriculture, manufacturing, services) generated in each region as a function of economic structure, labour force, endowment indicators and accessibility. Endowment indicators measure the suitability or capacity of a region for economic activity. They may include traditional location factors such as availability of business services, capital stock (i.e. production facilities) and intraregional transport infrastructure as well as 'soft' location factors, such as cultural facilities, housing and a pleasant climate and environment. Accessibility indicators are derived from the *Regional Accessibility* submodel. In addition, monetary transfers by the European Union or by national governments are considered, as these account for a sizeable portion of the economic development of peripheral regions. The results of the regional GDP per capita forecasts are adjusted in a way that the total of all regional forecasts multiplied by regional population meets the exogenous forecast of economic development (GDP) of Europe as a whole as defined by the *European Developments* submodel.

Regional Employment
Regional employment is calculated by combining the results of the GDP submodel with exogenous forecasts of regional labour productivity by industrial sector (GDP per worker), which in addition may be changed by effects of changes in regional accessibility.

Regional Population
Population forecasts are needed to represent the demand side of regional labour markets. The *Regional Population* submodel therefore predicts regional population change due to natural change and migration. Births and deaths are modelled by a cohort-survival model subject to

exogenous forecasts of regional fertility and mortality rates. Migration is modelled in a simplified migration model as annual net migration as a function of regional unemployment and other indicators expressing the attractiveness of the region as a place of employment and a place to live. The migration forecasts are adjusted to comply with total European immigration and outmigration forecast by the *European Developments* submodel and the limits on immigration set by individual countries. In addition, educational attainment, i.e. the proportion of residents with higher education, is forecast as a function of national education policy.

Regional Labour Force
Regional labour force is derived from regional population and exogenous forecasts of regional labour force participation rates modified by effects of regional unemployment.

Socio-economic Indicators
Total GDP and employment are related to population and labour force by calculating total regional GDP per capita and regional unemployment. Accessibility, besides being a factor determining regional production, is also considered a policy-relevant output of the model. In addition, equity or cohesion indicators describing the distribution of accessibility, GDP per capita and unemployment across regions are calculated.

3.2 Space and Time

The SASI model forecasts socio-economic development in the 201 regions at the NUTS-2 level defined for SASI for the fifteen EU countries (see Figure 3.2 and Annex Table A1). These are the 'internal' regions of the model. The 27 regions defined for the rest of Europe are the 'external' regions which are used as additional destinations when calculating accessibility indicators. The four regions representing the rest of the world are not used.

The spatial dimension of the system of regions is established by their connection via networks. In SASI road, rail and air networks are considered. The 'strategic' road and rail networks used in SASI are subsets of the pan-European road and rail networks developed by IRPUD and recently adopted for the GISCO spatial reference database of Eurostat. The 'strategic' road and rail networks contain all TETN links laid down in Decision No. 1692/96/CE of the European Parliament and the Council (European Communities, 1996) and the east European road and rail corridors identified by the Second Pan-European Transport Conference in Crete in 1994 as well as additional links selected for connectivity reasons. The SASI system of regions and the strategic networks used in SASI have also been used in the DGVII projects STREAMS, EUNET and STEMM.

The temporal dimension of the model is established by dividing time into discrete time intervals or periods of one year duration. By modelling relatively short time periods both short- and long-term lagged impacts can be taken into account. The base year of the simulations is 1981 in order to demonstrate that the model is able to reproduce the main trends of spatial development in Europe over a significant time period of the past with satisfactory accuracy. The forecasting horizon of the model is 2016.

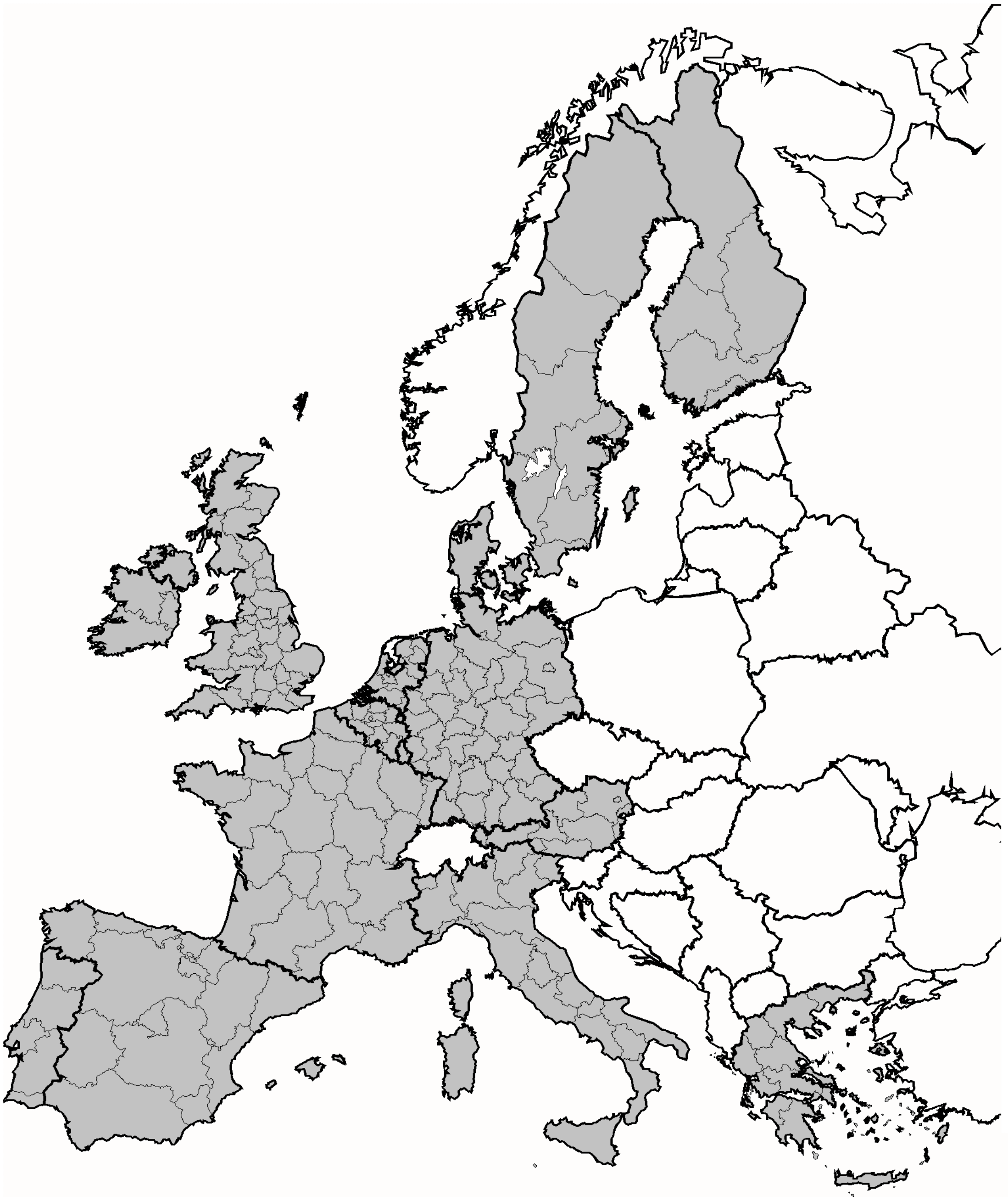


Figure 3.2. The SASI system of regions

In each simulation year the seven submodels of the SASI model are processed in a recursive way, i.e. sequentially one after another. This implies that within one simulation period no equilibrium between model variables is established; in other words, all endogenous effects in the model are lagged by one or more years. Figure 3.3 illustrates the recursive organisation of the model:

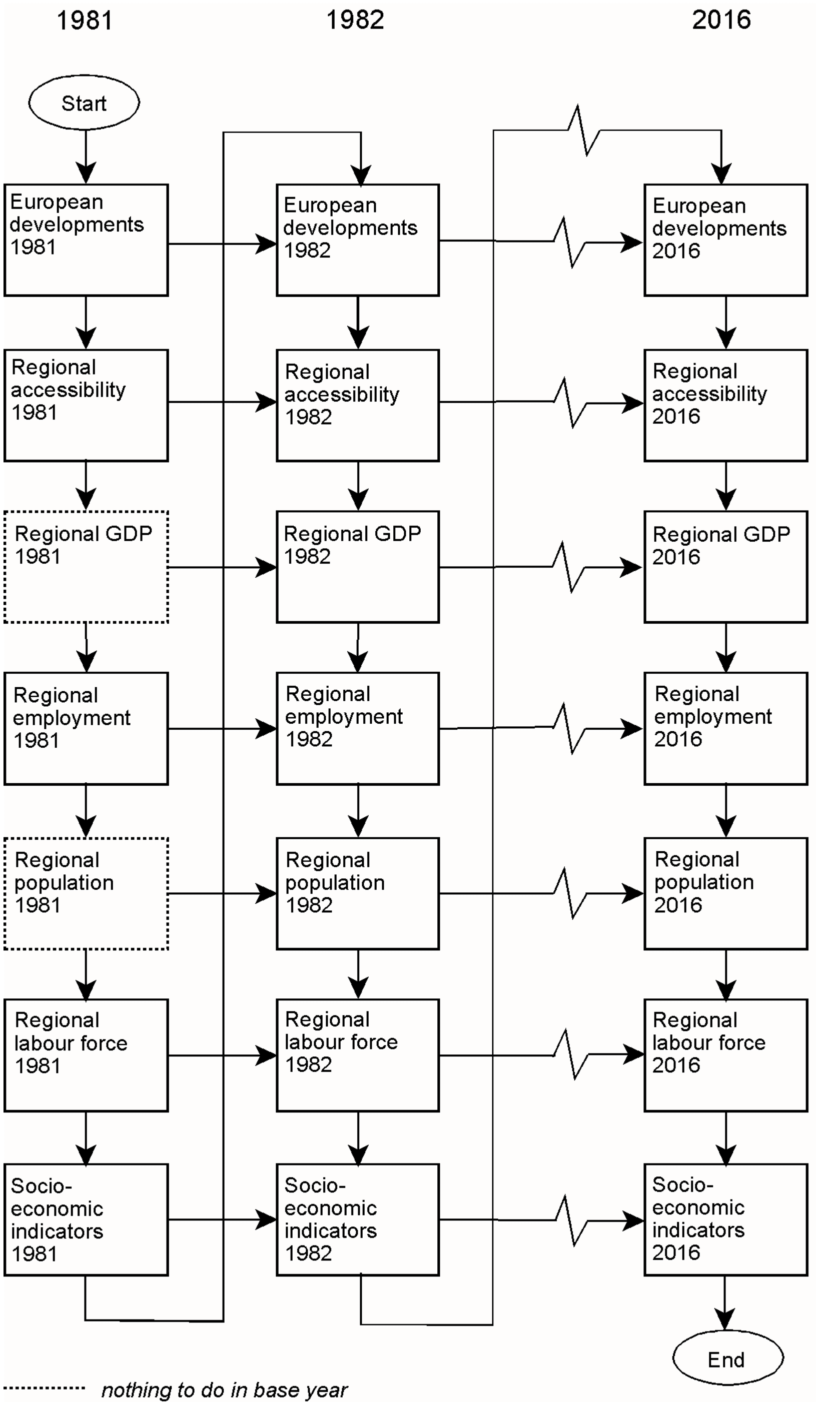


Figure 3.3. The recursive organisation of the SASI model

4. Submodels

In this section the specification of model variables and parameters of the seven submodels of the SASI model is presented in detail. The description of each submodel starts with the specification of the submodel as presented in Deliverable D8 (Wegener and Bökemann, 1998). Modifications in the model specification made since the completion of Deliverable D8 are pointed out and explained. The model software and the results of demonstration scenario simulations will be presented in Deliverables D13 and D15.

4.1 European Developments

The *European Developments* submodel is not a 'submodel' in the narrow sense because it simply prepares exogenous assumptions about the wider economic and policy framework of the simulations and makes sure that external developments and trends are considered in the model.

For each simulation period the simulation model requires the following assumptions about European developments:

(1) *Assumptions about the performance of the European economy as a whole*. The performance of the European economy is represented by observed values of sectoral GDP for the European Union as a whole and for 23 non-EU countries (see Figure 3.2 and Annex Table A1) for the years 1981 to 1997 and forecasts for the years 1998 to 2016. All GDP values are entered in ECU in prices of 1998.

(2) *Assumptions about immigration and outmigration across Europe's borders*. European migration trends are represented by observed annual net migration of the EU member states and the EU as a whole for the years 1981 to 1997 and of forecasts for the years 1998 to 2016.

These two groups of assumptions serve as constraints to ensure that the regional forecasts of economic development and population remain consistent with external developments not modelled. To keep the total economic development exogenous to the model means that the model is prevented from making forecasts about the general increase in production through transport infrastructure investments, although in principle its parameters are estimated in a way that makes it capable of doing that. Alternatively, it is possible to let the model determine the total level of annual GDP and to use the observed values of the period from 1981 to 1997 to validate these forecasts.

(3) *Assumptions about transfer payments by the European Union via the Structural Funds and the Common Agricultural Policy or by national governments to support specific regions.* European and national transfer payments are taken into account by annual transfers (in ECU of 1998) received by the regions in the European Union during the period 1981 to 1997 and forecasts for the period 1998 to 2016. These data are provided only for those regions that actually received financial support in the past or are assumed to receive support in the future.

(4) *Assumptions about immigration policies by European countries*. Given the expected rapid population growth and lack of economic opportunity in many origin countries, total European immigration will largely be influenced by policy decisions by national governments. These assumptions are reflected by upper limits for annual immigration from non-EU countries to the countries of the European Union for the years 1981 to 1997 and forecasts for the years 1998 to 2016.

The data for these four types of assumptions do not need to be provided for each year nor for time intervals of equal length as the model performs the required interpolations for the years in between.

(5) *Assumptions about the development of trans-European transport networks (TETN).* The European road, rail and air networks are backcast for the period between 1981 and 1996 and, based on assumptions on the development of trans-European networks, forecast until the year 2016, both in five-year increments. The *base forecast* or *base scenario* is defined as the implementation of the fourteen trans-European transport network priority projects approved on the Essen summit.

(6) *Assumptions about policy decisions on the trans-European networks*. A *policy scenario* is a time-sequenced investment programme for addition, upgrading or closure of links of the trans-European road, rail or air networks. Policy scenarios are specified by adding different subsets of the remaining TETN links such as all planned TETN road projects, all planned TETN rail projects or all planned TETN road and rail projects (Spiekermann and Wegener, 1999).

4.1.1 European GDP

Economic forecasts are known to have large margins of uncertainty, since they are often influenced by unanticipated events. Most forecasts are therefore usually short-term or medium term. In the light of the uncertainties associated with long term forecasts, they can only be seen as one scenario out of many different possible developments. The approach adopted here is based on an extrapolation of trends observed since 1980, which is combined with scenarios of low and high growth to assess likely developments of the European economy to 2016. The projections serve as constraints to ensure that the regional forecasts for economic development are consistent with the external developments not modelled.

European Union GDP

Growth in gross domestic product (GDP) of the European Union since 1980 has been steady (Figure 4.1), with the only exception of 1993. After severe tensions in currency markets and the collapse of the European Monetary System, the European economy slid into recession at the end of 1992. It then shrank in the following months so that the growth rate of GDP was negative in 1993.

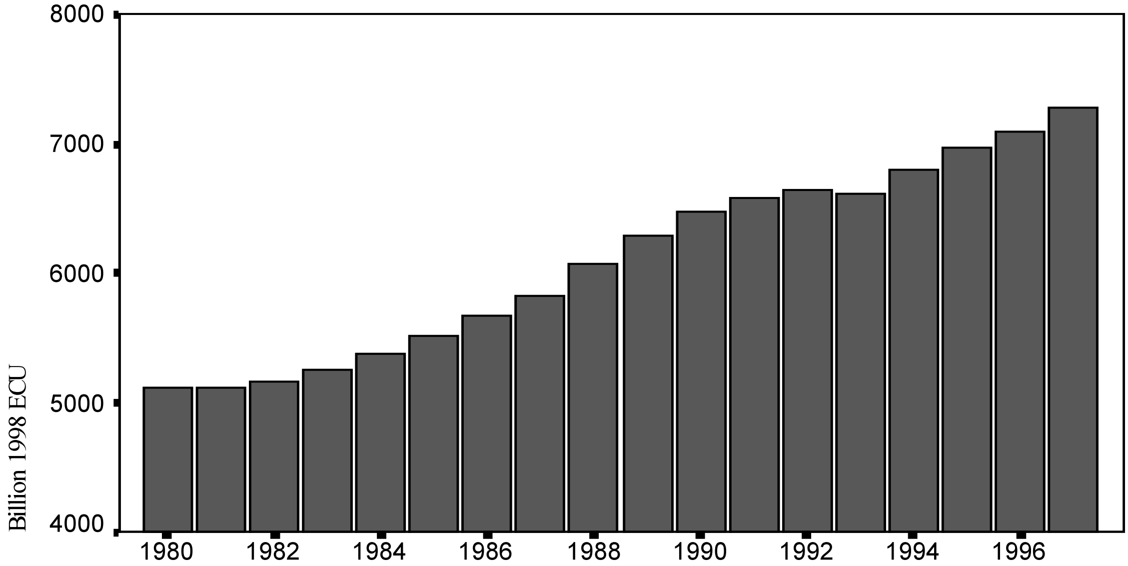


Figure 4.1. GDP in the European Union 1980-1997 in 1998 ECU (Eurostat, 1998a)

It can be seen that the average annual growth rate of GDP in the European Union has been lower in the first half of the 1990s than during the 1980s. Average GDP growth was about two percent between 1981 and 1986 and three percent in the second half of the 1980s, whereas in the first half of the 1990s average growth rates went down to only 1.5 percent.

The projections of total European Union GDP used as a model input are based on a univariate autoregressive integrated moving average (ARIMA) time series model of the Box-Jenkins type (Box and Jenkins, 1976). Rather than making use of explanatory variables to produce forecasts, time-series models rely only on the past behaviour of the variable being predicted. The first step in a Box-Jenkins analysis is to ensure that the variable to predict is 'stationary', that is, a variable whose mean, variance and higher order moments are invariant with respect to time. GDP is usually non-stationary because its mean and variance tend to grow with time. Taking first differences on the natural logarithm of GDP usually leads to stationarity. This creates a new series which is the input to the Box-Jenkins analysis. One advantage of the transformation is that the log in differences approximate ordinary growth rates, so that transforming the original series is almost like directly working on the growth rates.

GDP forecasts have been prepared for both the total European Union and individual member states. The models were estimated with only 18 observations, necessitating a model with only few parameters. The models applied incorporate a stochastic trend, that is, the difference operator was applied to the logarithm of the observed series to obtain a stationary transformation. The long-term growth rates are therefore only imprecisely estimated and, as a result, the confidence intervals of the projections increase exponentially.

Figure 4.2 presents observed GDP and GDP projections for the total EU. Incorporating 95 percent confidence intervals yield an optimistic and a pessimistic scenario besides the baseline scenario which is broadly consistent with the continuation of current trends. All of the three scenarios can be used to study the effect of different macro trends on the economies of the model regions.

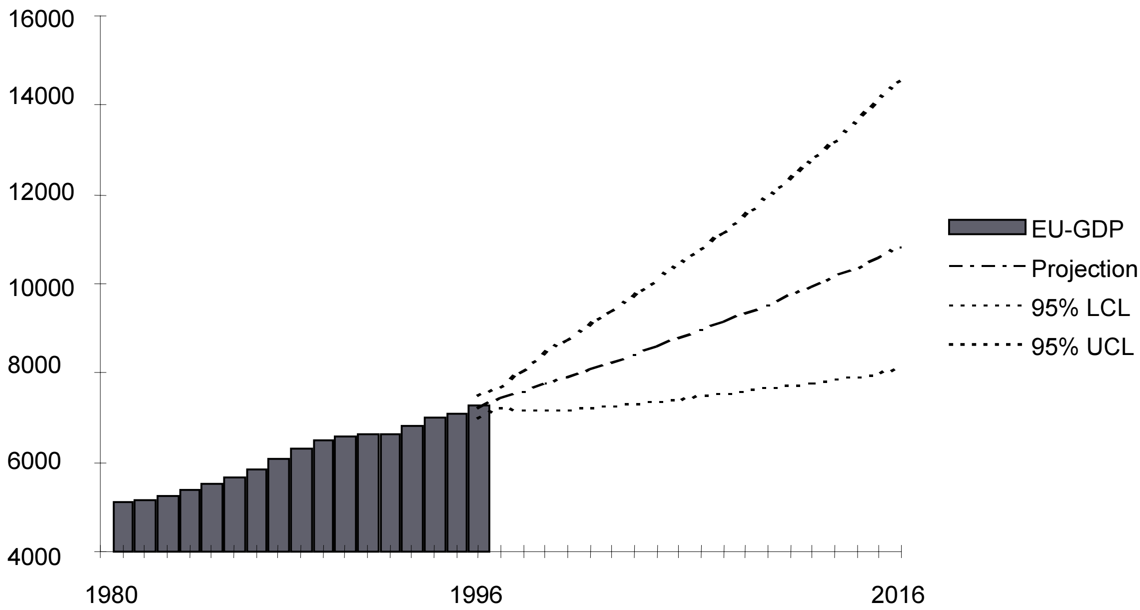


Figure 4.2. Observed and projected GDP of the EU 1980-2016 in Billion 1998 ECU

These GDP projections are very similar to the projections published by the OECD (1997), which are based on a sophisticated growth-accounting framework using structural equations for the main factors influencing factor productivity developments and economic policies (see Table 4.1). The OECD high-growth scenarios assume a continuing trend in liberalisation of trade and investment policies, accompanied by structural reforms and fiscal consolidation. The scenarios are based on assumptions of high rates of globalisation and international trade, leading to scale economies, higher capital productivity and a more efficient distribution of production world-wide. Following these assumptions, growth rates for all OECD countries rise significantly from those in the early 1990s to an average three percent per annum between 2000 and 2010 and decline slightly after 2010, largely as a result of demographic factors. Growth rate projections for the European Union are somewhat lower. Average annual growth under the high growth assumption for the European Union is projected at 2.8 percent between 2000 and 2010 and at 2.3 percent thereafter.

Table 4.1. OECD scenarios for average annual GDP growth (OECD 1997)

	1995-2000		2000-2010		2010-2020	
	High	Low	High	Low	High	Low
Total OECD	2.7	2.7	3.1	2.4	2.8	1.7
European Union	2.4	2.4	2.8	2.0	2.3	1.3
Other OECD Europe[1]	3.6	3.6	3.8	3.2	4.3	3.4
Non OECD	6.8	5.0	7.2	4.2	6.6	4.4
World	4.4	3.6	5.0	3.2	4.9	2.8

[1] *Other OECD Europe are: Czech Republic, Hungary, Iceland, Norway, Poland, Switzerland and Turkey.*

However all projections depend on factors such as the future development of the Single European Market, the position of the European Monetary Union and the Euro and international agreements on free trade as well as on the promotion of knowledge policies. Since the development of each of these factors is difficult to predict, long-term GDP projections remain uncertain.

The observed development of GDP by economic sector reflects the fact that the European economy continues to transform from what was fundamentally an industrial economy to a service economy sometimes characterised as 'post-industrial'. Services now dominate the EU economy not only in terms of output but also in terms of employment. The service sector accounts for well over 60 percent of GDP in all member states, with the exception of Finland and Ireland. Although the shares of the economic sectors differ considerably across the European Union, the trend of sectoral change has been observed in all member states over the last fifteen years. There has been a continuing steady decline of the shares of agriculture and manufacturing in total output (Quah, 1997).

Forecasting the sectoral composition of GDP is not as straightforward as the prediction of total GDP. While some experts suggest that past shifts in sectoral shares will sustain their dynamics in the future, others maintain that the sectoral composition of GDP is bound to settle at approximately current levels in the near future. For the SASI model a third in-between scenario is chosen, which combines different estimates by assigning likelihood values to each of them thus arriving at aggregate values for the future sectoral composition of GDP. As with overall GDP development, sectoral composition is contingent on a number of largely unpredictable factors ranging from EU transfer policies, such as the Common Agricultural Policy, to economic structures and trade patterns of future member states (OECD, 1997; Boin and O'Connor, 1997). The GDP input data used in the SASI model therefore represent rather moderate assumptions about future developments.

Non-EU countries

GDP forecasts for the 23 non-EU countries of the SASI system of regions are required for the calculation of accessibility indicators. These countries vary widely in their economic and political situation. The most significant difference exists between the advanced economies of the EFTA and EEA members Switzerland, Norway and Iceland and the rest of the European non-EU countries. However, even the transition economies of central and eastern Europe exhibit great disparities in economic performance. The prediction of GDP development in these countries is hampered by large margins of uncertainty related to political, social and economic changes. Previous GDP forecasts had to be amended several times in the light of new developments. Because of these uncertainties, several sources were compared for compiling GDP data for the 23 non-EU countries from 1981 to 2016 (United Nations, OECD, World Bank, IMF, Eurostat and European Commission DGII). In addition, individual adjustments were made based on estimations of the effect of political events such as continued tensions and military conflicts in ex-Yugoslavia.

4.1.2 Transfer Policies

The level of economic performance of a region is affected not only by its physical and human capital endowment and accessibility but also by transfer payments and subsidies by the European Union and by national governments. To promote the goal of equal standards of living and regional economic cohesion, the European Union and its member states provide funds for less developed and economically ailing regions. In this context, two categories of support payments relevant for the calculation of regional economic performance have to be distinguished. The first category comprises subsidies which are paid to producers, typically per unit or quantity of goods or services. Usually this type of subsidies is paid to offset the difference between the market price and a politically defined target price (European Commission et al., 1993). This category, which will be referred to as 'subsidies' in this report, are excluded from the calculation of the GDP at market prices. The second category comprises payments which are not targeted at securing pre-defined price levels and which serve to enhance the endowment with and the quality of production factors in private or public institutions or entire regions. Thus, payments by public institutions to private enterprises or public institutions, which are not price or market support but aim at promoting regional economic development, are referred to as 'transfer payments' in this report. Transfer payments are included in the calculation of GDP at market prices.

In published statistics, subsidies and transfer payments are categorised according to donor institutions (European Union, member states etc.). The only exception are the agricultural subsidies which are integrated into one category irrespective of the funding source. The following sections describe the categories as provided by the statistics and their assignment to either the 'subsidies' or 'transfer payments' type.

National transfer payments

At the national and regional levels, there is a broad variety of vertical and horizontal monetary flows targeted at stimulating economic growth and technological innovation. In 1980, the expenditure of member states for business investment incentives amounted to some ECU 5.1 billion and exceeded ECU 7 billion by the year 1983 (Yuill et al., 1990). Subsidies with a clearly regional framework account for only 25 percent of all economic aid regimes to the productive sector within the member states (Commission of the European Communities, 1990). For the purpose of the SASI model, all public and private expenditures on sectoral and individual business assistance (business rescue programmes, loans, tax breaks and all other incentives) are excluded from consideration because of the intractable nature of modelling general monetary flows in a region. In this context, only funds that are solely earmarked for regional purposes by public authorities are included in the database.

One of the few data sources on national transfer payments is provided in the European Commission's Fifth Report on Regional Cohesion and Competitiveness (European Commission, 1994). It contains per-capita expenditure in subsidised regions and the percentage of subsidised population by member state. However, the information provided is not sufficient to allocate the national totals to subsidised regions at the NUTS-2 level. A second data source is provided in the 1996 Cohesion Report (European Commission, 1996) in the form of a map which shows the distribution and intensity of national transfer payments. None of both sources provides regional data on national subsidies suitable for the SASI model.

However, by combining both the data on national totals and the spatial categorisation, it is possible to assign values for national subsidy payments to the SASI regions. The process is divided into the following steps:

(1) Calculate national total subsidies from per-capita subsidies in subsidised regions, percentage of subsidised population and population data.

(2) Assign distribution keys to regions using the map categories. As only positive monetary flows into regions are considered for the SASI model, regions with a negative balance are assigned to the category 'no subsidies'. For a second category of regions, it is assumed that these regions receive 30 percent of the average national per-capita subsidies, the third category receives 70 percent and the fourth 130 percent.

(3) Calculate weighted regional subsidised population by multiplying the population in the subsidised regions with the regional distribution keys.

(4) Distribute subsidies in ECU of 1998 to the regions for the years 1981, 1986, 1991 and 1996 in proportion to weighted regional subsidised population.

(5) Calculate per-capita subsidies in subsidised regions.

As a result of these calculations, a complete database for all SASI regions is available containing data on national subsidies for the years 1981 to 1996.

Regional subsidies by member states vary greatly throughout the European Union. Even though national transfers are not comparable at the European level, since they are based on considerations within national systems, it becomes clear that subsidies are highest in countries with geographically strongly polarised economies (Germany, Italy, Spain etc.). Figure 4.3 shows the distribution of national subsidies per capita in the European regions in 1996.

The method used to forecast national subsidies is mainly based on an extrapolation of previous trends, since subsidisation patterns remained relatively constant over the observed period (1981-1996). Additionally, impending policy changes are taken into account. In general, national policies will increasingly adopt the strategic guidelines the European Union has set up for structural funds. The following assumptions reflect the most likely development of national transfer payments until the year 2016:

- In the foreseeable future, member states will not cease to pursue their individual regional policy agendas. Nevertheless, as national policies will be tied more closely to EU policies and standards, a slight general decrease in national transfer payments can be assumed.

- Equivalently to EU policies, member states will increasingly abandon a categorisation of subsidised regions by the 'watering-can principle' (Santer, 1998). Most member states will focus the flow of subsidies on regions in genuine need, whereas the volume of subsidies for regions with less grave economic problems is likely to diminish in the future. In terms of the categorisation of regions used above, this can be reflected by a reduction of regions in the '30-percent' and '70-percent' categories in most countries.

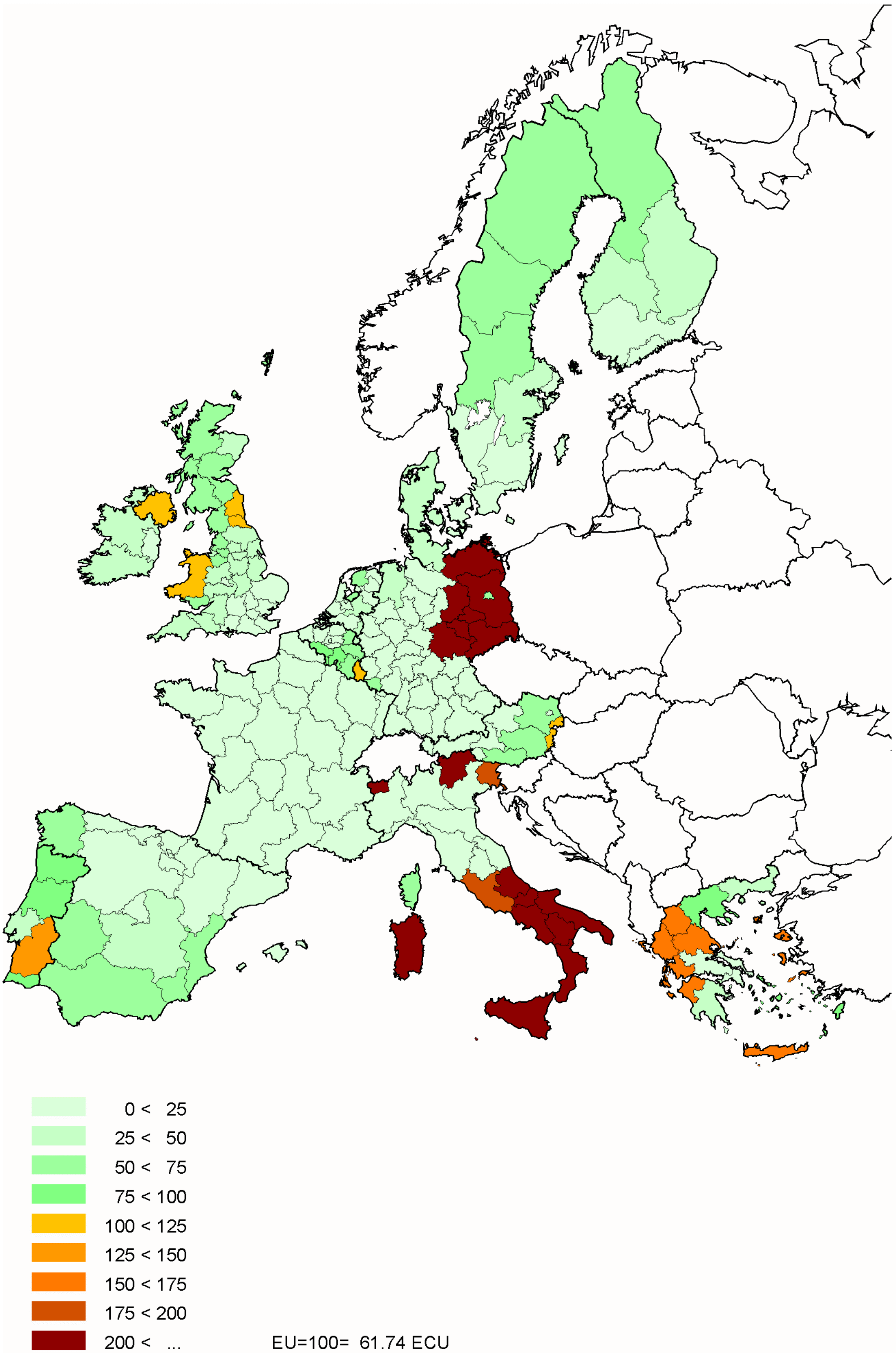


Figure 4.3 National transfer payments per capita in 1996

- EU guidelines require national institutions to align criteria for national subsidisation with EU standards. The definition of 'lagging' and 'leading' regions is therefore likely to refer to European rather than national standards which implies that the nationally subsidised regions will by and large be identical with the regions supported by the European Union (see below). In some cases, however, deviations from the European territorial definition will remain due to specific national policy considerations.

- Thanks to an extensive regional support policies, the new German Länder received 92.5 billion ECU of incentives and subsidies in 1998, of which about 8 billion ECU were subsidies in the narrower definition used here. It can be assumed that the current high level of subsidisation will not be maintained in the future because some of the support programmes are due to be phased out in the near future. A reduction of funds to 50 percent of the present volume within ten years seems to be a realistic forecast for the SASI model.

Based on these assumptions, national subsidies were predicted for each SASI region so that a complete database on national subsidies from 1981 to 2016 is available.

European Union Structural Funds

There are great disparities in economic performance between the regions in the European Union. One of the main political objectives of the European Union is the economic development of regions which are lagging behind the average of the Union. This is done by the EU Structural Funds. Today in some regions the magnitude of the structural expenditures by the EU is in the same range as the increase of the economy as such. Therefore transfer payments to assist specific regions are a factor to be included in the SASI model.

Data on the expenditures of the Structural Funds are provided in the Annex of European Commission (1997a) for the EU member states for the past and the current funding period. The past, terminated phase covered the years 1989-1993, while the current funding period covers the years 1994-1999. However, because the regions in the report are not in all cases similar to the NUTS-2 regions used in the SASI model, several transformations had to be made. For the terminated and the current funding period, transfer payments serving the following policy objectives are differentiated:

- Objective 1: Economic development of regions whose development is lagging behind
- Objective 2: Economic conversion of declining industrial areas
- Objectives 3 and 4: Economic support for youth and long-time unemployment
- Objective 5a: Economic adjustment of the agricultural sector and the fishing industry
- Objective 5b: Economic diversification of rural areas
- Objective 6: Development of sparsely populated regions in Sweden and Finland

Objective 6 was introduced with the entry of Sweden and Finland to the European Union. So this objective was not included in the first, terminated phase.

Besides assistance by Objectives, there have been attempts to assist specific regions: The *Integrated Mediterranean Programme* (IMP) was the precursor for the objective funding system before 1989. Because there has still been money spent from that programme at the beginning of the first funding period, it has to be considered. Objectives 1, 2, 5b, 6 and the Integrated

Mediterranean Programme are determined spatially, while the other objectives are not limited to certain means within the countries. The Cohesion Fund is exclusively for Greece, Spain, Ireland and Portugal, but is not further spatially determined to regions.

The total expenditures per region are calculated as the total over all Objectives, Community Initiatives, the Cohesion Fund and the IMP. Because the source contains data for the whole funding periods as such, the yearly amount is calculated by dividing the totals by the number of years. All these totals are broken down to NUTS-2 regions. In case there was no regional differentiation available, in particular for Objectives 3, 4, and 5a, the funds were allocated to the regions in proportion to regional population.

Figure 4.4 shows total public expenditures per capita per year in ECU by NUTS-2 region in the funding period 1994-1999. Portugal, Ireland and Greece received the highest level of transfer payments with more than 200 ECU per capita per year. Some regions in the north of Spain as well as the Highlands in Scotland show a similar level. Other regions in central Europe and in the United Kingdom received less than 60 ECU per capita per year, with the exception of the new German Länder, which received between 120 and 200 ECU.

The transfer payments received by a region have to be seen in relation to total regional per-capita GDP. In the funding period 1989-1993, transfer payments represented 0.02 percent of total GDP in Hamburg, whereas they amounted to 6.23 percent in Alentejo. The average share over all regions was about 0.6 percent. In the funding period 1994-1999 the smallest share was observed for Luxembourg with 0.03 percent, whereas again Alentejo showed the greatest share with 12.07 percent. The average share increased to about 1.0 percent.

Future transfer payments

In the context of the integration of east European countries and in anticipation of new member states of the EU, the European Commission decided to reform the system of Structural Funds in the Agenda 2000 (European Commission, 1999c). The propositions given there are the basis for the development of the Structural Funds until 2006. According to the Agenda 2000, the number of objectives is reduced to three:

- The new Objective 1 ('Development of regions whose development is lagging behind') is proposed to cover the old Objectives 1 and 6.

- The new Objective 2 ('Economic and social conversion of regions in structural crisis') is to cover the old Objectives 2 and 5b.

- The new Objective 3 ('Development of human resources') is proposed to cover the old Objectives 3 and 4.

This concentration of programmes aims at raising the effectiveness of the Structural Funds. The Agenda 2000 does not contain any regional differentiation of funds, but proposes detailed criteria for the distribution and for the definition of assisted regions.

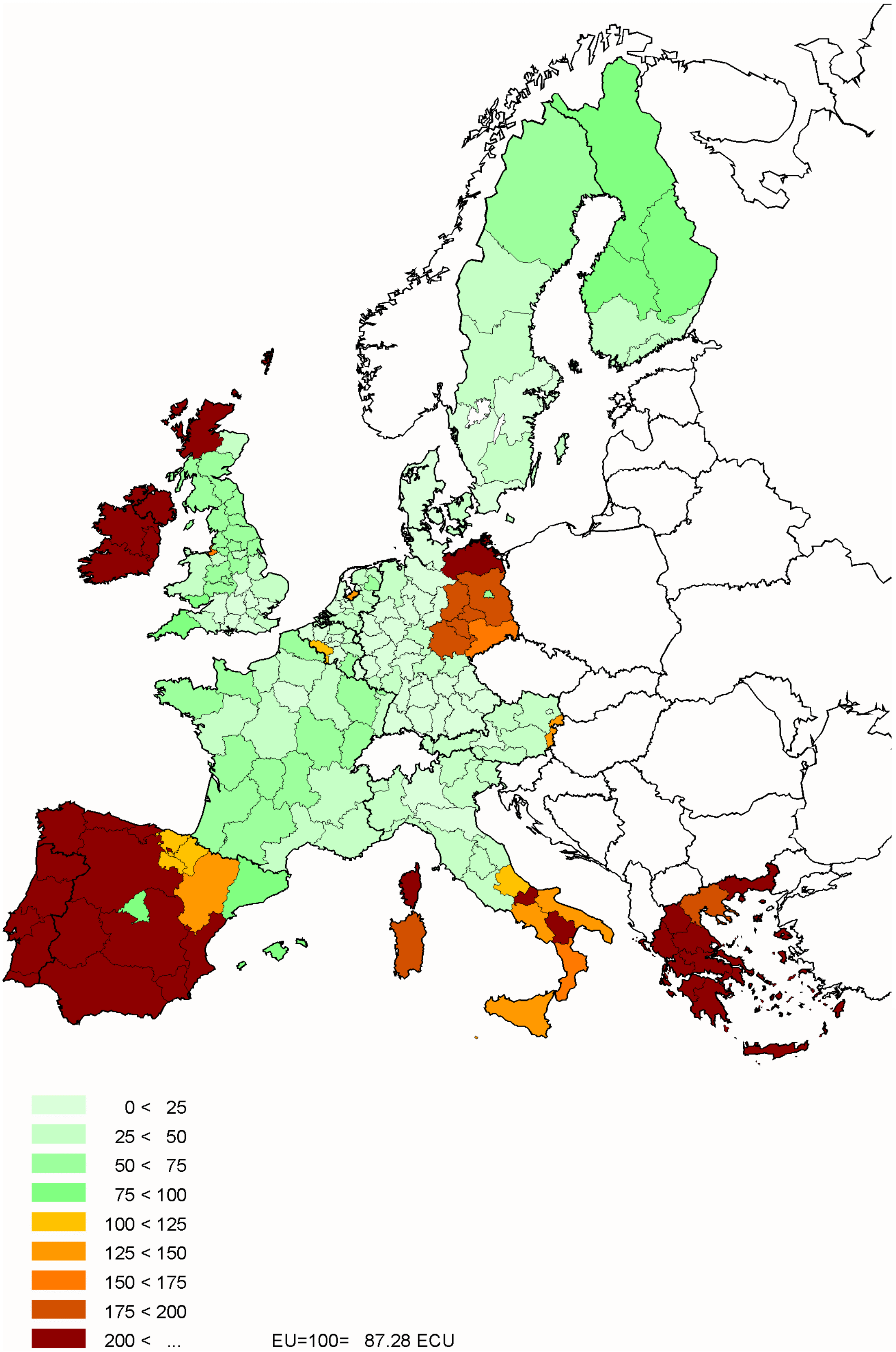


Figure 4.4. Total transfer payments per capita per year in 1994-1999

Regions eligible under Objective 1 are NUTS-2 level regions whose per-capita GDP (measured in PPS) is less than 75 percent of the Community average. Additionally, the overseas non-European French, Spanish and Portuguese regions plus regions currently eligible under Objective 6 are also automatically under the new Objective 1. The European Commission (1999a) established a list of regions which will be eligible for Objective 1 between 2000 and 2006 based on agreements made at the Berlin 1999 summit (see Figure 4.5). Funds for those regions in transition, which are still eligible under Objective 1 in the current funding period until end of 1999, but which do not meet the criteria for the new Objective 1, are phasing out as the amount of money is slowly reduced over the next years.

Regions eligible under the new Objective 2 are regions which satisfy one of the following criteria:

(a) industrial areas, whose unemployment rate is higher than the Community average and whose percentage share of employment in industry is higher than the Community average and where is a decline in this employment category;

(b) rural areas which satisfy one of the following criteria
- a population density of less than 100 people per km^2 or a share of agricultural employment in total employment which is at least double the Community average
- an unemployment rate above the Community average or a decline in population.

(a) urban areas which meet one of the following criteria
- a rate of long-term unemployment higher than the Community average
- a high level of poverty, including poor housing conditions
- a particularly degraded environmental situation
- a high crime rate
- a low level of education among the resident population.

(c) fisheries-dependent areas which have a significant share of employment in the fisheries sector and restructuring problems leading to a significant decline in employment in this sector.

The criteria for Objective 2 are to be applied to NUTS-3 regions. As the SASI model considers NUTS-2 regions, the areas and the number of people covered by Objective 2 are overestimated. Recently the European Commission (1999b) published a first list of areas undergoing socio-economic conversion which will benefit from new Objective 2 for Belgium, Denmark, Germany, the Netherlands and Finland. Final decisions on areas eligible under Objective 2 will be taken at end of 1999. Similar to Objective 1, areas covered by Objectives 2 and 5b for the 1994-1999 period, which do not meet the criteria for the new Objective 2, gain benefit from degressive transitory support until 2005.

Regions eligible under the new Objective 3 will be all regions outside the areas covered by the new Objectives 1 and 2. Because of the NUTS-3 level problem in Objective 2, regions assisted by Objective 3 are not only remaining regions not assisted by Objectives 1 and 2, but regions which also benefit from them. This means, it is assumed that all NUTS-2 regions assisted by the old Objective 3 will also be assisted in the next funding period with the same percentage shares as in the funding period 1994-1999.

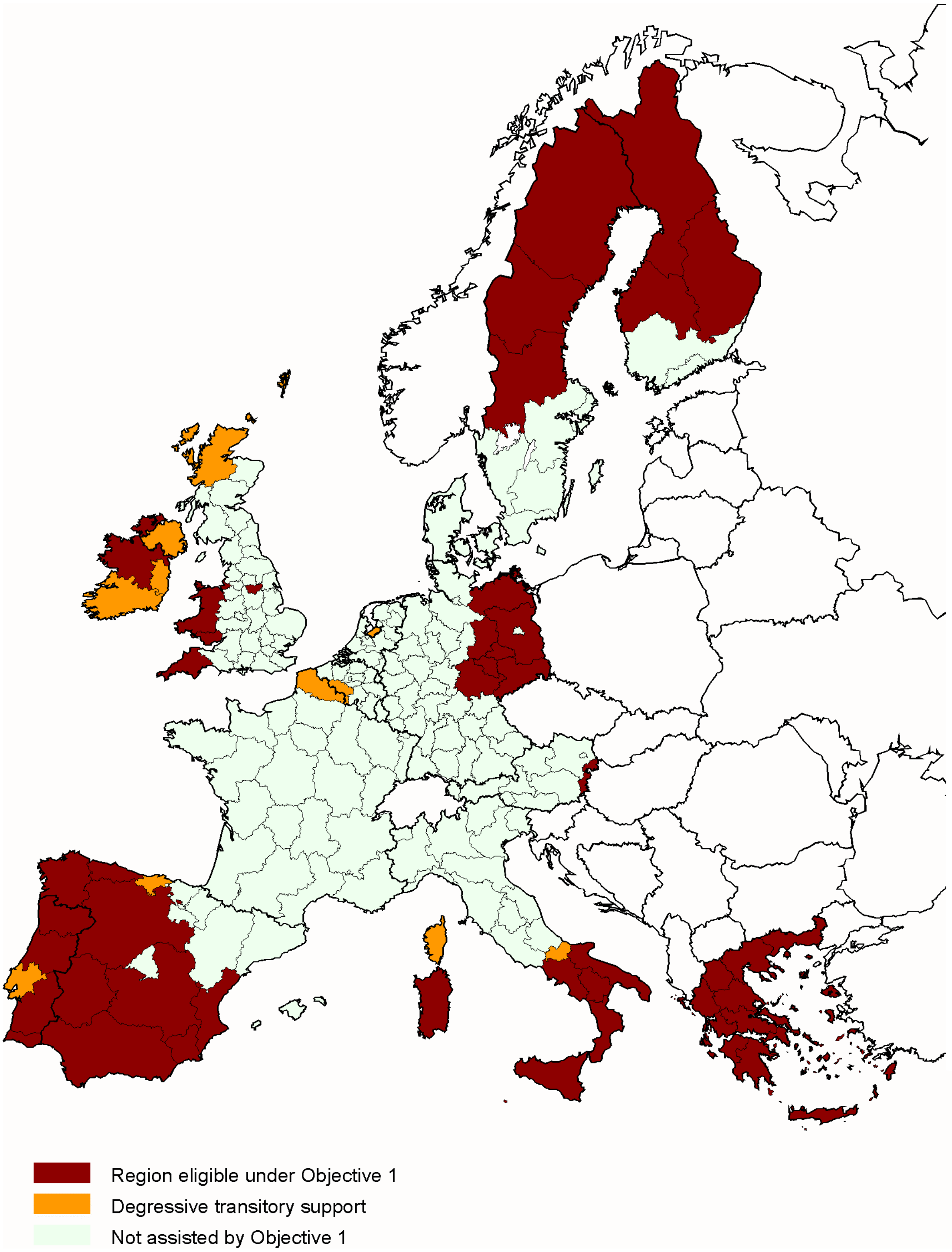


Figure 4.5. Regions eligible under the new Objective 1 (European Commission, 1999a)

Since regions eligible under new Objective 1 are approved and partly regions eligible under new Objective 2 are approved as well, only regions which are likely to be eligible under Objective 2 (for the remaining countries) and Objective 3 in the forthcoming funding period 2000-2006 have to be determined. This is done by applying the criteria given to the basic economic data as follows.

According to the Annex of European Commission (1998c), Table 4.2 gives the proposed total financial volume of the Structural Funds for the next funding phase. It is further proposed, that about 52 percent of the volume is spent for Objective 1, 25 percent for Objective 2 and 7 percent for Objective 3, and that the remaining volume of 16 percent is reserved for new EU member states, of which 2 percent is spent before their entry. After the determination of the eligible regions, the total expenditures are spatially broken down on the NUTS 2 level in proportion to population or, in case of Objective 3, by using the percentage shares of the last funding period. For the time period 2007-2016 it is assumed that the same regions as determined for the period 2001-2006 are assisted and that the amount of the expenditures will be as in 2006 (including inflation).

Table 4.2. Structural Funds for 2000-2006 in 1998 MEURO (European Commission, 1998c)

Objective	2000	2001	2002	2003	2004	2005	2006	Total
Objective 1 (52 %)	16.95	17.38	16.95	16.41	15.81	15.27	14.78	113.57
Objective 2 (25 %)	8.15	8.36	8.15	7.89	7.60	7.34	7.11	54.60
Objective 3 (7 %)	2.28	2.34	2.28	2.21	2.13	2.06	1.99	15.29
New member states (16 %)	5.22	5.35	5.22	5.05	4.87	4.70	4.55	34.88
Total Structural Funds	32.60	33.43	32.60	31.56	30.41	29.37	28.43	218.40

Agricultural transfer payments

Monetary and fiscal interventions in the primary sector are among the most prominent policies of the European Union. Support measures related to the Common Agricultural Policy (CAP) account regularly for more than fifty percent of the Union's total budget. The CAP is the single largest sectoral policy of the EU to incite large-scale income distributions in the form of transfer payments from consumers and taxpayers to the producers of agricultural goods (European Commission 1996, 60). Particularly in regions with a high share of agriculture and agriculture-related industries, CAP subsidies are an important factor in the regional economic accounts. This is why agricultural subsidies are considered in the SASI model.

Agricultural transfer payments follow a complex pattern of direct and indirect market support mechanisms at different levels. The OECD introduced a dichotomous model to categorise agricultural transfer payments which is also the basis for EU calculations (OECD 1996; European Commission, 1996, 140). This approach divides agricultural support measures into Producer Subsidy Equivalents (PSE) and Consumer Subsidy Equivalents (CSE), where PSE indicate the amount of monetary transfers to agricultural producers resulting from agricultural policies concerning domestic market supports (transfer from consumer to farmer) and direct subsidy transfer payments (transfer from taxpayer to farmer). Consequently, the CSE indicates the amount of monetary transfers to consumers as a result of agricultural policies. A negative value of this indicator signifies that consumers had to pay an implicit tax on agricultural products due to specific political regulations (NLE, 1998). For the purpose of modelling the economic regional and structural effects of agricultural transfer payments, PSE is the indicator to be considered. PSE is a compound measure that comprises direct payments and net trade gains of agricultural producers in a region. Since net trade gains are the outcome of complex trade and market structures, which are difficult to grasp in a model of regional economic development, it is more appropriate to consider solely gross direct subsidy transfers to agricultural producers.

Data on agricultural accounts comprising information on subsidies, taxes and gross value added in the primary sector can be extracted from the Regio electronic database. The database contains separate data series albeit in incomplete form for each of the above categories from 1980 to 1996 at NUTS-2 level. The following steps had to be taken to fill up the gaps in the database:

(1) *Disaggregation.* In some cases data were only available at the national level and not at the NUTS-2 level. Therefore, the national figures were disaggregated according to the distributions of another year for which a complete dataset was available. If NUTS-2 data were missing for all years, the national data was disaggregated in proportion to population.

(2) *Back- and forecasting.* Data on agricultural accounts are not available for all countries and all years in the 1980s. Missing national values were estimated using the average of the relative differences to the previous year for countries with complete datasets and modifying the base values accordingly.

As a result, a database on agricultural subsidies, agricultural taxes and agricultural GVA is available for all NUTS-2 regions from 1980 to 1996 (Figure 4.6). Figures are even available for countries which joined the EU after 1980 (Greece, Spain and Portugal) because national subsidies are contained in the figures as well.

Agricultural transfers make up a large percentage of the agricultural value added in most regions. The average share of subsidies on the market value of agricultural produce of all regions is 17.4 percent. A comparison of the absolute amounts of agricultural subsidies shows that the volume of these payments has increased steadily over time so that the total sums for most countries exceed 1 billion ECU per year, in some cases they amount to more than 5 billion ECU in 1996 (France 8.3 billion, Germany 6.1 billion and Spain 4.6 billion). Data broken down to the regional level reveal that the total amount of agricultural subsidies varies greatly within the member states.

Major policy changes are imminent with the implementation of the Agenda 2000 of the European Union with severe cutbacks of agricultural subsidies and market support measures being expected. The contents of the reform are influenced by the frequent cases of inefficient allocation of funds in the past, the agricultural structure of the membership applicants and the outcomes of the negotiations on global tariff agreements in the agricultural sector. The following assumptions concerning the development of agricultural subsidies can be derived from the Agenda 2000:

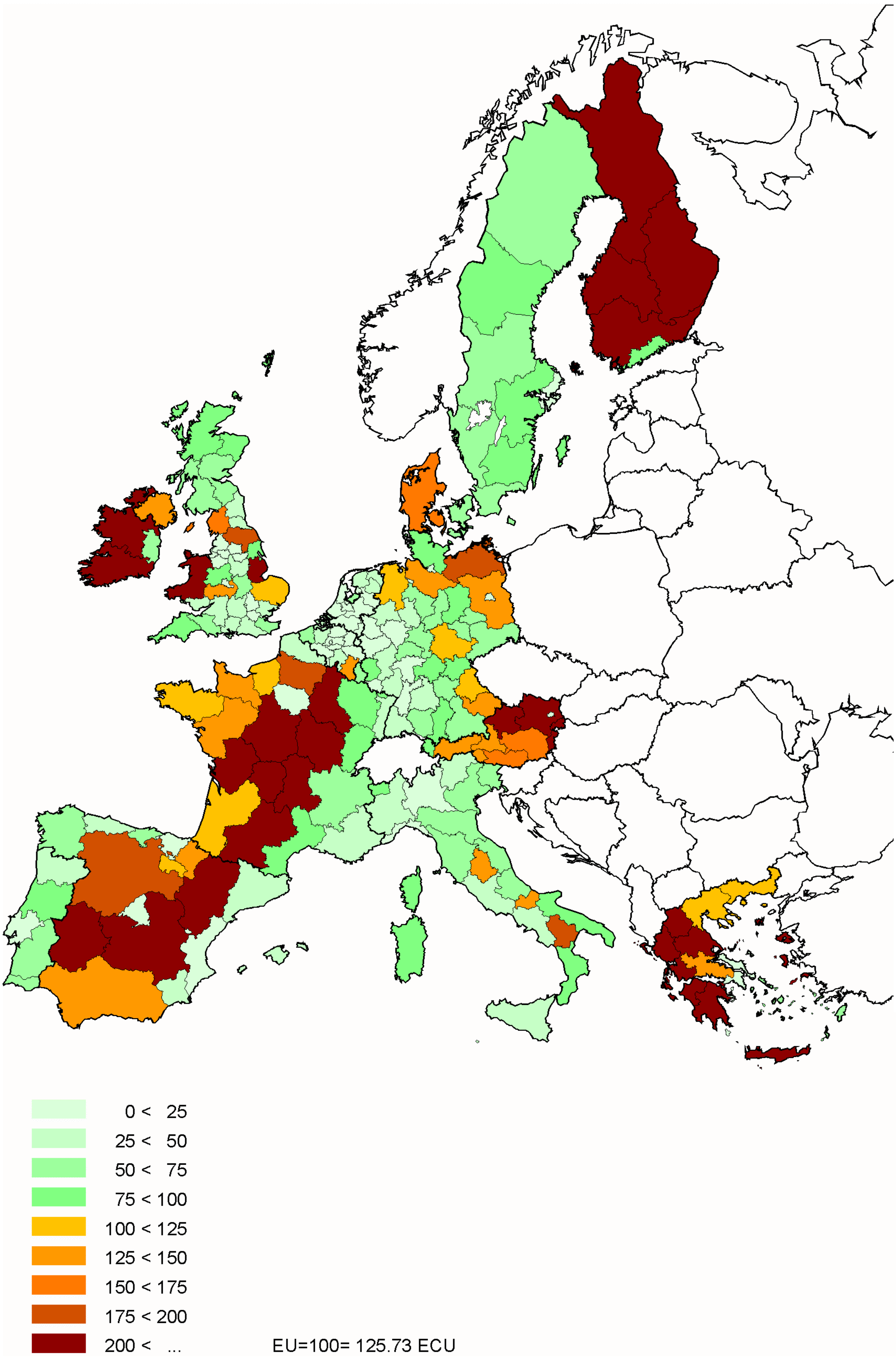


Figure 4.6. Agricultural subsidies per capita in 1996

- The overall principle of the Agenda 2000 with respect to agriculture is to cut down the market and price support measures (CSE) and increase the volume of subsidies paid directly to the farmers (PSE). International pressure on the European Union to abandon price support measures increases the probability of a severe CSE cutback after the 1999 global talks on market liberalisation. However, as only PSE transfers are considered in the SASI model, it can be assumed that subsidies will rise with the advent of Agenda 2000 policies.

- The rise in PSE transfers is likely to be limited at the aggregate level because of the changing structure of the agricultural sector. The share of agriculture in economic activities is likely to decline further and, in addition, the agricultural produce will be produced by an ever diminishing number of active persons. The planned CSE reductions will catalyse this process. Therefore, in spite of growing volumes in agricultural goods production, the number of PSE recipients is likely to decline in the current member states. However, rationalisation and structural change potentials have to be assessed for each SASI region separately.

- Future member states are the most difficult factor in predicting the general development of agriculture in the EU. On the one hand, the new member states will require additional funding for technological modernisation and organisational adjustment. On the other hand, their mostly low-priced products would distort the current EU price system were they to join the Union now. In order to support modernisation, it is foreseeable that a special support and subsidisation system will be worked out for the new member states. It can therefore be assumed that the old member states will follow the guidelines of the Agenda 2000 as outlined above irrespective of the special requirements of the new member states.

Based on these assumptions, agricultural subsidies were predicted for each SASI region so that a complete database on this category from 1981 to 2016 is available.

4.1.3 Trans-European Networks and Transport Policies

The SASI model forecasts socio-economic development in the 201 SASI regions that have been defined as the 'internal' regions of the model (see Figure 3.2 and Annex Table A1). The 27 regions defined for the rest of Europe are the 'external' regions which are used only as destinations when calculating accessibility indicators. The four regions representing the rest of the world are neglected in the model.

The spatial dimension of the system of regions is established by their connection via networks. The centres of the regions are connected to the network by so-called access links. In SASI road, rail and air networks are considered. The 'strategic' road and rail networks used in the SASI model are subsets of the pan-European road and rail networks developed by IRPUD and recently adopted for the GISCO spatial reference database of Eurostat. The 'strategic' road and rail networks contain all TETN links laid down in Decision No. 1692/96/CE of the European Parliament and the Council (European Communities, 1996) and the east European road and rail corridors identified by the Second Pan-European Transport Conference in Crete in 1994 (European Communities, 1995) as well as additional links selected for connectivity reasons. The 'strategic' air network is based on the TEN airports and other important airports in non-EU countries and contains all flights between these airports.

Technically, the strategic networks are stored as separate ArcInfo coverages. The development of the networks over time is represented by link attributes. The coverages contain for each link in which year it is part of the strategic network and the respective attributes for those years. Export macros automatically generate input files for the accessibility model.

The networks will be used to calculate regional accessibility (see Section 4.2). For that the historical and future developments of the networks are required as input information. This development of the network over time is reflected in intervals of five years in the database, i.e. the established network database contains information for the years 1981, 1986, 1991, 1996, 2001, 2006, 2011 and 2016. The following sections describe the road, rail and air networks in more detail.

Strategic road network

The definition of the strategic road network starts with the generation of the 1996 network from the IRPUD base networks. The strategic road network includes all TEN road links, the *Crete Corridors* as well as some additional links to guarantee connectivity of all centroids of the SASI system of regions. For each link information on length, link category (motorway, dual carriageway, other road, car ferry and Eurotunnel) and national speed limits for that link category are stored.

The historical networks for 1981, 1986 and 1991 are derived from the 1996 network. The principle is to have the same connectivity in the past networks as exists in the 1996 network. In general, two cases have to be distinguished for this:

- A link has been upgraded in the past, e.g. from a national road to a motorway, but the alignment has not changed. In that case the link category is altered for the respective year of the network.

- A new link has been constructed with new alignment (e.g. new motorway). In that case, the new link is part of the road network since its opening. In order to have the connectivity of the new link also in former years, an appropriate link of the base network is put into the strategic network. This link usually stems from a lower link category.

Once a link became part of the strategic network, the link will also be part of the strategic networks for the following years and will not be dropped. This results in increasing total network lengths over time.

Link categories of past networks are compiled from Shell (1981; 1992), ADAC (1987; 1991), Reise- und Verkehrsverlag (1987) and Michelin (1992a; 1992b). National speed limits are derived from ADAC (1999).

The generation of the strategic networks describing the future base scenario is based on the same principles as described above. Main sources for the future development of the road network are the recent TETN implementation report and a recent report on the priority projects of the European Commission (1998a, 1998b). It contains detailed information on a link by link base on the current status of the work (under construction, completed, planned or under study), the type of the project (motorway or high quality road, number of lanes, new construction or upgrading) and the estimated year(s) of completion. All TEN road links that are already completed in 1998 or are under construction will be used in the base scenario network; the links that are planned or are under study will be used in the infrastructure scenarios (see below).

Additional information for future road network developments for the European Union was compiled from ARAL (1997) and from other national sources for Belgium (Road Directorate Belgium, 1998), Germany (Bundesministerium für Verkehr 1992; 1997a; 1997b; DEGES 1995; 1996; 1998), Denmark (Road Directorate Denmark, 1998), Spain (Direccion General de Trafico, 1998), Finland (Finnish Road Administration, 1998), Sweden (Vägverket, 1997; 1998) and the UK (Department of the Environment, Transport and the Regions, 1997; Highway Agency, 1998a; 1998b; National Roads Directorate, 1998). The national sources give information on construction work of links that are included in the strategic network, but not part of the TEN programme. If no information is available for a link, it is assumed that no change will take place and the 1996 link category and alignment will be kept for the future networks. According to the supposed opening years of the links, the link attributes in the 2001, 2006, 2011 or 2016 network will be adequately changed or new links are included.

Table 4.3 shows that the total length of the strategic network is constantly increasing over time. There is a shift in link categories from roads to dual carriageways and motorways. While the length of regular roads is decreasing, there is, in particular, an increasing motorway length of approximately 4,000 km per five-year increment. The development of the strategic networks over time in terms of link category is presented in two sample maps: Figure 4.7 presents the strategic road network for 1996 and Figure 4.8 presents changes in the road network between 1996 and 2016.

Table 4.3. Road network length 1981-2016 by link category (in km)

Link category	1981	1986	1991	1996	2001	2006	2011	2016
Access link	1,042	1,042	1,042	1,042	1,042	1,042	1,042	1,042
Motorway	31,264	33,572	35,904	39,928	45,985	49,256	52,571	52,717
Dual carriageway	6,362	9,490	12,976	16,518	16,202	16,692	16,706	16,687
Other road	85,362	81,412	77,516	73,353	71,111	69,612	68,534	68,531
Car ferry	19,388	19,388	19,388	19,388	19,388	19,388	19,388	19,388
Eurotunnel	-	-	-	49	49	49	49	49
Total	143,418	144,904	146,826	150,278	153,777	156,039	158,290	158,414

The *Accessibility Submodel* requires for each link a link travel time. For the road network link travel times are derived from link categories (e.g. motorway, dual carriageway). Country-specific speed limits for each link category are used to estimate average link travel times, which take into account that in reality typical travel times are below speed limits. There are two exceptions from this principle, car ferries and border crossings.

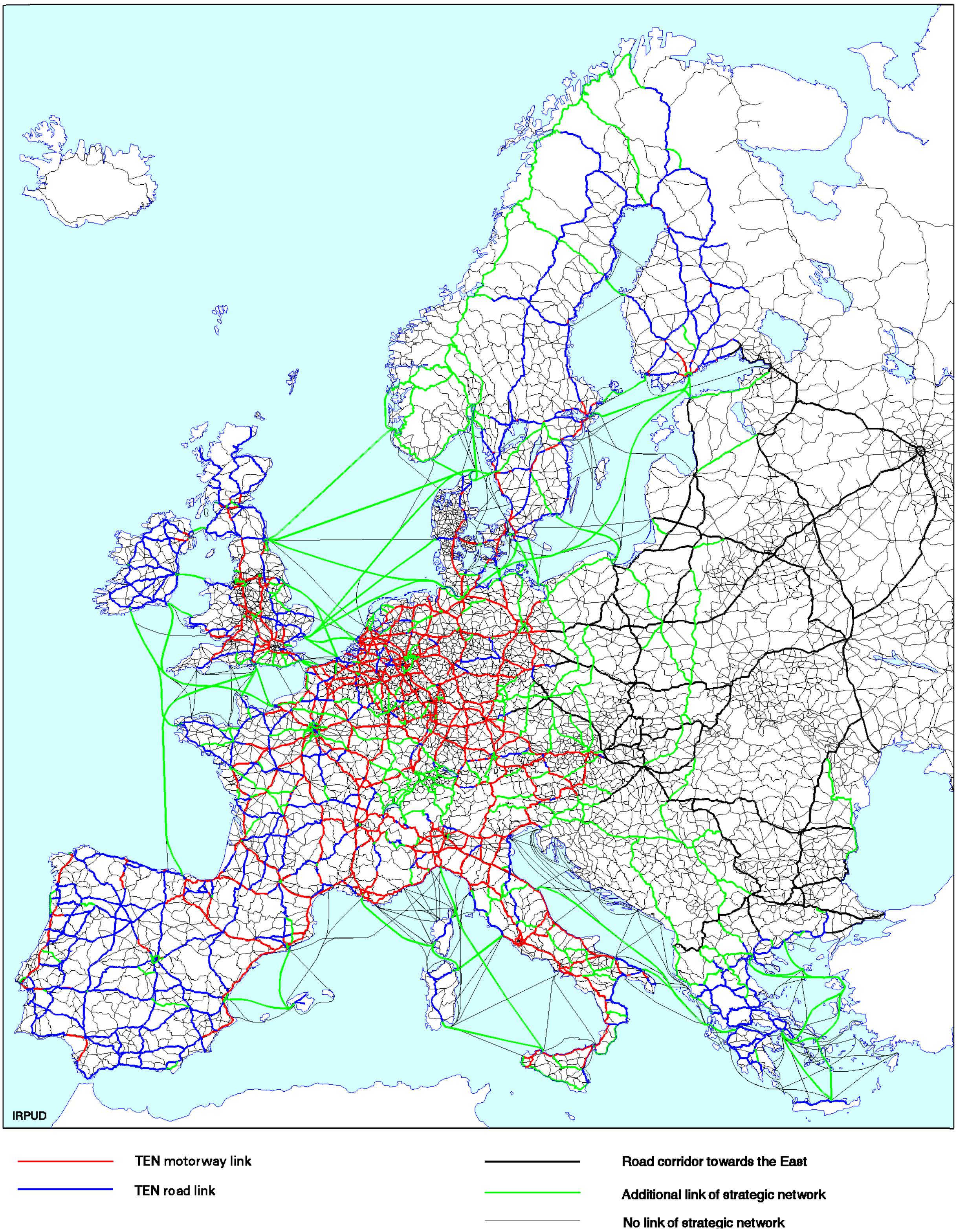


Figure 4.7. The SASI strategic road network by link category in 1996

Figure 4.8. Changes in the SASI strategic road network 1996-2016

The strategic road network contains car ferries in order to connect islands and to represent major European road travel routes, e.g. to Scandinavia, to the UK or to Greece. For car ferries, real travel times compiled from timetables or maps are used. A terminal time of 60 minutes is added to each ferry link.

Border waiting times had been a major concern in the past and will continue to be an issue for some European countries. In the road network border crossings are introduced as border links to which border waiting times have been assigned. Because there have been reductions and increases of waiting times during the last few years, a data set has been prepared which contains border delays between neighbouring countries for the years 1981, 1986, 1991, 1996 and as an assumption for the years 2001, 2006, 2011 and 2016. The fact that some states formed a single state in former years (e.g. USSR) and armed conflicts (former Yugoslavia) are taken into account. The waiting times are distinguished by trip direction, because especially between EU and non-EU countries the delays differ significantly. Waiting times for all border crossings between two neighbouring countries are equal and do not take account of different link categories or local circumstances. Table 4.4 gives an extract of the border waiting time data set produced for the entire time period 1981 to 2016.

Table 4.4. Examples of waiting times at road border crossings

Countries	Waiting times (min)							
	1981	1986	1991	1996	2001	2006	2011	2016
AT-DE	15	15	10	5	0	0	0	0
BA-HR	0	0	15	25	10	10	5	5
DE-PL	120	120	100	110	90	15	10	10
PL-DE	110	110	80	90	60	20	15	10
DE-BE	15	15	10	5	0	0	0	0

Strategic rail network

Similar to the road network the definition of the strategic rail network starts with the generation of the 1996 network from the IRPUD rail base network. Again, the strategic rail network contains all links defined in the TEN programme as well as the *Crete Corridors.* Furthermore, some additional links are added to guarantee connectivity of all centroids of the SASI system of regions. For each link information on length, link category (number of tracks, electrification, suitability for high-speed) and travel time are stored.

The generation of the past strategic rail networks differs from the procedure described for the road network. For rail, it was first checked which links of the 1996 network existed already in 1981. Most of the current links existed already in 1981 with the exception of the few new high-speed lines. In order to have the connectivity of the current high-speed lines in the 1981 network, corresponding conventional links are introduced in the 1981 strategic rail network. The new high-speed links are introduced into the strategic networks of 1986, 1991 or 1996 according to their opening year by replacing the corresponding conventional links. Figure 4.9 presents as a sample the SASI railway network for 1996.

Figure 4.9. The SASI rail network by TEN category in 1996

The definition of the future base scenario rail network follows the connectivity principle. The main source for the future development of the rail network is the recent TETN implementation report of the European Commission (1998a). It contains detailed information on a link-by-link base on the current status of the work (under construction, completed, planned or under study), the type of the project (upgrading or new construction, conventional or high-speed link) and the estimated year(s) of completion. If new railway links are to be constructed, these links are introduced to the network according to their estimated completion year as indicated in the TETN implementation report. If already existing links are to be upgraded, the link travel times are adjusted according to the type of the project. All TEN rail links that had been completed by 1998 or are presently under construction are used in the base-scenario network; links that are planned or are under study will be used in the infrastructure scenarios (see below).

Additional information from national sources was compiled for Belgium (Federal Ministry of Communications and Infrastructure, 1998), Denmark (Øresundskonsortiet, 1999), Germany (Bundesministerium für Verkehr, 1992; 1996; 1997c; Deutsche Bahn AG, 1999), Hungary (IMAV, 1998) and Sweden (Banverket, 1999; Øresundskonsortiet, 1999; Malmö City Tunnel Project, 1999). The national sources give information on the construction of links that are included in the strategic network but are not part of the TEN programme. If no information is available for a link, it is assumed that no change will take place and the 1996 link category and alignment is kept for the future networks.

Link travel times are not based on average speeds on link categories as in the road network but on real link travel times for 1981 and 1996 extracted from rail travel timetables (Thomas Cook 1981; 1996; Deutsche Bahn AG, 1996). Rail travel times for 1986 and 1991 have been generated by interpolating the travel times of 1981 and 1996. Only in case of new high speed railway lines (e.g. TGV lines in France, ICE lines in Germany) travel times are not interpolated but taken from travel timetables.

The TETN implementation report contains information on planned new (high speed or conventional) lines or planned upgraded lines. This information is used to make assumptions for speed and travel time changes on a country-by-country basis with respect to the new link categories. In some cases published future travel times for railway sections are used. If no upgrading is planned for a link, a modest acceleration of ten percent is assumed which reflects improvements in signalling systems, carriage technology and railway construction.

Strategic air network

The generation of the strategic air network had to be different from the generation of the road and rail networks. This is mainly because air networks do not consist of physical link infrastructure. The only physical infrastructure are the airports. Therefore, the generation of the strategic air network started with the definition of airports of strategic interest.

The airports forming the base of the strategic air network are all airports contained in the TEN programme. In addition, important airports in eastern Europe and other non-EU countries are included to guarantee connectivity of these regions.

The criterion for an airport to be a node in the air network is that it has at least one regular daily flight. Eight smaller airports (according to the TEN nomenclature so-called 'Regional and Accessibility Points') have only charter flights or flights on demand and have been excluded from the strategic network.

The airport systems in London, Paris, Berlin, Milano and Stockholm consisting of two or three airports each are treated as one single airport. So all flight connections are focussed vicariously on one airport (i.e. London-Heathrow, Paris-Charles de Gaulle, Berlin-Tegel, Milano-Linate, Stockholm-Arlanda).

All in all there are 327 airports establishing nodes of the air network. All regular flight connections between these airports form the 1996 air network. The information has been extracted from the *Air Traffic Databank* produced and maintained by Mkmetric (1998). The air network contains only non-stop relations between two airports. This means, for example, a flight from Madrid to Berlin via Frankfurt is divided into two flights, the first one from Madrid to Frankfurt and the second one from Frankfurt to Berlin. Furthermore, outward and return flights are stored as two separate relations. In total, there are 4,156 relations stored in the database. Charter flights, non-regular flights or tourist flights are not included. Figure 4.10 shows the SASI air network.

The travel time for each relation is based on scheduled flight times and given as an average travel time calculated over all flights over all wind exposures over all kind of planes of a certain relation. A terminal time of 60 minutes is added to each flight. Another important information is the number of flights on each relation. Because even the regular flights show great differences in the number of flights over the year, it is difficult to give a single value for the number of daily flights. Therefore, a frequency index is used as a measure for the quality of the relation. Lower frequencies are transformed into additional time penalties for a flight. The penalties are to be seen as an approximation for reduced opportunities to travel along that link and, in particular, for reduced possibilities for connection flights:

- 180 minutes for relations not every day with one flight per day at maximum
- 60 minutes for relation not every day but several flights per day possible
- 120 minutes for every day relation with one flight per day at maximum
- no time penalty for every day relation with several flights per day.

The creation of past air networks is a difficult task. There is no source available which gives air networks for the past for entire Europe. Therefore simple assumptions had to be made about the air networks for 1981, 1986 and 1991. The basic assumption is that regional airports played a minor or no role at all in the beginning of the 1980s. This was reflected by adding a time penalty on 1996 air travel times for flights going from or to regional airports: the time penalty was 30 percent for 1981, 20 percent for 1986 and 10 percent for 1991.

The generation of the future air network is a difficult task as well. Because the basic characteristic of the air network is that all airlines design their own flight connection system on own responsibilities, there are no official plans or even planning authorities for the development of the air network. Given that and the focus of the project on changing rail and road infrastructures the future air networks will be the same as the current air network, i.e. no changes will be implemented neither for the base scenario nor for the infrastructure policy scenarios.

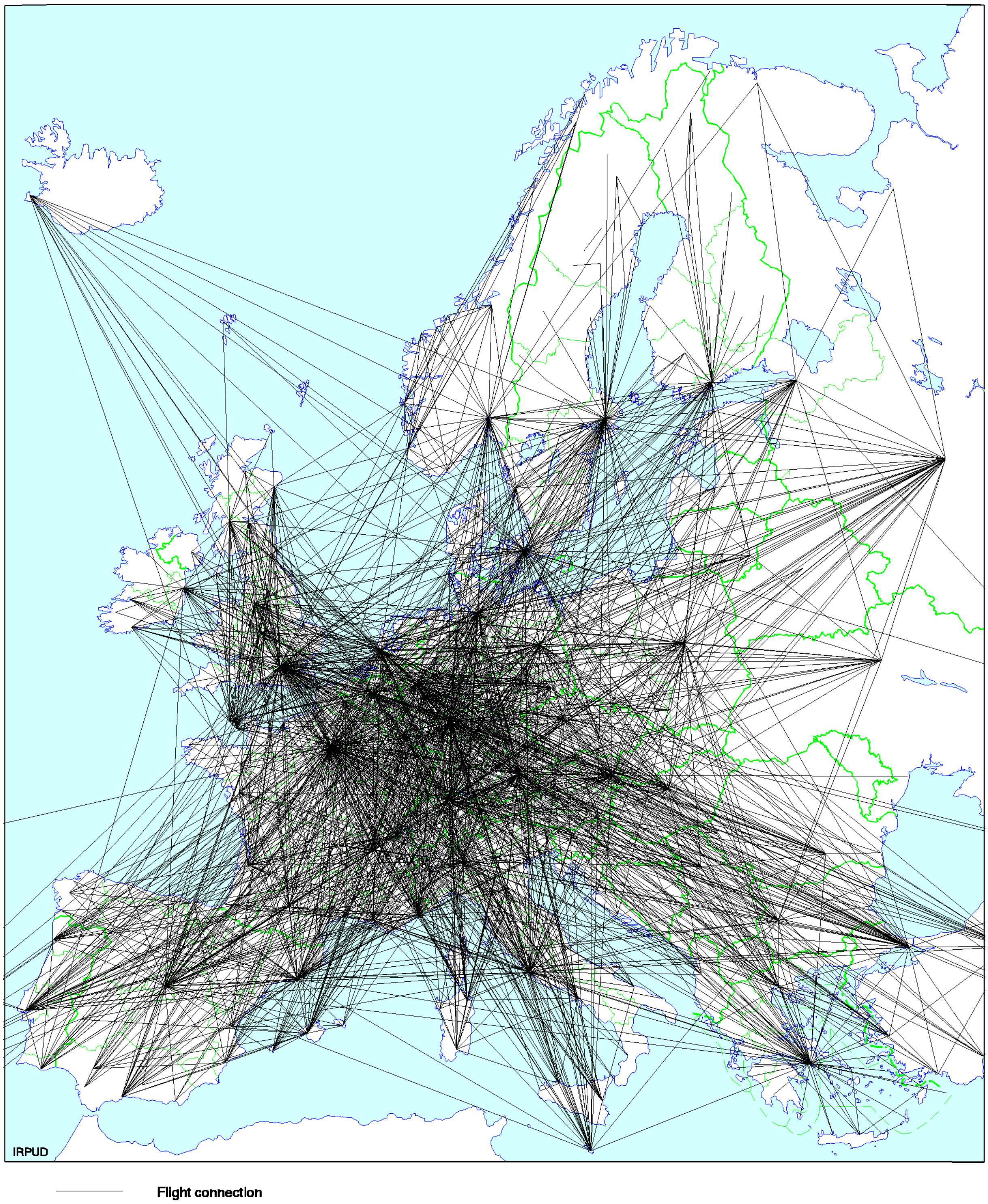


Figure 4.10. The SASI strategic air network in 1996

Transport infrastructure scenarios

The main objectives of the trans-European transport networks is to ensure cohesion, interconnection and interoperability between the transport networks of the member states and between the modes to establish a common access quality for all people living in the EU (European Communities, 1996). As the purpose of the SASI project is to estimate impacts of different policy decision on the TETN programme, several policy scenarios have to be established. The 'backbone' of these scenarios is the network development over time from 1981 to 2016.

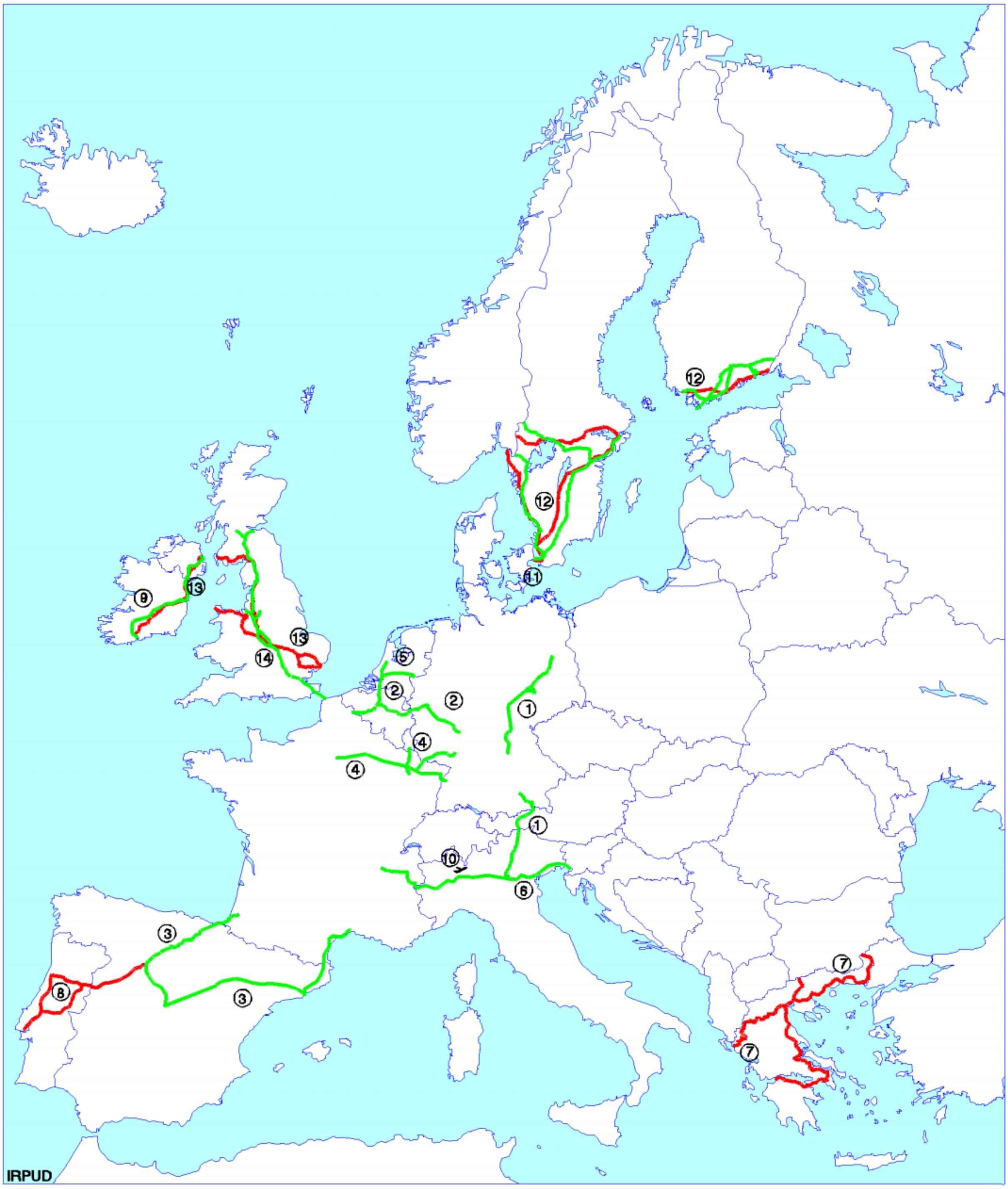
All scenarios are based on assumptions about the development of trans-European transport networks. The implementations of these assumptions have first the form of a 'backcast' of the evolution of the road, rail and air networks between 1981 and 1996. This backcast is similar for all transport infrastructure scenarios. The scenarios differ in their assumptions on the future development of the networks between 1996 and 2016. So, a infrastructure scenario is a time-sequenced investment programme for addition, upgrading or closure of links of the trans-European road, rail or air networks. The scenarios will be implemented in five-year increments. Three scenario types are to be distinguished:

- *Do-nothing-scenario.* For this scenario no development of the trans-European transport infrastructure is foreseen, i.e. the networks will remain in future years as in 1996. Even new links currently under construction or even in operation are not part of this scenario. The main purpose of the do-nothing scenario is to serve as reference and to improve the understanding of the work-together of the submodels without any future infrastructure variation.

- *Priority scenario*. This scenario contains the fourteen trans-European transport network priority projects defined by the Christopherson group and approved on the Essen summit (European Commission, 1998b). The scenario can be considered as a reference case on which all policy scenarios are based. Figure 4.11 shows the fourteen priority projects.

- *Policy scenarios.* These scenarios are specified by adding different subsets of the remaining TETN links such as all planned TETN road projects, all planned TETN rail projects or all planned TETN road and rail projects to the priority scenario (Spiekermann and Wegener, 1999). In addition to these all-or-nothing scenarios, policy scenarios may be defined also in terms of single projects or groups of single projects which are added or even removed from the priority scenario.

The policy scenarios used in the demonstration runs of the SASI model will be presented in the forthcoming Deliverable D15.



1 High-speed train / combined transport North-South
2 High-speed train Paris-Bruxelles-Köln/Frankfurt-Amsterdam-London
3 High-speed train South
4 High-speed train East
5 Betuwe Line
6 High-speed train / combined transport France-Italy
7 Greek motorways Pathe and Via Egnatia
8 Multimodal link Portugal-Spain-Central Europe
9 Conventional rail Cork-Dublin-Belfast-Larne-Stranraer
10 Malpensa 2000. Milano Airport
11 Oeresund fixed rail/road link Denmark-Sweden
12 Nordic triangle multimodal corridor
13 Ireland / United Kingdom / Benelux road link
14 West coast main line

Figure 4.11. The fourteen TETN priority projects

4.1.4 European Migration

Assumptions on demographic trends play an important role in determining regional development in the SASI model. Demographic time-series data are used as input data for the migration submodel and for the validation of the model results. Since birth rates are continuously declining and are presently below replacement level in the European Union, interregional migration flows gain importance as a balancing factor for demographic development (Eurostat, 1998a). International migration contributes about two thirds to population growth in Europe. Developments of future net migration as the principal component of demographic change in Europe will therefore be of particular importance.

The analysis of international migration in Europe, and especially migration from outside the area of the European Union, is limited by patchy availability of data and the lack of unambiguous and consistent data on stocks of foreign population and flows of international migrants. The main problems of existing data arise from variations in national practices and incompatibility of sources, concepts and definitions. Moreover, the data do not include a substantial number of unregistered, illegal and irregular migration (Salt et al., 1994). These data problems affect the analysis of patterns and trends, and hence also any projections of future potential movements.

Despite the fact that Europe now largely consists of countries with a positive migration balance, it is far from being a continent of immigration (Münz, 1996). As the latest available data from Eurostat (1998b) for 1995 show, only around 5 percent of the total EU population were foreign nationals, of which almost one third were EU citizens living in another EU country. Less than one third were from the rest of Europe including the former Soviet Union.

However, the scenarios of mass migration initially envisaged after the fall of the Iron Curtain turned out to be exaggerated (Thränhardt, 1996). East-West migration has been less intensive than anticipated, and many of the migrants came at the invitation of western governments, namely ethnic migrants to Germany and Greece. In the case of asylum seekers, as their number grew, regulations were generally tightened. From 1992 onwards a steep fall of the numbers of immigrants could be observed, with EU net migration declining to about 0.8 million persons in 1994 and 1995, mainly as a result of the drop in the number of asylum-seekers and a decrease in refugees from the former Yugoslavia (Salt, 1996).

Besides migration flows to the 'traditional' immigration countries of western and northern Europe, immigration into southern European countries is a relatively new, yet substantial phenomenon. The flows consist of three components, i.e. net inflows of returning nationals, retirement migration (see 4.5.2 'Quality of life') and attraction of labour immigrants especially from North Africa (Salt et al, 1994), all of which are spurred by sustained upswings in southern European economies in the last two decades.

Data coverage for immigration and emigration is generally low and is in addition distorted by different accounting and legal systems in the member states. Therefore only net migration is taken into account in the SASI model.

Forecasts

The long-term international migration scenarios which are used as input and control data in the SASI model were developed by De Jong and Visser (1997). Besides a baseline scenario, in which observed developments are continued and which in most cases resembles national forecasts, they include a low and high scenario. The low and high scenarios describe possible alternatives, assuming a different economic and political context, affecting push and pull factors, in particular the need for workers and changes in migration policies. Table 4.5 shows the projections of net migration for the three Eurostat scenarios as developed by De Jong and Visser (1997) for European total net migration and the 15 member states.

Table 4.5. Future net migration into EU countries in 1,000s (De Jong and Visser, 1997)

Country		Low scenario			Baseline scenario			High scenario		
	1994	2000	2005	2010	2000	2005	2010	2000	2005	2010
Austria	13	10	12	15	15	19	23	26	30	30
Belgium	19	6	6	10	10	13	15	18	19	20
Germany	316	300	213	150	391	283	200	500	369	250
Denmark	11	6	5	5	11	105	10	16	16	15
Spain	24	5	23	40	31	46	60	57	72	80
Finland	4	-1	0	0	6	5	5	12	11	10
France	50	20	25	30	50	50	50	80	75	70
Greece	27	14	17	20	22	23	25	30	30	30
Ireland	-3	-10	-7	-5	-8	-5	-3	-3	-1	0
Italy	153	20	40	60	50	65	80	80	90	100
Luxembourg	4	2	1	1	3	2	2	4	4	3
Netherlands	20	10	15	20	33	34	35	57	53	50
Portugal	10	6	13	20	12	19	25	29	29	30
Sweden	51	6	7	10	15	18	20	32	30	30
UK	84	16	13	20	38	38	45	73	69	70
EU	784	411	382	396	680	714	592	1,010	897	788

In the long term, the baseline scenario assumes a continuing trend in economic growth, but with only moderate creation of new jobs and little changes in unemployment. Therefore, labour demand is expected to be too low to absorb additional foreigners. Hence, migration regulations will continue to be strict. As assumed in the short term, due to family reunification and migration pressures, immigration levels in the long term will also decline only moderately. The high scenario is based on assumptions of higher economic growth, leading also to increases in labour demand. With increasing educational levels of EU citizens, imbalances in demand and supply of particularly low skilled labour are expected, causing a need for workers from outside the EU. This leads to more relaxed regulations on immigration, resulting in an increase of labour migration to the European Union, reinforced by family reunification and family formation. The low scenario foresees economic stagnation in Europe. High unemployment further deepens negative attitudes towards foreigners and leads to even tighter restrictions on immigration. The restrictive measures are assumed to be effective and to be accompanied by emigration of foreigners due to the unfavourable situation and negative public attitudes towards foreigners.

In quantitative terms it is assumed that in the low scenario net migration will continue to decrease. The restrictive immigration policies in the early 1990s have resulted in a drop of net migration by almost 40 percent in only two years. However, it is assumed that such a rate of reduction cannot continue in the future, given the migration pressures of Second- and Third-World countries. The assumption is made that net migration will be further halved to about 400 thousand per year in the next decade and stay constant from 2005 onwards at this annual level. The baseline scenario, on the other hand, assumes that long-run net migration moves to a level that equals the average of the last years, which is about 600 thousand. The high scenario assumes an increase in the short run, rising to the average levels observed from 1990 to 1994, which was about 1.1 million and falling slightly from 2000 to 0.8 million in 2010 due to political pressures. The decline would, however be smaller than the declines observed in recent years, mainly because of the assumed economic growth, resulting in increased need for foreign labour.

The above described projections are assumed for the target year 2010 and kept constant thereafter. Since the summation of net migration between the EU countries is assumed to be zero, net migration at the EU level reflects the difference between immigrants from outside the EU and emigrants leaving the EU. Net migration data for migration flows between member states and non-EU countries is not readily available. However, these data can be estimated by using supplementary data such as the development of non-EU citizens by member state which are available for previous years. This, however, will not be done for the present implementation of the SASI model.

4.2 Regional Accessibility

This submodel calculates regional accessibility indicators expressing the locational advantage of a region determined by the travel time or travel cost (or both) needed to reach relevant destinations by the strategic road, rail and air networks.

4.2.1 Basic Structure

The method to calculate disaggregate accessibility indicators used for the SASI model was described in SASI Deliverable D5 (Schürmann et al., 1997). For calculating quasi-continuous accessibility surfaces of Europe, the European territory is disaggregated to some 70,000 raster cells of 10 kilometres width. Accessibility is calculated by using each raster cell both as origin and destination, i.e. by generating a 70,000 by 70,000 origin-destination matrix. The results are accessibility values for all raster cells, which are then aggregated to regions.

The generation of the disaggregate input data base with population and GDP by raster cell for 1995 was described in SASI Deliverable D5 (Schürmann et al., 1997, Section 5.1). This method was used to generate disaggregate distributions of population and GDP for the years 1995 and 1992, respectively. These distributions are used during the simulation as ancillary information to allocate population and GDP as predicted by the model for each region *pro rata* to the raster cells belonging to that region.

For the selection of accessibility indicators to be used in the model three, possibly conflicting, objectives are relevant: First, the accessibility indicators should contribute as much as possible to explaining regional economic development. Second, the accessibility indicators should be meaningful by itself as indicators of regional quality of life. Third, the accessibility indicators should be consistent with theories and empirical knowledge about human spatial perception and behaviour. In the light of these objectives, a wide range of combinations of basic accessibility indicators, regional aggregation procedures and modes were tested (see SASI Deliverable D5, Schürmann et al., 1997, Section 3.2; and SASI Deliverable D8, Wegener and Bökemann, 1998, Section 5.2). There are three basic accessibility concepts implemented in the regional accessibility submodel:

- *Average travel time or cost* is measured from each raster cell to a predefined set of destinations, i.e. cities with a population greater or equal to 250,000 or 1,000,000 inhabitants. In a second version of the indicator travel time or cost is weighted by the population.

- *Daily accessibility* is measured as the accumulated number of population or GDP that can be reached from a raster cell by a return trip by a certain mode during a work day with a minimum stay of five hours, i.e. it is assumed that five hours one-way travel time is the maximum for allowing five hours of activities at the destination.

- *Potential accessibility* is the sum of destination activities in terms of population or GDP in all 70,000 destination cells weighted by a negative exponential function of travel time or cost by a certain mode, i.e. it is assumed that the attraction of a destination increases with size and declines with distance or travel time or cost.

The aggregation of accessibilities of raster cells to the accessibility of regions required by the SASI model can be done in three different ways. The accessibility of a region is

- calculated as the average of the accessibilites of the raster cells belonging to that region,

- represented by the maximum of the accessibilites of its raster cells,

- represented by the accessibility of the raster cell of its centroid.

The accessibility model is implemented for three transport modes: road, rail and air. *Modal* accessibility indicators can be used separately or can be aggregated to one indicator expressing the combined effect of alternative modes. There are essentially two ways of aggregating accessibility indicators across modes:

- *Fastest or least cost mode* means to use as impedance term in the accessibility model only the fastest or least cost mode between origin and destination and to ignore all other modes on that relationship.

- *Logsum impedance* means to replace the modal impedance term by the composite or logsum impedance.

The combination of three basic accessibility concepts, three aggregation possibilities from raster values to regional accessibility and three modes plus two aggregations across modes results in a set of 45 potential accessibility indicators to be used in the regional production function. The choice of accessibility indicators and the way of aggregation and standardisation eventually used in the model will be presented in Section 4.2.3.

A final issue when calculating accessibility indicators is whether to standardise them or not. One way of standardisation is to express accessibility in percent of the average accessibility of all regions of the European Union weighted by population. Standardisation has the advantage of showing *relative* changes in regional accessibility. Relative changes disclose that even when accessibility grows everywhere, there may be winner and loser regions as some regions become less accessible in relative terms although in absolute terms their accessibility has increased. Absolute accessibility, on the other hand, may be more appropriate when calculating the effect of accessibility on regional labour productivity.

4.2.2 Political and Cultural Barriers

The driving force of the SASI model are the changes in locational advantages represented by accessibility indicators in the production function. The impedance term of the accessibility indicators can be travel time or travel cost or a combination of both, i.e. generalised cost or generalised travel time (for *daily accessibility* usually travel time is used). Rail travel times are timetable travel times, road travel times are calculated from road-type specific travel speeds, and air travel times are based on average link flight times plus terminal times. Travel costs can be calculated from link-type specific cost parameters.

However, link-based travel times or cost neglect an important locational aspect for regional development, namely political and cultural barriers between countries. It can be argued that the decision to make a cross-border trip, to establish international trade relationships or to move or to establish a firm or a household permanently in a different country is not only influenced by accessibility but also by less tangible factors. Different political systems, bureaucracies and legislation, different languages, different cultural or historical backgrounds, and also tolls, trade restrictions or psychological barriers influence all kinds of cross-border spatial interactions. In other words, there are additional cost factors that have to be considered for international spatial interaction that do not play a role in intra-national interaction.

One example for a quantification of such barriers is Bröcker (1996). He developed an economic 'single-sector static equilibrium model' to estimate trade impediments between European countries. The objective was to estimate (a) how much higher are internal EC trade flows than trade flows with non-EC-countries and (b) how much more money are representative firms able to pay to their factors only because of higher access to markets if the technology used were the same in all locations. Expressed in physical distance the trade barriers are equivalent to 375 km between EC countries for the year 1970 and equivalent to 600 km between EC and non-EC-countries.

Given the theoretical considerations and the relative high importance of these factors estimated in other studies political and cultural barriers and their development over time are included in the SASI model. The only way to express such relationships between regions in different countries in the SASI model is via the accessibility model.

Political and cultural barriers are introduced in the SASI model as additional costs in the generalised cost term of the impedance function in the accessibility model. The general cost term for the potential accessibility will comprise two elements:

$$c_{ij} = c_{ijm}(t) + b_{i'j'}(t)$$

in which $c_{ijm}(t)$ is the pure travel time between cells i and j by mode m in year t along the network and through the raster cells and $b_{i'j'}(t)$ is an additional cost term for political and cultural diversity in year t between the countries i' and j' to which cells i and j belong. Barrier costs are expressed in time units, i.e. can be considered as a time penalty in the accessibility submodel. Daily accessibility and average travel cost indicators do not include barrier costs.

In order to reflect different aspects of cultural and political barriers the time penalty comprises three components:

$$b_{i'j'}(t) = e_{i'j'}(t) + l_{i'j'} + s_{i'j'}$$

in which $e_{i'j'}(t)$ is the *European integration factor* reflecting in which supranational structures the two countries are embedded, i.e. which political and economic relationship exists between them in year t, $l_{i'j'}$ is a *language factor* describing the grade of similarity of the mother language(s) spoken in the two countries and $s_{i'j'}$ is the *cultural similarity factor* reflecting roughly how similar are cultural attitudes of the two countries, it contains also particular historical relationships between two countries. The three factors are operationalised in the following way.

The *European integration factor* reflects the economic and political relationships between countries. It takes account of the different supranational structures countries are integrated in and also of political instabilities and armed conflicts such as in former Yugoslavia. Changes over time are incorporated, i.e. this factor reflects the past and most realistic future economic and political integration of Europe, in particular anticipating the changes in eastern Europe.

All European countries are classified for each year of the period 1981-2016 with respect to their integration in supranational structures (member of the European Union, non-EU country in western Europe, east-European country partly westwards oriented, east-European country or isolated country). The indication of future members of the European Union is based on current negotiations with Hungary, Poland, Estonia, the Czech Republic and Slovenia about their membership in the EU. It is assumed here that these countries will become EU members and that the full integration effect will come in place in 2006. Bulgaria, Lithuania, Latvia, Romania and Slovakia have applied for membership, but negotiations have not started. It is assumed here that these countries will become EU members eventually and that the integration effect will be there in 2011. In addition, it is assumed that Turkey will become an EU member in the long run, that most of the countries in eastern Europe will orient themselves much more towards western Europe and that armed conflicts will be stopped soon.

The translation of the country classification into a European integration factor is presented in Table 4.6. To all possible combinations of relationships between two countries a time penalty in minutes has been assigned. The developments over time, i.e. the decreasing time penalties, reflect several integration processes such as the Single European Market and the Monetary Union, the European Economic Area and the opening of eastern Europe. Very high time penalties for isolated countries reflect that these countries are not accessible. The European integration factor for those countries of today that formed a single state in earlier years (e.g. USSR) is set to 0 minutes for those years.

Table 4.6. European integration factor, 1981 – 2016

Countries	Time penalty (minutes)							
	1981	1986	1991	1996	2001	2006	2011	2016
EU-EU	90	60	40	30	20	10	10	10
EU-NEU	120	120	90	60	30	30	20	20
EU-EEW	180	180	120	120	90	60	60	60
EU-EE	240	240	180	180	180	120	120	120
NEU-NEU	120	120	90	60	30	30	20	20
NEU-EEW	180	180	120	120	90	60	60	60
NEU-EE	240	240	180	180	180	120	120	120
EEW-EEW	120	120	120	120	90	90	90	90
EEW-EE	120	120	120	120	90	90	90	90
EE-EE	120	120	120	120	90	90	90	90
all-IC	300	300	300	300	300	300	300	300

EU *Member of the European Union,*
NEU *Non-EU country in western Europe*
EEW *East-European country, partly westwards oriented*
EE *East-European country*
IC *Isolated country*

The *language factor* forms an important component in the barrier effect. Language has practical implications but works also as a psychological obstacle. The language factor will be kept constant over years, i.e. it is not reflected here, that because of improved education and migration the general knowledge of foreign languages is increasing over time or even decreasing because of no longer daily use of former official languages as it is the case with the Russian language in the Baltic states. Four cases describing roughly the language relationship between two countries are distinguished (see Table 4.7). The language factor ID has been assigned to the full matrix of relationships between countries. However, there is no differentiation by direction that might reflect the fact that the inhabitants of one country speak very well the language of the second but not vice versa as it is the case between the Netherlands and Germany.

Table 4.7. Language factor

Language relationship	Language factor ID	Time penalty (minutes)
Same language in both countries, e.g. Germany-Austria	1	0
Good knowledge of other country's language, partly because of close linguistic relationship between languages, e.g. Italy-Spain	2	20
Some knowledge of other country's language or good knowledge of third language, e.g. Netherlands-Denmark	3	40
No language widely available to communicate, e.g. Spain-Netherlands	4	60

The *cultural similarity factor* expresses the degree of cultural resemblance, e.g. the way daily, political or business life is organised or whether there are particular historical relationships as for instance between Finland and Estonia. Though there might be some convergence of cultures in Europe the factor will be kept constant over years. Four cases are distinguished (see Table 4.8). The cultural similarity factor ID has been assigned to the full matrix of relationships between countries.

Table 4.8. Cultural similarity factor

Cultural relationship	Cultural similarity factor ID	Time penalty (minutes)
Very high, e.g. Germany-Austria	1	20
High, e.g. Germany-Denmark	2	40
Medium, e.g. Germany-Italy	3	60
Low, e.g. Germany-Portugal	4	80

The result of this estimation of political and cultural barriers are eight matrices, one for each year, containing the time penalties between the countries. To illustrate the combined working of the three factors a few examples for selected countries are given in Table 4.9.

Table 4.9. Examples of the time penalty for cultural and political differences

Countries	Formula	Time penalty							
		1981	1986	1991	1996	2001	2006	2011	2016
DE-NL	$e(t)$+20+40	150	120	100	90	80	70	70	70
DE-ES	$e(t)$+60+60	240	180	160	150	140	130	130	130
DE-PL	$e(t)$+40+60	280	280	220	220	190	110	110	110
IT-NL	$e(t)$+60+60	210	180	160	150	140	130	130	130
IT-ES	e(t)+20+40	180	120	100	90	80	70	70	70
IT-PL	$e(t)$+60+80	320	320	260	260	220	150	150	150

Two out of the three factors, the language and the cultural similarity factor, are kept constant over time, i.e. the temporal dynamic is fully based on the European integration factor. Time penalties for cultural and political barriers between the selected countries range from 320 minutes for Italy and Poland in 1981 to only 50 minutes for Italy and Spain in 2016.

4.2.3 Accessibility and Regional Economic Development

The accessibility model is able to provide a wide range of indicators, much more than needed in the sectoral production functions. Therefore it is necessary to select those indicators that might explain a good portion of the regional economic performance. SASI Deliverable D5 (Schürmann et al., 1997, Chapter 6) has already provided a first and tentative assessment of the relationship between accessibility and regional economic development. In order to eventually select the indicators to be used in the production function the bivariate analysis will be performed again. The main difference to Deliverable D5 is that the accessibility model now contains a detailed air network (see Section 4.1.3) and provides indicators aggregated across modes such as fastest mode accessibility and logsum impedance (see Section 4.2.1).

Tables 4.10 to 4.12 present the results of the bivariate analysis in form of correlation coefficients of different accessibility indicators and GDP per capita for the three economic sectors considered for the years 1981, 1986, 1991 and 1996. As proposed in Deliverable D5 outlier regions, i.e. regions in East Germany, Finland and Sweden are excluded. The results suggest the following conclusions:

- *Agriculture.* The correlation of accessibility indicators with GDP per capita produced in agriculture is much less than for other economic sectors. Surprisingly, correlation with air, and consequently with indicators aggregated across modes is highest. However, this is definitely a mode that plays only a minor role, if at all, for agricultural production. Therefore, it is suggested to use that accessibility indicator for agriculture that will be selected for manufacturing.

Table 4.10. Correlation of accessibility and GDP per capita in agriculture

Indicator	Mode	Correlation (r^2)			
		1981	1986	1991	1996
Average travel time	Road	0.09	0.09	0.14	0.17
	Rail	0.11	0.11	0.18	0.20
	Air	0.30	0.30	0.33	0.34
	Fastest mode	0.31	0.31	0.33	0.34
Daily accessibility	Road	0.18	0.17	0.16	0.16
	Rail	0.20	0.19	0.19	0.19
	Air	0.28	0.28	0.26	0.26
	Fastest mode	0.30	0.30	0.28	0.28
Potential accessibility ($\beta = 0.007$)	Road	0.20	0.19	0.18	0.17
	Rail	0.22	0.21	0.20	0.20
	Air	0.34	0.33	0.33	0.34
	Fastest mode	0.34	0.33	0.32	0.33
	Logsum (rail, road)	0.21	0.20	0.19	0.19
	Logsum (rail, road, air)	0.34	0.33	0.32	0.32
Potential accessibility ($\beta = 0.003$)	Road	0.15	0.14	0.17	0.19
	Rail	0.16	0.15	0.18	0.19
	Air	0.33	0.33	0.35	0.37
	Fastest mode	0.34	0.33	0.35	0.37
	Logsum (rail, road)	0.16	0.15	0.18	0.19
	Logsum (rail, road, air)	0.34	0.33	0.35	0.36

Table 4.11. Correlation of accessibility and GDP per capita in manufacturing

Indicator	Mode	Correlation (r^2)			
		1981	1986	1991	1996
Average travel time	Road	0.37	0.42	0.46	0.44
	Rail	0.38	0.44	0.46	0.43
	Air	0.20	0.30	0.33	0.33
	Fastest mode	0.21	0.31	0.34	0.35
Daily accessibility	Road	0.28	0.35	0.40	0.36
	Rail	0.24	0.32	0.34	0.36
	Air	0.11	0.19	0.21	0.21
	Fastest mode	0.17	0.25	0.29	0.29
Potential accessibility ($\beta = 0.007$)	Road	0.30	0.37	0.40	0.36
	Rail	0.27	0.35	0.36	0.36
	Air	0.18	0.27	0.29	0.30
	Fastest mode	0.23	0.32	0.34	0.35
	Logsum (rail, road)	0.30	0.37	0.40	0.37
	Logsum (rail, road, air)	0.23	0.33	0.35	0.36
Potential accessibility ($\beta = 0.003$)	Road	0.37	0.43	0.48	0.43
	Rail	0.34	0.41	0.44	0.42
	Air	0.19	0.28	0.32	0.32
	Fastest mode	0.23	0.32	0.36	0.36
	Logsum (rail, road)	0.37	0.43	0.47	0.44
	Logsum (rail, road, air)	0.23	0.33	0.36	0.37

Table 4.12. Correlation of accessibility and GDP per capita in services

Indicator	Mode	Correlation (r^2)			
		1981	1986	1991	1996
Average travel time	Road	0.43	0.41	0.39	0.37
	Rail	0.46	0.45	0.42	0.39
	Air	0.48	0.47	0.48	0.47
	Fastest mode	0.48	0.47	0.48	0.47
Daily accessibility	Road	0.29	0.26	0.28	0.24
	Rail	0.28	0.28	0.28	0.27
	Air	0.45	0.43	0.45	0.44
	Fastest mode	0.49	0.47	0.49	0.47
Potential accessibility (β = 0.007)	Road	0.35	0.33	0.32	0.29
	Rail	0.35	0.35	0.34	0.33
	Air	0.51	0.50	0.50	0.50
	Fastest mode	0.51	0.50	0.49	0.48
	Logsum (rail, road)	0.36	0.34	0.34	0.31
	Logsum (rail, road, air)	0.50	0.49	0.49	0.47
Potential accessibility (β = 0.003)	Road	0.42	0.39	0.38	0.35
	Rail	0.42	0.41	0.40	0.37
	Air	0.51	0.50	0.51	0.50
	Fastest mode	0.52	0.51	0.51	0.50
	Logsum (rail, road)	0.42	0.40	0.39	0.36
	Logsum (rail, road, air)	0.52	0.51	0.51	0.50

- *Manufacturing.* The correlation with this economic sector is very high for road and rail accessibility or combinations of these and rather low for air accessibility. This corresponds to the common observation that both road and rail are important transport modes for manufacturing industries. In order to reflect the similar importance of both modes logsum for road and rail (β = 0.003) is selected as accessibility indicator for the production function for manufacturing.

- *Services.* Correlation of services is highest with accessibility by air and aggregation across modes including air. As road and rail are important modes for service industries logsum for road, rail and air is an appropriate indicator. Such logsum correlation has been calculated for two β, i.e. for two different impedance functions. As the correlation figures are very similar for the two logsums, a steeper impedance function is selected (β = 0.007), because this reflects better time sensitivity of business and shopping trips.

Figures 4.12 and 4.13 present the spatial distribution of the selected accessibility indicators. Figure 4.12 displays the logsum accessibility of road and rail, Figure 4.13 logsum accessibility of all three modes. It can be seen that without air transport the accessibility distribution is rather smooth, whereas the inclusion of air leads also to the fact that some areas with low accessiblity for road and rail, but with international airports such as Rome or Copenhagen are clearly above European average.

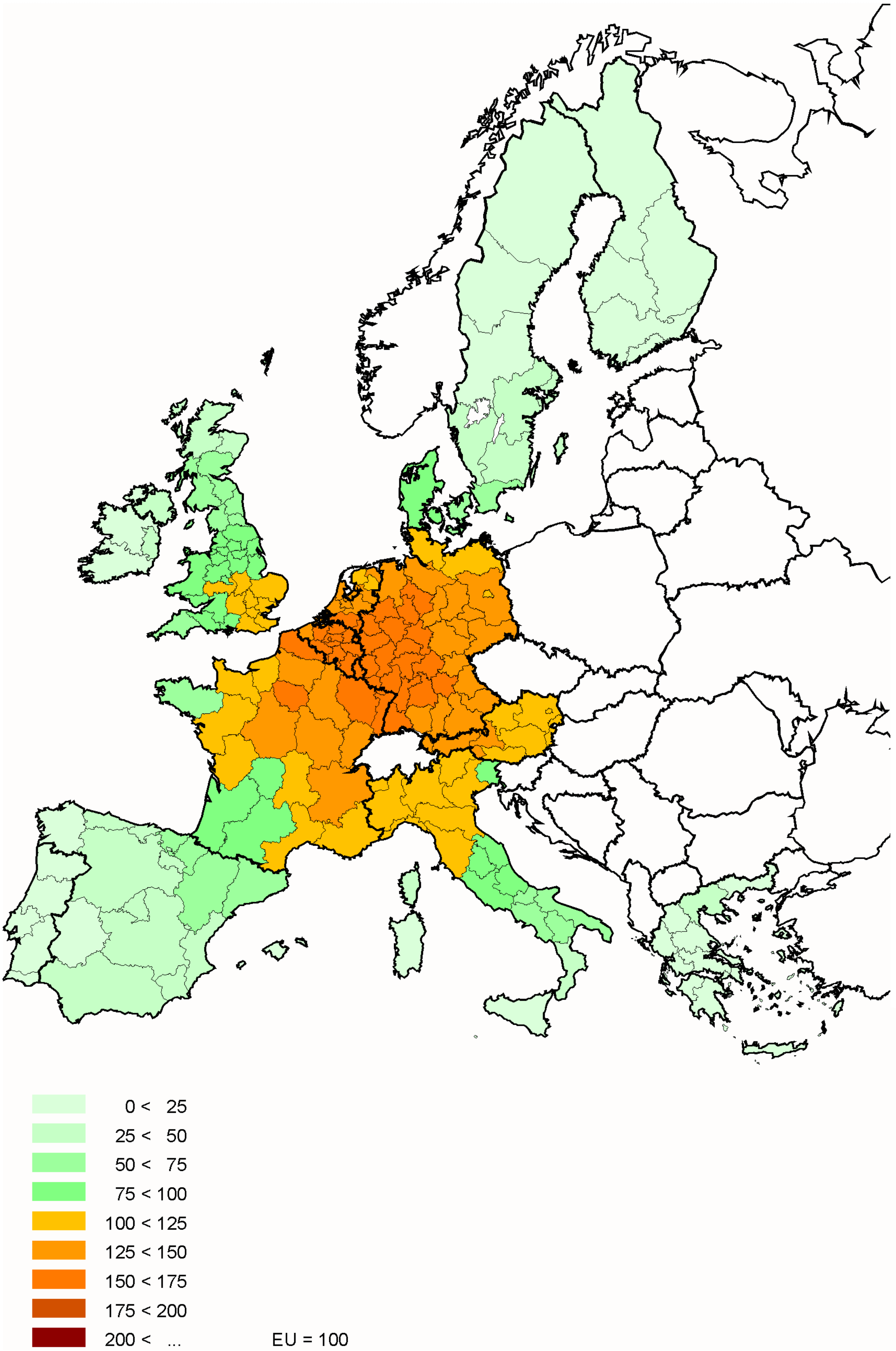


Figure 4.12. Accessibility potential, logsum road, rail in 1996

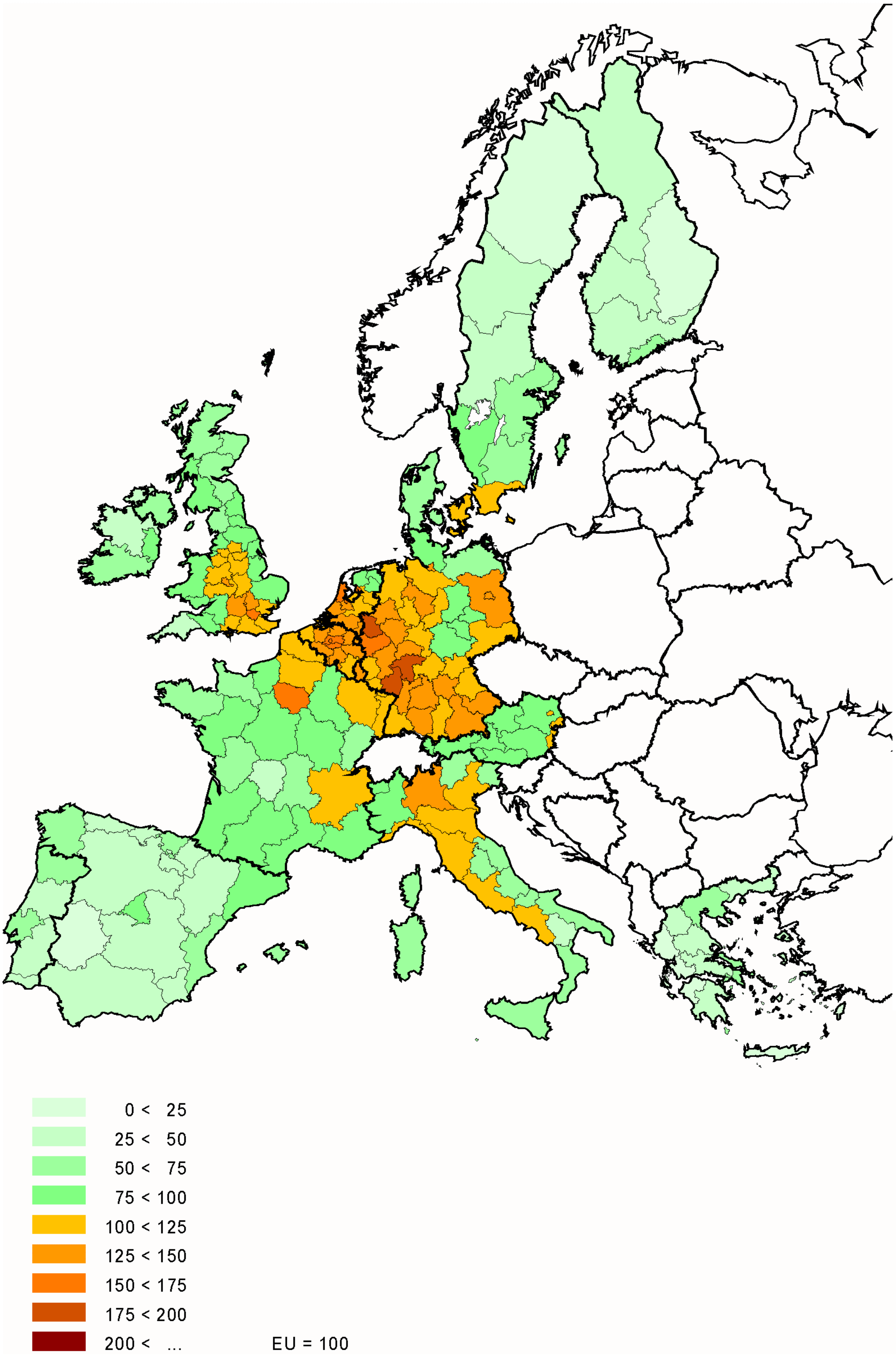


Figure 4.13. Accessibility potential, logsum road, rail, air in 1996

Figure 4.14 shows the relationship between GDP by sector and the selected accessibility indicator over time. Accessibilities and GDP by sector are standardised for 1981 and 1996 to the European averages, i.e. relative changes are displayed. There is a considerable change in the position of the regions over time. The changes for accessibility are up to about ten percentage points, whereas the economic dynamic is more intensive.

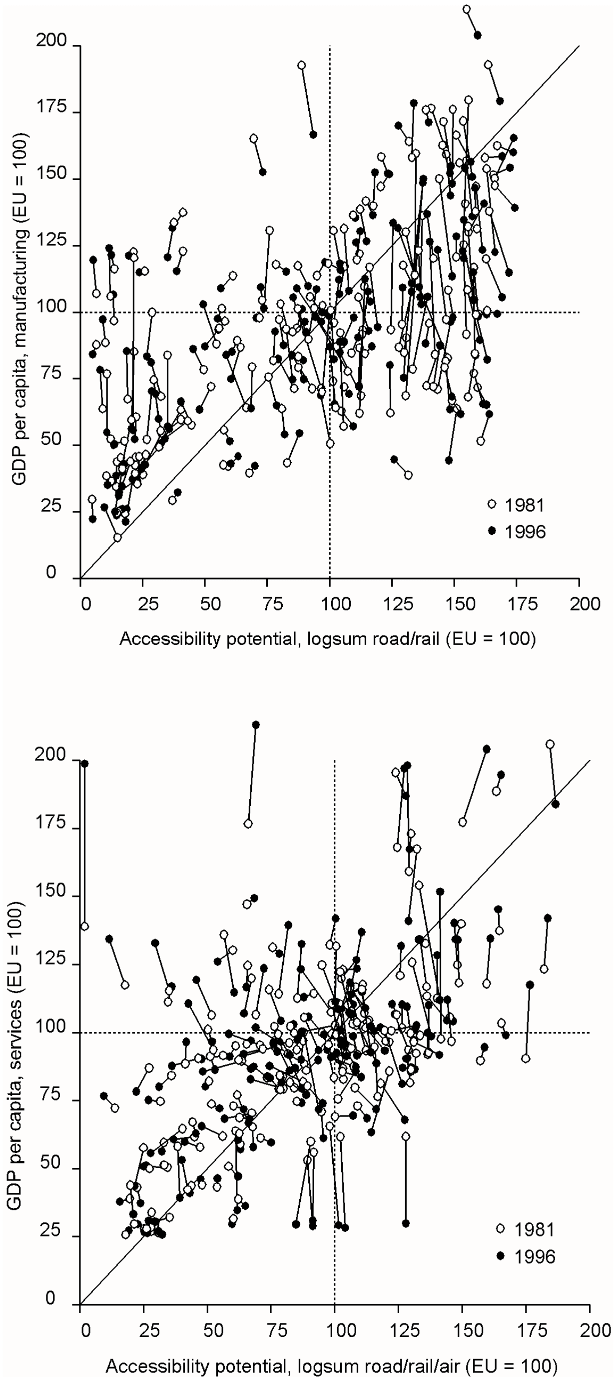


Figure 4.14. Accessibility and GDP per capita 1981 and 1996

4.2.4 Specification

The previous section concluded that in the regional production functions of the SASI model two different accessibility indicators should be used. Logsum (road, rail) accessibility should be used for the agricultural sector and the manufacturing industries and logsum (road, rail, air) for the service sector. This section presents the specification and the parameters used.

The accessibility of region r in year t, $A_r(t)$, is the accessibility of raster cell k of its centroid:

$$A_r(t) = a_k(t)$$

This way of aggregating regional accessibilities has been used because it has the advantage that the accessibility of only one raster cell per region has to be calculated, which vastly reduces the computational load of the model.

For the calculation of the accessibility of the centroid of the region the potential accessibility of the centroid's raster cell k is the sum of destination population $P_j(t)$ in all 70,000 destination cells j in year t weighted by a negative exponential function of travel time $c_{kj}(t)$ between centroid k and destination cells j. Different β are used in the potential models for different economic sectors to reflect the differences in travel time sensitivity. For the production functions to be estimated for the agricultural sector and the manufacturing sector a β of 0.003 is used:

$$a_k(t) = \sum_j P_j(t) \exp\left[-0.003\, c_{kj}(t)\right]$$

For the service sector the potential function is as follows:

$$a_k(t) = \sum_j P_j(t) \exp\left[-0.007 c_{kj}(t)\right]$$

The travel time impedance $c_{kj}(t)$ is represented by the composite or logsum impedance. For the different economic sectors different modes m are integrated. For the agricultural and manufacturing sectors the travel time impedance is calculated as:

$$c_{kj}(t) \ = \ -\frac{1}{0.03} \ln \sum_{\substack{m \in \mathbf{M}_{kj} \\ m \neq 3}} \exp\left[-0.03\, c_{kjm}(t)\right]$$

where $\mathbf{M}_{kj}$ is the set of modes available between raster cells k and j. Mode 3 is air transport and considered not important for the two sectors, i.e. the regional accessibility is based on aggregate rail and road accessibility.

For the service sector all available transport modes are aggregated to the logsum impedance:

$$c_{kj}(t) = -\frac{1}{0.03} \ln \sum_{m \in \mathbf{M}_{kj}} \exp\left[-0.03\, c_{kjm}(t)\right]$$

4.3 Regional GDP

This submodel forecasts gross domestic product (GDP) generated annually in each region as a function of endowment factors, accessibility and transfers - for a discussion of the choice of GDP as indicator see SASI Deliverables D4 and D8 (Bökemann et al., 1997; Wegener and Bökemann, 1998).

4.3.1 Basic Structure

The GDP submodel is based on a quasi-production function incorporating accessibility as additional production factor. The economic output of a region is forecast separately for each economic sector (agriculture, manufacturing, services) in order to take different requirements for production by each sector into account. The regional production function predicts annual regional GDP:

$$Q_{ir}(t) = \mathrm{f}\,[\mathbf{C}_{ir}(t), L_{ir}(t), \mathbf{A}_{ir}(t), S_r(t), R_{ir}]$$

where Q_{ir}(t) is annual GDP of industrial sector i in region r in year t, $\mathbf{C}_{ir}(t)$ *is* a vector of endowment factors relevant for industrial sector i in region r in year t, L_{ir}(t) is labour relevant for industrial sector i in region r in year t, $\mathbf{A}_{ir}$ is a vector of accessibility indicators relevant for industrial sector i in region r in year t, S_r are annual transfers received by the region r in year t and R_{ir} is a region-specific residual taking account of factors not modelled (see below). Note that, even though annual GDP is in fact a flow variable relating to a particular time interval (year), it is modelled like a stock variable.

Sectoral GDP, however, does not only contain the actual economic output of a region, but also includes different kinds of subsidies, which can apparently not be explained by the production conditions within a region. Consequently, sectoral GDP has to be reduced by transfer payments and their multiplier effects (see Section 4.1.2 and the Section 'Subsidies and transfers' in this chapter). The production function than becomes

$$Q_{ir}(t) - S_{ir}(t) = \mathrm{f}\,[\mathbf{C}_{ir}(t), L_{ir}(t), \mathbf{A}_{ir}(t), R_{ir}]$$

This production function differs from the one presented in Deliverable D8 (Wegener and Bökemann, 1998) in that it estimates total regional GDP instead of GDP per capita, a change necessary to get plausible and statistically significant coefficients which met the self-imposed requirements for calibration (see Section 2.3) and in addition passed a test of temporal robustness over the period 1981 to 1991.

Another problem in the specification of the function is the question whether the production factors should be linked additively or multiplicatively. Assuming that the different production factors can be substituted by each other only to a certain degree, a multiplicative function which reflects a limitational relation between the factors has been chosen. Since this kind of function introduces the coefficients as exponents of the explaining variables it is possible to interpret the coefficients as elasticities of production reflecting the importance of the different production factors for economic growth in a sector.

Due to different ways of production, each economic sector depends on different production conditions and factors. Therefore the three sectoral functions contain different explanatory variables. In spite of that the functions show the same basic structure. All of them use the following four types of explanatory variables:

- regional labour force
- accessibility
- economic structure
- endowment factors

The operational specification of the regional production functions used in the SASI model is:

$$Q_{ir}(t) - S_{ir}(t) = L_{ir}(t)^{\alpha} A_{ir}(t)^{\chi} q_{ir}(t-1)^{\beta} X_{ir}(t)^{\delta} \varepsilon + R_{ir}(t)$$

where $Q_{ir}(t)$ is economic output (GDP) of sector i in region r in year t, S_{ir}(t) are transfer payments in region r relevant for sector i in year t, L_{ir}(t) is labour force in region r in year t, $A_{ir}(t)$ is accessibility of region r relevant for sector i in year t, $q_{ir}(t-1)$ is economic structure of region r (sectoral share of sector i in year t-1), $X_{ir}(t)$ is a vector of endowment factors in region r relevant for sector i in year t, $R_{ir}(t)$ denotes regression residuals of the estimated GDP values of sector i in region r in year t and α, β, χ, δ, and ε are regression coefficients.

Using the economic structure as an explanatory variable to predict sectoral output has been discussed controversially during the estimation process, especially using the sectoral share in GDP of the previous year. On closer examination and reflection, however, it has been decided to include this variable on the grounds that the conditions for production in a certain sector depend heavily on the given sectoral structure, a fact which reflects historic developments and path dependencies that are not covered by any other indicator in the equation. Not including such an indicator would probably result in an overestimation of the role of the other explanatory variables which would distort the estimation. Statistical evidence of the estimation (see Section 4.3.3) justifies this approach.

4.3.2 Data Requirements

A series of regionally disaggregated data are needed for calibrating the three sectoral production functions. In this chapter the indicators and data used for assessing the coefficients of the three equations are presented.

GDP data

As discussed in Deliverable D4 (Bökemann et al., 1997), GDP continues to be the most suitable indicator for measuring the economic performance of a region. GDP at market prices represents the result of the production activity of resident producer units. The definition of the European System of Integrated Economic Accounts (ESA) published by Eurostat (1993) points out that the GDP corresponds to the total output of goods and services of an economy minus intermediate consumption plus value-added tax (VAT) on products and net taxes on imports (excluding VAT).

The total GDP data used for calibrating the equations originally comes from the Eurostat's Gross Domestic Product Data Set (Regio database), which was complemented by national statistics. The values, however, show GDP data at current prices, which impedes their interpretation and comparison because of regionally different inflation rates. Since the GDP model estimates the role of different production factors for economic output, the effect of inflation on GDP growth needs to be eliminated by converting the data into GDP values at constant prices. For that purpose it was necessary to set up national deflators which free economic performance data from inflation and to give all GDP values in prices of 1998.

These data were sectorally disaggregated by using sectoral value-added shares from data Economic Branch Accounts Data Set (Regio) and information from several regional and national statistics. The sectoral GDP used in the model is given in millions of ECU at constant prices of 1998. The following notation is used:

$Q_{1r}(1981)$ GDP in agriculture in region r in 1981
$Q_{2r}(1981)$ GDP in manufacturing in region r in 1981
$Q_{3r}(1981)$ GDP in services in region r in 1981

Subsidies and transfers

Subsidies on products are excluded from the calculation of regional GDP at market prices, whereas transfer payments are included (see Section 4.1.2). Even though transfer payments and subsidies are important factors particularly in economies undergoing restructuring or striving to attain the average European welfare standard, it is reasonable to exclude them from the production function in order to measure *actual* economic performance of a region. Subsidies represent allocations of public revenues just like any other government activity which is taken account of in the GDP measurement. Some scholars argue that GDP is understated in national accounts when subsidies are excluded and particularly so in regions where subsidies account for a substantial share of a region's economic performance level (Rankin, 1998, 4). In the SASI model subsidies are excluded beforehand to obtain GDP values reflecting the actual effective level rather than a measure based on theoretical considerations about proper adjustments of national accounts at different stages of the value-added approach. Following the calculation of GDP values through the production function, subsidies and transfer payments may be added again to make the calculated values comparable to published GDP data.

It is essential to distinguish different types of subsidies and transfer payments at this point. Of the three categories taken account of in the SASI model, i.e. agricultural subsidies, EU Structural Funds and national subsidies, the latter two represent transfer payments which are included in the GDP at market prices, whereas agricultural subsidies have been subtracted beforehand. Agricultural subsidies paid by the European Union in connection with the Common Agricultural Policy (CAP) are mainly price and income guarantees to farmers. They are paid to bridge the gap between a 'market price' and a politically determined 'target price'. Since these subsidies are subsidies on product prices, it can be assumed that they are not contained in the GDP at market prices as available from Eurostat sources (see Section 4.1.2).

Accordingly, the adjusted GDP of agriculture in the model is:

$$Q_{1r}^{*}(t) = Q_{1r}(t) - S_{1r}(t)\ m_1$$

where Q_{1r}^{*} is the adjusted regional GDP of agriculture sector (i.e. without subsidies and their multiplier effects), Q_{1r} is the non-adjusted GDP of agriculture, S_1 are agricultural subsidies and m_1 denotes a sector-specific multiplier effect.

The corresponding equation for manufacturing and services is:

$$Q_{ir}^{*}(t) = Q_{ir}(t) - S_{ir}(t)\ (1 + m_i) \qquad i = 2, 3$$

Since the GDP values of these two sectors contain transfer payments, they need to be subtracted in addition to their multiplier effects to adjust the GDP values correctly. Transfer payments are assigned to industrial sectors according to their share in overall GDP.

Multiplier effects are assumed to be $m_1 = 0.2$, $m_2 = 2.0$, $m_3 = 2.0$, where a factor of 2.0 implies that 1 ECU of transfer payments results in another 2 ECU of output as a multiplying effect. The choice of these multiplier effects is based on a review of results obtained by various macro-economic models (Samuelson and Nordhaus, 1985; Fromm and Klein, 1975). Moreover, it is assumed that multiplier effects spread equally across the manufacturing and service sector whereas the agricultural sector does not benefit significantly from transfer payments assigned to the other two sectors.

Labour force data

The total labour force of a region is expressed by the number of economically active people living there. The data used for calibrating the model are based on the Eurostat Labour Force Survey for the European Union and has been completed and corrected with the help of national statistics. Since these data are not based on a unified definition of labour force and active population, they had to be adapted to the official nomenclature of Eurostat in which 'active population' is defined as the number of employed people registered at their place of residence plus the number of unemployed. For countries which have not been members of the EU in the year 1981, some values had to be estimated by backcasting available data or disaggregating NUTS-1 data. In the calibration the following data have been used:

$L_r(1981)$ Active population in region r in 1981 (1,000 persons)

Accessibility data

Regional accessibility is calculated in the accessibility submodel as described in Section 4.2. To capture the different production requirements of the three economic sectors two accessibility indicators were chosen for the calibration:

$A_{1r}(1981)$ Logsum accessibility rail/road ($\beta = 0.003$) in region r in 1981
$A_{2r}(1981)$ Logsum accessibility rail/road ($\beta = 0.003$) in region r in 1981
$A_{3r}(1981)$ Logsum accessibility rail/road/air ($\beta = 0.07$) in region r in 1981

where the rail/road logsum accessiblity is applied to the agricultural and manufacturing sector and the rail/road/air accessibility is considered for services.

Economic structure data

Estimating the economic output of an economic sector requires a variable indicating the pre-existing sectoral structure of a region. The economic structure of a region is measured by the share of the sector of total GDP of the previous year, including transfer payments and their multiplier effects. The following data have been used in the calibration:

$q_{1r}\,(1980)$	Share of the agricultural sector in total GDP in region r in 1980
$q_{2r}\,(1980)$	Share of the manufacturing sector in total GDP in region r in 1980
$q_{3r}\,(1980)$	Share of the service sector in total GDP in region r in 1980

Regional endowment

Based on the assumption that different economic activities have different demands and needs for regional production, different sets of endowment indicators for the three economic sectors were defined. Since each of the three sectors is composed by heterogeneous industries, production factors had to be determined that are typical for most of the activities within a sector. The endowment factors used can be assigned to three main groups. Educational attainment, natural conditions and real capital endowment play an important role for the economic performance of a region. For statistical reasons, the endowment factors are not used as single explanatory variables. Instead they are multiplied to a composite endowment indicator for each economic sector.

Educational attainment. The general level of education and skills is of prime importance for the economic performance and development of a region. Access to knowledge and specific skills is a decisive factor in national and international competition because it enables people to develop innovative products and grasp new economic opportunities. In the model this factor is represented by educational attainment data for the population aged 25 to 59. The indicator used in the model is based on the International Standard Classification of Education (ISCED), which was defined to facilitate the international comparison of educational attainment. It gives the share of people with upper secondary (ISCED 3) or tertiary (ISCED 5, 6, 7) education. The following notation is used:

$h_r\,(1981)$	Share of persons with higher educational attainment level in region r in 1981

Natural conditions. Since agricultural production largely depends on natural conditions, the first indicator used as explanatory variable in the agricultural production function gives information about the average soil quality within a region. It is measured by the yearly yield of cereals in tons per hectare of arable land published in the New Cronos database for NUTS-2 regions. Although the data is only available for 1991, it was used for calibration since it can be assumed that soil quality remains constant over a few decades. This also applies to the amount developable land in a region which has been derived from a population density model. All areas with a population density of less than 100 inhabitants per square kilometre are defined as developable land. This approach yields regional data of sufficient accuracy for determining the spatial development potential of a region. A third indicator reflects the quality of life within a region, which is an important location factor particularly for service firms. It is defined as a composite indicator derived from a multicriteria analysis considering the three main categories climate, landscape and tourist facilities, which are composed of three subindicators each. As the quality-of-life indicator is also used in the migration submodel, it is explained in Section 4.5.2. To sum up, natural production conditions are represented by the following indicators:

o_r Soil quality (yield of cereals in t/ha) in region r
d_r Developable land (percent of total area) in region r
v_r Quality of life in region r

Real capital endowment. The real capital endowment of a region cannot be measured by one simple indicator. Therefore proxies have to be used to describe the quality and the utility of the real capital available in a region. Especially the conditions for innovative production play a prominent role for economic performance and development. To assess the 'innovation capital' of a region, often research and development (R&D) activities are selected as indicator for the innovative potential of a region. In the model, R&D investment as a percentage of total GDP is used. The New Cronos database provides this data for most NUTS-2 regions, though not for all years. Therefore values from different years (mostly in the mid-1980s) had to be combined with national or NUTS-1 data. Since there is no information about the future development of R&D activities, these values are kept constant over the whole simulation period. The indicator is named

w_r R&D investment (percent of total GDP) in region r

Residuals

In contrast to the other indicators discussed in this section, the residuals are not input to the calibration process but result from it. After the calibration of the model with 1981 data, the model equations can be used to 'predict' 1981 regional GDP. Depending on the goodness of fit of the model, the 'predicted' values differ more or less from the values observed in 1981 (see below). The regional regression residual R_{ir} is defined as the difference between the GDP of sector i predicted for region r in 1981 and observed GDP of sector i in region r in 1981. This residual can be interpreted as a term reflecting production factors not covered by the other indicators and as such can be introduced into the forecasting equation. Since the variables 'behind' this term are not known, it is not possible to forecast it. Hence the residuals are kept constant over all simulation periods. The following notation is used to identify residuals:

R_{1r} Residual of the agriculture production function of region r
R_{2r} Residual of the manufacturing production function of region r
R_{3r} Residual of the services production function of region r

4.3.3 Calibration Results

In the calibration process the guidelines for calibration formulated in Deliverable D8 (see Section 2.3) were taken into account: that wherever possible in the calibration explanatory variables should be selected that are theory-based, positive ('pull' rather than 'push'), policy-relevant and plausible.

The three sectoral production functions were calibrated using 1981 data of 193 regions. The new German Länder were excluded from the calibration because of their exceptional socio-economic characteristics. By using multiple non-linear regression techniques, the coefficients of the three functions were assessed so that the deviation of the estimation results from the actual GDP values observed was minimised.

Goodness-of-fit measure and 95-percent confidence intervals of the coefficients were calculated for each of the three industrial sectors to show the statistical significance of the estimation. An analysis of confidence intervals showed that all coefficients are sufficiently significant when using 1981 data. In order to check whether the coefficients show satisfying stability over time, the equations and coefficients have additionally been assessed with 1991 data. The estimation results of this second calibration are presented for comparison and show that this additional condition is fulfilled as well. The coefficients give information about the influence of the corresponding variable on the economic performance of a certain sector and can be interpreted as elasticities of production. That means that a value of one stands for a linear interrelation between the corresponding variable and the economic performance. In that case a particular increase of the variable considered induces the same relative rise of the economic output, while a value larger than one causes output to increase more than the variable changed. This fact allows to interpret the coefficients assessed with regard to their importance for economic growth and development. The results of the calibration process by industrial sector are described in the subsequent sections:

Agriculture

In addition to the production factors regional labour force, accessibility and economic structure, which appear in all three functions, regional soil quality and the share of developable land are considered to explain specific regional conditions for agricultural production. For statistical reasons these two variables are multiplied to yield one combined endowment indicator. Applying multiple non-linear regression leads to the following specification of the production function for agriculture:

$$Q^*_{1r}(t) = L_{1r}(t)^{1.02735}\, A_{1r}(t)^{0.16961}\, q_{1r'}(t-1)^{0.84777}\, (o_r d_r)^{0.20002}\, 0.25821$$

The goodness of fit was $r^2 = 0.94$. An analysis of confidence intervals confirmed that all variables perform reasonably well. However, the low coefficient of accessibility shows that the elasticity of agricultural production to improvements in accessibility is rather low. Doubling the accessibility level of a region would for example only induce a 12-percent increase in agricultural output. As will be shown later, accessibility plays a more prominent role in the two other sectors manufacturing and services.

As a first step towards validation of the model, predicted regional GDP in agriculture per capita was calculated by dividing predicted total regional GDP in agriculture by population and comparing it with observed regional GDP in agriculture per capita in 1981. The correlation between estimated and observed GDP was $r^2 = 0.81$.

Manufacturing

Testing various endowment variables in the regression showed that education level and R&D investment have a significant impact on production in manufacturing. These findings are highly plausible since the quality of human capital and the availability of real capital are included in most production functions in the literature. Again, these two factors have been combined into one endowment indicator, besides labour force, accessibility and economic structure. The specification of the production function for manufacturing is as follows:

$$Q^*_{2r}(t) = L_{2r}(t)^{1.0885} A_{2r}(t)^{0.25994} q_{2r'}(t-1)^{0.98461} (h_r w_r)^{0.05966} 0.13628$$

The model fit was calculated as $r^2 = 0.97$. As a first step towards validation, predicted regional GDP in manufacturing per capita was calculated by dividing predicted total regional GDP in manufacturing by population and compared with observed regional GDP in manufacturing per capita in 1981. With $r^2 = 0.61$ the correlation between estimated and observed GDP was less than in the case of agricultural GDP yet rather high for a model of this kind.

As indicated by the coefficient of 0.26, manufacturing depends more on accessibility than agriculture. This finding is to be expected because it is obvious that transport plays a more important part in industrial production than in agriculture. Industrial production highly depends on the efficient transport of intermediate inputs from different locations and of finished products on demand by potential customers. Both requirements are determined by the settlement structure and the traffic infrastructure and are therefore appropriately reflected by accessibility indicators.

Services

Education level and quality of life turned out to be the most important endowment factors determining regional production of services. The tertiary sector is the most heterogeneous of the three economic sectors comprising both simple personal services such as haircutting and complex business services using high-tech equipment. The distinctive mark of service activities is that they produce 'immaterial goods', which does not say much about their specific requirements. It can, however, be assumed that a large part of all services has to do with collection, processing and application of information and knowledge, which makes specific skills necessary for most service activities. It is widely accepted that the education level of the regional population influences the possibilities and opportunities of the service sector in a region. Therefore investing in the education system and supporting advanced training are common measures of regional policy in Europe.

The second endowment factor playing a prominent role in service production is the quality of life in a region. When choosing a location, more and more service firms, especially from the growing business services, attach importance to 'soft' location factors, such as climate and landscape or cultural and leisure attractions. This is especially true for tourism which largely depends on the environmental and cultural attractiveness of a region.

Apart from education level and quality of life, again regional labour force, accessibility and economic structure are considered in the production function for services. A different accessibility indicator including accessibility by air is used in this equation. Since service activities rely on face-to-face contacts, it can be assumed that the sensitivity towards distance is higher in services than in manufacturing. Therefore a value of β = 0.007 has been chosen for the accessibility indicator used in this function (see Section 4.2.4). Non-linear regression of the production function so defined yielded the following equation:

$$Q^*_{3r}(t) = L_{3r}(t)^{1.054}\, A_{3r}(t)^{0.43905}\, q_{3r'}(t-1)^{0.9362}\, (h_r v_r)^{0.21302}\, 0.00214$$

The model fit was calculated as $r^2 = 0.97$. Again, predicted regional GDP in services per capita was calculated by dividing predicted total regional GDP in manufacturing by population and compared with observed regional GDP in services per capita in 1981. The correlation between estimated and observed GDP was $r^2 = 0.60$.

The regression coefficient of 0.44 shows that accessibility plays a more prominent role for services than for industrial production - though due to the different accessibility indicators used the two coefficients cannot be compared in a strict sense. Nevertheless, it can be concluded that the elasticity of services to changes in accessibility is rather high.

Total GDP

The total GDP is calculated by summing up the results of the three sectoral production functions:

$$Q^*_r(t) = \sum_i Q^*_{ir}(t)$$

It is then possible to compare total GDP per capita observed in 1981 are to the corresponding model results. This step allows to evaluate the overall model fit by analysing the regional distribution patterns in detail.

In Figure 4.15 the deviations of the model estimates from reality are demonstrated by means of a scatterplot comparing observed and estimated values of total regional GDP per capita. The figure confirms that the majority of predicted GDP values match reasonably well with observed values and that the number of outliers, which cannot be appropriately explained by the model is quite low. Although these outliers impair the model fit as a whole, the correlation between observed and estimated total GDP amounts to $r^2 = 0.504$, which is less than the goodness of fit of the three sectoral models but can be considered acceptable for a model explaining regional GDP.

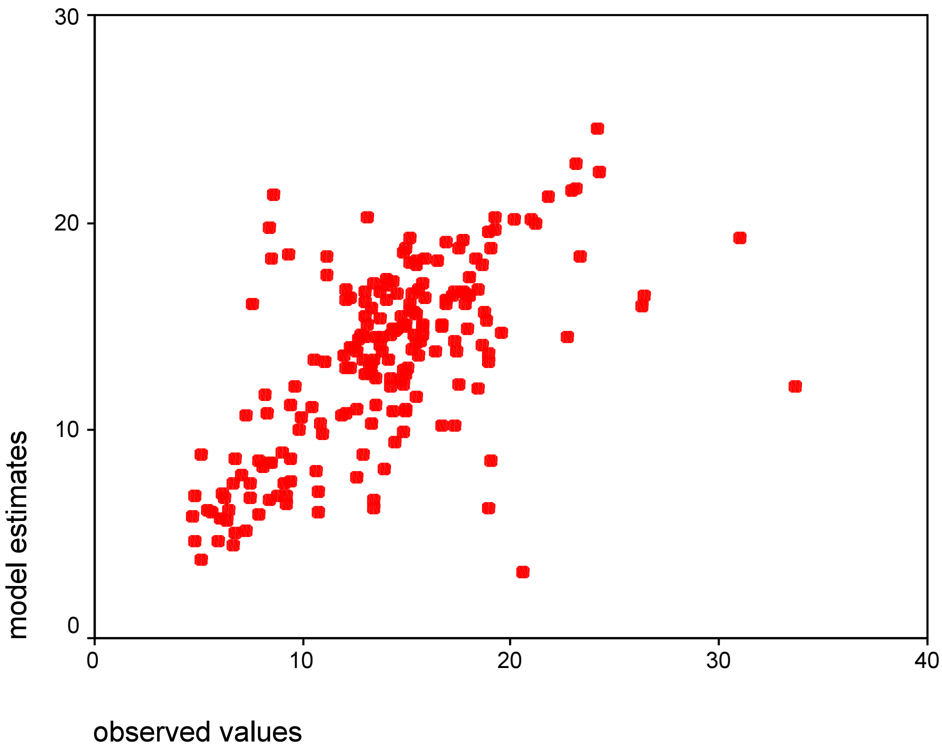


Figure 4.15. Observed and predicted GDP per capita in 1981 (1,000 ECU)

There could be two reasons for the mismatches between observed and predicted values. The first could be that production factors that play an important part in the economic performance of a region are not considered in the functions. For instance, real capital endowment may not be reflected sufficiently by R&D investment, or the skill of the labour force may not be adequately reflected by the standard classification used here. The second reason for model deviations could be that the impacts of the explanatory variables on economic performance are not the same everywhere, because some regions may be able to benefit from certain production factors or to compensate the lack of some production factors better than others.

Figure 4.16 shows the spatial distribution of residuals in percent of observed values of the 193 regions that were used for the calibration. A positive residual means that a region is underestimated, whereas a negative residual indicates that a region's performance is actually lower than predicted by the model.

It can be seen that the model is able to explain regional disparities in GDP per capita between the highly developed regions in central Europe and the poorer regions at the European periphery as well as the differences between agglomerations and rural regions. On closer examination, however, it can be seen that in some parts of Europe the estimates deviate from the observed values.

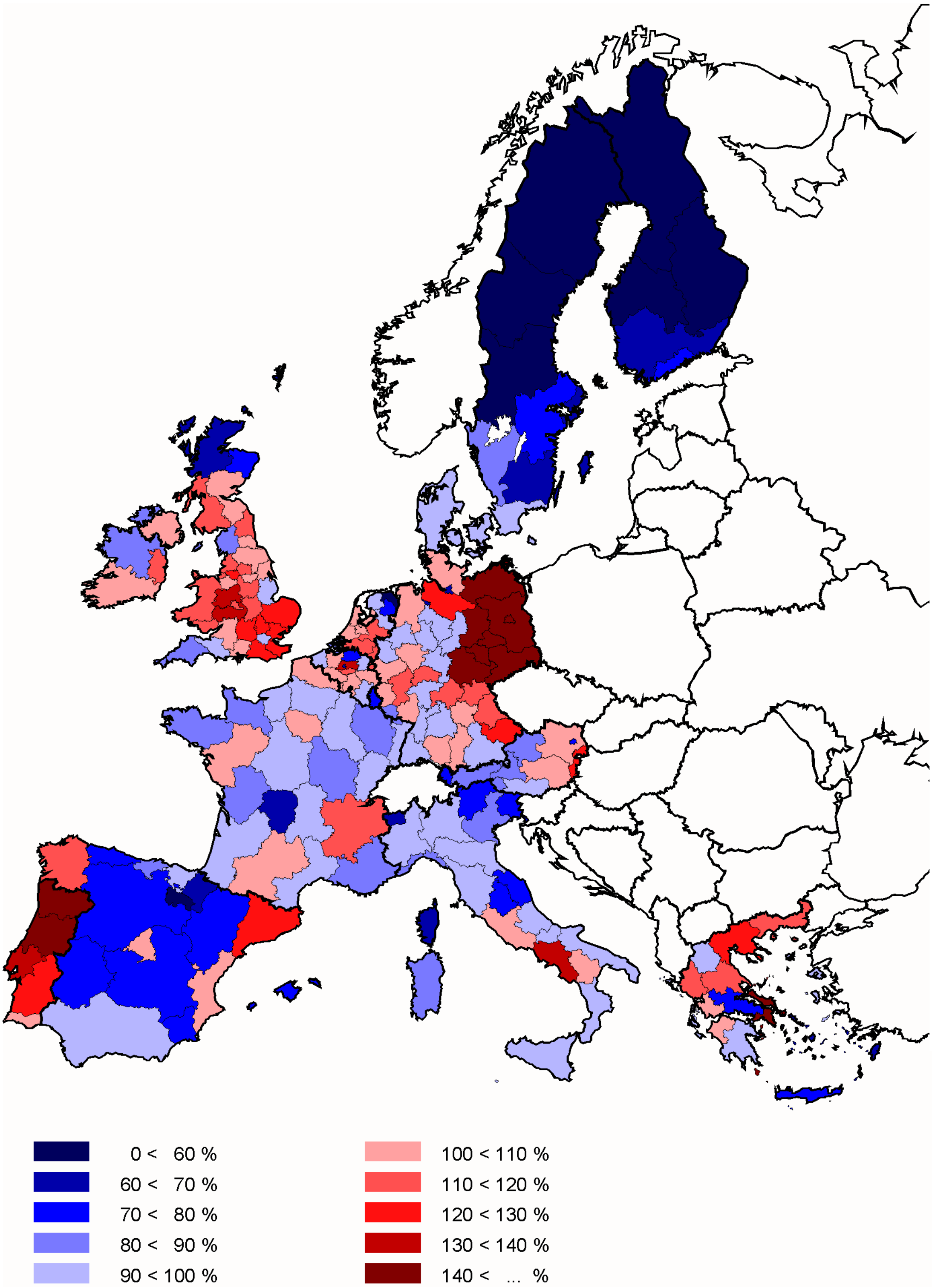


Figure 4.16. Predicted v. observed GDP in percent of observed GDP in 1981

The Scandinavian countries show a much better economic performance than expected from their conditions for production. In particular the economic output of Finland and Sweden is underestimated by the model. In the remote parts of the two countries the negative impact of low accessibility seems to be less than in other peripheral regions in Europe. According to the argumentation given before it could also be argued that the high education levels in Scandinavia are used more efficiently in economic production or that low urbanisation does not cause locational disadvantages for those regions.

On the other hand there are regions in the European core which do not show the economic performance to be expected from their central geographical position. Especially the highly industrialised parts of central England and the rural northern parts of Portugal perform worse than estimated by the model.

Apart from these areas, regions that tend to be overestimated or underestimated by the model are spread out over the whole continent. This indicates that there seems to be no fundamental mistake in explaining regional GDP values but that the residuals are caused by specific regional characteristics that could not be covered by regional endowment indicators. Further research would be necessary to find indicators that cover important production factors that have not been considered in the model.

To sum up, it can be concluded that the GDP submodel covers a wide range of production factors and is able to sufficiently explain regional sectoral GDP.

Forecasting

Moreover, the predictive (not explanatory) power of the model is vastly improved by the introduction of the residuals explained above. For forecasting, the results of the sectoral production functions are modified by adding the regional residuals derived from the calibration:

$$Q_{ir}^{**}(t) = Q_{ir}^{*}(t) + R_{ir}$$

To make these forecasts comparable to GDP figures published in national accounts and by Eurostat, the transfer payments previously subtracted (see Section 4.3.2) are added again:

$$Q_{1r}(t) = Q_{1r}^{*}(t) + S_{1r}(t)\ m_1$$

$$Q_{ir}(t) = Q_{ir}^{*}(t) + S_{ir}(t)\ (1 + m_i) \qquad i = 2,3$$

where $S_{ir}(t)$ are regional transfers to sector i in region r and m_i is the assumed sectoral multiplier (see Section 4.3.2).

In each period, regional sectoral GDP are scaled up or down so that their total over all regions matches the exogenously assumed sectoral GDP of the whole EU provided by the *European Developments* submodel (see Section 4.1.1).

4.4 Regional Employment

Regional employment by industrial sector is derived from regional GDP by industrial sector and regional labour productivity.

Regional labour productivity by industrial sector is partly forecast exogenously and partly affected endogenously by changes in accessibility. It is assumed that labour productivity by economic sector in a region is predominantly determined by historical conditions in the region, i.e. by its composition of industries and products, technologies and education and skill of labour and that it grows by an average sector-specific growth rate. However, it is also assumed that it is positively affected by growth in accessibility:

$$p_{ir}(t) = p_{ir}(t-1)\,\frac{p_{ir'}(t)}{p_{ir'}(t-1)} + \varepsilon_i\,\frac{A_r(t)}{A_r(t-1)} \qquad \text{with } r \in \mathbf{R}_{r'}$$

where $p_{ir}(t)$ is labour productivity, i.e. annual GDP per worker, of industrial sector i in region r in year t, $p_{ir'}(t)$ is average labour productivity in sector i in year t in country or group of regions $\mathbf{R}_{r'}$ to which region r belongs, $A_r(t)$ is accessibility of region r in year t (aggregated across modes as above), and ε_i is a linear elasticity indicating how much the growth in labour productivity is accelerated by a growth in accessibility. As indicated above, absolute rather than relative accessibility is preferable here.

For the past period 1981 to 1994, observed values of regional labour productivity by economic sector are used. Since data on labour productivity on the NUTS-2 region level are not directly available, regional GDP by sector and regional employment by sector are used to calculate productivities for 1981, 1986, 1991 and 1994. GDP and employment data are compiled from r-cade database. Data for former East Germany are estimated using data from the statistical yearbook of the German Democratic Republic and national values taken from the United Nations yearbook of national accounts. Regional data for the former non-EU countries Austria, Finland and Sweden are calculated by regionalising Eurostat national accounts data (European Commission, 1996) with data obtained from national statistical yearbooks.

Because of different accounting systems employment data do not match labour force data. The main reason is the increasing flexibility of the labour market and part-time employment in Europe: Persons that do have two (part) time jobs are registered as one person having labour but at the same time this is counted as two jobs. So, in general the number of jobs is higher than the number of persons having a job. In order to process with a consistent data set within the model, the national employment totals were scaled in such a way that they are equal to the national labour force minus the persons registered as unemployed. This is based on the assumption that international commuting does not play a significant role in Europe.

For forecasting labour productivity, average country- and sector-specific growth scenarios were used. Depending on country and sector, assumed annual growth rates vary between one and two percent, depending on the productivity development between 1981 and 1994. As an exception, for Luxembourg 0.5 percent (agriculture), 0.2 percent (manufacturing) and 1.0 percent (services) were assumed.

In addition, the model allows to replace country-based growth rates by growth rates for regions or groups of regions in order to take account of the fact that the development of labour productivity in some countries is spatially highly inhomogeneous. In the agricultural sector of some countries, at the same time increasing and decreasing labour productivity can be observed. In other countries and sectors growth rates differ significantly between regions, so that it seemed preferable to use region-specific growth rates where available. On the other hand it is still difficult to separate individual cases caused by special local circumstances from the overall economic development of the country and its balancing effect on the economic development of individual regions.

However, Becker (1989) showed for the agricultural sector that most outlier regions, compared with regions in line with the overall development of a country, suffer from obstacles such as climate and weather or specific market and policy conditions. By taking account of these intervening variables (which could not be modelled anyway) Becker obtained much clearer results when calculating agricultural productivity for Germany over a long period (1952-1987) - he found a steady increase by a on average two percent per year. This observation is corroborated by other empirical and theoretical studies, such as European Commission (1995, 45), Dansk Strukturdirektoratet for Landbrug- og Fiskeri (1998, 7) or Heinrichsmeyer and Witzke (1991). Similar effects can be found for manufacturing and services, so that it seems reasonable to use much simpler country-specific growth rates.

The effects of changes in accessibility on labour productivity have not yet been thoroughly investigated. Therefore in the present model implementation ε_i is taken to be zero, i.e. accessibility effects are excluded.

Regional employment by industrial sector is then calculated as follows:

$$E_{ir}(t) = Q_{ir}(t) / p_{ir}(t)$$

where $E_{ir}(t)$ is employment in industrial sector i in region r in year t, $Q_{ir}(t)$ is the GDP of industrial sector i in region r in year t and $p_{ir}(t)$ is the annual GDP per worker of industrial sector i in region r in year t.

4.5 Regional Population

The *Regional Population* submodel forecasts regional population by five-year age groups and sex through natural change (fertility, mortality) and migration. Population forecasts are needed to represent the demand side of regional labour markets.

4.5.1 Cohort Survival Model

Changes of population due to births and deaths are modelled by a cohort-survival model subject to exogenous forecasts of regional fertility and mortality rates. To reduce data requirements, a simplified version of the cohort-survival population projection model with five-year age groups is applied. The method starts by calculating survivors for each age group and sex:

$$P'_{asr}(t) = P_{asr}(t-1)\,[1-d_{asr'}(t-1,t)] \qquad \text{with } r \in \mathbf{R}_{r'}$$

where $P'_{asr}(t)$ are surviving persons of age group a and sex s in region r in year t, $P_{asr}(t-1)$ is population of age group a and sex s in year $t-1$ and $d_{asr'}(t-1,t)$ is the average annual death rate of age group a and sex s between years $t-1$ and t in country or group of regions $\mathbf{R}_{r'}$ to which region r belongs.

Next it is calculated how many persons change from one age group to the next through ageing employing a smoothing algorithm:

$$g_{asr}(t-1,t) = 0.12\,P'_{asr}(t) + 0.08\,P'_{a+1sr}(t) \qquad \text{for } a = 1,19$$

where $g_{asr}(t-1,t)$ is the number of persons of sex s changing from age group a to age group $a+1$ in region r. Surviving persons in year t are then

$$P_{asr}(t) = P'_{asr}(t) + g_{a-1sr}(t-1,t) - g_{asr}(t-1,t) \qquad \text{for } a = 2,19$$

with special cases for the last and first age groups:

$$P_{20sr}(t) = P'_{20sr}(t) + g_{19sr}(t-1,t)$$

$$P_{1sr}(t) = P'_{1sr}(t) + B_{sr}(t-1,t) - g_{1sr}(t-1,t)$$

where $B_{sr}(t-1,t)$ are births of sex s in region r between years $t-1$ and t:

$$B_{sr}(t-1,t) = \sum_{a=4}^{10} 0.5\,[P'_{a2r}(t) + P_{a2r}(t)]\; b_{asr'}(t-1,t)\; [1-d_{0sr'}(t-1,t)] \qquad \text{with } r \in \mathbf{R}_{r'}$$

where $b_{asr'}(t-1,t)$ are average number of births of sex s by women of child-bearing five-year age groups a, $a = 4,10$ (15 to 49 years of age) in country or group of regions $\mathbf{R}_{r'}$ to which region r belongs between years $t-1$ and t, and $d_{0sr'}(t-1,t)$ is the death rate during the first year of life of infants of sex s in country or group of regions $\mathbf{R}_{r'}$ to which region r belongs.

4.5.2 Fertility and Mortality

The model presently uses country-specific fertility and mortality rates, i.e. its built-in potential to apply region-specific fertility rates to distinguish between, say, rural and urban regions, is presently not utilised. Also the different fertility behaviour of different population groups, such as native and immigrant population, is presently not taken account of.

Fertility rates

Country-specific fertility rates are input to the model as live births per year of 1,000 women of age groups 16-20, 21-25, 26-30, 31-35, 36-40, 41-45 and 46-50 years of age for the years of 1981 to 1993, 1994 or 1995, depending on the country. The fertility rates were calculated by combining data sources and disaggregating the data to five year age groups. Data on fertility rates was obtained from the New Cronos database provided by Eurostat. Additional data provided by the Council of Europe have been integrated to complete the database. Thus, a complete set of data covering fertility rates by member state for each year from 1981 to 1995 became available. To work the data on births into the cohort survival model which is disaggregated by sex, the number of male births per 1,000 female births was assumed to be 1,055 throughout.

The fertility rates represent differences in fertility behaviour between countries as well as their changes over time. Figure 4.17(a) to (c) compares the most recent age-specific fertility rates by country. It can be seen that there still exist substantial differences in fertility behaviour in the countries of Europe, with relatively high fertility rates in the Nordic countries, Ireland, Belgium, Luxembourg and France and relatively low rates in Austria, Germany and the Mediterranean countries. Figure 4.17(d) shows the dramatic changes in fertility that have occurred in Italy and the new German Länder.

No specific forecast of fertility in the member states was undertaken for SASI. Instead it was assumed that the most recent available fertility rates of a country will prevail during the forecasting period.

Mortality rates

Mortality is input to the model in the form of sex-specific survival rates by five-year age group. Country-specific survival rates were collected for the years 1981, 1986 and 1991 from the Eurostat Population Statistics Data Set but had to be disaggregated into survival rates by five year age group by applying various country-specific assumptions as to the distribution among age groups. Thus, a complete set of data covering survival rates by member state for the years 1981, 1986 and 1991 became available. The model interpolates between these years.

No specific forecast of mortality in the member states was undertaken for SASI. Instead it was assumed that the most recent available mortality rates of a country will prevail during the forecasting period.

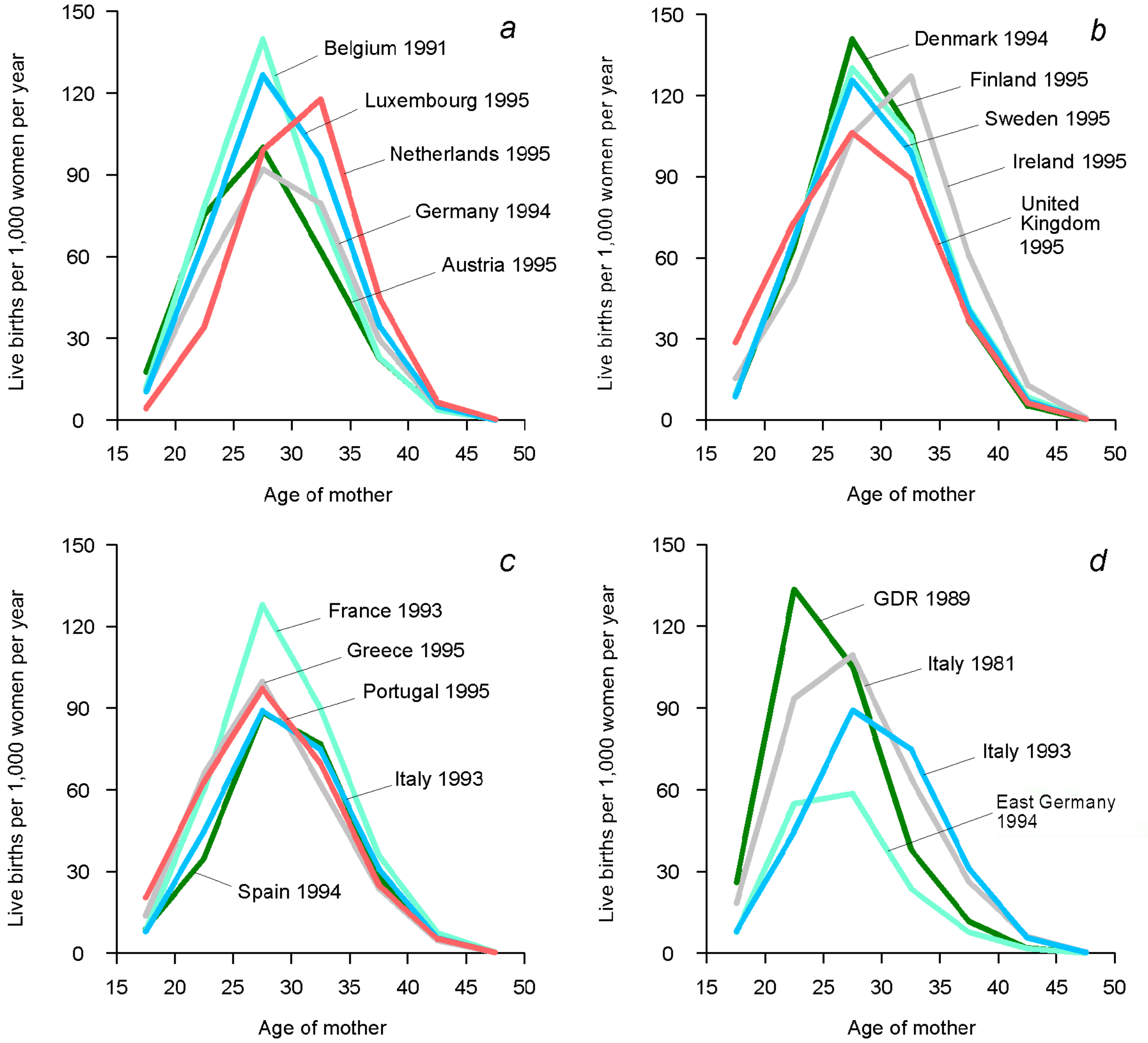


Figure 4.17. Age-specific fertility rates in EU member states 1993-1995 (a-c) and change of fertility rates over time in Italy 1981-1993 and in East Germany 1989-1994 (d)

4.5.3 Migration

In the draft model specification in Deliverable D8 (Wegener and Bökemann, 1998) it was envisaged that interregional migration within the European Union and immigration from countries outside the European Union would be modelled in two separate submodels. This could not be implemented due to lack of spatially disaggregate migration data. Therefore a combined simplified model was implemented.

Both migration within the European Union and immigration from non-EU countries is modelled as annual regional net migration rate as a function of the regional unemployment rate $u_r(t\text{-}1)$ in year t-1 (see below) and a vector $\mathbf{X}_r(t)$ of regional indicators expressing the attractiveness of a region as a place of employment and a place to live (quality of life):

$$m_r(t,t+1) = \mathrm{f}\ [u_r(t-1),\ \mathbf{X}_r(t)]$$

where $m_r(t,t+1)$ is the number of net migration per 1,000 population at time (t) between years t and t+1. Because at the time of execution of the *Regional Population* submodel regional unemployment in year t is not yet known, unemployment in the previous year t–1 is used.

The calibration of this model used regional net migration rates synthetically derived from demographic data:

$$m_r(t-1,t) = \frac{P_r(t) - P_r(t-1) - B_r(t-1,t) + D_r(t-1,t)}{P_r(t-1)}$$

where $P_r(t)$ is population in region r at time t and $B_r(t\text{-}1,t)$ and $D_r(t\text{-}1,t)$ are births and deaths in region r between times t-1 and t. Figure 4.18 shows accumulated net migration between 1981 and 1991 by country.

Calibration

The calibrated forecasting equation for regional net migration is

$$m_{t,t+1} = 0.175\ [B_r(t-1,t) - D_r(t-1,t)] + 0.119\ w_r - 11.27\ u_r(t-1) - 5.004$$

where w_r is the regional quality-of-life indicator (see Section 4.5.4) and $u_r(t\text{-}1)$ is the regional unemployment rate. With r^2 = 0.23 the goodness of fit of the model is low but significant at the 0.00 level.

Significant better results over time were achieved with the following model:

$$m_{t,t+1} = 0.175\ [B_r(t-1,t) - D_r(t-1,t)] + 0.06\ q_r(t) + 0.06\ w_r - 11.27\ u_r(t-1) - 5.004$$

i.e. by introducing regional GDP per capita in percent of average EU GDP per-capita $q_r(t)$ as further pull variable into the equation.

As the total of the forecasts of regional net migration do not necessarily add up to the total European net migration assumed in the European migration scenarios, they are adjusted to comply with total European net migration forecast by the *European Developments* submodel (see Section 4.1.4).

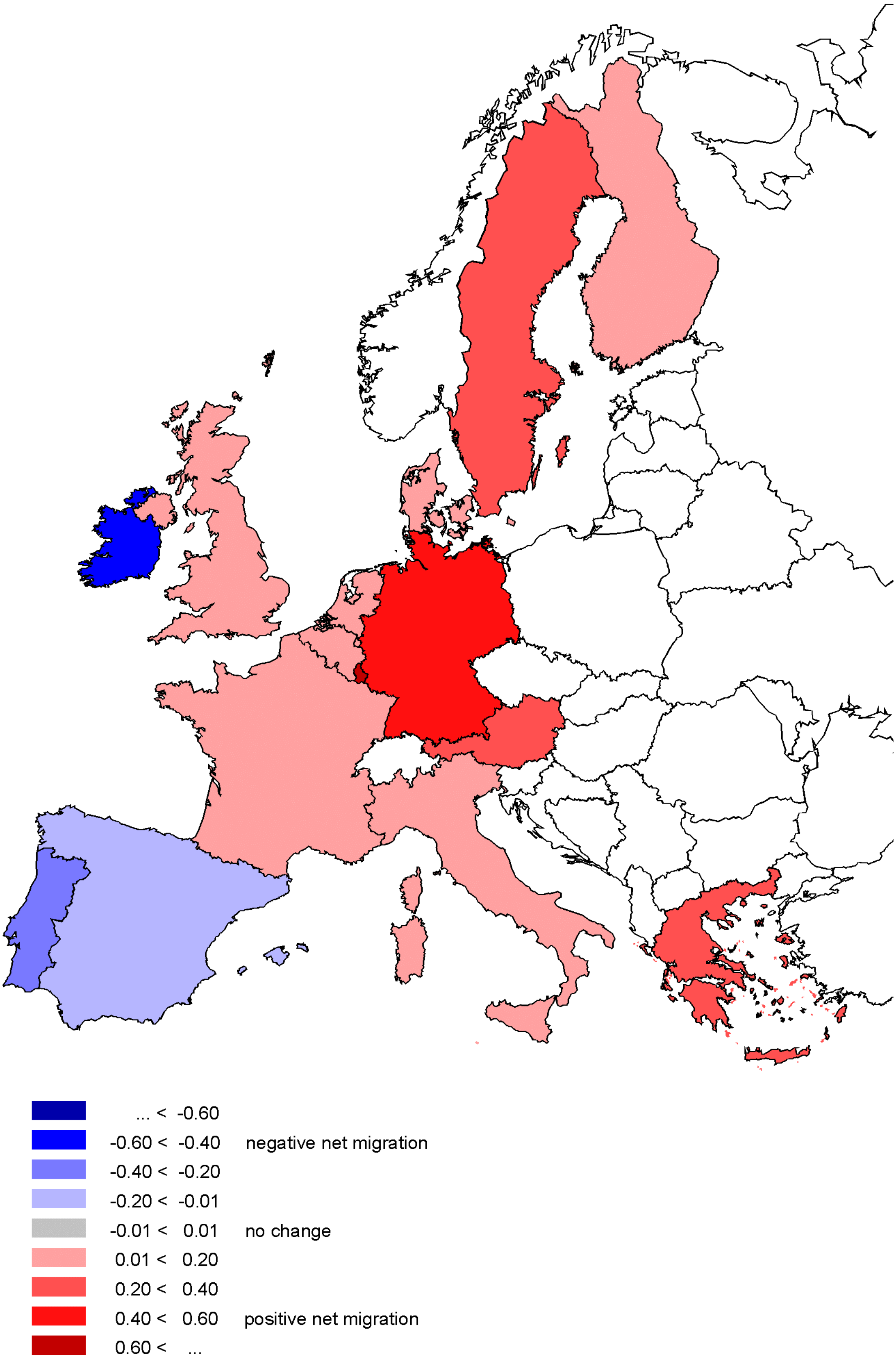


Figure 4.18. Net migration 1981-1995 by country

Quality of Life

Migration depends partly on the attractiveness of a region as a place to live. Not only highly skilled persons but also pensioners who want to spend their retirement age at the countryside, at the shores or other attractive places account for a large percentage of European migration flows. These flows are nearly independent of the economic situation of regions.

Therefore the *Migration* submodel includes a regional quality-of-life indicator. This indicator is a composite indicator derived by multicriteria analysis (Schürmann, 1999).

The indicator compares three categories, climate, landscape and tourist facilities. The climate category considers the fact that retirement migration prefer regions with rather warm and rainless climate. The beauty and variety of the landscape plays also a prominent role. Last but not least the number and the degree of development of leisure and tourist facilities is also an import point for many people in their decisions regarding migration targets.

Each of the three categories is composed of three subindicators. The resulting nine subindicators are as follows (with the categories given in brackets):

- *Temperature* (Climate). The temperature subindicator gives the long-time average temperatures in July taken from Westermann (1997) expressed in degrees centigrade.

- *Sunshine* (Climate). The daily global radiation on the ground is used as a proxy for sunshine, because information on the number of sunshine hours for the entire European continent is not available. The radiation data are given as the average of the years 1966-1975 of the annual averages over all months in kWh/m^2 and are taken from Palz and Greif (1995).

- *Rainfall* (Climate). The rainfall subindicator is measured as the long-time average yearly amount of rain in millilitres and is based on Westermann (1997).

- *Slope gradient* (Landscape). The average slope gradients are used as a first proxy for the surface variety. They are derived from a European three-dimensional surface elevation model produced at the IRPUD (1998) and are measured in percentage slope.

- *Elevation differences* (Landscape). The elevation differences are used as a second proxy for the surface variety and are also taken from the European three-dimensional surface elevation model (IRPUD 1998). They are calculated as the difference between the maximum and minimum elevation within one region and are measured in meters.

- *Open space* (Landscape). The open space subindicator gives the percentage of open space on the region's area. Open space includes all forest areas as well as the utilised agricultural areas and arable land. The data are taken from Eurostat (1998c).

- *Tourist area* (Tourist facilities). The tourist area subindicator represents the degree of development of regions with (soft) tourist facilities such as footpaths, resting places, hotels, other recreation facilities, mountain railways, tourist information services etc. This is a qualitative indicator adopted from Ritter (1966) differentiating between (a) areas which are totally influenced and formed by tourism, (b) areas which are locally influenced and formed by tourism, (c) areas with tourism but which are only sparsely formed by tourist facilities,

(d) areas which are not influenced and not formed by tourism and finally (e) agglomerations (no tourist regions).

- *Attractive towns* (Tourist facilities). The attractive towns subindicator counts the numbers of historical and winter sports towns as well as the number of health and seaside resorts and relates it to the size of the region. The cities are taken from Westermann (1983).

- *Development of shores* (Tourist facilities). The development of shores subindicator represents the degree of the development of tourist facilities in coastal regions. Again, this is an qualitative indicator adopted from Ritter (1966) which differentiates between regions with (a) totally developed shores, (b) well developed shores, (c) sparsely developed shores, (d) no developed shores or (e) no shores at all.

Of the tourist facilities category, the *tourist-area* subindicator considers the development of facilities of the countryside, the *attractive-towns* subindicator considers the development of facilities of the cities and agglomerations, the *development-of-shores* subindicator considers the development of facilities of the seaside.

All subindicators are either directly derived from various sources (e.g. rainfall, temperature) or are generated by using individual generation functions (tourist areas, development of shores). However, in any case mapping functions are used to transform the observed values into utilities which are used within the multicriteria analysis. The mapping functions used are displayed in Figure 4.19 in a summarised form. The x-axes indicate the indicator values, whereas the left y-axes show the frequencies of indicator values and the right y-axes show the utilities of the mapping functions.

Figure 4.20 shows the hierarchy of the subindicators and the weights of the indicators in brackets.

The weights are based on expert ratings. The three categories (climate, landscape, tourist facilities) are equally weighted with 33.3 percent each:

- Within the climate category, the subindicators *temperatur*e and *rainfall* have both a weight of 30, whereas *sunshine* has a weight of 40.

- Within the landscape category, the *slope gradient* and the *elevation differences* subindicators have weights of 20 and 30, respectively, i.e. taking both together as the ‘relief energy’, they have the same weight as the *open space* subindicator (50).

- Of the tourist facilities, the main subindicator is *development of shores* with a weight of 50, whereas the attractive *towns* and *tourist area* subindicators have both a weight of 25. The assumption behind this is that seaside regions are more attractive than hinterland regions. Moreover, historical towns are to some extent an attraction factor but they are unlikely to be the only criterion in a migration choice.

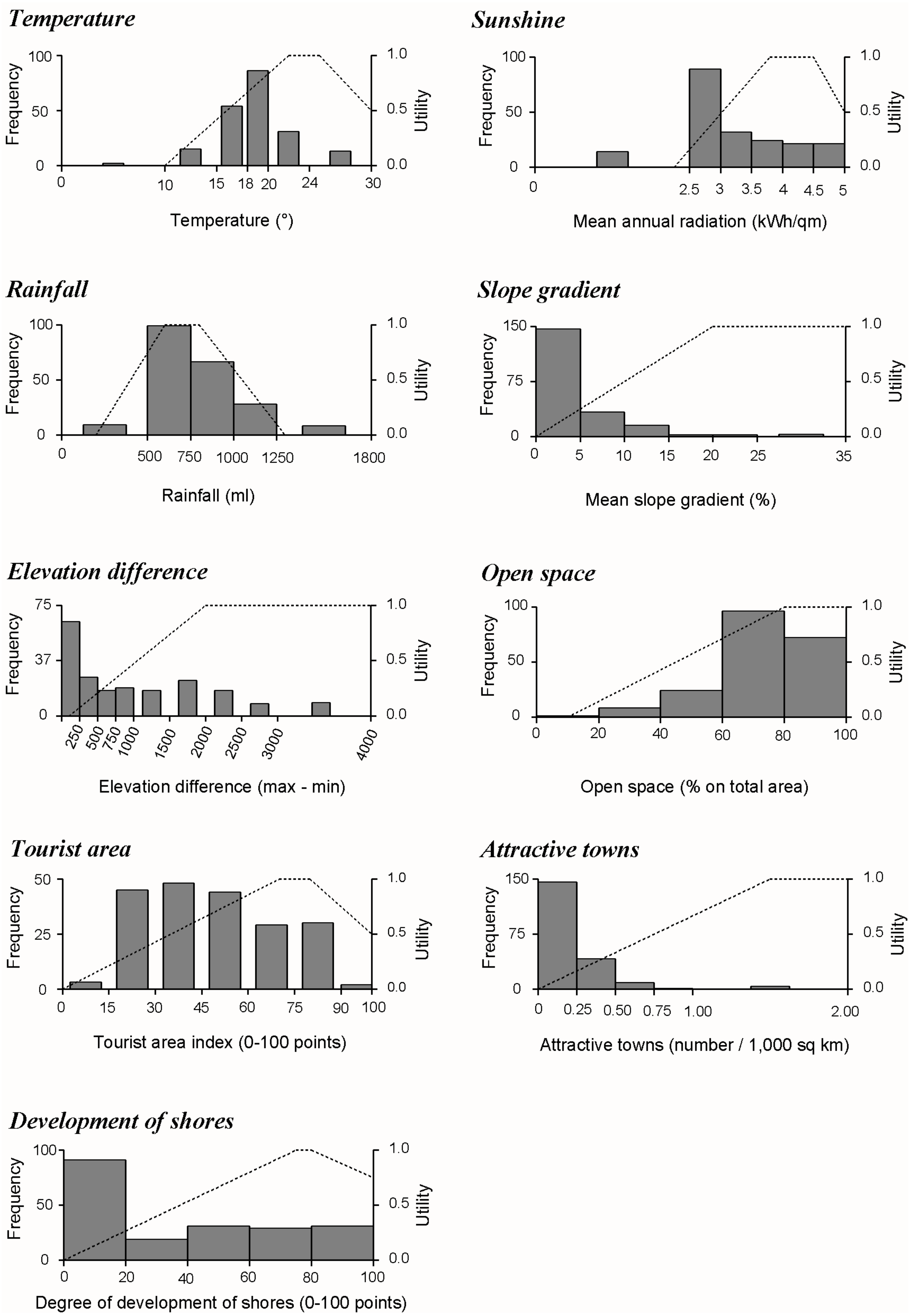


Figure 4.19. Mapping functions of the nine subindicators

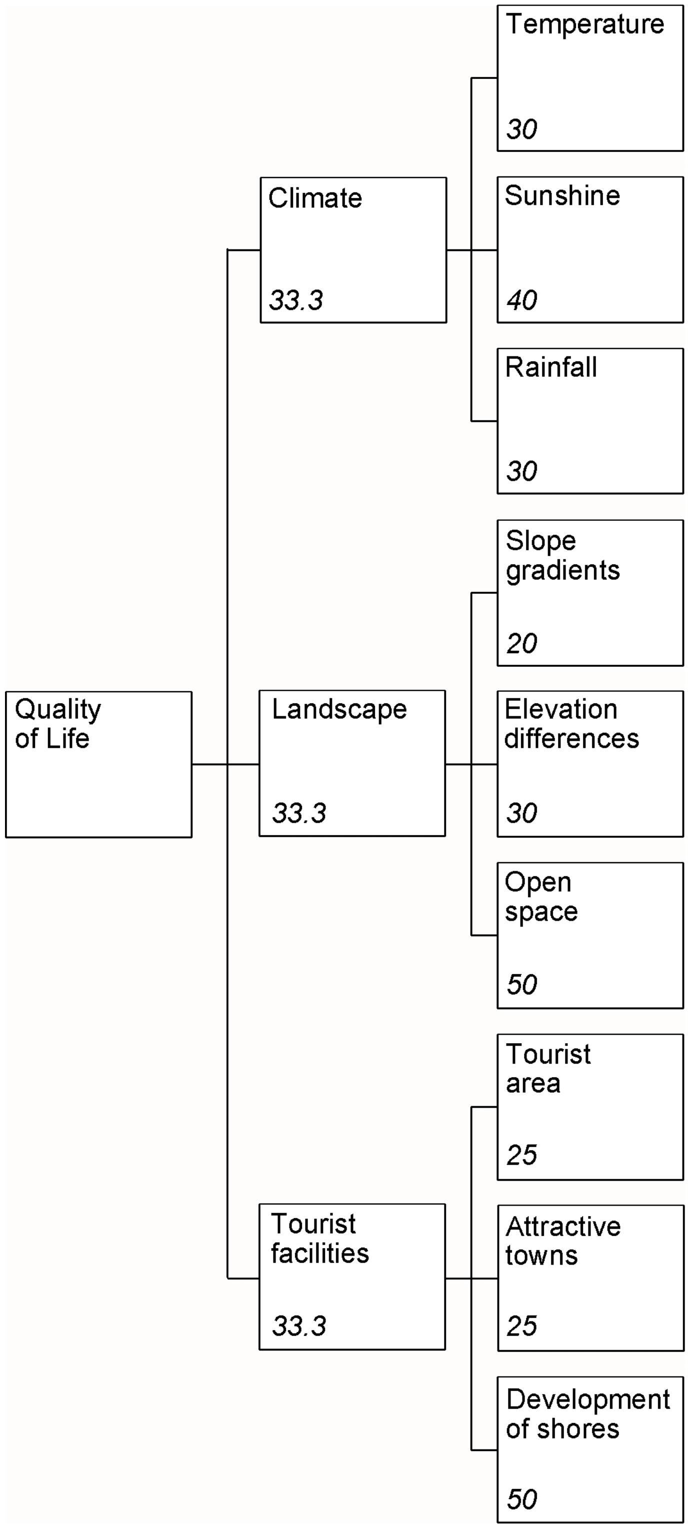


Figure 4.20. Composition of the regional quality-of-life indicator

Figure 4.21 shows the overall results of the multicriteria analysis, i.e. the regional quality-of-life indicator for NUTS-2 regions. Some of the Mediterranean regions of France, Italy and Spain obtain the highest values. The south of Italy is slightly decreasing in comparison to the northern parts, mainly because the climate is too extreme (temperatures are too high, almost no rainfall) and because of the Naples agglomeration area. The Spanish dry hinterlands obtain values between 45 and 60 points, i.e. lower values in comparison to the coastal regions. Some regions in Germany (Oberbayern, Arnsberg, Braunschweig) obtain also relatively high values mainly because of their surface variety and open space, while other German regions obtain values between 45 and 60 points with the exception of the three city-states Berlin, Hamburg and Bremen. Similarly, most of the Benelux regions obtain only values between 30 and 45 points (flat relief, low share of open space). In Austria, Tirol and Salzburg show also values between 30 and 45 points, because of the high amount of rain. The north of Scandinavia, Scotland and Ireland obtain the smallest values, because of their climatic conditions.

Development over time

It is assumed that the regional quality-of-life indicator is an exogenous, static-in-time indicator, which is not predicted endogenously by the SASI model. There are several reasons for this assumption:

- The climate can be considered to stay constant over the forecast period, although there might be changes in the climate. These changes, however, take place slowly over long time periods, so that the three climate subindicators can be assumed to be constant.

- Similarly to the climate category, changes in the relief energy evolve in time periods far beyond people's imagination. Again, both relief energy subindicators can be assumed to stay constant. The share of open space might significantly change within the modelling period, but taking all subindicators together, *open space* has a relatively low weight, so that again the assumption to remain constant seems to be justifiable.

- The three tourist facilities subindicators are qualitative indicators measuring the degree of development of the regions. It can be assumed that changes in the degree of development of one particular region is a matter of many years, and moreover, if development takes place these development will take place in regions which are already highly developed, these three subindicators can also be assumed to remain constant over the modelling period.

Regional Unemployment

Regional unemployment is the major push variable of the migration model. Regional unemployment rates are calculated in the *Socio-economic Indicators* submodel (see Section 4.7).

For calibrating the migration model, unemployment rates were taken from harmonised unemployment data of the Eurostat regional database.

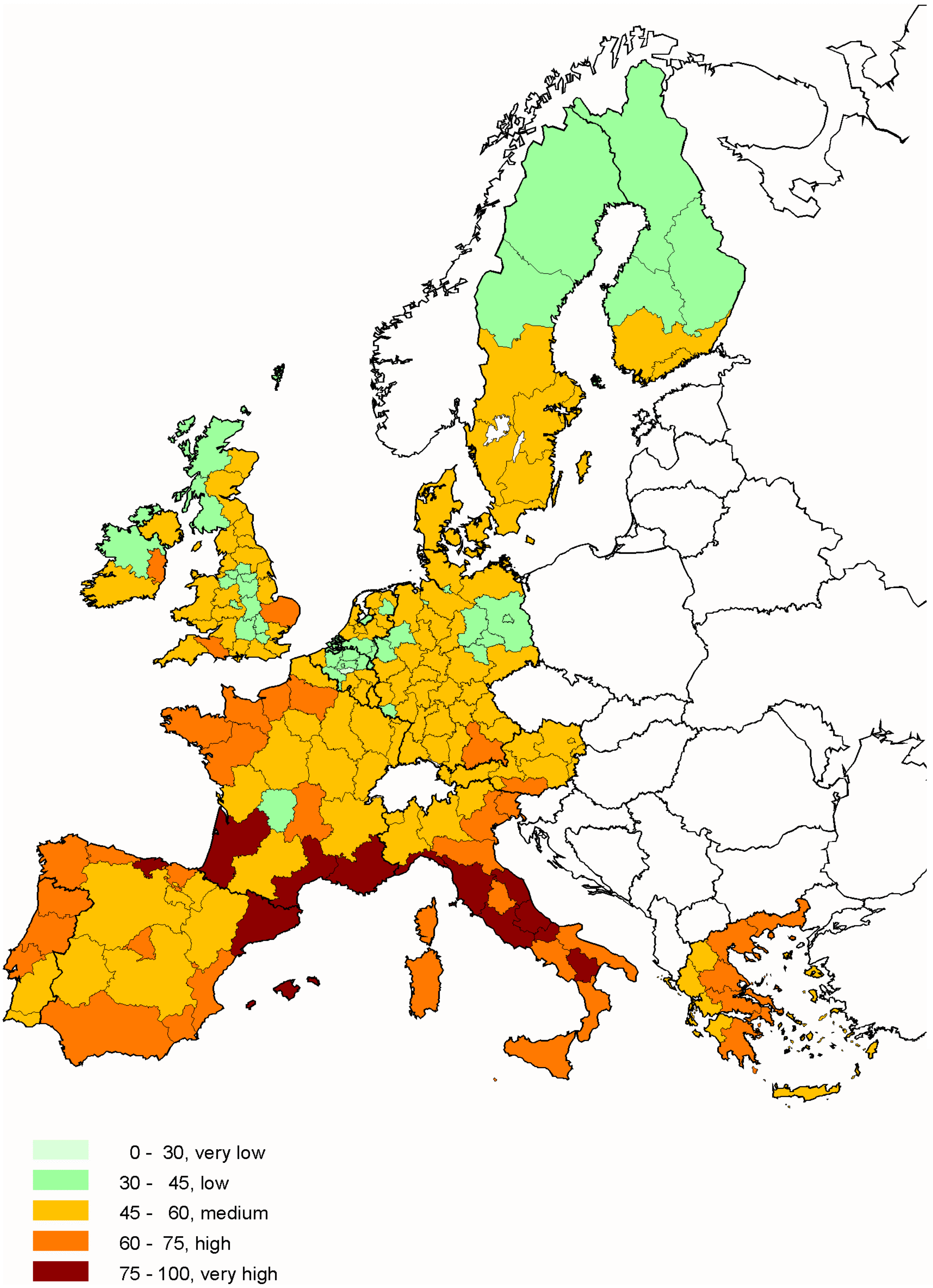


Figure 4.21. Spatial distribution of the regional quality-of-life indicator

4.5.4 Educational Attainment

The economic performance of a region depends not only on physical infrastructure but to a great extend also on the skills of the regional labour force. Skilled labour force and "higher education institutions have the potential to make a considerable contribution to the economic development of the region in which they are located. Their involvement in regional development is enhanced by the growing importance of knowledge and information within the global economy" (Thanki, 1999, 85).

As a key indicator of the availability of skilled labour in the regions the educational attainment of working age population can be used (European Commission, 1999c). The highest level of education completed is the most easily measurable proxy for the overall qualifications of the workforce (OECD, 1999).

The data used in the SASI model is based on the International Standard Classification of Education (ISCED), which was defined to facilitate the international comparison of educational attainment. The ISCED classification is commonly aggregated to three broad groups (e.g. Eurostat, 1998):

- *ISCED <3* comprises pre-primary education, primary education and lower secondary education. The end of lower secondary education often coincides with the end of full-time compulsory schooling.

- *ISCED 3* is upper secondary education. It begins around the age of 14 or 15 and refers to either general, vocational or technical education. It can lead to the standard required for admission to tertiary education.

- *ISCED 5, 6, 7* is tertiary education. It covers programmes outside universities for which successful completion of upper secondary level is required, leading to university degrees or equivalent or leading to a second, post graduate university degree.

For the SASI model the regional proportion of residents in working age with upper secondary and tertiary education has been selected as appropriate endowment factor describing human resources (see Section 4.3.2).

Data based on the ISCED classification for the population aged 25 to 59 are available for 1991 by country (CERI, 1993) and for 1993 and 1996 by region (Eurostat, 1995; 1998d). Figure 4.22 shows the regional percentages of persons in that age class having medium (ISCED 3) or higher (ISCED 5,6,7) education. It can be seen that there are great disparities in educational attainment across Europe and even within countries. In Portugal only 25 percent of the population aged 25 to 59 have a qualification beyond compulsory schooling; in other less developed countries this share is one third as in Spain and Italy or about 50 percent as in Greece, Ireland and Luxembourg. In most countries educational attainment is higher in urban regions than in rural areas.

According to an information given by Eurostat past data on educational attainment is not available in a systematic manner. Therefore, regional educational attainment data for 1981 to 1990 were estimated using backcasting based on national trends observed in the period between 1991 and 1996.

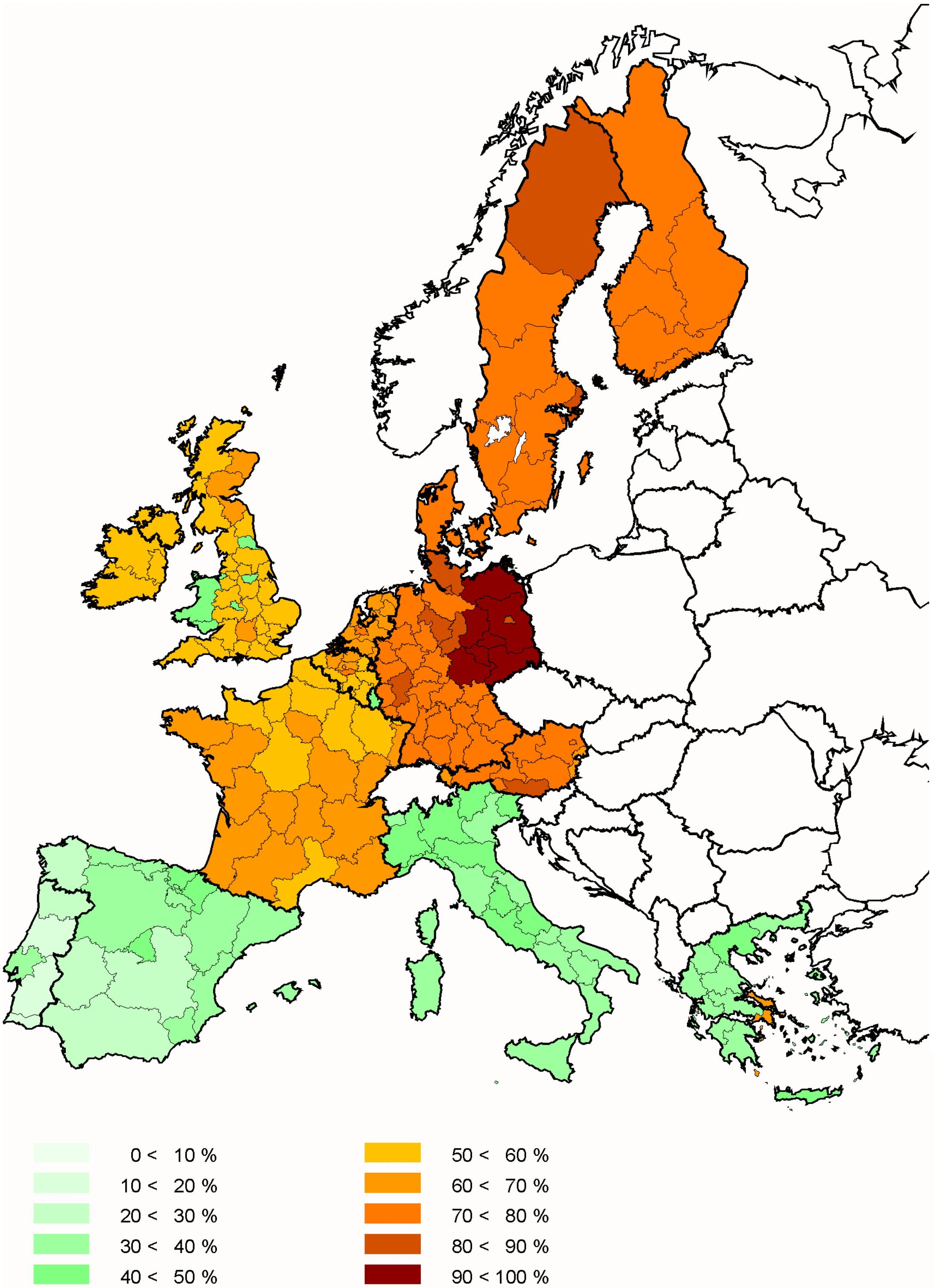


Figure 4.22. Medium and higher educational attainment of persons aged 25 to 59

For future years regional educational attainment is forecast exogenous assuming that it grows as in the country or group of regions to which region *r* belongs:

$$h_r(t) = h_r(t-1)\frac{h_{r'}(t)}{h_{r'}(t-1)} \qquad \text{with } r \in \mathbf{R}_{r'}$$

where $h_r(t)$ is the proportion of residents with medium and higher education in region *r* in year *t,* and $h_{r'}(t)$ is the average proportion of residents with medium and higher education in country or group of regions $\mathbf{R}_{r'}$ to which region *r* belongs. The national forecasts used for this is based on expectations for future educational attainment by the OECD (1998) for the year 2005 which has been extrapolated to 2016.

Figure 4.23 displays the past and future development of educational attainment for the fifteen member states of the European Union as used for backcasting and forecasting the regional figures to be used in the SASI model as exogenous data.

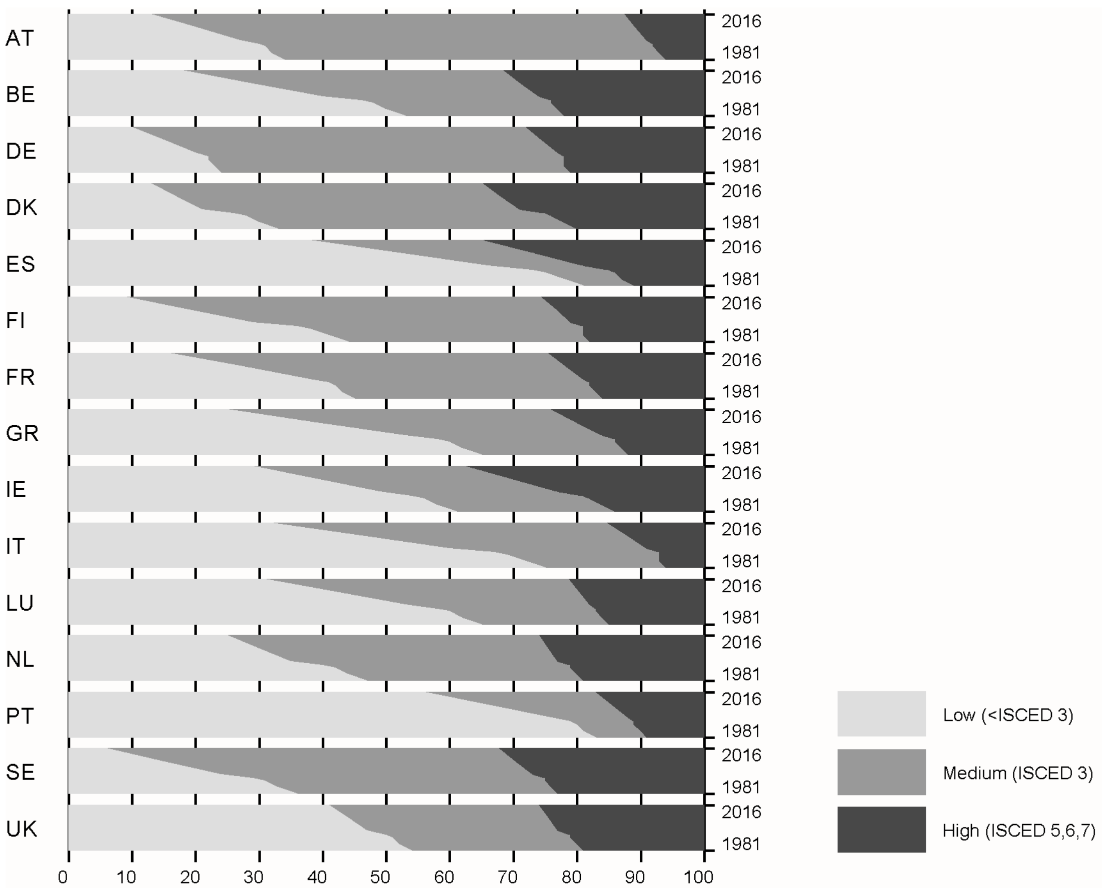


Figure 4.23. Educational attainment of persons aged 25 to 59 by country, 1981-2016

4.6 Regional Labour Force

Regional labour force is derived from regional population and regional labour force participation.

Regional labour force participation by sex is partly forecast exogenously and partly affected endogenously by changes in job availability or unemployment. It is assumed that labour force participation in a region is predominantly determined by historical conditions in the region, i.e. by cultural and religious traditions and education and that it grows by an average country-specific growth rate. However, it is also assumed that it is positively affected by availability of jobs (or negatively by unemployment):

$$\ell_{sr}(t) = \ell_{sr}(t-1)\, \ell_{sr'}(t) / \ell_{sr'}(t-1) - \varphi_s\, u_r(t-1) \qquad \text{with } r \in \mathbf{R}_{r'}$$

where $\ell_{sr}(t)$ is labour force participation, i.e. the proportion of economically active persons of sex s of regional population of sex s 15 years of age and older, in region r in year t, $\ell_{sr'}(t)$ is average labour participation of sex s in year t in country or group of regions $\mathbf{R}_{r'}$ to which region r belongs, $u_r(t-1)$ is unemployment in region r in the previous year $t-1$ (see below), and φ_s is a linear elasticity indicating how much the growth in labour productivity is accelerated or slowed down by regional unemployment. Because at the time of execution of the *Regional Labour Force* submodel regional unemployment in year t is not yet known, unemployment in the previous year $t-1$ is used.

Regional labour force by sex s in region r, $L_{sr}(t)$, is then

$$L_{sr}(t) = P_{sr}(t)\, \ell_{sr}(t)$$

where $P_{sr}(t)$ is population of sex s 15 years of age and older in region r at time t and $\ell_{sr}(t)$ is the labour force participation rate of sex s in region r in year t. Regional labour force is disaggregated by skill level in proportion to educational attainment in the region calculated in the *Population* submodel (see Section 4.5):

$$L_{sr1}(t) = h_r(t)\, L_{sr}(t)$$

with $L_{sr1}(t)$ being skilled labour and the remainder unskilled labour:

$$L_{sr2}(t) = L_{sr}(t) - L_{sr1}(t)$$

There are three types of data which have been collected as a model input:

Firstly, national labour force participation rates by sex have been obtained from the Bureau of Statistics of the International Labour Office with some time series data missing which had to be calculated with interpolation and extrapolation methods so that a complete data set the of national activity rate from 1981-2016 became available.

Secondly, regional labour force participation rates have been gathered from the Eurostat Statistical Yearbooks covering the years 1986-1996. To obtain a complete dataset backcasting methods had to be applied to 1986 data to estimate 1981 data.

Thirdly, regional labour force in 1,000 persons is required as a model input. Since these data are not readily available, data from various sources had to be compiled and adjusted. The basis of the dataset is the Labour Force Survey for the European Union and the Harmonised unemployment data set of Eurostat as contained in the Regio Database and the r-cade Online Service from the Universities of Durham and Essex.

Data for 1981, 1986 and 1991 and data for Greece for 1981 and 1986 has been obtained from the national statistical offices. For some years, regional data for a number of countries were retained from national statistical offices. The data referring to countries which have accessed the European Union after 1981 (Austria, Finland, Sweden, Greece, Spain and Portugal) had to be obtained completely from the respective national census bureau of statistics. Data for the regions of the former German Democratic Republic for years prior to 1990 is taken from the Statistical Yearbook of the German Democratic Republic.

4.7 Socio-Economic Indicators

Total GDP and employment represent only the supply side of regional socio-economic development. To derive policy-relevant indicators, they have to be related to the demand side, i.e. to population and labour force. This is done be calculating total regional GDP per capita and regional unemployment.

Since accessibility, besides being a factor determining regional production (see Section 4.2), is also an indicator of regional locational advantage and quality of life, accessibility indicators are a considered policy-relevant output of the model.

Accessibility, GDP per capita and unemployment are therefore the main socio-economic and spatial indicators produced by the SASI model.

In addition, equity or cohesion indicators describing the distribution of accessibility, GDP per capita and unemployment across regions are calculated.

Accessibiliy

Regional accessibility indicators are calculated in the *Regional Accessibility* submodel (see Section 4.2)

GDP per capita

Total regional GDP per capita is calculated by dividing total regional GDP including transfers (see Section 4.3.4) by regional population:

$$q_r(t) = Q_r(t) / P_r(t)$$

Unemployment

The regional unemployment rate $u_r(t)$ in year t is

$$u_r(t) = \frac{L_r(t) - \sum_s T_{rs}(t) + \sum_s T_{sr}(t) - E_r(t)}{L_r(t)}$$

where $L_r(t)$ is total labour in region r in year t, $E_r(t)$ is total employment in region r in year t and $T_{rs}(t)$ are commuters from region r to region s in year t calculated from a doubly constrained spatial-interaction work trip model:

$$T_{rs}(t) = \quad L_r(t)\ A_r\ \ E_s(t)\ B_s \exp[-\beta\ c_{rs}(t)]$$

where $c_{rs}(t)$ is travel time and/or cost between regions r and s in year t and A_r and B_s are balancing factors to ensure that origins and destinations match:

$$A_r = \frac{1}{\sum_s E_s(t)\ \exp[-\beta\, c_{rs}(t)]}$$

$$B_s = \frac{1}{\sum_r L_r(t)\ \exp[-\beta\, c_{rs}(t)]}$$

Because NUTS-2 regions were considered as too large for the analysis of commuter flows, commuter flows were calculated at the NUTS-3 level and then aggregated to NUTS-2 regions. To make the analysis reasonably fast, only commuter flows of less than two hours duration were considered.

It is important to note that the unemployment rate so derived only serves to compare different scenarios within the SASI project and is not comparable to the standardised unemployment rates calculated by Eurostat.

Cohesion indicators

From the policy-relevant indicators so derived, equity or cohesion indicators describing their distribution across regions are calculated. Cohesion indicators are macroanalytical indicators combining the indicators of individual regions into one measure of their spatial concentration. Changes in the cohesion indicators predicted by the model for future transport infrastructure investments reveal whether these policies are likely to reduce or increase existing disparities in those indicators between the regions. A large number of cohesion indicators was proposed in SASI Deliverable D4 (Bökemann et al., 1997, Section 3.2.3).

Cohesion indicators will be used in Deliverable D15 to analyse the cohesion impacts of the demonstration policy scenarios. Here, in a preview of the application of cohesion indicators in Deliverable D15, two cohesion indicators will be demonstrated using regional accessibility as an example:

- The coefficient of variation. The coefficient of variation, i.e. the standard deviation of regional indicator values expressed in percent of their European average:

$$V = \frac{\sqrt{\sum_r (\bar{X} - X_r)^2 / n}}{\bar{X}} 100$$

  The coefficient of variation informs about the degree of homogeneity or polarisation of a spatial distribution. The greater the coefficient of variation, the more polarised is the distribution. A coefficient of variation of zero indicates that all regions have the same indicator values. The coefficient of variation can be used to compare two accessibility scenarios with respect to cohesion or equity goals or two points in time of one scenario with respect to whether convergence or divergence occurs.

  Figure 4.24 shows the temporal development of the coefficient of variation for the two types of accessibility shown in Figures 4.12 and 4.13 between 1981 and 2016.

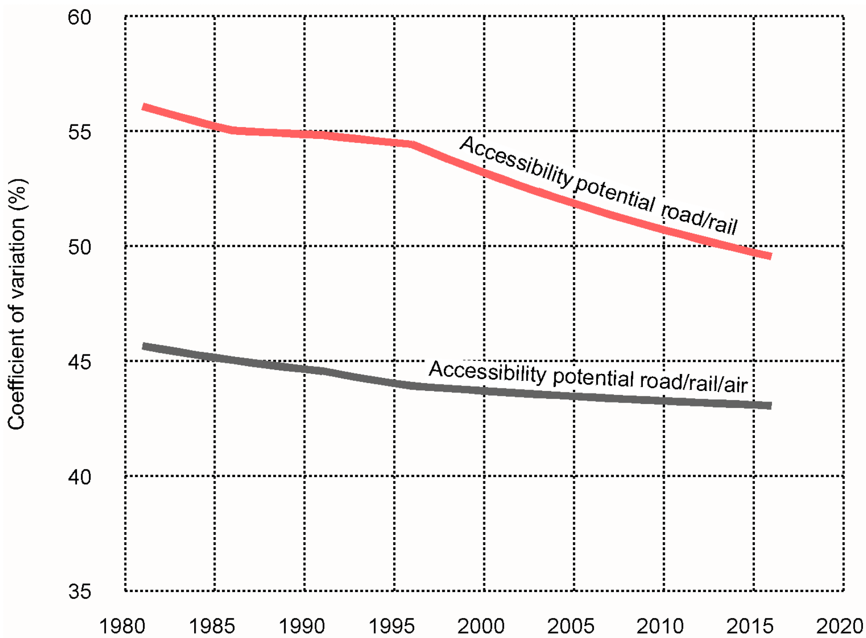


Figure 4.24. Coefficient of variation of SASI accessibility indicators 1981-2016

- The Lorenz curve compares a rank-ordered cumulative distribution of indicator values of regions with a distribution in which all regions have the same indicator values. This is done graphically by sorting regions by increasing indicator value and drawing their cumulative distribution against a cumulative equal distribution (an upward sloping line). The area between the two cumulative distributions indicates the degree of polarisation of the distribution of indicator values of regions. The GINI coefficient calculates the ratio between that area and the triangle under the upward sloping line of the equal distribution. The equation for the GINI coefficient is

$$G = 1 + 1/n - 2/(n^2 \overline{X}) \sum_r r\, X_r$$

where X are indicator values of regions sorted in decreasing order. The equation is used to measure the inequality in indicator values between regions, with V_r being the indicator value of region i, $\overline{X}$ the average indicator value of all regions, and n the number of regions. A GINI coefficient of zero indicates that the distribution is equal-valued, i.e. that all regions have the same indicator values. A GINI coefficient close to one indicates that the distribution of indicator values is highly polarised, i.e. few regions have very high indicator values and all other regions very low values. The different size of regions can be accounted for by treating each region as a collection of individuals having the same indicator values. The GINI coefficient is used in SASI to compare the inequality in accessibility and socio-economic indicators between regions for two different years. A growing GINI coefficient indicates that inequality in accessibility and socio-economic indicators between regions has increased, a declining coefficient indicates that disparities have been reduced. Similarly the GINI coefficient can be used to compare two scenarios. A larger GINI coefficient indicates that a scenario leads to greater disparities, a lower GINI coefficient indicates that it leads to more cohesion between regions.

The upper two diagrams of Figure 4.25 contain Lorenz curves comparing the spatial distribution of the two SASI accessibility indicators shown in Figures 4.13 and 4.14 in 1996 and in the TEN scenario in 2016, i.e. with all transport infrastructure projects of the TEN outline plan implemented. The two diagrams confirm Figure 4.24: There is a slight convergence in accessibility if only road and rail are taken into account, whereas the relative distribution of accessibility remains almost unchanged if also air is considered. The inclusion of air makes the distribution of accessibility much more homogeneous.

The lower two diagrams of Figure 4.25 compare accessibility indicators and scenarios. The left-hand diagram highlights the difference in distribution between the two accessibility indicators. The right-hand diagram compares the distribution of road-and-rail accessibility in 2016 in the hypothetical do-nothing scenario, in which no transport infrastructure investments occur after 1996, and in the TEN scenario mentioned above. It is seen that the TEN scenario results in a slightly more homogeneous distribution of regional accessibility.

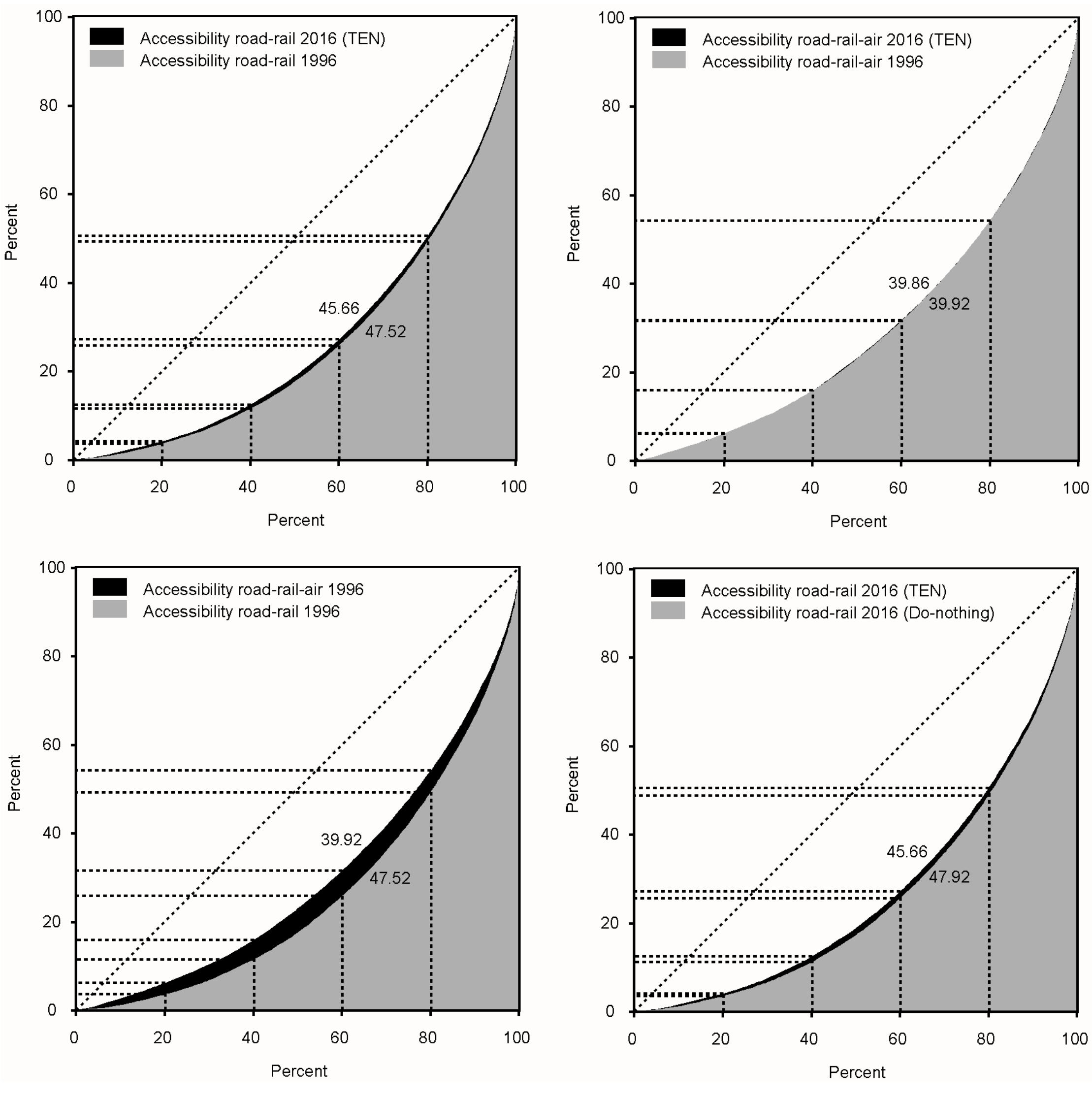


Figure 4.25. Lorenz curves of accessibility of NUTS-2 regions 1996-2016

5. Conclusions

This deliverable described the implementation of the SASI model i.e. the application of empirical data to the model and the estimation and calibration of its parameters. Where modifications in the model specification had to be made since the completion of Deliverable D8, this was pointed out.

Main results

It was shown that the SASI model is capable of modelling the impacts of transport infrastructure investments and transport system improvements with regard to all the indicators outlined in the original model structure, even though some slight modifications had to be made in the calibration process.

- All necessary data could be provided from Eurostat and various additional national and regional statistics and using standard data preparation and adjustment methods, such as forecasting, backcasting and data interpolation.

- The model calibration and specification of the production function led to satisfying results regarding the capability of the model to re-produce base-year distributions of socio-economic indicators in the 201 SASI regions.

- The model proved to be resilient and robust with respect to possible interfering externalities yet sensitive enough to detect the impacts even of partial or medium-scale changes, such as variants of TEN scenarios in a specific region. At a recent international research seminar in Copenhagen, the SASI team presented a comparison of two scenarios produced by the model, one with, the other one without the Øresund tunnel and bridge which will soon connect Denmark and Sweden. The comparison showed that the impact of a single link on regional development in the adjacent regions can be forecast by the model. It is worth noting that the results of the SASI model were very similar to those of another model presented at the seminar (Bröcker, 1999), even though both models have very different structures.

Problems

The implementation of the SASI model revealed some methodological problems which caused unexpected delays in the time schedule. Data collection and data preparation turned out to be much more difficult and time-consuming than anticipated:

- The backcasting of the IRPUD pan-European road and rail networks from the present to the year 1981 and the development of consistent TEN scenarios until 2016 involved an immense effort of data collection and digitisation. In addition it was necessary to overcome the weakness of current geographical information systems in storing temporal data.

- The regional GDP data supplied by Eurostat in the Regio and New Cronos databases turned out to be far from complete and consistent. This made it necessary to estimate missing data with rigorous attention to detail by means of alternative data sources or by interpolation.

- In addition to that the problem of inflation had to be tackled in order to transform time series of sectoral GDP to constant monetary units. Considerable effort had to be put into determining the correct deflators for converting GDP into 1998 ECU equivalents.

- The incompatibility of published national employment, labour force and unemployment data required extensive adjustments to arrive at a consistent framework of data for time-series forecasts of regional productivity.

- Ancillary data for the regional production functions such as indicators of quality of life and national and EU subsidies required additional theoretical and data collection efforts.

- Population data by age-group and sex was not available for all required years, which made the development of a special estimation procedure necessary.

In addition, the calibration of model functions revealed a number of conceptual and statistical problems which necessitated detailed specific investigations:

- The estimation and forecasting of sectoral productivity over time turned out to be difficult because of incompatible national GDP and employment statistics. In particular the calculation of GDP accounts in terms of Purchasing Power Standards, GDP at market prices, GDP at factor costs in national accounts and the identification of appropriate deflators proved to be a complex task.

- It became obvious that subsidy payments had to be taken into account when explaining the economic performance of a region. To meet these requirement, data on national and European subsidies were collected from many different sources and had to be compared and standardised. The appropriate consideration of national and EU transfer payments in the estimation of regional production functions gave rise to significant conceptual and data problems.

- The unavailability of consistent data on migration flows between regions in different member states and between regions and non-EU countries made the adoption of a simplified migration model based on forecasting net migrations necessary.

- Further inconsistencies between the available data on GDP, labour productivity, employment, population, labour force participation and unemployment made the estimation of labour market conditions and unemployment difficult.

Altogether, the calibration process confirmed the experience that the cross-sectional statistical calibration of a complex dynamic socio-economic spatial model, as it was performed here, is only the first step in a long iterative process of fine-tuning and validation of such models. In the absence of reliable techniques for the *dynamic* calibration of such models, the process of fine-tuning and validation consists of repeated applications of the model over an extended period of both past and future and the thorough examination of model behaviour using computer-based visualisation techniques and expert judgement. Only through such an interactive learning process can the model eventually become a robust and reliable tool for policy analysis and decision support.

Future work

Current work in the project concentrates on fine-tuning remaining sensitive parts of the SASI model and implementing the TETN scenarios. A number of scenarios of possible TETN implementation schedules have been formulated and tested, among them the Øresund scenarios indicated above. The results of this work will be presented in the forthcoming and final two deliverables. The software of the SASI model will be presented in Deliverables D13 and the results of the scenario demonstrations in Deliverable D15.

In addition, future work with a medium- to longer time-perspective not covered by the current project is envisaged:

- In the short-term future work will focus on extensions of the database and structure of the model to make it more responsive to other non-transport policies, such as regional economic policies and immigration policies, and transport policies, such as policies addressing multimodality and intermodality. These extension would require a further disaggregation of the economic sectors currently included in the model and the adoption of a more sophisticated and policy-responsive migration model.

- In the medium term it will be necessary to enable the model to address issues arising from the accession of new member states from eastern and southern Europe to the EU and the transport infrastructure investments connected with them and their likely impacts on regional economic development both in the new member states and the present EU. These extensions would require the extension of the geographical scope of the model to include the potential accession countries.

- In the long run it would be desirable to link the model to environmental submodels able to forecast also the ecological impacts of future TETN policies in terms of greenhouse gas emissions, air pollution and land take. These extension would require an increase in the spatial resolution of the model (probably from NUTS 2 to NUTS 3) and the addition of a mesoscopic, 'strategic' transport model.

6. References

ADAC (1987): *Der große ADAC Europa Atlas. Deutschland und Europa.* München: Mairs Geographischer Verlag.

ADAC (1991): *ADAC Straßenatlas 1991. Deutschland mit Europateil.* Berlin, Gütersloh, München, Stuttgart: Reise- und Verkehrsverlag.

ADAC (1999): *ADAC online*. http://www.adac.de

ARAL (1997): *ARAL Kartensatz Deutschland und Europa 97/98.* Dortmund: Kartographischer Verlag Busche.

Banverket (1999): *Construction projects.* http://www.banverket.se.

Becker, H. (1989): *Productivity Development in the Agricultural Sector of the Federal Republic of Germany*, Arbeitsbericht 1, Braunschweig: Bundesforschungsanstalt für Landwirtschaft.

Bökemann, D., Hackl, R., Kramar, H. (1997): *Socio-Economic Indicators Model and Report*. SASI Deliverable D4. Report to the European Commission. Wien: Institut für Stadt- und Regionalforschung, Technische Universität Wien.

Boin, O., O'Connor, D. (1997): 'The world economy in 2020'. *The OECD Observer*, 207, 9-12.

Box, G.E.P., Jenkins, G.M. (1976): *Time Series Analysis: Forecasting and Control.* San Francisco: Holden-Day.

Bröcker, J. (1996): 'Measuring accessibility in a general equilibrium framework'. Paper presented at the 5th World Congress of the RSAI, Tokyo, 2-6 May.

Bröcker, J. (1999): 'The economic impacts of the TEN projects on the Øresund region: an equilibrium modeling approach'. Paper presented at the 'International seminar on regional development impacts of the Øresund bridge', Copenhagen, 28 November 1999.

Bundesministerium für Verkehr (1992): *Bundesverkehrswegeplan 1992.* Bonn: BMV.

Bundesministerium für Verkehr (1996): *Bericht zum Ausbau der Schienenwege 1996.* Bonn: BMV.

Bundesministerium für Verkehr (1997a): *Verkehrsprojekte Deutsche Einheit. Sachsstand der einzelnen VDE-Projekte.* Newsletter 4/97. Bonn: BMV.

Bundesministerium für Verkehr (1997b): *Verkehrsinfrastrukturinvestitionen des Bundes in den neuen Bundesländern.* Bonn: BMV. http://www.bmv.de/vde.htm.

Bundesministerium für Verkehr (1997c): *Fünfjahresplan für den Ausbau der Schienenwege des Bundes in den Jahren 1998 bis 2002*. Bonn: BMV.

Centre for Educational Research and Innovation (CERI) (1993): *Education at a Glance. OECD Indicators.* Paris: OECD.

Dansk Strukturdirektoratet for Landbrug- og Fiskeri, DSLF (1998): *Landbrugets strukturudvikling. Betænkning fra udvalget vedrørende landbrugets strukturudvikling. Betænkning nr. 1351.* http://www.strukdir.dk/

DEGES (1995): *Verkehrsprojekte Deutsche Einheit Nr. 14 - A14 Magdeburg-Halle.* Different working materials. Berlin: DEGES.

DEGES (1996): *Verkehrsprojekte Deutsche Einheit Nr. 11 - A2 Hannover-Berlin A10 Berliner Ring (Süd- und Ostring).* Berlin: DEGES.

DEGES (1998): *Verkehrsprojekte Deutsche Einheit Nr. 10 - A20 Lübeck Stettin. Planfeststellungsverfahren, Planfeststellung, Baubeginn.* Berlin: DEGES.

De Jong, A., Visser, H. (1997): *Long-term International Migration Scenarios for the European Economic Area.* Eurostat working paper E4/1997-6, Luxembourg: Eurostat.

Department of the Environment, Transport and the Regions (1997): *Roads Review - Consultation Document. What Role for Trunk Roads in England?* http://www.detr.gov.uk/nrpd/hpp/trunk/index.htm

Deutsche Bahn AG (1996): *Elektronisches Kursbuch 1996. 02.06.96-28.09.96.* Hannover: HaCon.

Deutsche Bahn AG (1999): *Schienenverkehrsprojekte Deutsche Einheit.* http://www.bahn.de/db_netz/news/technik/db_netz_schienenverkehrsprojekte_deutsche_einheit.shtml.

Direccion General de Trafico (1998): *Inauguraciones de Tramos de Carreteras*. Madrid. Ministerio del Interio. http://www.dgt.es/cgi-bin/inauguraciones/inaugusr.cgi.

European Commission (1991): The Regions in the 1990s. Fourth Periodic Report on the Social and Economic Situation and Development of the Regions of the Community.

European Commission (1994): *Wettbewerbsfähigkeit und Kohäsion: Tendenzen in den Regionen*. Bruxelles, Luxembourg: European Commission.

European Commission (1995): *The Agricultural Situation in the European Union: 1995 Report*. Bruxelles, Luxembourg: European Commission.

European Commission (1996): *Erster Bericht über den wirtschaftlichen und sozialen Zusammenhalt 1996*. Bruxelles, Luxembourg: European Commission.

European Commission (1997a): *Cohesion and the Development Challenge Facing the Lagging Regions*. Fourth Cohesion Report. Regional Development Studies. Luxembourg: Office for Official Publications of the European Communities.

European Commission (1997b): *The Likely Macroeconomic and Employment Impacts of Investments in Trans-European Networks*. Commission Staff Working Paper. Bruxelles: European Commission.

European Commission (1997c): *Agenda 2000: For a Stronger and Wider Union*. Luxembourg:: Office for Official Publications of the European Communities.

European Commission (1998a): *Proposal for a Council Regulation (EC) Laying Down General Provisions on the Structural Funds*. Explanatory Memorandum. COM(1998) 131 final, Brussels, 18 03 1998.

European Commission (1998b): *Supplement C. Economic Reform Monitor, Economic Situation and Economic Reform in Central and Eastern Europe*. 6, 4/98, European Commission DGII/F.1.

European Commission (1998c): *Transeuropean Transportation Network. Report on the Implementation of the Guidelines. Basic Data on the Networks.* Report to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions on the implementation of the guidelines for the development of the trans-European transport network (Decision 1692/96/EC).

European Commission (1999a): 14 TEN Priority Projects. http://europa.eu.int/en/comm/dg07/tentpp9807/index.htm.

European Commission (1999b): *Which regions receive EU financial assistance?* http://inforegio.cec.eu.int/wbpro/prord/guid/euro_eu.htm.

European Commission (1999c) *Sixth Periodic Report on the Social and Economic Situation and Development of Regions in the European Union.* Luxembourg: Office for Official Publications of the European Communities.

European Communities (1995): *Trans-European Transport Network Outline Plan.* December 1995. Luxembourg: Office for Official Publications of the European Communities.

European Communities (1996): Decision No. 1692/96/CE of the European Parliament and of the Council of 23 July 1996 on the Community guidelines for the development of the trans-European transport networks. *Official Journal of the European Communities* 39, L 228, 9 September 1996, 1-104.

Eurostat (1993): *European System of Integrated Economic Accounts (ESA)*. Luxembourg: Office for Official Publications of the European Communities.

Eurostat (1995): *Education Across the European Union. Statistics and Indicators.* Theme 3: Population and social conditions. Series A: Yearbooks and yearly statistics. Luxembourg: Office des publicatioins officielles des Communautés europóeenes.

Eurostat (1998a): *Regions.* Statistical Yearbook. Luxembourg: Eurostat.

Eurostat (1998b): First results of the demographic data collection for 1997. In: *European Statistics in Focus: Population and Social Conditions, 1998-9*.

Eurostat (1998c): *EU Has Nearly 5 Million People From 'Med12'*. Memo, No. 0498. http://www.europa.eu.int/en/comm/eurostat/compres/en/3798/6303798a.htm.

Eurostat (1998d): *Education Across the European Union. Statistics and Indicators 1998.* Theme 3: Population and social conditions. Series A: Yearbooks and yearly statistics. Luxembourg: Office des publicatioins officielles des Communautés européenes.

Federal Ministry of Communications and Infrastructure (1998): Planning future roads and railways in Belgium. Written email answer as of 23 June 1998.

Finnish Road Administration (1998): *Development of main Roads in Finland - Major projects on E- and TEN-Roads.* Helsinki.

Fromm, G., Klein, L. (1973): 'A comparison of eleven econometric models of the United States'. *American Economic Review* 05/1973.

Heinrichsmeyer, W., Witzke, H. (1991): *Agrarpolitik, Band 1: Agrarökonomische Grundlagen*. Stuttgart: Ulmer.

Highway Agency (1998a): *Business Plan 1997/98.* London.

Highway Agency (1998b): *DBFO - Value in Roads.* London.

IMAV (1998): *Planned railway projects in Hungary*. Letter of 22 September 1998. Budapest.

IRPUD (1998): *Pan-Europe surface model (TIN)*. Dortmund: IRPUD.

Linneker, B. (1997): *Transport Infrastructure and Regional Economic Development in Europe: A Review of Theoretical and Methodological Approaches.* TRP 133. Sheffield: Department of Town and Regional Planning, University of Sheffield.

Malmö City Tunnel Project (1999): *Welcome to the Tunnel.* http://www.citytunnel.malmo.se.

Masser, I., Craglia, M., Holl, A. (1997), *Data Requirements and Structures*. SASI Deliverable D7. Sheffield: Department of Town and Regional Planning, University of Sheffield.

Michelin (1992a): *Michelin Reisekarte Großbritannien: Wales, West Country, Midlands*. Stand 1992. Paris: Michelin.

Michelin (1992b): *Michelin Reisekarte Großbritannien: South East, Midlands, East Anglia*. Stand 1992. Paris: Michelin.

Mkmetric (1998): *Subset of the Air Traffic Database*. Karlsruhe.

Münz, R. (1996): A continent of migration: European mass migration in the twentieth century. *New Community*, 22, 2, 201-226.

National Roads Directorate (1998): *Information on major road schemes opened to traffic in Scotland.* Written answer as of 29 July 1998. Edinburgh: The Scottish Office. Development Department.

National Library for the Environment (NLE) (1998*): Glossary of Terms. Programs and Laws*. http://www.cnie.org/nle/AgGlossary/AgGlossary.htm

OECD (1996): *Globalisation and Linkages: Macro-Structural Challenges and Opportunities*, Economics Department Working Paper No.181, OCDE/GD (97)147.

OECD (1997): *Towards a new Global Age: Challenges and Opportunities, Policy Report*. Paris: OECD.

OECD - Directorate for Education, Employment and Labour Affairs (1998): Social indicators: an illustrative compilation. In: OECD (ed.): *Sustainable Development Indicators. Proceedings of an OECD Workshop.* Paris: OECD, 45-80.

OECD (1999): *Education at a Glance. OECD Education Indicators 1998.* Paris: OECD.

Øresundskonsortiet (1999): *The Øresund Fixed Link*. http://www.oresundskonsortiet.com.

Palz, W. , Greif, J. (1995): *European Solar Radiation Atlas. Solar Radiation on Horizontal and Inclined Surfaces.* 3rd revised edition, sponsored by DGXII of the Commission of the European Communities. Berlin, Heidelberg, New York: Springer.

Quah, D.T. (1997) Increasingly weightless economies, *Bank of England Quarterly Bulletin*, 37, 1, 49-56.

Rankin, K. (1998): *Income Taxes Are Production Taxes*. http://pl.net/~keithr/rf98_Prod_Tax.html

Reise- und Verkehrsverlag (1987): *Interrent-Straßenatlas.* Berlin, Gütersloh, München, Stuttgart: Reise- und Verkehrsverlag.

Ritter, W. (1966): *Fremdenverkehr in Europa. Eine wirtschafts- und sozialgeographische Untersuchung über Reisen und Urlaubsaufenthalte der Bewohner Europas.* Europäische Aspekte. Reihe A: Kultur, No. 8. Leiden: A. W. Sijthoff Verlag.

Road Directorate Belgium (1998): *Planning for futureRroads in Belgium. Standards and Databases*. Federal Ministry of Communication and Infrastructure. Brussels.

Road Directorate Denmark (1998): *Anlägsprogram for Motorveje og större Hovedlandeveje (Omfartsveje)*. Copenhagen: Ministry of Transport.

Salt, J., Singleton, A., Hogarth, J. (1994): *Europe's International Migrants: Data Sources, Patterns and Trends*. London: HMSO.

Salt, J. (1996): 'Current trends in international migration in Europe'. 6th Conference of European Ministers Responsible for Migration Affairs, Warsaw, 16-18 June 1996.

Samuelson, P., Nordhaus, W. (1985): *Volkswirtschaftslehre: Grundlagen der Makro- und Mikroökonomie*. Köln: Bund-Verlag.

Santer, J. (1998): 'Shaping Europe's Future'. Speech delivered at the International Bertelsmann Forum, Schloss Bellevue, Berlin, 3 July 1998. http://www.geocities.com/ Capitol-Hill/2916/demo4.htm

Schürmann, C. (1999): *Quality of Life in European Regions: A Multi-Criteria Analysis*. Arbeitspapier 165. Dortmund: Institute of Spatial Planning.

Schürmann, C., Spiekermann, K., Wegener, M. (1997): *Accessibility Indicators*. SASI Deliverable D5. Berichte aus dem Institut für Raumplanung 39. Dortmund: Institute of Spatial Planning.

Shell (1981). *Der große Shell Atlas Deutschland/Europa 81/82.* Hamburg: Shell.

Shell (1992). *Der große Shell Atlas Deutschland/Europa 92/93.* Hamburg: Shell.

Spiekermann, K., Wegener, M. (1999): Socio-economic and spatial impacts of trans-European transport networks: the SASI project. In: Meersman, H., Van de Voorde, E., Winkelmans, W. (Hg.): World Transport Research. Volume 4: Transport Policy. Selected Proceedings of the 8th WCTR. Elsevier, 1999.

Thanki, R. (1999): How do we know the value of higher education to regional development? *Regional Studies* 33, 1, 84-89.

Thomas Cook (1981): *Thomas Cook European Timetable. Railway and Shipping Services throughout Europe*. Peterborough: Thomas Cook.

Thomas Cook (1996): *Thomas Cook European Timetable. Railway and Shipping Services throughout Europe*. Peterborough: Thomas Cook.

Thränhardt, D. (1996), European migration from East to West: present patterns and future directions, *New Community*, 22 (2), 227-242.

Vägverket (Ed.) (1997): *Annual Report 1996.* Stockholm.

Vägverket (Ed.) (1998): *Nationell Plan för Vägtransportsystemet 1998-2007.* Stockholm.

Wegener, M., Bökemann, D. (1998): *The SASI Model: Model Structure*. SASI Deliverable D8. Berichte aus dem Institut für Raumplanung 40. Dortmund: Institute of Spatial Planning.

Westermann (1983): *Diercke Weltatlas*. Braunschweig: Westermann, 998-999.

Westermann (1997): *Diercke Weltatlas*. Braunschweig. Westermann, 116-117.

Yuill, Allen, Bachtler, Wishlade (1990): European Regional Incentives. London: MSS.

8. Annex

The Annex contains a list of the regions used in the SASI model as discussed in Section 3.2 (Table A1).

Table A1. SASI regions

Country	No	Region	NUTS 1995 or equivalent code	Internal/ external	Centroid
Österreich	1	Burgenland	AT11	Internal	Eisenstadt
	2	Niederösterreich	AT12	Internal	St.Pölten
	3	Wien	AT13	Internal	Wien
	4	Kärnten	AT21	Internal	Klagenfurt
	5	Steiermark	AT22	Internal	Graz
	6	Oberösterreich	AT31	Internal	Linz
	7	Salzburg	AT32	Internal	Salzburg
	8	Tirol	AT33	Internal	Innsbruck
	9	Vorarlberg	AT34	Internal	Dornbirn
Belgique/ België	10	Bruxelles/Brussel	BE1	Internal	Bruxelles/Brussel
	11	Antwerpen	BE21	Internal	Antwerpen
	12	Limburg (BE)	BE22	Internal	Hasselt
	13	Oost-Vlaanderen	BE23	Internal	Gent
	14	Vlaams Brabant	BE24	Internal	Leuven
	15	West-Vlaanderen	BE25	Internal	Brugge
	16	Brabant Wallon	BE31	Internal	Wavre
	17	Hainaut	BE32	Internal	Charleroi
	18	Liege	BE33	Internal	Liege
	19	Luxembourg (BE)	BE34	Internal	Arlon
	20	Namur	BE35	Internal	Namur
Deutschland	21	Stuttgart	DE11	Internal	Stuttgart
	22	Karlsruhe	DE12	Internal	Mannheim
	23	Freiburg	DE13	Internal	Freiburg i.Br.
	24	Tübingen	DE14	Internal	Tübingen
	25	Oberbayern	DE21	Internal	München
	26	Niederbayern	DE22	Internal	Landshut
	27	Oberpfalz	DE23	Internal	Regensburg
	28	Oberfranken	DE24	Internal	Bamberg
	29	Mittelfranken	DE25	Internal	Nürnberg
	30	Unterfranken	DE26	Internal	Würzburg
	31	Schwaben	DE27	Internal	Augsburg
	32	Berlin	DE3	Internal	Berlin
	33	Brandenburg	DE4	Internal	Potsdam
	34	Bremen	DE5	Internal	Bremen
	35	Hamburg	DE6	Internal	Hamburg
	36	Darmstadt	DE71	Internal	Frankfurt am Main
	37	Giessen	DE72	Internal	Giessen
	38	Kassel	DE73	Internal	Kassel
	39	Mecklenburg-Vorpommern	DE8	Internal	Rostock
	40	Braunschweig	DE91	Internal	Braunschweig
	41	Hannover	DE92	Internal	Hannover
	42	Lüneburg	DE93	Internal	Lüneburg
	43	Weser-Ems	DE94	Internal	Oldenburg
	44	Düsseldorf	DEA1	Internal	Düsseldorf
	45	Köln	DEA2	Internal	Köln
	46	Münster	DEA3	Internal	Münster
	47	Detmold	DEA4	Internal	Bielefeld
	48	Arnsberg	DEA5	Internal	Dortmund
	49	Koblenz	DEB1	Internal	Koblenz
	50	Trier	DEB2	Internal	Trier
	51	Rheinhessen-Pfalz	DEB3	Internal	Mainz
	52	Saarland	DEC	Internal	Saarbrücken

Table A1. SASI regions (continued)

Country	No	Region	NUTS 1995 or equivalent code	Internal/ external	Centroid
Deutschland (continued)	53	Sachsen	DED	Internal	Leipzig
	54	Dessau	DEE1	Internal	Dessau
	55	Halle	DEE2	Internal	Halle
	56	Magdeburg	DEE3	Internal	Magdeburg
	57	Schleswig-Holstein	DEF	Internal	Kiel
	58	Thüringen	DEG	Internal	Erfurt
Danmark	59	Hovedstadtsregionen and Øst for Storebælt	DK11 (DK001-7)	Internal	København
	60	Vest for Storebælt	DK12 (DK008-F)	Internal	Arhus
España	61	Galicia	ES11	Internal	Santiago
	62	Principado de Asturias	ES12	Internal	Oviedo
	63	Cantabria	ES13	Internal	Santander
	64	Pais Vasco	ES21	Internal	Bilbao
	65	Comunidad Foral de Navarra	ES22	Internal	Pamplona
	66	La Rioja	ES23	Internal	Logrono
	67	Aragón	ES24	Internal	Zaragoza
	68	Comunidad de Madrid	ES3	Internal	Madrid
	69	Castilla y Leon	ES41	Internal	Valladolid
	70	Castilla-la Mancha	ES42	Internal	Toledo
	71	Extremadura	ES43	Internal	Mérida
	72	Cataluña	ES51	Internal	Barcelona
	73	Comunidad Valenciana	ES52	Internal	Valencia
	74	Islas Baleares	ES53	Internal	Palma de Mallorca
	75	Andalucia	ES61	Internal	Sevilla
	76	Región de Murcia	ES62	Internal	Murcia
Suomi/ Finland	77	Uusimaa	FI11	Internal	Helsinki
	78	Etelä-Suomi	FI12	Internal	Tampere
	79	Itä-Suomi	FI13	Internal	Kuopio
	80	Väli-Suomi	FI14	Internal	Jyväskylä
	81	Pohjois-Suomi	FI15	Internal	Oulu
	82	Ahvenanmaa/Åland	FI2	Internal	Maarianhamina
France	83	Île de France	FR1	Internal	Paris
	84	Champagne-Ardenne	FR21	Internal	Reims
	85	Picardie	FR22	Internal	Amiens
	86	Haute-Normandie	FR23	Internal	Le Havre
	87	Centre	FR24	Internal	Orleans
	88	Basse-Normandie	FR25	Internal	Caen
	89	Bourgogne	FR26	Internal	Dijon
	90	Nord-Pas-de-Calais	FR3	Internal	Lille
	91	Lorraine	FR41	Internal	Metz
	92	Alsace	FR42	Internal	Strasbourg
	93	Franche-Comté	FR43	Internal	Besancon
	94	Pays de la Loire	FR51	Internal	Nantes
	95	Bretagne	FR52	Internal	Brest
	96	Poitou-Charentes	FR53	Internal	Poitiers
	97	Aquitaine	FR61	Internal	Bordeaux
	98	Midi-Pyrénées	FR62	Internal	Toulouse
	99	Limousin	FR63	Internal	Limoges
	100	Rhône-Alpes	FR71	Internal	Lyon
	101	Auvergne	FR72	Internal	Clermont-Ferrand
	102	Languedoc-Roussillon	FR81	Internal	Montpellier
	103	Provence-Alpes-Côte d`Azur	FR82	Internal	Marseille
	104	Corse	FR83	Internal	Ajaccio

Table A1. SASI regions (continued)

Country	No	Region	NUTS 1995 or equivalent code	Internal/ external	Centroid
Ellada	105	Anatoliki Makedonia, Thraki	GR11	Internal	Kavala
	106	Kentriki Makedonia	GR12	Internal	Thessaloniki
	107	Dytiki Makedonia	GR13	Internal	Kozani
	108	Thessalia	GR14	Internal	Larissa
	109	Ipeiros	GR21	Internal	Ioannina
	110	Ionia Nisia	GR22	Internal	Kerkyra
	111	Dytiki Ellada	GR23	Internal	Patrai
	112	Sterea Ellada	GR24	Internal	Lamia
	113	Peloponnisos	GR25	Internal	Tripolis
	114	Attiki	GR3	Internal	Athinai
	115	Voreio Aigaio	GR41	Internal	Mytilini
	116	Notio Aigaio	GR42	Internal	Ermoupolis
	117	Kriti	GR43	Internal	Irakleion
Ireland	118	Dublin, Mid-East	IE11 (IE002-3)	Internal	Dublin
	119	Border, Midland-West	IE12 (IE001, IE004, IE008)	Internal	Galway
	120	Mid-West, South-East, South-West	IE13 (IE005-7)	Internal	Cork
Italia	121	Piemonte	IT11	Internal	Torino
	122	Valle d'Aosta	IT12	Internal	Aosta
	123	Liguria	IT13	Internal	Genova
	124	Lombardia	IT2	Internal	Milano
	125	Trentino-Alto Adige	IT31	Internal	Bolzano
	126	Veneto	IT32	Internal	Venezia
	127	Friuli-Venezia Giulia	IT33	Internal	Trieste
	128	Emilia-Romagna	IT4	Internal	Bologna
	129	Toscana	IT51	Internal	Firenze
	130	Umbria	IT52	Internal	Perugia
	131	Marche	IT53	Internal	Ancona
	132	Lazio	IT6	Internal	Roma
	133	Abruzzo	IT71	Internal	Pescara
	134	Molise	IT72	Internal	Campobasso
	135	Campania	IT8	Internal	Napoli
	136	Puglia	IT91	Internal	Bari
	137	Basilicata	IT92	Internal	Potenza
	138	Calabria	IT93	Internal	Reggio
	139	Sicilia	ITA	Internal	Palermo
	140	Sardegna	ITB	Internal	Cagliari
Luxembourg	141	Luxembourg	LU	Internal	Luxembourg
Nederland	142	Groningen	NL11	Internal	Groningen
	143	Friesland	NL12	Internal	Leeuwarden
	144	Drenthe	NL13	Internal	Emmen
	145	Overijssel	NL21	Internal	Enschede
	146	Gelderland	NL22	Internal	Apeldoorn
	147	Flevoland	NL23	Internal	Lelystad
	148	Utrecht	NL31	Internal	Utrecht
	149	Noord-Holland	NL32	Internal	Amsterdam
	150	Zuid-Holland	NL33	Internal	Rotterdam
	151	Zeeland	NL34	Internal	Middelburg
	152	Noord-Brabant	NL41	Internal	Eindhoven
	153	Limburg (NL)	NL42	Internal	Maastricht

Table A1. SASI regions (continued)

Country	No	Region	NUTS 1995 or equivalent code	Internal/ external	Centroid
Portugal	154	Norte	PT11	Internal	Porto
	155	Centro (PT)	PT12	Internal	Coimbra
	156	Lisboa e Vale do Tejo	PT13	Internal	Lisboa
	157	Alentejo	PT14	Internal	Evora
	158	Algarve	PT15	Internal	Faro
Sverige	159	Stockholm	SE01	Internal	Stockholm
	160	Östra Mellansverige	SE02	Internal	Uppsala
	161	Småland med Öarna	SE03	Internal	Jönköping
	162	Sydsverige	SE04	Internal	Malmö
	163	Västsverige	SE05	Internal	Göteborg
	164	Norra Mellansverige	SE06	Internal	Gävle
	165	Mellersta Norrland	SE07	Internal	Sundsvall
	166	Övre Norrland	SE08	Internal	Umea
United Kingdom	167	Cleveland, Durham	UK11	Internal	Middlesbrough
	168	Cumbria	UK12	Internal	Carlisle
	169	Northumberland, Tyne and Wear	UK13	Internal	Newcastle upon Tyne
	170	Humberside	UK21	Internal	Kingston upon Hull
	171	North Yorkshire	UK22	Internal	Harrogate
	172	South Yorkshire	UK23	Internal	Sheffield
	173	West Yorkshire	UK24	Internal	Leeds
	174	Derbyshire, Nottinghamshire	UK31	Internal	Nottingham
	175	Leicestershire, Northamptonshire	UK32	Internal	Leicester
	176	Lincolnshire	UK33	Internal	Lincoln
	177	East Anglia	UK4	Internal	Cambridge
	178	Bedfordshire, Hertfordshire	UK51	Internal	Luton
	179	Berkshire, Buckinghamshire, Oxfordshire	UK52	Internal	Reading
	180	Surrey, East-West Sussex	UK53	Internal	Brigthon
	181	Essex	UK54	Internal	Southend-On-Sea
	182	Greater London	UK55	Internal	London
	183	Hampshire, Isle of Wight	UK56	Internal	Southampton
	184	Kent	UK57	Internal	Maidstone
	185	Avon, Gloucestershire, Wiltshire	UK61	Internal	Bristol
	186	Cornwall, Devon	UK62	Internal	Plymouth
	187	Dorset, Somerset	UK63	Internal	Bournemouth
	188	Hereford & Worcester, Warwickshire	UK71	Internal	Warwick
	189	Shropshire, Staffordshire	UK72	Internal	Newcastle-under-Lyme
	190	West Midlands (County)	UK73	Internal	Birmingham
	191	Cheshire	UK81	Internal	Warrington
	192	Greater Manchester	UK82	Internal	Manchester
	193	Lancashire	UK83	Internal	Blackpool
	194	Merseyside	UK84	Internal	Liverpool
	195	Clwyd, Dyfed, Gwynedd, Powys	UK91	Internal	Wrexham Maelor
	196	Gwent, Mid-South-West Glamorgan	UK92	Internal	Cardiff
	197	Borders, Central, Fife, Lothian, Tayside	UKA1	Internal	Edinburgh
	198	Dumfries & Galloway, Strathclyde	UKA2	Internal	Glasgow
	199	Highlands, Islands	UKA3	Internal	Inverness
	200	Grampian	UKA4	Internal	Aberdeen
	201	Northern Ireland	UKB	Internal	Belfast

Table A1. SASI regions (continued)

Country	No	Region	NUTS 1995 or equivalent code	Internal/ external	Centroid
Shqipëria	202	Shqipëria	AL	External	Tiranë
Bosna i Hercegovina	203	Bosna i Hercegovina	BA	External	Sarajevo
B?lgarija	204	B?lgarija	BG	External	Sofija
Belarus	205	Belarus	BY	External	Minsk
Schweiz	206	Schweiz (West)	CH1	External	Bern
	207	Schweiz (East)	CH2	External	Zürich
Česko	208	Česko	CZ	External	Praha
Eesti	209	Eesti	EE	External	Tallinn
Hrvatska	210	Hrvatska	HR	External	Zagreb
Magyarország	211	Magyarország	HU	External	Budapest
Island	212	Island	IS	External	Reykjavik
Lietuva	213	Lietuva	LT	External	Vilnius
Latvija	214	Latvija	LV	External	Riga
Moldova	215	Moldova	MD	External	Chisinau
Republica Makedonija	216	Makedonija	MK	External	Skopje
Norge	217	Norge	NO	External	Oslo
Polska	218	Polska (East)	PL1	External	Warszawa
	219	Polska (North-West)	PL2	External	Poznan
	220	Polska (South-West)	PL3	External	Wroclaw
România	221	România	RO	External	Bucuresti
Rossija	222	Rossija (Moskva)	RU1	External	Moskva
	223	St. Peterburg	RU2	External	St. Peterburg
Slovenija	224	Slovenija	SI	External	Ljubljana
Slovensko	225	Slovensko	SK	External	Bratislava
Türkiye	226	Türkiye	TR	External	Istanbul
Ukraina	227	Ukraina	UA	External	Kyiv
Jugoslavija	228	Jugoslavija	YU	External	Beograd
West Africa and the Americas	229	America	AM	External	Model node
East Africa, Asia, Australasia	230	Asia	AS	External	Model node
Egypt and the Middle East	231	Middle East	ME	External	Cairo
Morocco, Algeria, Tunisia, Libya	232	North Africa	NA	External	Alger

Note:

The system of regions consists of 232 regions. There are 201 'internal' regions. Of these there are 196 NUTS-2 regions for all EU countries except Danmark and Ireland. NUTS-0/1/2 regions DK (Danmark) and IE (Ireland) were further subdivided into two and three groups of NUTS-3 regions, respectively, because of modelling requirements. NUTS-2 region ES63 (Ceuta e Mellila) and NUTS-1 regions ES7 (Canarias), FR9 (Départements d'outre mer), PT2 (Açores) and PT3 (Madeira), which are not part of the European continent, are not included in the system of regions. There are 27 'external' regions for other European countries outside the EU. Of theses, 20 countries are handled as whole countries. Three countries are further subdivided: Poland into three regions, Switzerland into two regions, and Russia has a separate region for St. Peterburg. There are four external regions for the rest of the world indicating the direction from where commodity flows enter or leave Europe.