Institut für Raumplanung

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Berichte aus dem Institut für Raumplanung

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The SASI Model: Demonstration Examples

Deliverable D15 of the EU Project
Socio-Economic and Spatial Impacts of
Transport Infrastructure Investments
and Transport System Improvements
(SASI)

Dortmund, January 2000

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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 fifteenth deliverable of the EUNET project and the seventh of the SASI sub-project, describes the results of the demonstration scenario simulations done with the SASI model based on the previous SASI Deliverables D4 (Bökemann et al., 1997), D5 (Schürmann et al., 1997), D7 (Masser et al., 1997), D8 (Wegener and Bökemann, 1998), D11 (Fürst et al., 1999) and D13 (Wegener et al., 2000).

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 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 functions 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 results of demonstration scenario simulations done with the SASI model i.e. the application of the model to a set of different assumptions on TEN infrastructure investments and the presentation of its likely socio-economic impacts on the European regions. The objective of the deliverable is to show that the model is able to model the development of the interaction between infrastructure and regional development in the past and to provide reasonable results on the regional effects of different infrastructure network scenarios.

This deliverable D15 is the last report of the SASI project. 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* (1997) 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 D15 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 3.1) as well as the calculation of regional endowment factors for the *Regional GDP* submodel (see Section 3.1) 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.

The fifth deliverable of SASI, or D11 of EUNET (Fürst et al., 1999) presented the implementation and calibration of the model, i.e. the final form of the input data used and the statistical analyses performed to test hypotheses about factors to be included in the regional production and migration functions and their numerical specification. It was shown that the SASI model is capable of modelling the impacts of transport infrastructure investments and transport system improvements on the socio-economic indicators proposed in the model specification in D8 (Wegener and Bökemann, 1998). All necessary data could be provided from Eurostat and various additional national and regional statistics 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 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.

The sixth deliverable of SASI, or D13 of EUNET (Wegener et al., 2000) describes the model software package developed for the SASI model. The deliverable illustrates the software package, i.e. tools for network scenario generation, the model input files, the model database and output files, the model software itself and finally the programmes developed for analysing and visualising the model results. These tools form the comprehensive SASI software package enabling the user to define different policy scenarios, generating scenario networks, assessing the socio-economic impacts of the scenarios chosen and finally analysing the results by selecting appropriate graphical outputs.

This deliverable D15 is the last report of the SASI project. It describes the results of demonstration scenario simulations done with the SASI model i.e. the application of the model to a set of different assumptions on TEN infrastructure investments and the presentation of its likely socio-economic impacts on the European regions. The objective of the deliverable is to show that the model is able to model the development of the interaction between infrastructure and regional development in the past and to provide reasonable results on the regional effects of different infrastructure network scenarios.

This report starts, in Section 3, with a brief outline of the SASI model structure which has been described in detail in Deliverable D8. Section 4 presents the definition of the transport infrastructure scenarios used as demonstration examples. Section 5 presents results of the scenario simulations for the three selected network policy scenarios for each scenario separately and compared against each other. Moreover, Section 6 shows the results of a project evaluation for the Øresund link to demonstrate sensitivity of the SASI model to single TEN projects. The following Section 7 concludes this deliverable by assessing the strengths and weaknesses of the model, summarising main project results and finishes with further work to refine, extend and improve the SASI model.

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.

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.

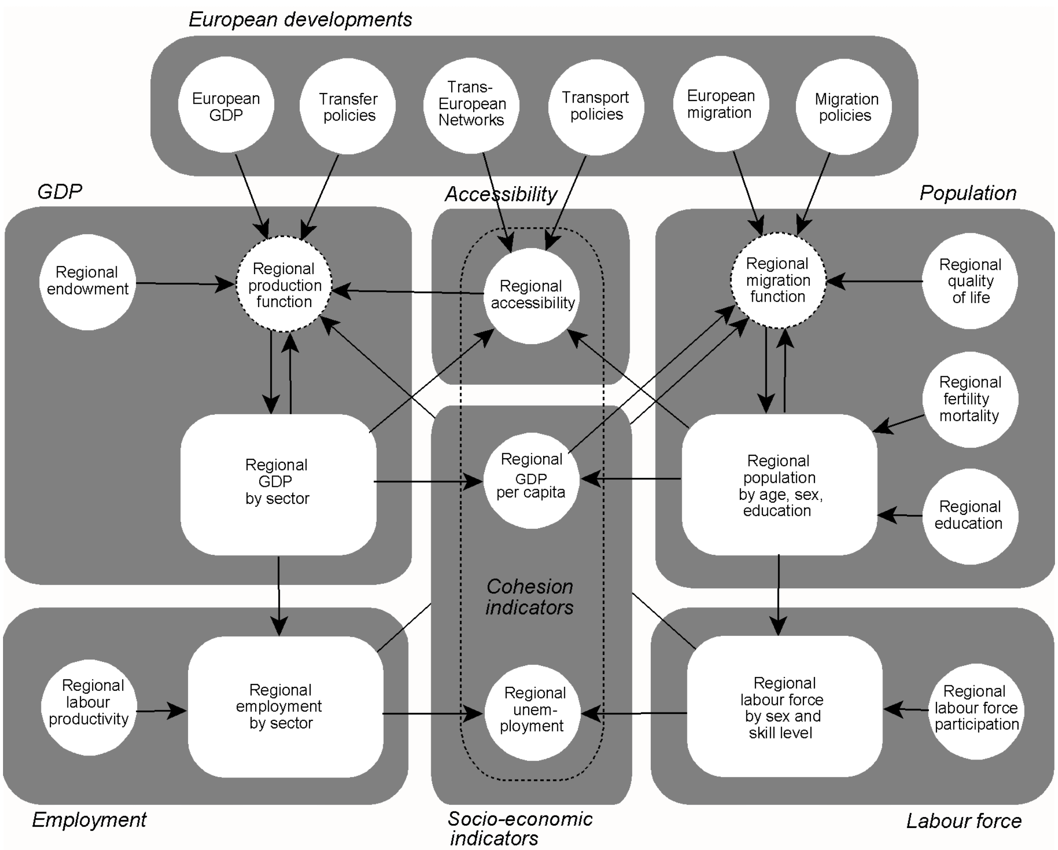


Figure 3.1. The SASI model

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). 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.

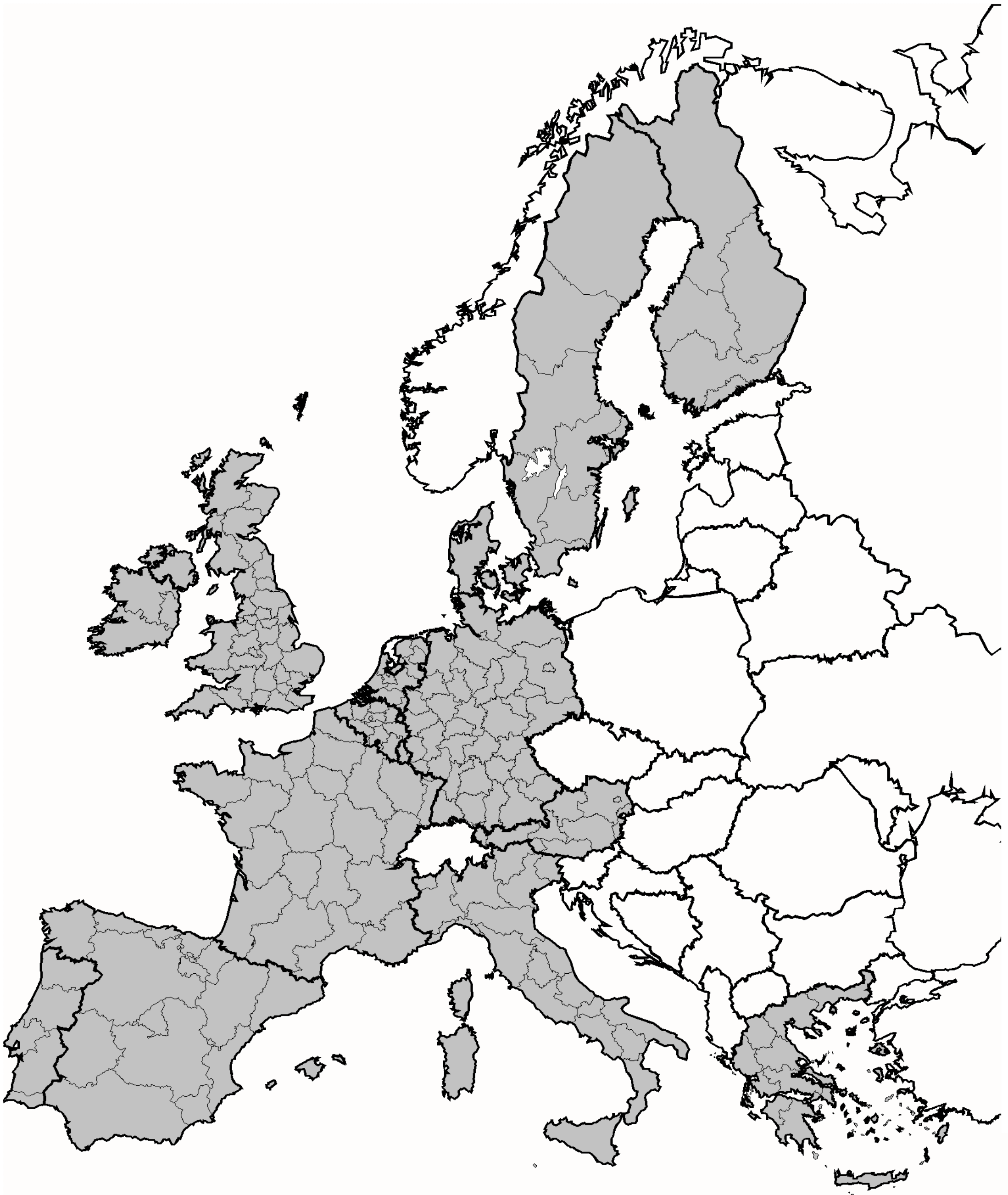


Figure 3.2. The SASI system of regions

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:

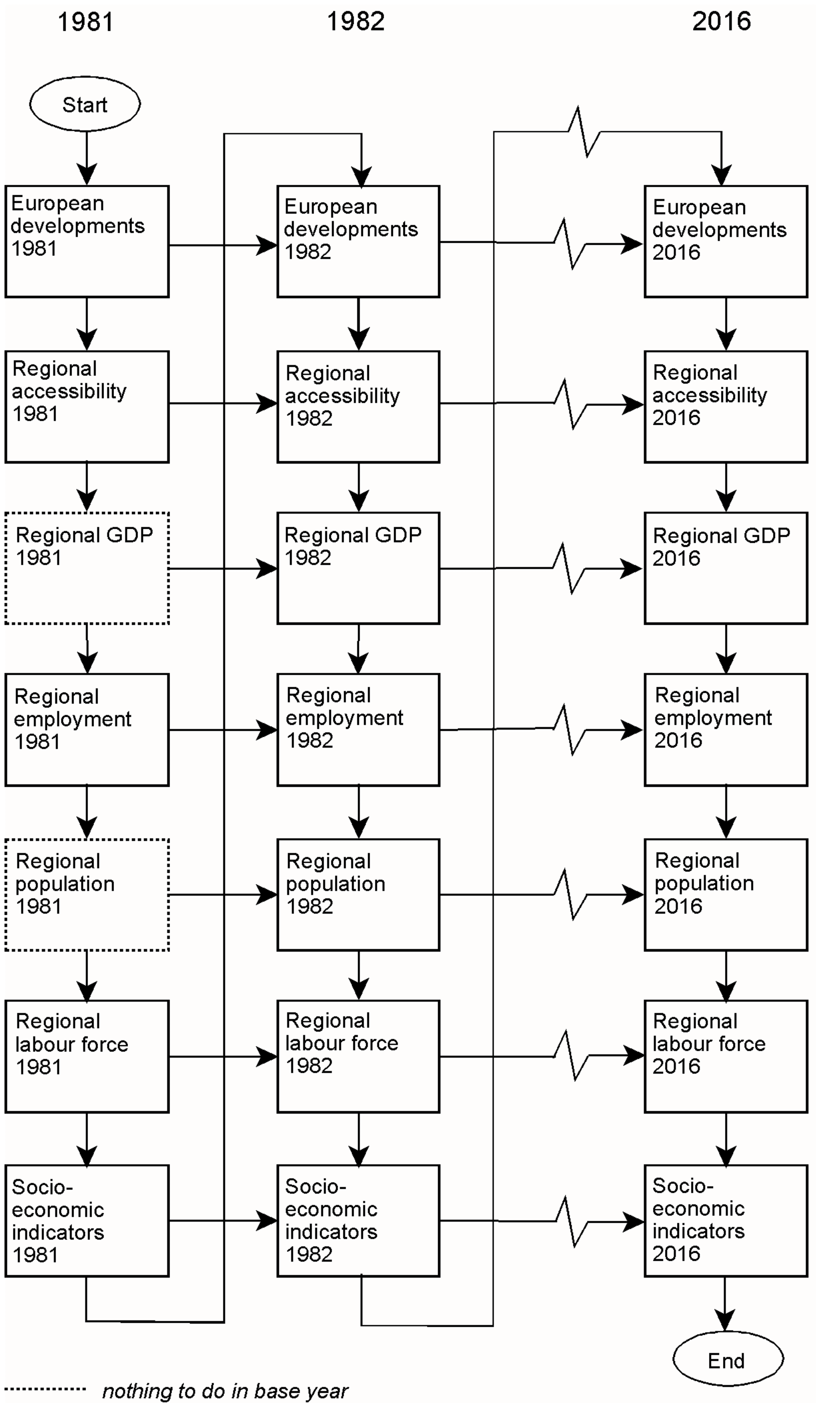


Figure 3.3. The recursive organisation of the SASI model

4. Scenario Definition

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 regarding the TETN programme, several policy scenarios have been established as demonstration examples of the SASI model.

The 'backbone' of these scenarios is the network evolution over time from 1981 to 2016 (see Deliverable D11, Fürst et al., 1999). 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, an infrastructure scenario is a time-sequenced investment programme for addition, upgrading or closure of links of the trans-European road or rail networks. Because of the inherent characteristics of aviation networks, which depend mainly on the distribution of slots among the aviation companies, it is impossible to define reasonable future air networks, wherefore the 1996 air network remains unchanged for future years. The assumptions of the road and rail network scenarios will be implemented in five-year increments.

For the SASI model demonstration examples four scenarios belonging to three scenario types are implemented, a 'do-nothing scenario', two 'network policy scenarios' and a 'project policy scenario'.

Do-nothing scenario (Scenario 00)

For this scenario no development of the trans-European transport infrastructure is foreseen, i.e. the networks will remain constant 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. Figure 4.1 presents the 1996 road and Figure 4.2 the 1996 rail networks, i.e. at the same time the do-nothing scenario for all future years, differentiated by link categories.

Network policy scenarios (Scenarios 10 and 20)

The network policy scenarios contain assumptions on the overall development strategy for the trans-European networks. Scenario 10, the *TEN Scenario*, assumes that all road and rail links of the TEN network will be implemented until 2016. In Scenario 20, the *Rail TEN Scenario*, it is assumed that only the rail links of the TEN programme will be implemented and that nothing happens regards road.

Figure 4.1. 1996 road network by link category (Do-nothing Scenario 00)

High speed line — Upgraded high speed line — Conventional line

Figure 4.2 . 1996 rail network by link category (Do-nothing Scenario 00)

All TEN projects are applied to the scenarios with respect to their estimated completion times as laid down in the TEN implementation report (European Commission, 1998). If no specification on the completion year is available, the projects will be first introduced in the 2011 networks. Figure 4.3 displays planned TEN road links for the TEN scenario with respect to their estimated completion year and Figure 4.4 presents a similar map for the railway network. It has to be mentioned that in these two figures only those projects are displayed which will be newly constructed or which result in changing network capacities on existing links (e.g. adding a lane to a motorways or a second track to railways) or changing speeds, whereas other projects such as removing level crossings in the rail network are not displayed (nevertheless they are included in the network database).

The network dynamics shown in the figures are obvious. As Figure 4.3 presents, most of the TEN road projects will be completed by 2001, particularly projects in Spain and Portugal, some projects will be implemented in 2006, particularly projects in France, whereas most Greek motorway projects and the motorway projects in Eastern Germany are going to be completed by 2011. For the rail network most of the projects in Germany, Spain and UK will be completed until 2006, whereas in Italy the project majority will be completed by 2001. For Sweden, most of the projects will be implemented until 2011. Unfortunately, for some rail links information on the start of operation was not available in the TEN implementation report, in particular for France no completion years for the high speed lines are available. As part of the assumptions in Scenarios 10 and 20 this links are assumed to be in operation by the year 2011.

Project policy scenario (Scenario 09)

A project policy scenario serves to demonstrate that the SASI model is also able to handle single projects. Scenario 09 is the *Øresund ferry scenario, i.e.* Scenario 10 in which the Øresund bridge is replaced in both future road and rail networks by current ferry services. Because the remaining networks in Scenario 09 are identical to Scenario 10 it is possible to isolate the socio-economic impacts of this single project.

Table 4.1 summarises the main characteristics of the demonstration examples. The purpose of the scenarios is to show the general applicability of the SASI model and to investigate socio-economic impacts of different implementations of the TEN infrastructure investment programme with respect to accessibility, GDP and unemployment in a systematic way. This will be done in Section 5 for the do-nothing scenario and the network policy scenarios and in Section 6 for the project policy scenario taking the Øresund priority project as example.

Table 4.1. Scenarios used as demonstration examples

Scenario number	Scenario name	Description
Scenario 00	Do-Nothing	No network changes beyond 1996
Scenario 10	TEN	Evolution of road and rail networks according to TEN programme
Scenario 20	Rail TEN	Evolution of rail networks according to TEN programme, no change for road beyond 1996
Scenario 09	Øresund Ferry	Scenario 10 in which the Øresund bridge is replaced by current ferry services

Figure 4.3. Network evolution of planned TEN road project (Scenario 10)

Figure 4.4. Network evolution of planned TEN railway projects (Scenarios 10 and 20)

5. Results of Transport Infrastructure Scenarios

The three network scenarios defined in the previous section have been developed with the purpose to evaluate the socio-economic impacts of infrastructure development. In this chapter, the results of scenario runs are being presented focussing on the SASI output indicator, namely accessibility, and the two cohesion indicators gross domestic product (GDP) and unemployment with each scenario being presented with a standard set of maps and diagrams.

5.1 Regional Impact of the Do-Nothing Scenario 00

In this scenario, whose results serve as a reference for variations in transport infrastructure development in other possible scenarios, the underlying transportation networks are kept constant from the year 1996 onwards, while all socio-economic variables such as population, employment and labour force are allowed to develop over time. Consequently, the logsum accessibility of the SASI regions in the year 2016 remains exactly at the 1996 level (Figures 5.1 and 5.2). As regards the regional economic performance of this scenario, a general, continuous upward trend in GDP development (in Euro/capita) can be detected (Figure 5.3, top). It is noteworthy that the clear distinction of two groups - one well performing group of countries around or above the Union average and a second group comprising the cohesion funds countries tends to become blurred over time with some countries of the upper tier exhibiting lower growth rates than the cohesion countries. However, the overall spread in per capita values among member states increases over time. By standardising GDP values on the European average, relative gains and losses can be evaluated better than in absolute terms (Figure 5.3, bottom). In this illustration a general trend of economic convergence between the previously sharply dichotomised member states can be observed until the year 2000, but not beyond.

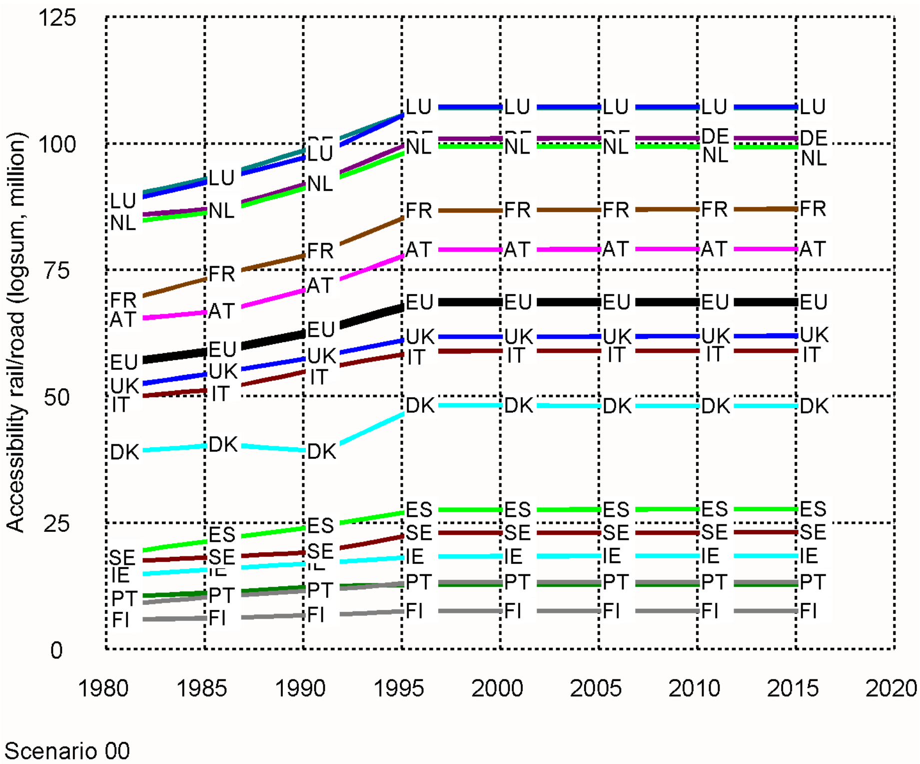


Figure 5.1. Scenario 00, accessibility rail, road (logsum) by country, 1981-2016

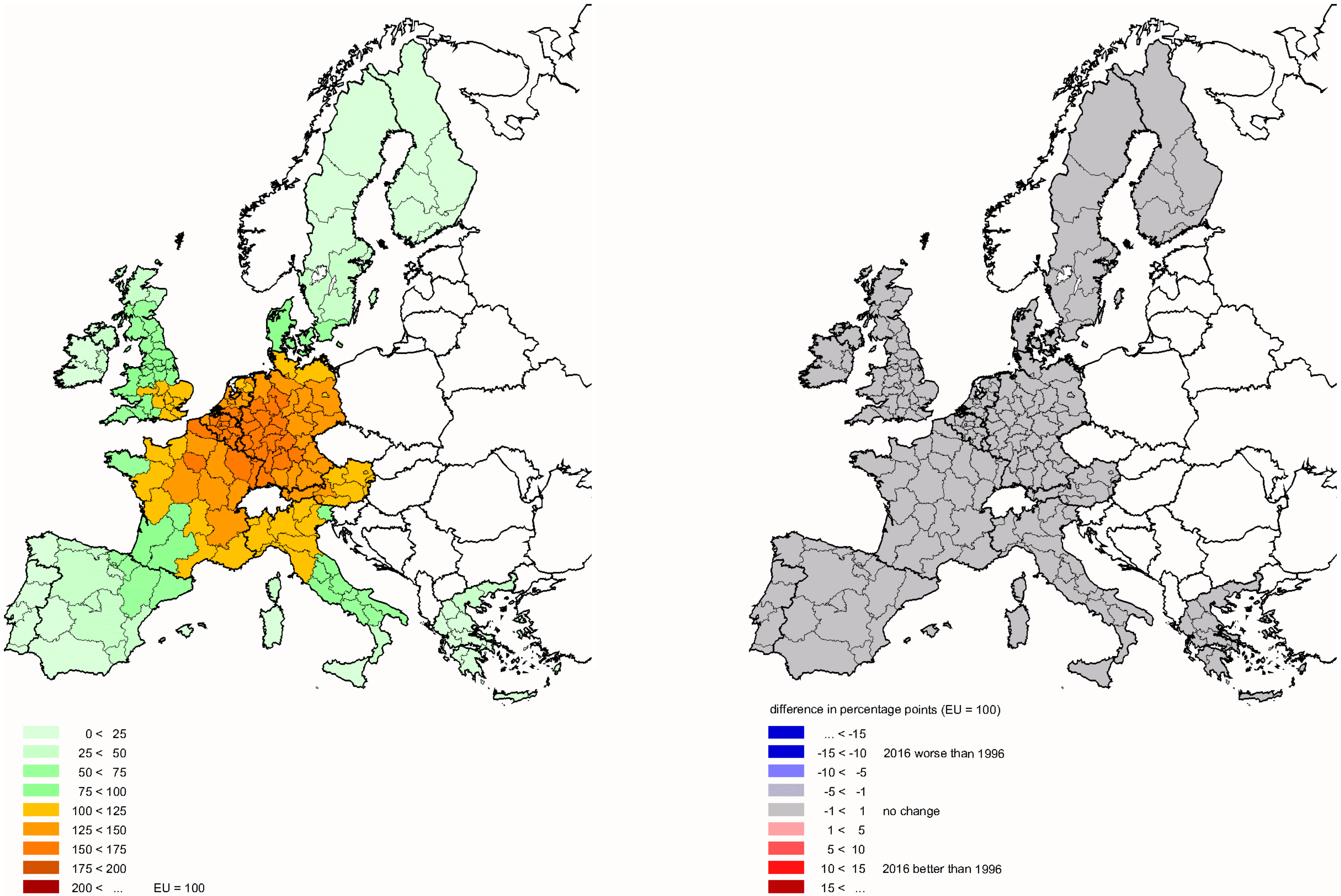
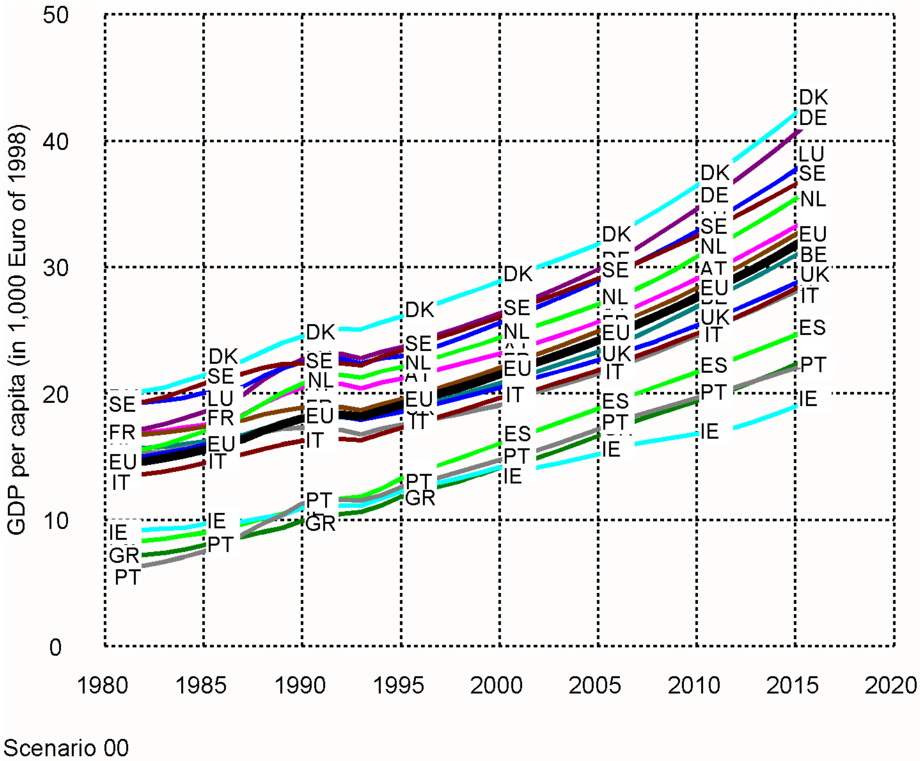


Figure 5.2. Scenario 00, accessibility road/rail (logsum) by region, 2016 (left), change 1996-2016 (right)



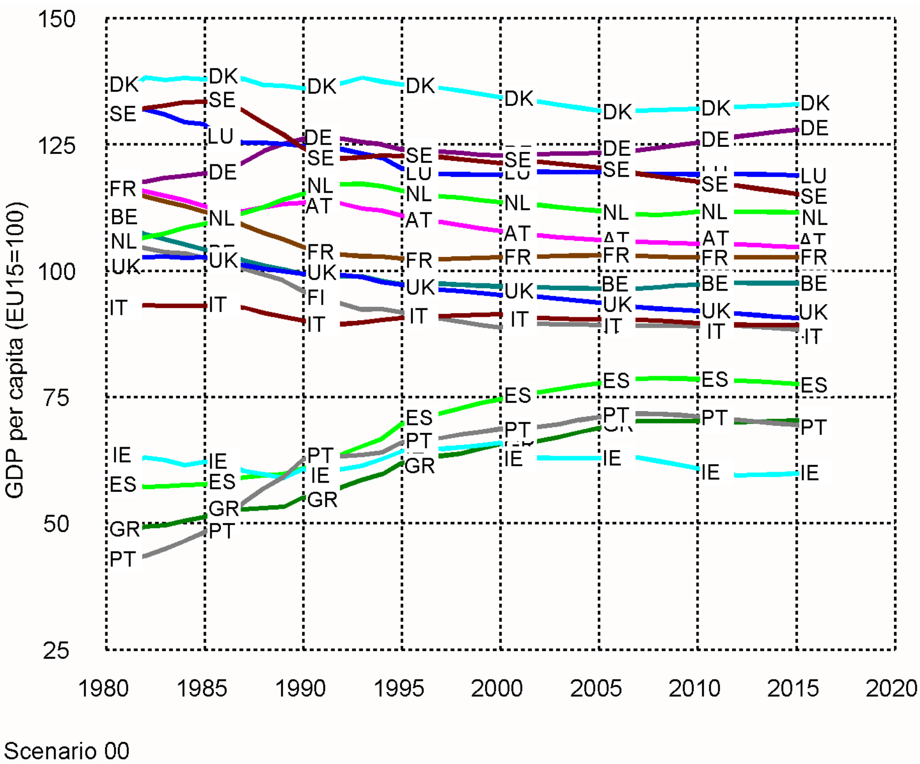


Figure 5.3. Scenario 00, total GDP per capita (top),standardised GDP per capita (bottom), by country 1981-2016

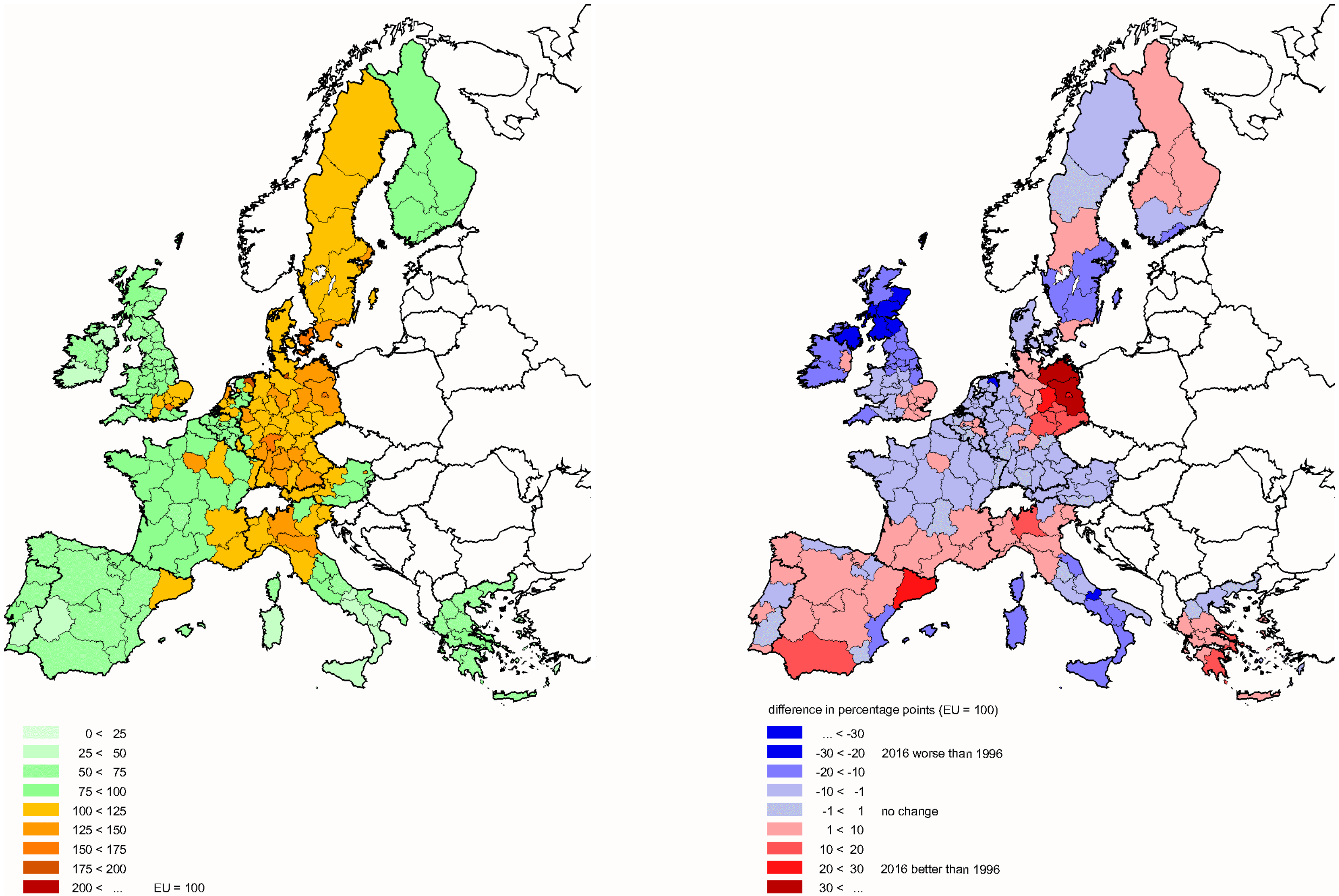


Figure 5.4. Scenario 00, GDP per capita by region, 2016 (left), change 1996-2016 (right).

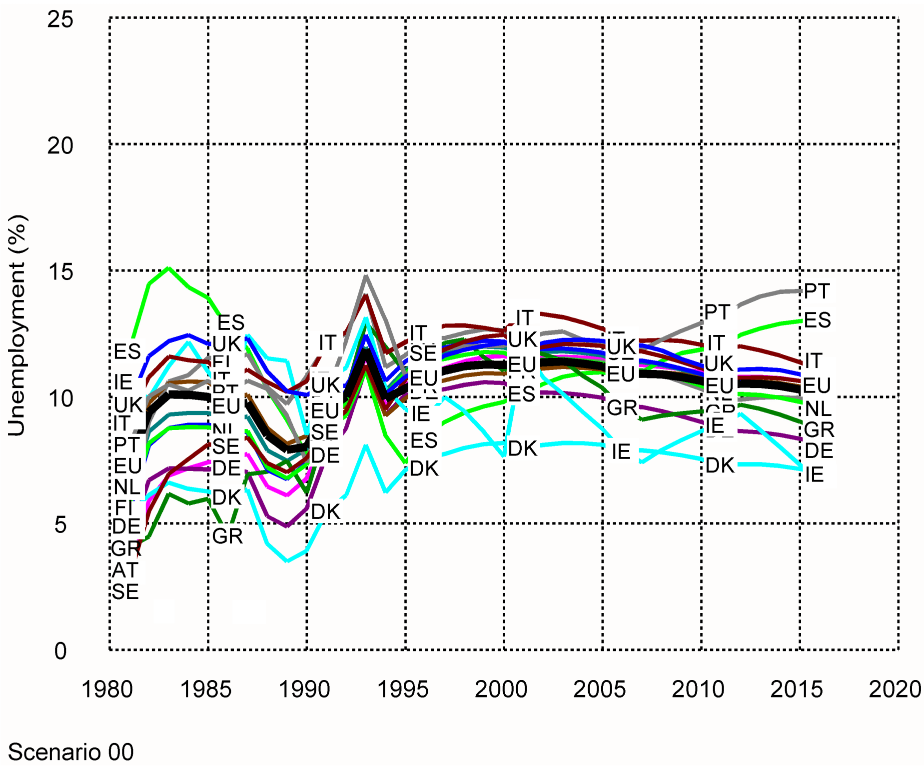


Figure 5.5. Scenario 00, unemployment rates by country, 1981-2016

Figure 5.4 (left) shows GDP per capita for the SASI regions standardised to the European Union's average. It can be seen that in 2016 the majority of economically well performing regions is situated in the geographical core of the European Union. Considering the relative change over time between 1996 and 2016, expressed as change of the regions compared to the European Union's averages of those years (Figure 5.4, right); yields that both the most dynamic regions and the regions with the greatest relative losses are preponderantly located at the periphery, an observation which is in line with empirically observed tendencies in the past. Remarkable is also the large gain in the new Länder in Germany which is a consequence of the future continuation of massive subsidies for those regions assumed in the model.

Figure 5.5 shows the model results for unemployment rates. It is obvious that this indicator is particularly volatile since it is derived from two intermediate model output terms, i.e. labour force and employment figures both of which are in an order of magnitude which requires a very precise prediction of both variables to be able to issue a meaningful prediction of the comparatively small residual of these figures, i.e. unemployment. Nevertheless, unemployment rates have been modelled so that some of the basic values and patterns match with empirical observations for the past period notwithstanding the fact that this part of the SASI cohesion indicator system requires intense refinement in order to produce reliable and policy relevant results. For this reason, unemployment rates forecast by the SASI model have to be considered with caution as to interpretations and conclusions and will therefor not be presented for regions and other scenarios.

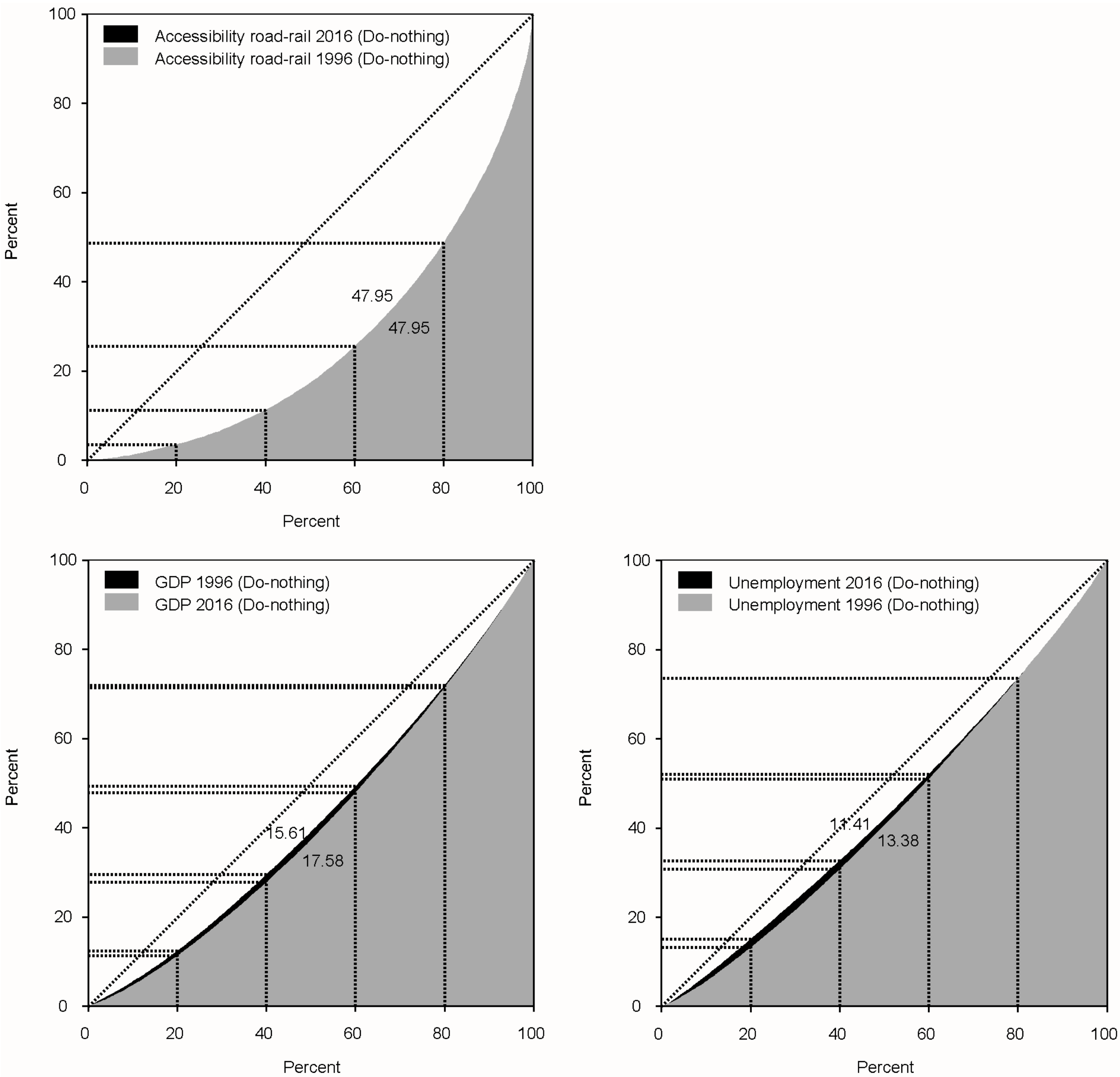


Figure 5.6. Scenario 00, Lorenz curves of regions 1996-2016, accessibility (top), GDP (bottom, left) and unemployment (bottom, right)

Figure 5.6 shows Lorenz curves comparing a rank-ordered cumulative distribution of indicator values of regions with a distribution in which all regions have the same indicator values where the area between the two cumulative distributions indicates the degree of polarisation of the distribution of indicator values of regions. The general pattern to be observed for all three indicators in the do-nothing scenario is that accessibility is the most unequally distributed indicator in the European regions. The cohesion indicators GDP values and especially unemployment show a relatively low distributive inequality compared to accessibility. As to the development over time, the accessibility distribution remains exactly the same in the regions as a result of the scenario definition, while economic performance is slightly more polarised in 2016 than in 1996. Equivalently, the model predicts that unemployment will also be more equally distributed in 2016, even though the differences between both years are rather small averaged over all EU regions.

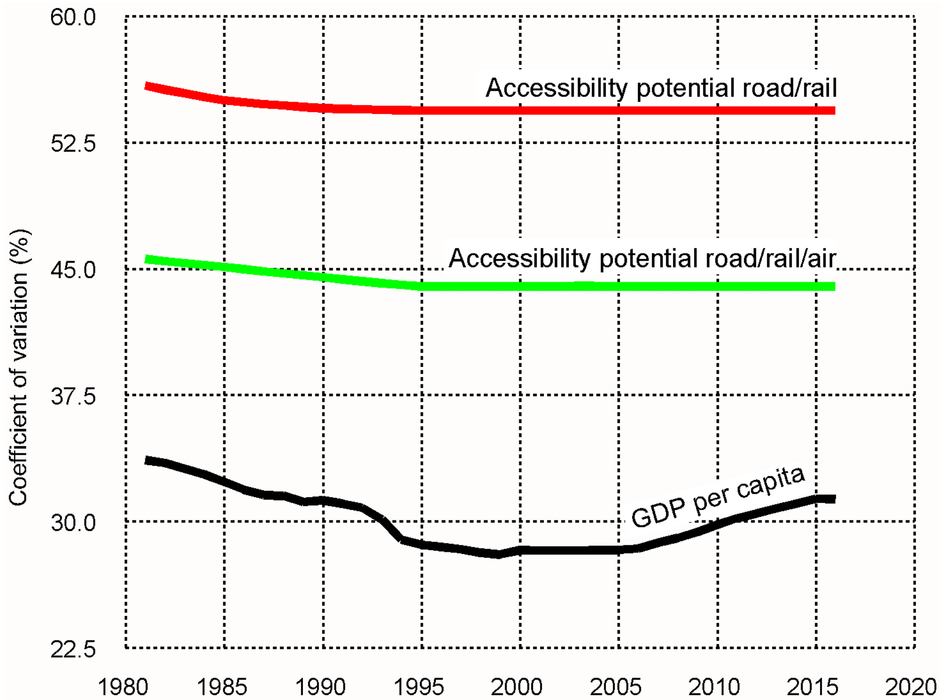


Figure 5.7. Scenario 00, coefficient of variation for accessibility and GDP per capita

A further distributive standard measure to be applied in cohesion and equity issues is the coefficient of variation which indicates the spread of a set of data as a proportion of its mean in percentage points. Figure 5.7 shows that road and rail accessibility exhibits the greatest variations among the regions of the study area. When air is considered additionally, the variation coefficient is generally lower, thus confirming the commonsense assumption that flight connections might help some remote regions to catch up with the overall accessibility standard in Europe.

The results for GDP per capita which generally has a lower range of variation corroborate the findings derived from the Lorenz curves that regional variation in economic performance is expected to be greater in 2016 than in 1996 but both values are significantly below the 1981 level which is the all-time high in GDP value dispersion in the considered time period. It also has to be kept in mind that a range of 5 percent difference in the variation coefficient within 35 years characterises the GDP as relatively stable over time despite the changes that become visible.

5.2 Regional Impacts of TEN Scenario 10

The TEN Scenario 00 envisions the implementation of all road and railway links laid down in the trans-European Transport Outline Plan (European Communities, 1995). Figure 5.8 illustrates the resulting changes in accessibility for the member states of the European Union. It is obvious that all regions will experience gains or at least remain stable as to accessibility in the time period considered in the model (1981-2016). Thus it can be concluded that all member states derive benefits from the construction of trans-European transport infrastructure lines in absolute terms, at least on the member state level. It also becomes apparent that the general development of accessibility values is more dynamic in some countries (such as Spain and France) than in others (such as Sweden and Finland). Nevertheless, the rank distribution of accessibility in the member states remains unaltered over time with the single exception of Portugal which obtains higher accessibility values than Ireland at the very end of the observed period from 2011 onwards. The geographical distribution of accessibility in the regions shows that the known pattern of accessibility distribution will still be valid in the year 2016 with regions in the European core obtaining the highest values (Figure 5.9 left). However, when differences in percentage points of the European Union's averages are considered (Figure 5.9 right), it becomes evident that it is mainly the core regions which will be worse off in 2016 than in 1996. Conversely, regions at the geographical periphery of Europe, particularly the regions of the Iberian peninsula, experience the highest growth rates with regard to the European average.

As concerns GDP levels, the general distribution pattern in 2016 will still be familiar to contemporary observers (Figure 5.10 left) with the remarkable exception of the new Länder in Germany which attain GDP levels above the European average. Similarly, the new Länder exhibit the highest gains between 1996 and 2016 compared to the European average (Figure 5.10 right). Due to the previous extraordinary political and socio-economic development of these regions, the model results have to be considered with caution with regard to validity in these regions. The overall picture in the European Union is that most peripheral regions are more dynamic than the European average with the exception of Ireland and the northern regions of Great Britain which are expected to experience relative losses.

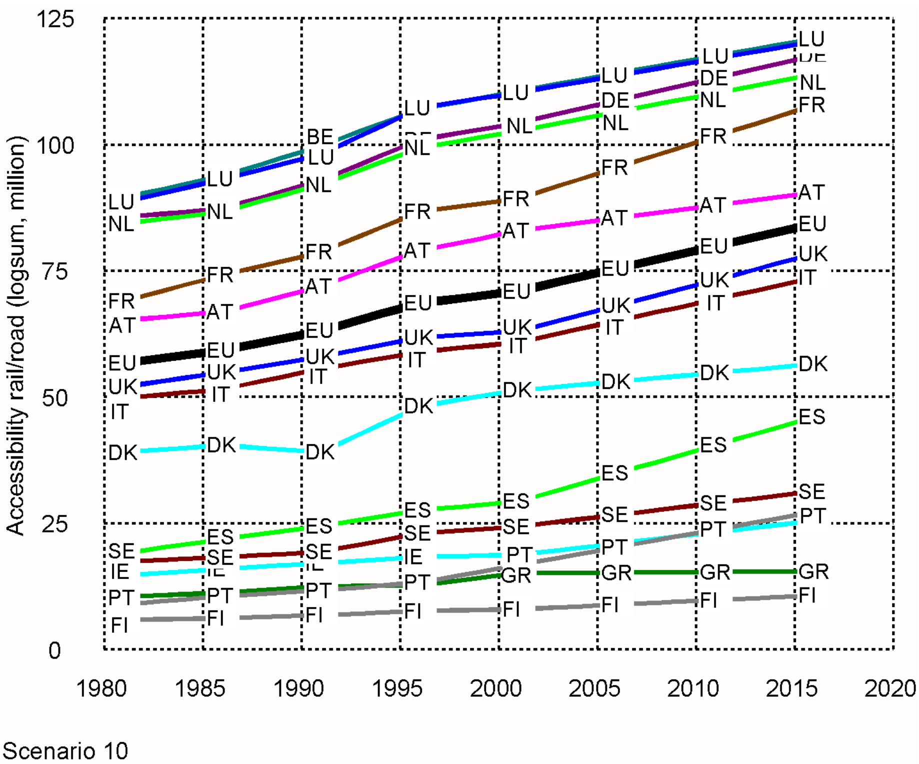


Figure 5.8. Scenario 10, accessibility rail, road (logsum) by country, 1981-2016

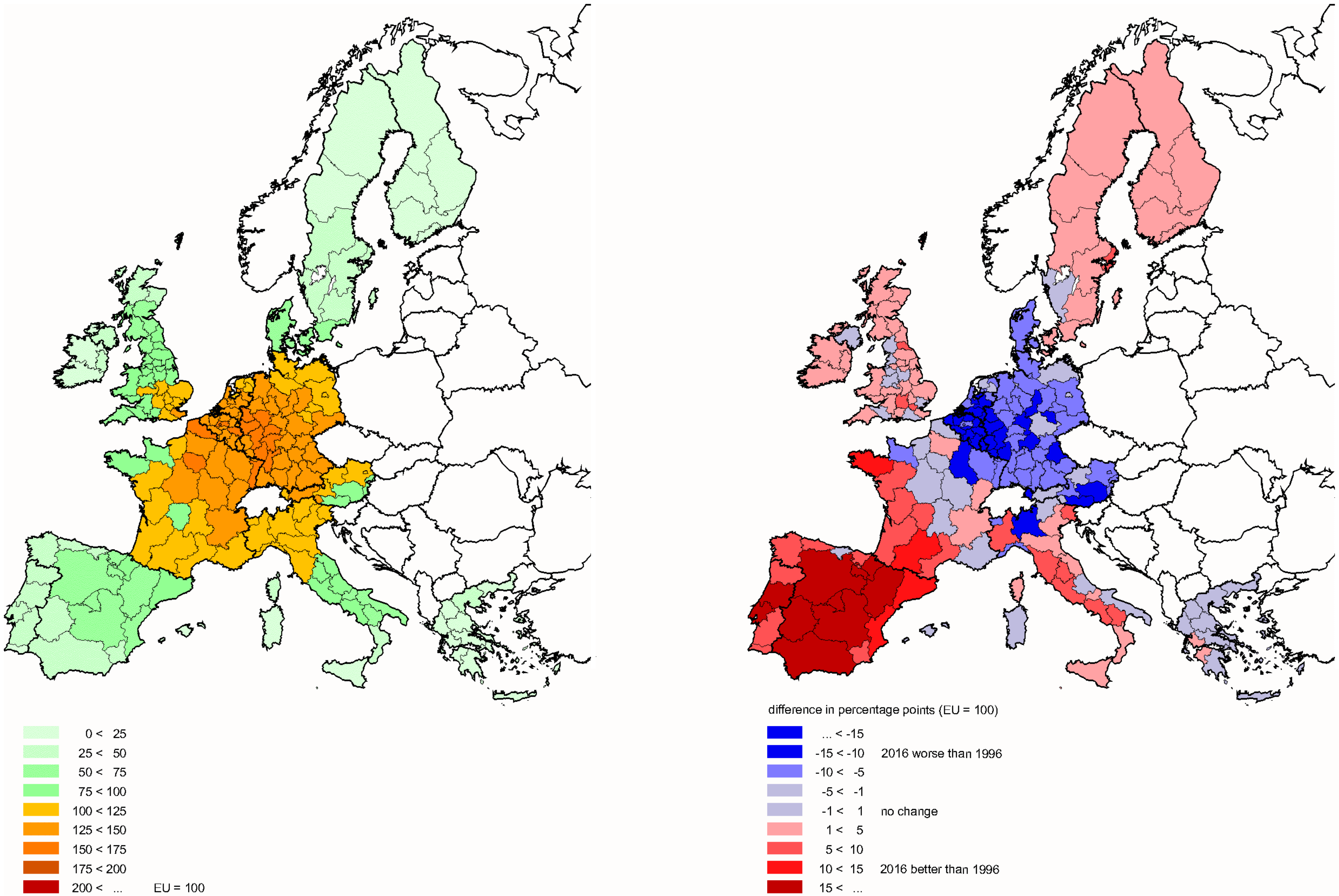


Figure 5.9. Scenario 10, accessibility road, rail (logsum) by region, 2016 (left), change 1996-2016 (right)

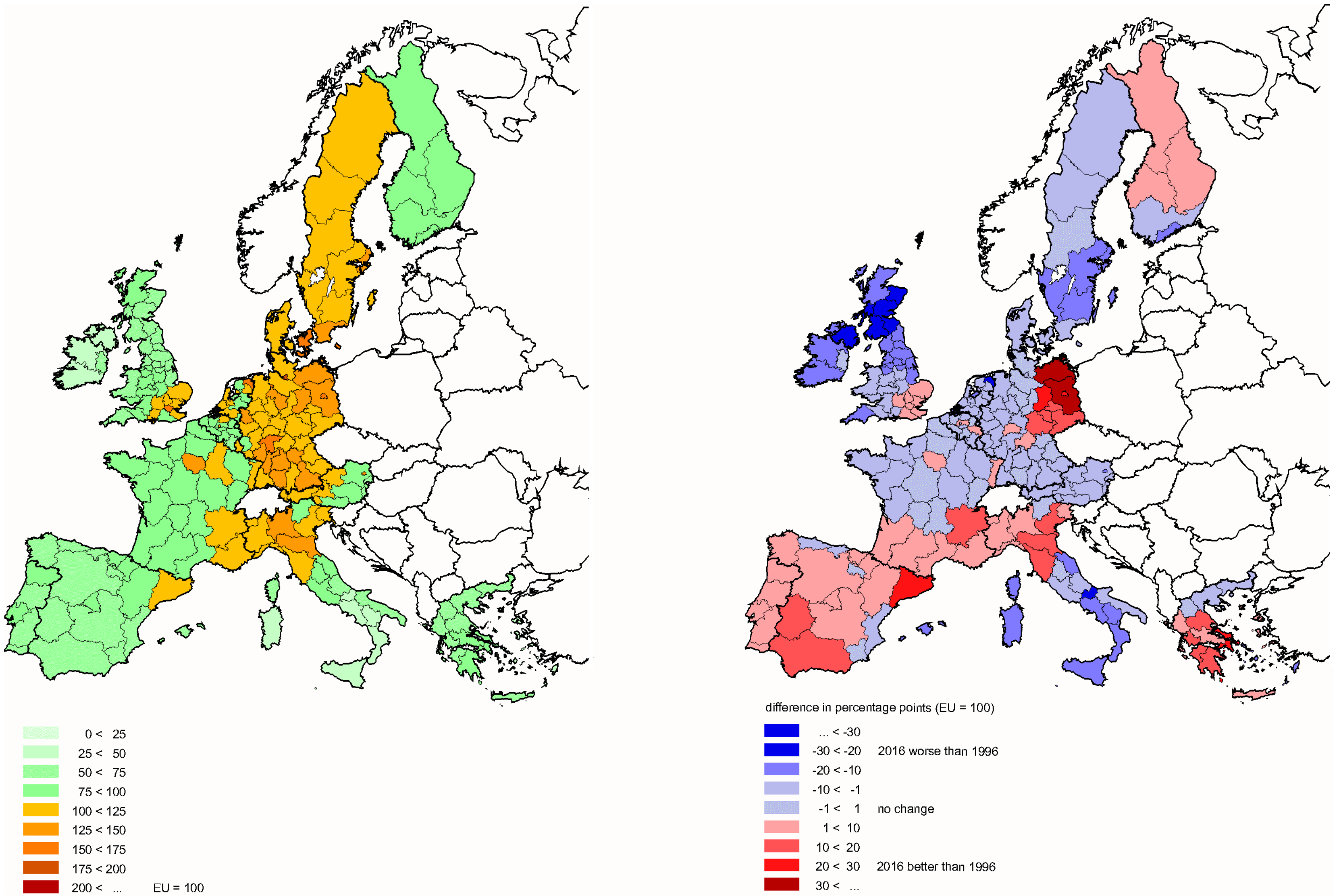


Figure 5.10. Scenario 10, GDP per capita by region, 2016 (left), change 1996-2016 (right)

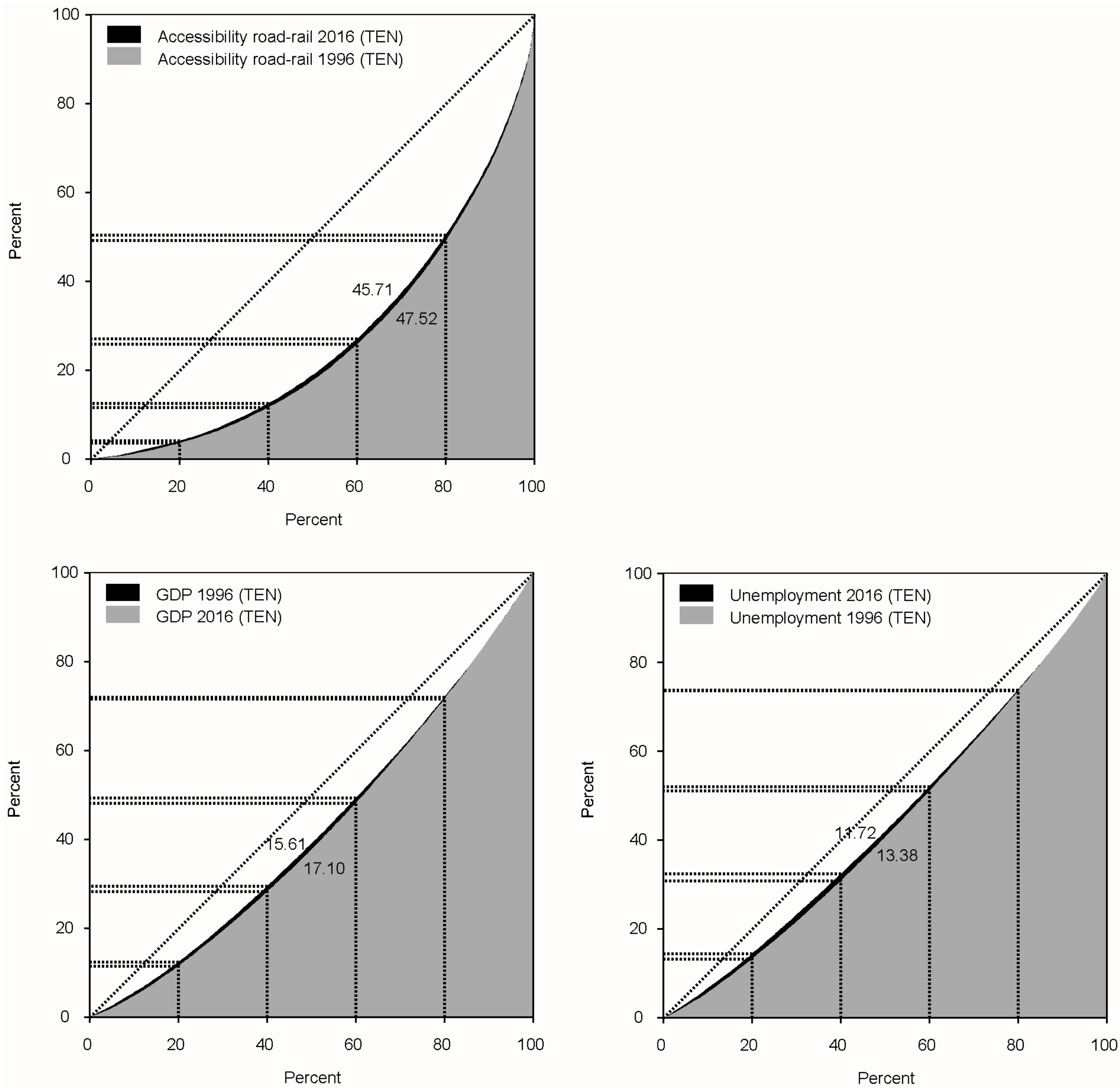


Figure 5.11. Scenario 10, Lorenz curves of regions 1996-2016, accessibility (top), GDP (bottom, left) and unemployment (bottom, right)

The Lorenz curves for the TEN scenario reveal that distribution inequality in accessibility is expected to be slightly mitigated in 2016 compared to 1996 (Figure 5.11). GDP and unemployment distribution, however, will be more polarised in the future, albeit within small margins at the European total level.

The coefficient of variation reveals some significant findings with regard to cohesion indicator development (Figure 5. 12). While the potential accessibility for road and rail is marked by a greater variation than is the case with road, rail and air, the gap between both types accessibility decreases over time. This effect which can be attributed to the construction of the trans-European networks hints at a potentially equalising effect of the TEN with regard to accessibility.

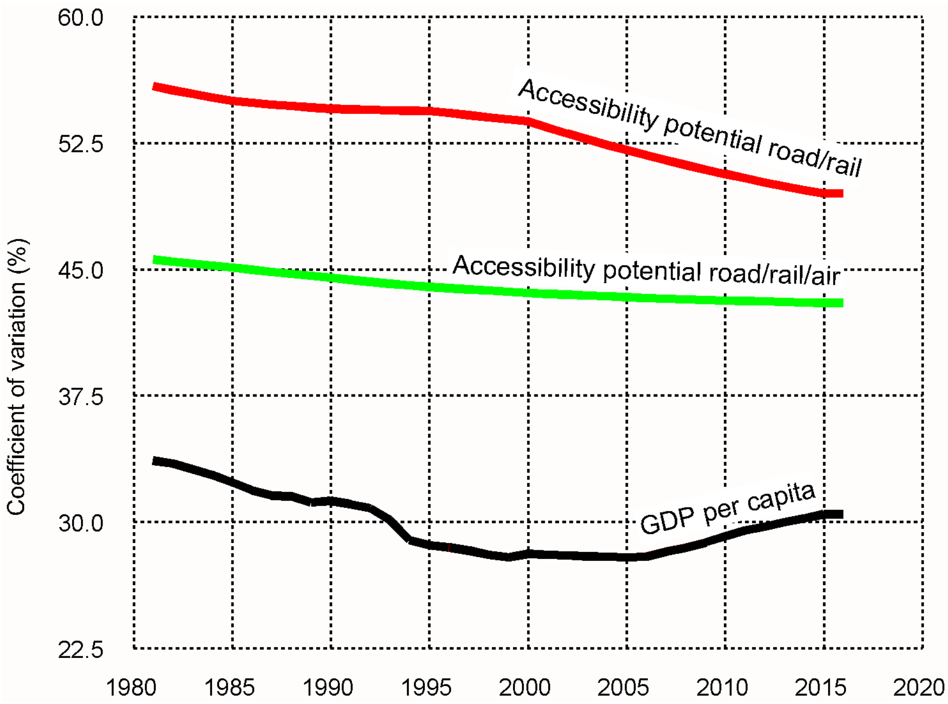


Figure 5.12. Scenario 10, coefficient of variation for accessibility and GDP per capita

This also confirms the assumption that not only large-scale investment in air transport infrastructure is apt to bring about convergence in European accessibility. Regional variation in economic performance is expected to be greater in 2016 than in 1996 but values for both years are significantly below the 1981 level which is the all-time high in GDP value dispersion in the considered time period.

5.3 Regional Impacts of Rail TEN Scenario 20

This scenario includes only the construction of railway TEN infrastructure, while other transport infrastructure networks remain unmodified from 1996 onwards. The illustration of accessibility development from 1981 to 2016 (Figure 5.13) indicates that leaving aside investments in road infrastructure does not lead to an overwhelmingly different picture than in the TEN Scenario. All member states experience gains in accessibility over the model time interval with some countries being more dynamic in their development than others. Country ranks of aggregated accessibility also remain stable in this scenario with the previously observed exception of Portugal which surpasses Ireland's accessibility level after 2011.

The regional distribution of accessibility (Figure 5.14 left) shows that the densely populated core of the European Union maintains its comparatively high accessibility standards whereas accessibility in peripheral regions is in most cases still below the EU average. When mapping only the changes in accessibility, standardised to the European Union's averages, that occurred in the period 1996 to 2016 (Figure 5.14 right), a general trend towards convergence becomes visible. According to the SASI model results, peripheral regions will experience the highest relative gains, while most of the core regions will be worse off in 2016 than in 1996 when measured at the EU average.

Economic performance is highest in the core regions and lower in the peripheral regions (Figure 5.15 left). The distribution in this scenario resembles very much the results of the other two scenarios. Considering the differences between 1996 and 2016 in percentage points corroborates the assumption that peripheral regions are likely to have the highest relative gains, while the European core will experience relative losses (Figure 5.15 right). However, some of the highest relative losses can be found at the periphery (southern Italy, north western Great Britain, Sweden). The unexpectedly high gains in the new Länder of Germany also occur in this scenario and need to be examined in detail as to their soundness and plausibility.

The Lorenz curves for this scenario reveal that distributive inequality in accessibility can be expected to be lower in 2016 than in 1996 (Figure 5.16). In contrast to these developments in accessibility, GDP levels in the SASI regions tend to become more polarised over time. The same result applies to unemployment. Nevertheless, the differences between both years are so small for either cohesion indicator that significant polarisation effects do not become manifest, at least not at the European level.

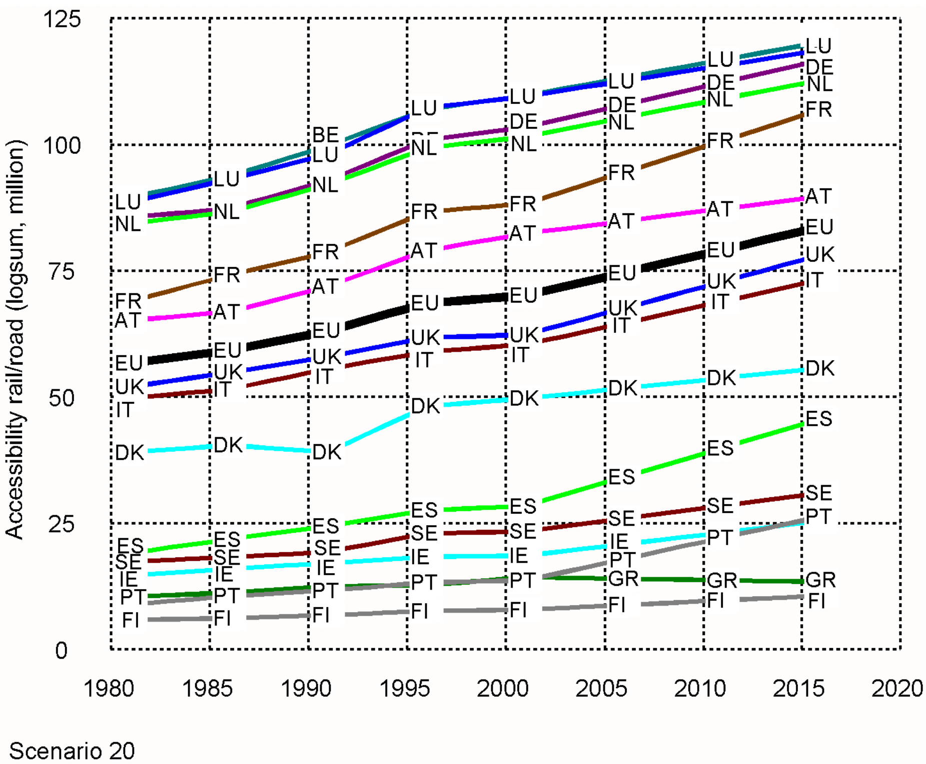


Figure 5.13. Scenario 20, accessibility rail, road (logsum) by country, 1981-2016

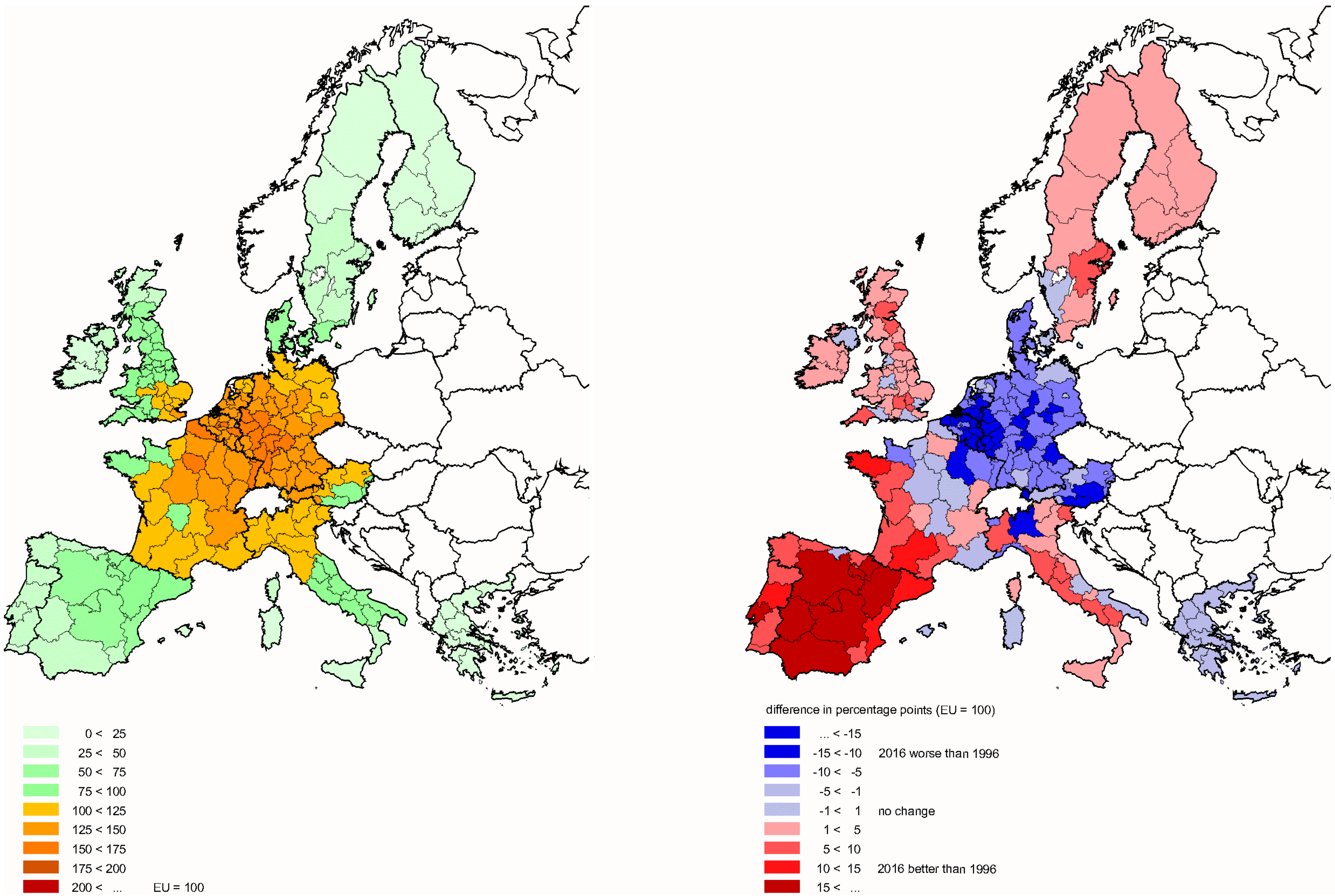


Figure 5.14. Scenario 20, accessibility road, rail (logsum) by region, 2016 (left), change 1996-2016 (right)

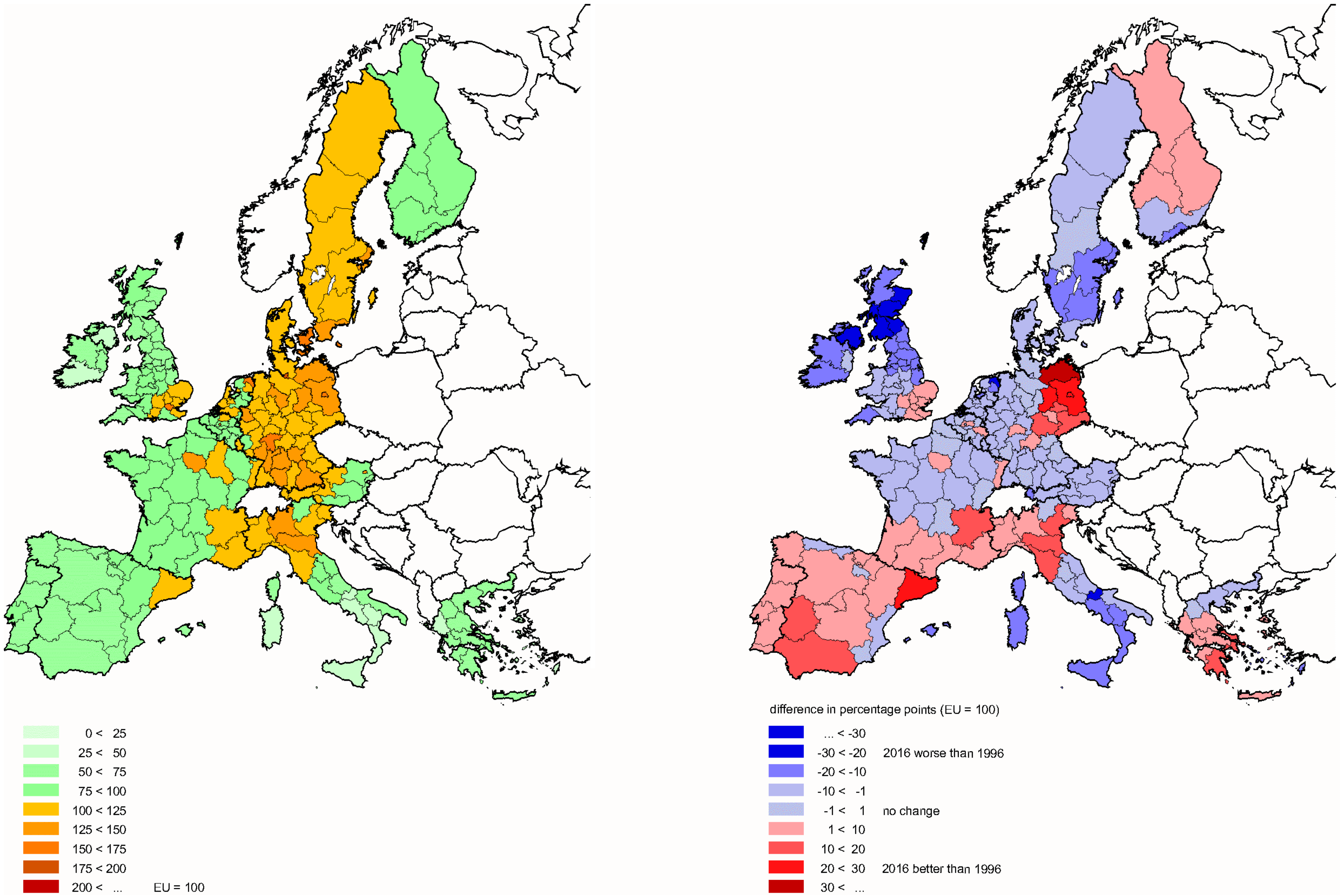


Figure 5.15. Scenario 20, GDP per capita by region, 2016 (left), change 1996-2016 (right)

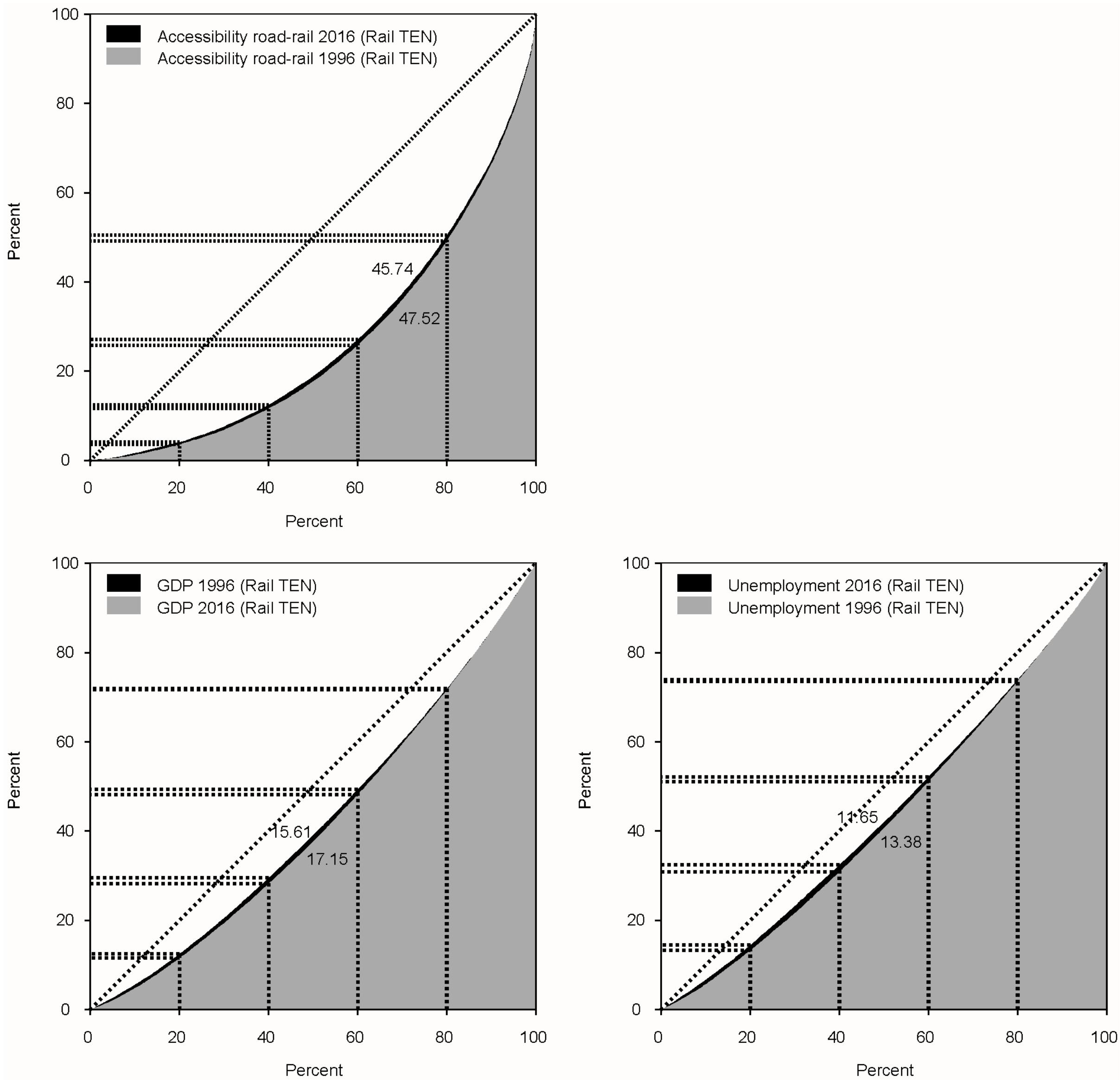


Figure 5.16. Scenario 20, Lorenz curves of regions 1996-2016, accessibility (top), GDP (bottom, left) and unemployment (bottom, right)

The coefficient of variation shows the typical order of variation spans for accessibility road/rail, accessibility road/rail/air and GDP per capita (Figure 5.17). A convergence of variations in the two accessibility measures can be detected, particularly so after the year 2000. The coefficient of variation for GDP yields a concave curve when considered from 1981 to 2016, implying that the range of variations has been highest in 1981, lowest in 1996 and rose again slightly but relatively steadily until the year 2016.

Whether or not these detected polarisation effects are caused or enhanced by TEN infrastructure investment will be explored in the following section which contrasts the results for different scenarios.

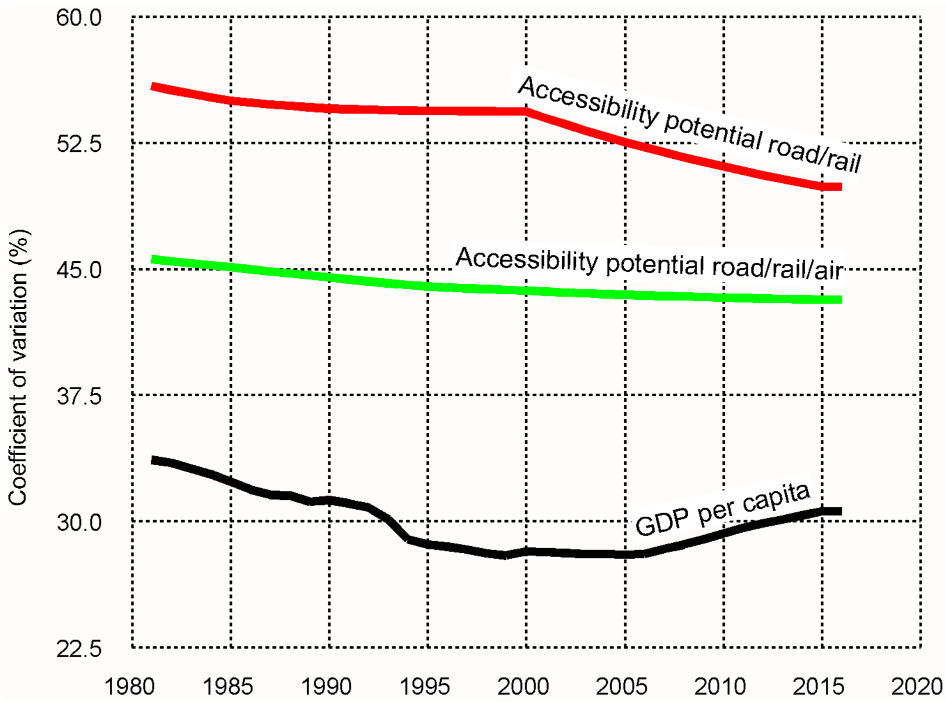


Figure 5.17. Scenario 20, coefficient of variation for accessibility and GDP per capita

5.4 Comparison of Scenarios

The synopsis of scenario results of the previous section proved that the development trajectories of the main indicators remain largely identical in each of the scenarios so that differences between scenarios are hardly visible when the scenario results are presented separately. The prima facie similarity of the results must, however, not lead to the premature conclusion that socio-economic development in the European regions is insensitive to the large-scale investments in trans-European networks. Instead, it is clear that the driving forces and macro-trends behind socio-economic development such as the ageing of the population, shifting labour force participation rates, increases in labour productivity, globalisation or competition of regions have a much stronger impacts on the development trajectories of the cohesion indicators than different transport infrastructure scenarios. Small as the differences of transport infrastructure scenarios may be at an aggregate level, they can nonetheless be important in altering regional development paths.

There exist a wide variety to present differences between two scenarios. In this subsection differences are presented as

- *relative regional differences* expressed in percent of the regions' values of one of the two scenarios,

- *absolute regional differences* expressed as percentage of one scenario's average value,

- *standardised regional differences* in which for both scenarios each regional value is standardised to the European averages of the scenarios, the difference between the two standardised values is the change in percentage points compared to the European average.

- *cohesion indicators* such as the GINI coefficient or the coefficient of variation.

Comparison TEN Scenario 10 versus Do-Nothing Scenario 00

For determining the socio-economic impact of TEN construction over time it is pertinent to compare the TEN Scenario 10 with the do-nothing Scenario 00 since this comparison allows to isolate potential effects of TEN investment from other political, economic and demographic variables contributing to regional development. Figure 5.18 shows a comparison of changes in accessibility for the TEN scenario and the do-nothing scenario in percent. The greatest gains appear to be in the periphery, notably on the Iberian peninsula where gains exceed 80 percent in some regions and amount to 150 percent in Lisbon. Gains are relatively small in core regions of the European Union. Apart from differences in volume, it is obvious that all European regions benefit from TEN investment through increased accessibility.

In order to eliminate the size effect contained in the measurement related to percentage changes over differing regional accessibility levels, Figure 5.19 considers changes in accessibility in percent of the overall European Union average in the do-nothing scenario. Here the picture is less unequivocal than in the previous illustration. Changes based on a fixed average reveal that absolute gains are also high in the core regions even though these changes translate into smaller percentages of change based on the region's previous accessibility level when the level is already high as is the case in most of the core regions. It is also visible that the regions along major trans-European transport infrastructure lines, particularly high-speed railway lines, such as the south west of France and north east of Spain benefit most from the construction of new transport infrastructure. Notwithstanding distributive differences, all European regions experience gains from TEN investment in absolute terms.

Apart from the absolute positive gains for all regions it is important to analyse relative changes and possible reversals in the accessibility rank system. Figure 5.20 discloses a pattern which differs considerably from the previous illustrations. Taking differences in percentage points standardised on the European average shows that relative losses in the order of magnitude of roughly three to four percentage points are to be expected from TEN investment for the core regions, while most of the more peripheral regions, especially in the south west of Europe encounter positive effects. There is a number of cases where gains exceed even 30 percentage points of the European average.

Figure 5.21 shows how TEN investments translate into changes in regional economic performance by considering regional differences in percent for both scenarios. Most regions in the European core and the northern European regions encounter absolute and relative losses in GDP from TEN investment, while most regions at the periphery are characterised by considerable gains. This distribution pattern hints at a convergence effect of TEN investment in GDP development since most regions in the cohesion countries experience gains (with the exception of Ireland and a small number of regions in Spain and Greece), while the richer regions experience losses.

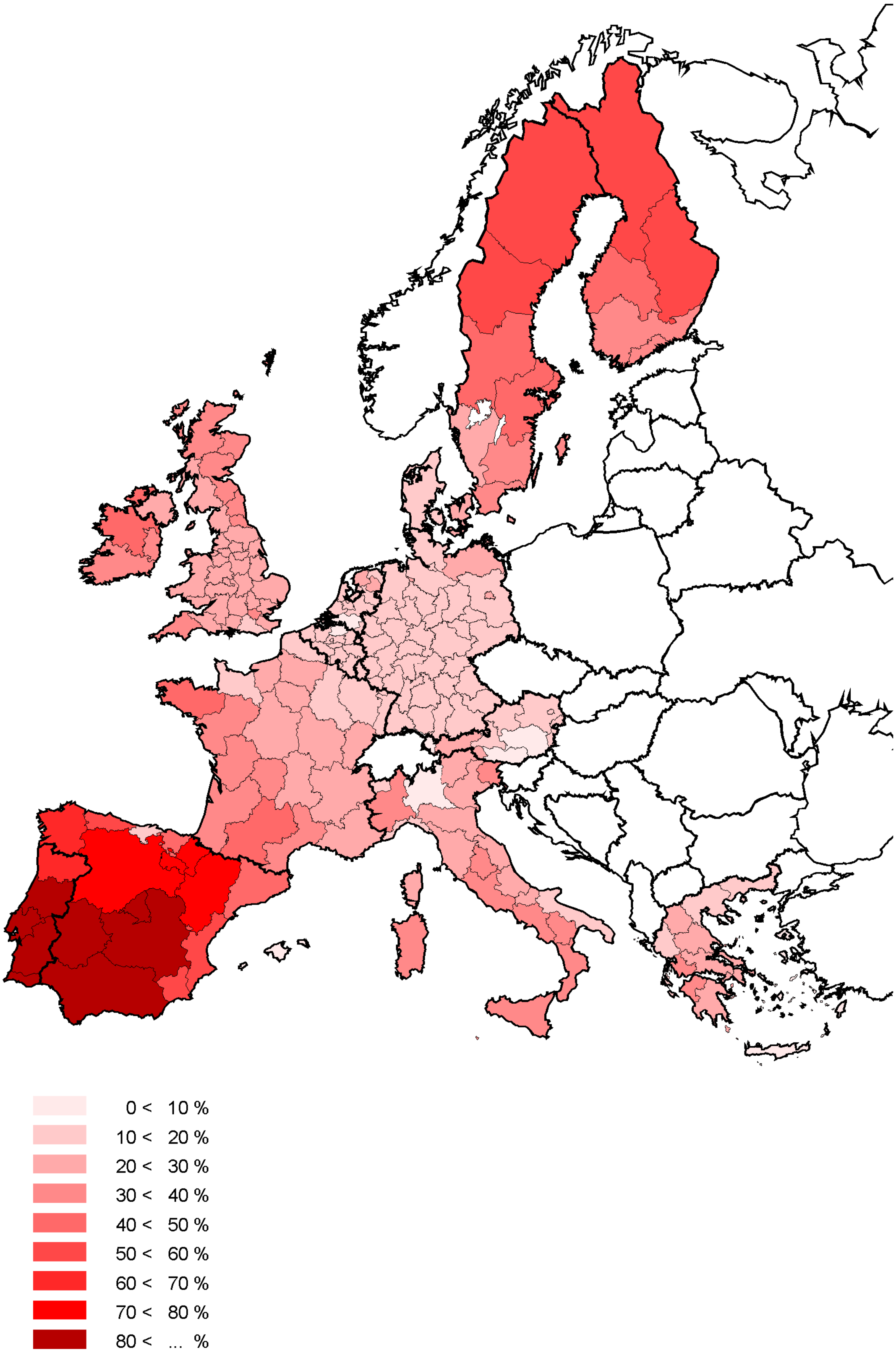


Figure 5.18. Scenario 10 v. Scenario 00, accessibility, relative difference, 2016

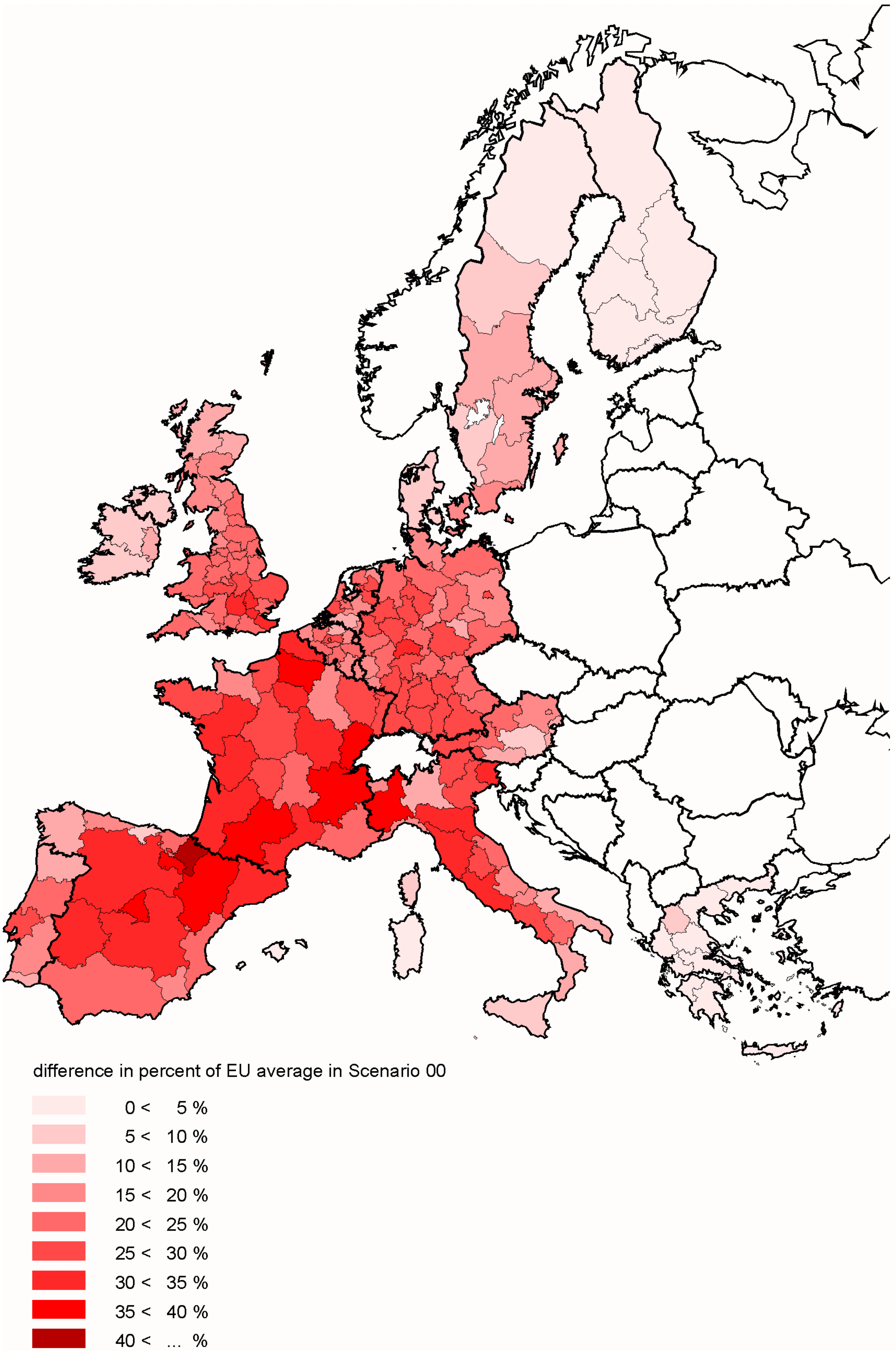


Figure 5.19. Scenario 10 v. Scenario 00, accessibility, absolute difference, 2016

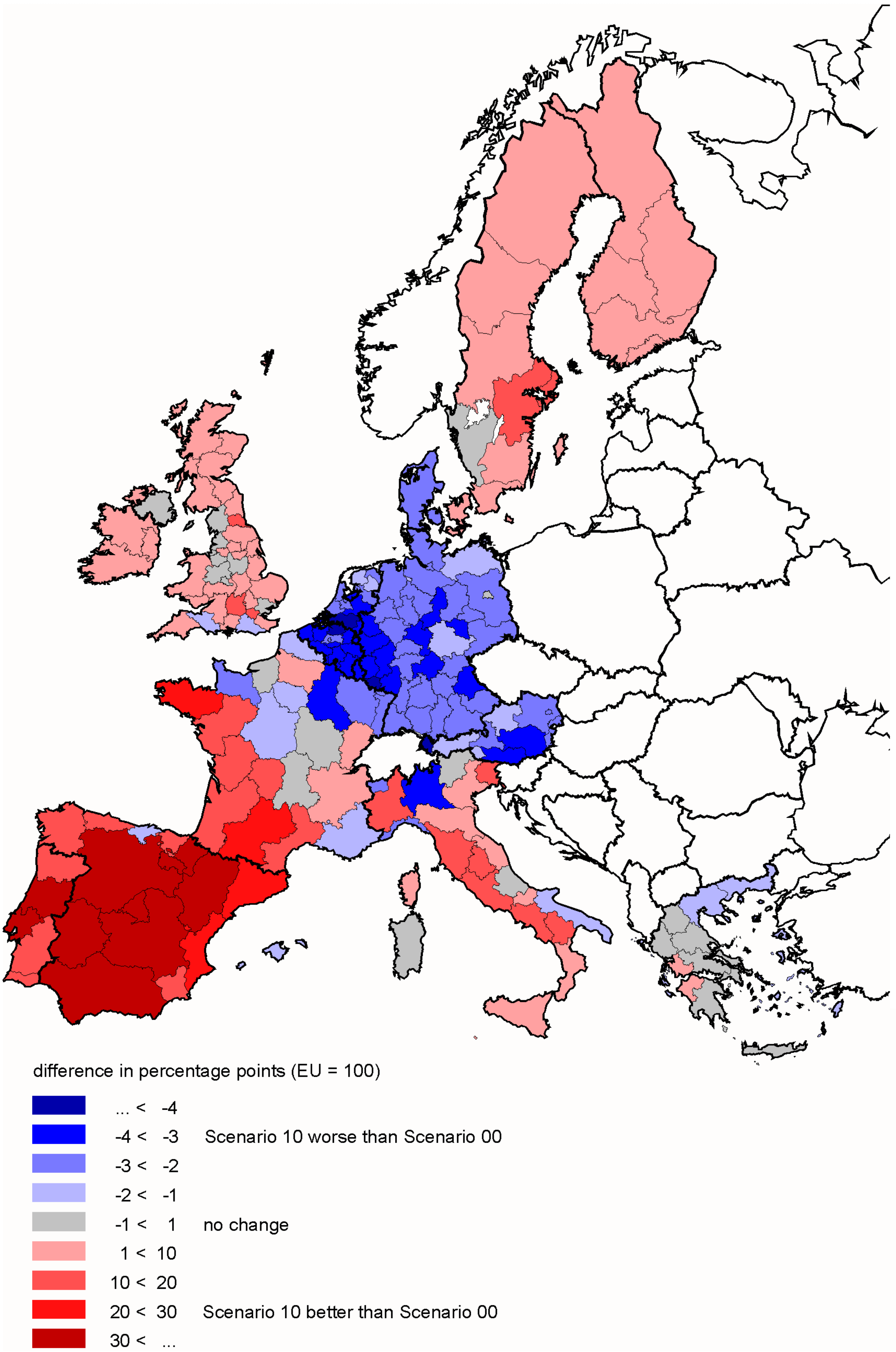


Figure 5.20. Scenario 10 v. Scenario 00, accessibility, standardised difference, 2016

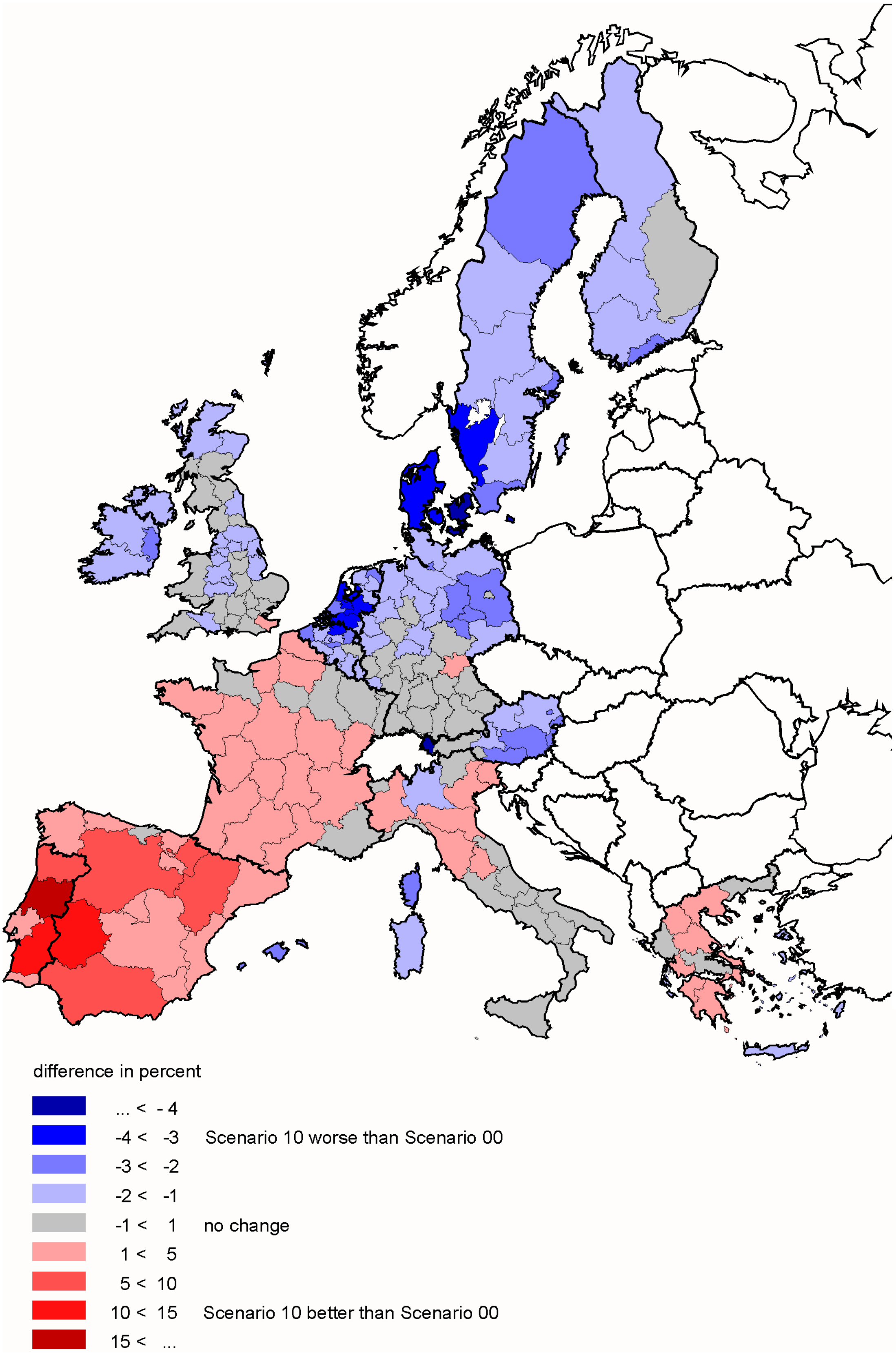


Figure 5.21. Scenario 10 v. Scenario 00, GDP per capita, relative difference, 2016

However, this picture is not unequivocal and differences between both scenarios are only marginal in most regions when compared to the order of magnitude of changes over time (see Figure 5.10). The distribution of equivalent changes standardised to the European average is identical in this case, because of the fact that overall European GDP is put exogenously and does not allow for differences in the aggregate economic performance of the European Union in different scenarios. Moreover, considering absolute differences in Euro per capita also provides a pattern which is very similar to the one described above.

Comparing absolute changes in accessibility and absolute changes in GDP, it is remarkable that especially in the British, Irish and Scandinavian regions positive changes in accessibility do not generate positive effects in GDP/capita. This phenomenon is explained by the fact that the very high accessibility gains of a number of other European regions give these successful regions a comparative advantage that negatively affects regional economic development in less successful regions in this zero-sum game.

Comparison Rail TEN Scenario 20 versus Do-Nothing Scenario 00

A comparison of Scenario 20 and Scenario 00 allows an evaluation of TEN investment in rail infrastructure since road infrastructure projects are excluded in this scenario. In parallel to the distribution of the comparison between Scenarios 10 and 00 described in the previous section, the picture conveyed by taking differences in accessibility in percentage points standardised on the European average shows for this comparison that relative losses of approximately three to four percentage points are to be expected from TEN rail investment for the core regions (Figure 5.22). Most of the more peripheral regions, especially in the south west of Europe encounter positive effects with the most successful regions experiencing gains of over 30 percentage points of the European average. Most Scandinavian, British and Italian regions also experience relative gains in accessibility.

How do these changes in accessibility affect regional economic development? Figure 5.23 shows that railway investment generates positive economic effects mainly along the high-speed railway lines, notably in the south western regions of Europe. Of the four cohesion countries, Spain and Portugal which benefit from the construction of high-speed railway connections experience preponderantly positive effects, while Greece and Ireland are negatively affected with the exception of the two metropolitan regions of Greece. Heavy relative losses are encountered by the Benelux and Southern Scandinavian regions.

Comparison TEN Scenario 10 versus Rail TEN Scenario 20

Contrasting Scenarios 10 and 20 serves to evaluate the effect of TEN road infrastructure investment since Scenario 20 includes all TEN links except road infrastructure projects. Figure 5.24 shows that relative gains are to be expected in regions scattered all over Europe. Comparing this distribution with the outline plan of TEN road projects (see Figure 4.3) reveals that the gains occur almost exclusively in regions for which massive road construction projects are planned. Especially some of the new German Länder and Portugal with a number of motorway construction projects, some regions in northern and central France as well as the mainland of Greece experience substantial relative gains in accessibility.

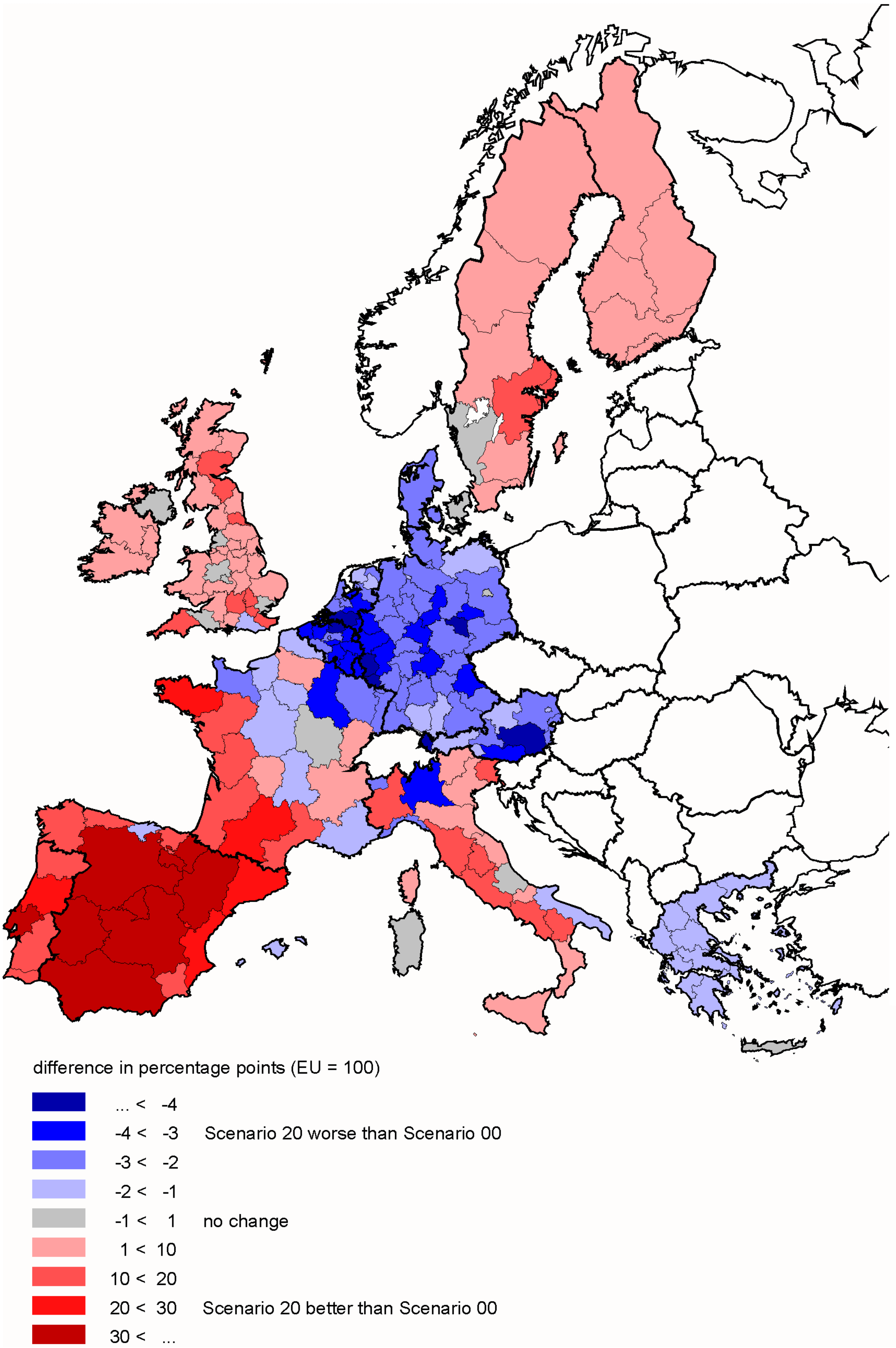


Figure 5.22. Scenario 20 v. Scenario 00, accessibility, standardised difference, 2016

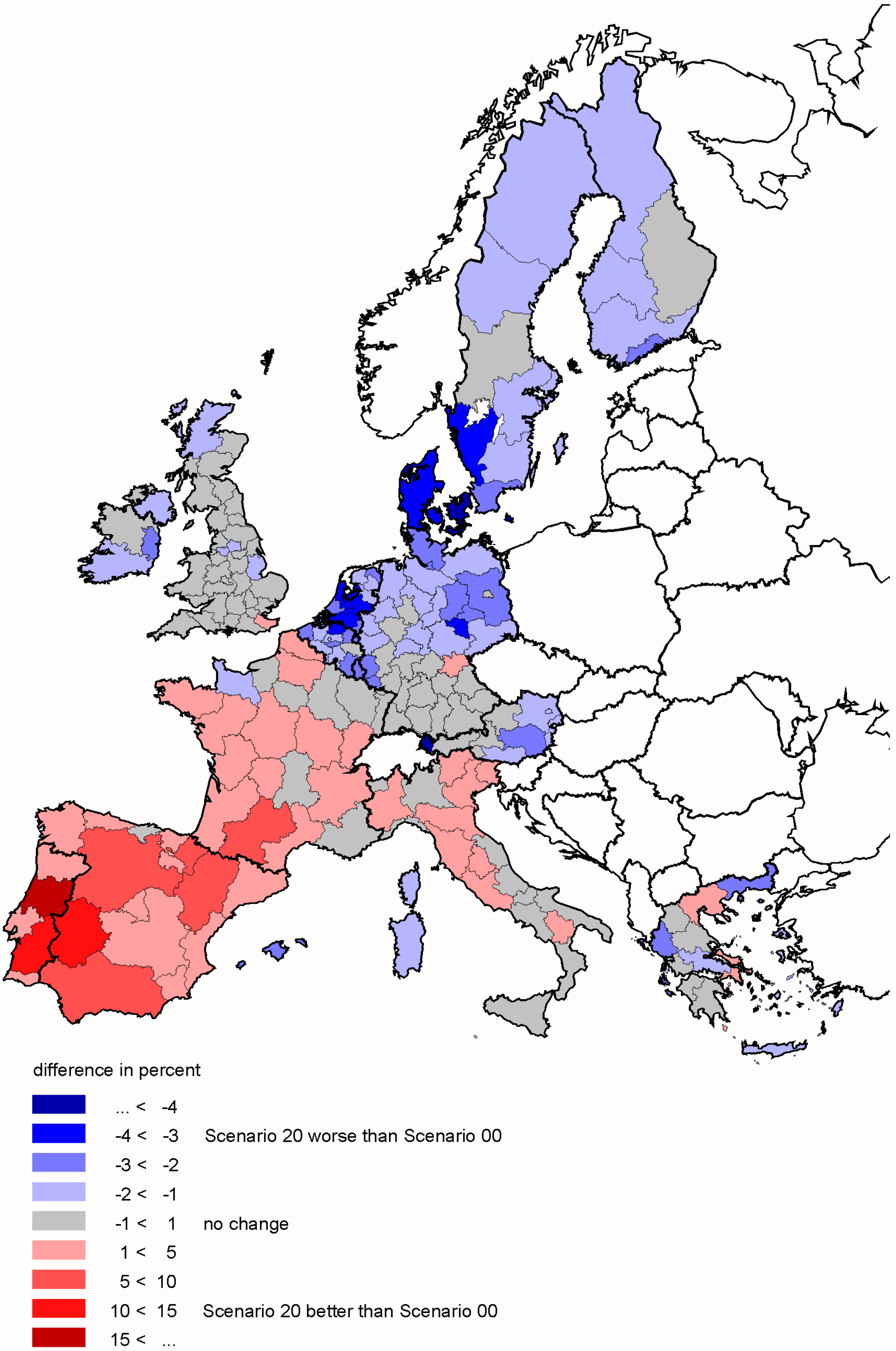


Figure 5.23. Scenario 20 v. Scenario 00, GDP per capita, relative difference, 2016

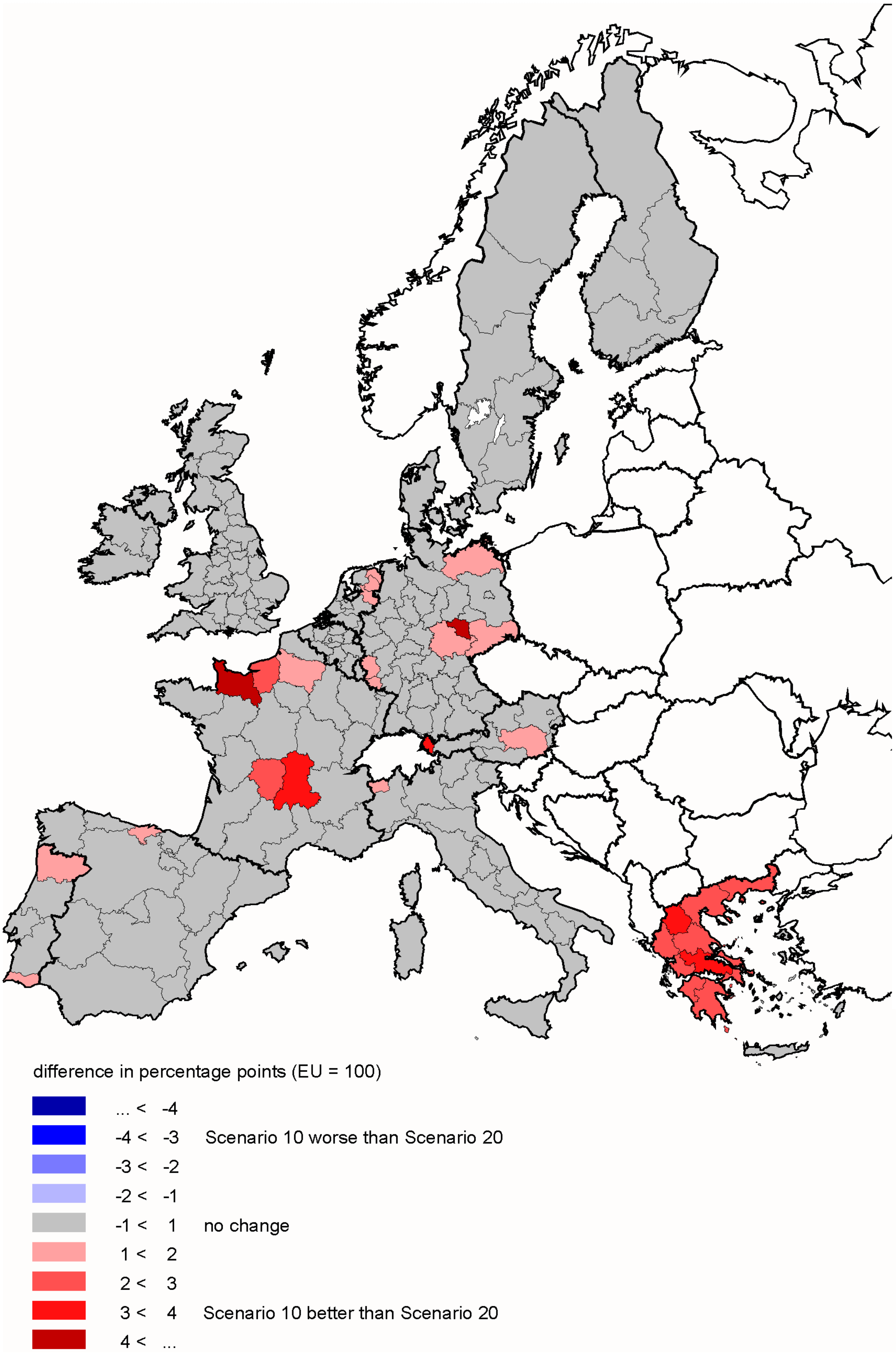


Figure 5.24. Scenario 10 v. Scenario 20, accessibility, standardised difference, 2016

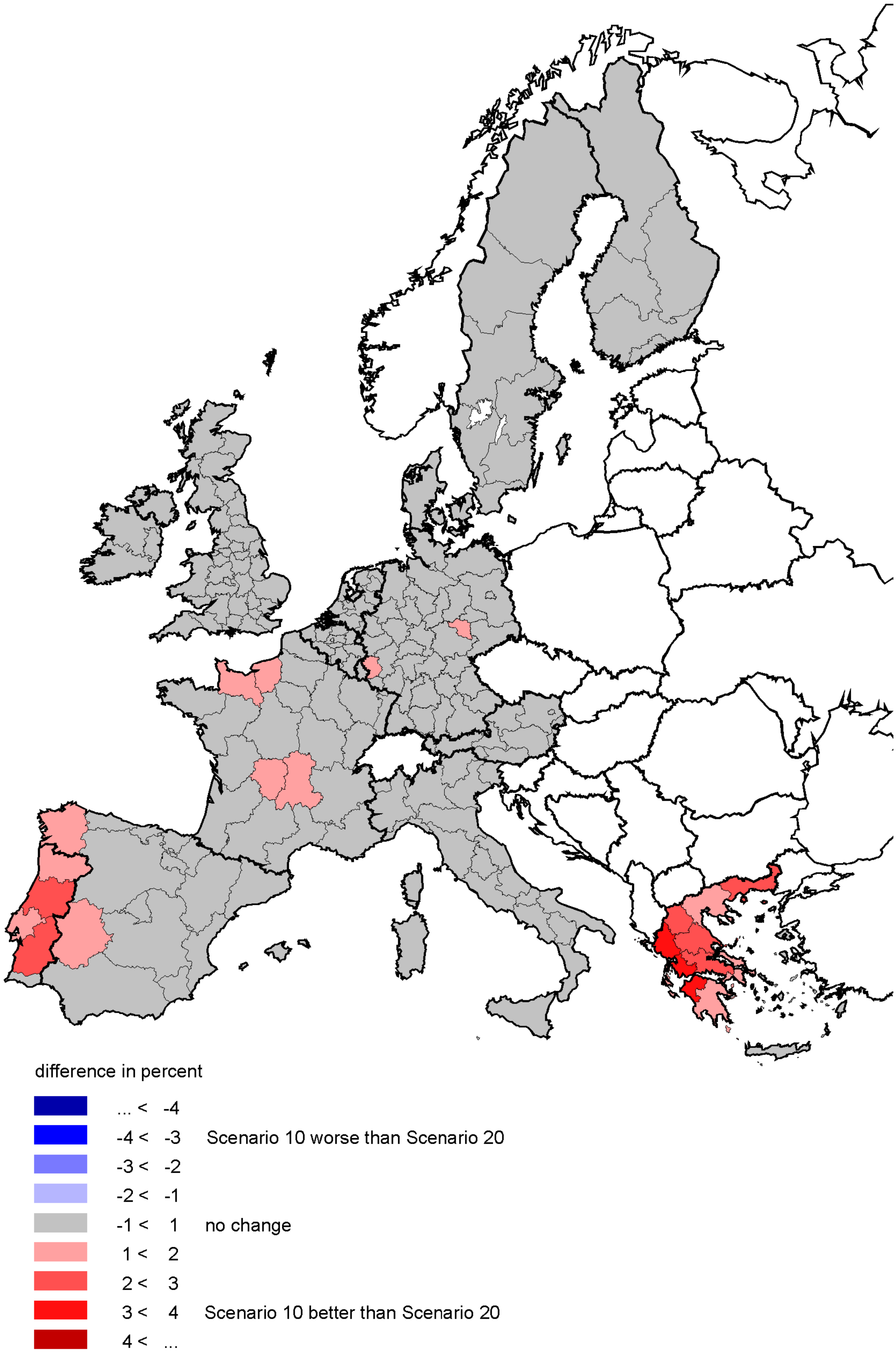


Figure 5.25. Scenario 10 v. Scenario 20, GDP per capita, relative difference, 2016

Differences in GDP per capita values for both scenarios are illustrated in Figure 5.25. Not surprisingly, the countries that benefit economically are again the ones where accessibility is increased by major road construction projects. However, it is interesting to note that some regions in Portugal derive a higher relative gain in GDP than in standardised accessibility changes from these infrastructure projects. Conversely, the regions of Germany and France do not benefit economically to the same degree as they benefit in terms of relative accessibility. The relative gains made by some regions are balanced by minor losses in other regions which do not show up in this map because they are all within the one percent tolerance threshold of the category 'no change'.

Scenario implications for cohesion

One fundamental aim of establishing and developing TEN projects is "to 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" (European Communities, 1996). Assessing the actual contribution of the TEN projects to this aim is not a straightforward tasks in the presence of a variety of possible aspects, indicators and methodologies.

A standard method for evaluating cohesion is the Lorenz curve which has been applied in the previous sections. Figure 5.26 shows Lorenz curves for the three scenario comparisons in the year 2016. Comparing Scenarios 10 and 00 (top, left) suggests that the TEN scenario yields a more equal distribution of accessibility among European regions which implies a moderate cohesion effect of the TEN - compared to the do-nothing scenario. The order of magnitude of the differences between the scenarios makes it difficult to draw reliable conclusions from the results of this Lorenz curve.

Comparing Scenarios 20 and 00 (top, right) shows approximately the same moderate convergence effect, while the marginal difference between Scenario 10 and Scenario 20 suggests a vaguely higher convergence trend for Scenario 10 which comprises the full array of TEN rail and road projects. However, it is important to emphasise that none of the differences are significant enough to allow an unambiguous assessment of the TEN cohesion effect.

Figure 5.27 shows coefficients of variation for accessibility in the year 2016 which indicates the spread of a set of data as a proportion of its mean in percentage points. Please note that the scale of percentages on the vertical axis is not identical in all the diagrams of coefficients of variation presented here which limits the visual comparability of the diagrams. In this diagram the axis covers the range from 48 to 58 percent with two percent steps in between. There is a significant reduction of the coefficient in the order of magnitude of about four percent in 2016 for the TEN scenarios, with the full TEN Scenario 10 showing slightly less variation than the Rail TEN Scenario 20. It is clearly visible that reductions in the coefficient of variation increase steadily over time until the end of the forecast period. This pattern gives a further hint for a mild convergence effect of the TEN.

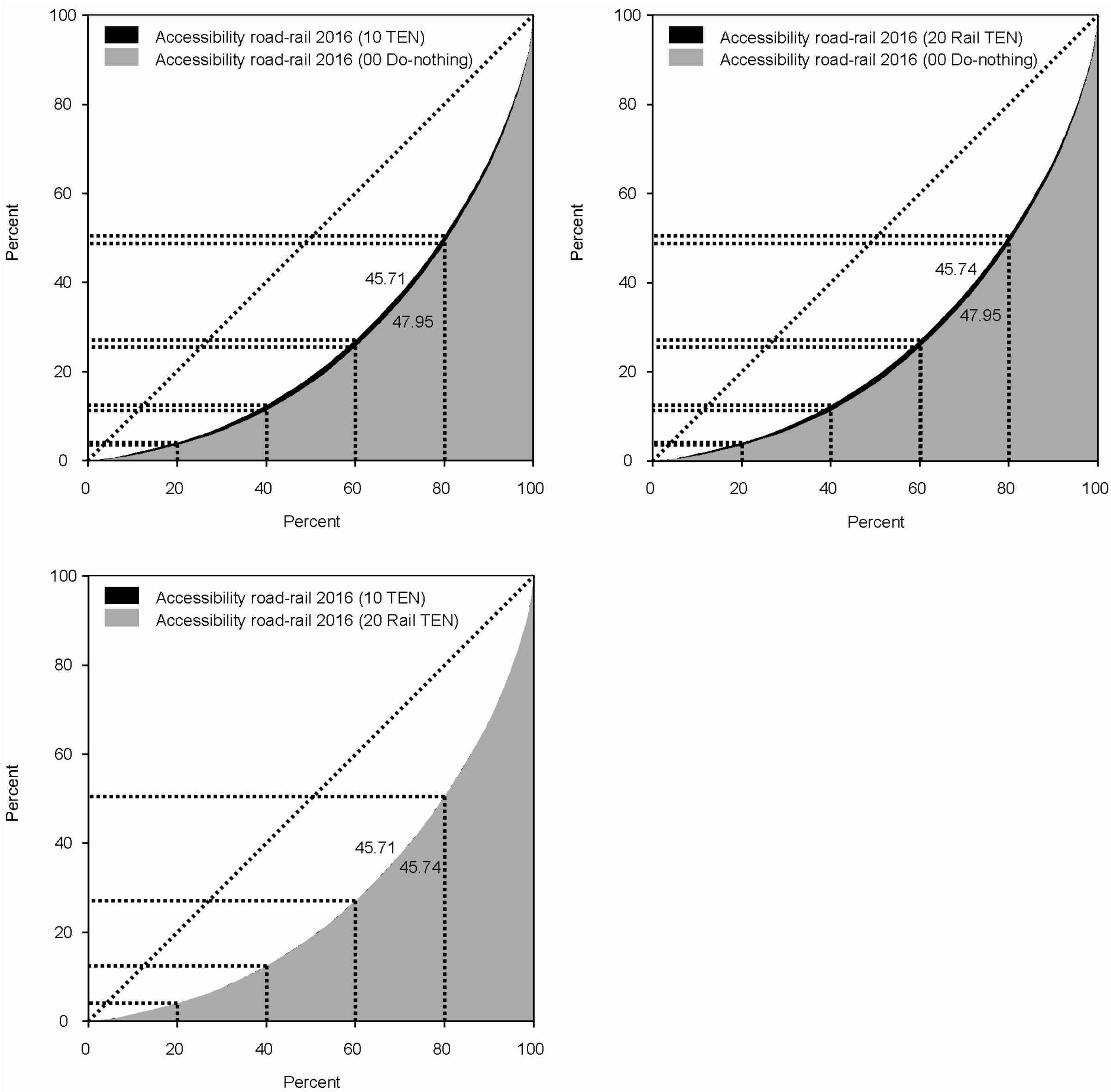


Figure 5.26. Scenarios 00, 10 and 20, Lorenz curves of regions for accessibility, 2016

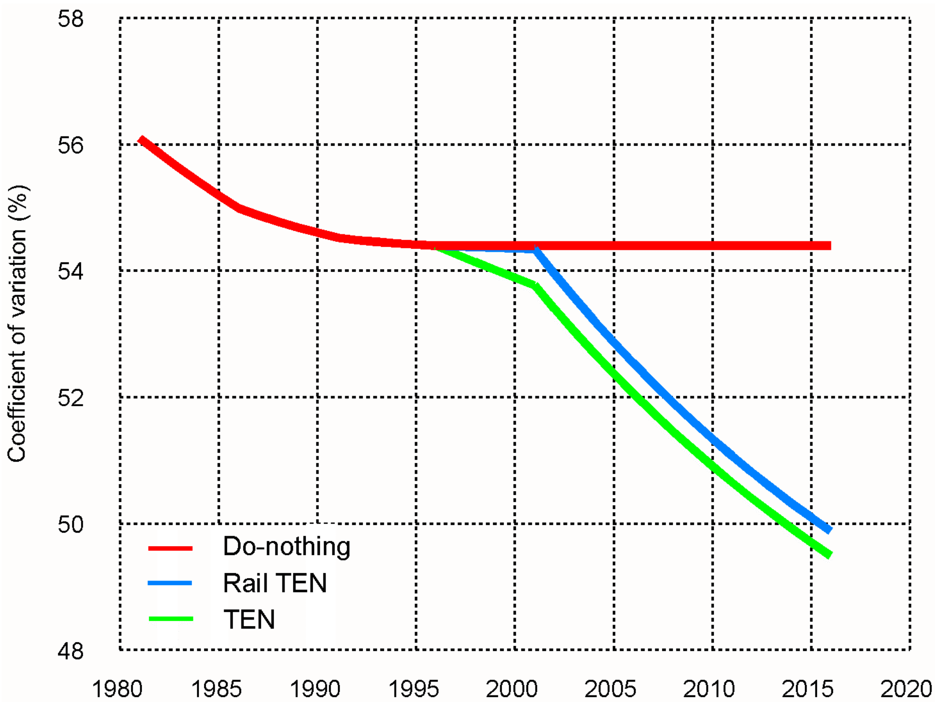


Figure 5.27. Scenarios 00, 10, and 20, coefficient of variation for accessibility, 1981-2016

Reiterating the same procedure for GDP convergence gives a similar yet less pronounced picture. Figure 5.28 shows Lorenz curves for the three scenario comparisons in the year 2016. It is obvious that GDP is generally more equally distributed than accessibility (GINI coefficient of 17 for GDP compared to 45 for accessibility). Comparing Scenarios 10 and 00 (top, left) suggests that the TEN scenario leads to a slightly more equal distribution of GDP among European regions which implies a moderate economic cohesion effect of the TEN. Comparing Scenarios 20 and 00 (top, right) shows approximately the same moderate convergence effect, while the marginal difference between Scenario 10 and Scenario 20 suggests a vaguely higher convergence trend for Scenario 10 which comprises the full array of TEN rail and road projects. The convergence effect is however relatively small in all cases.

Figure 5.29 shows coefficients of variation for GDP per capita from 1981 to 2016. Please note that the scale of percentages on the vertical axis is not identical in all the diagrams of coefficients of variation presented here which limits the visual comparability of the diagrams. In this diagram the axis covers the range from 20 to 45 percent with five percent steps in between. A slight reduction of the coefficient in 2016 for the TEN and Rail TEN scenarios can be observed. The previously reported moderate convergence effect of the TEN scenarios compared to the do-nothing scenario is also visible here albeit somewhat smaller than in accessibility. Beyond that, it seems that the TEN scenarios cannot reverse the general trend of slightly polarised development as implied by the coefficient of variation curve for the do-nothing scenario, but can only mitigate this development. Moreover, evaluating the convergence impact of scenarios is hampered by the fact that the dynamics of all three curves over time is much greater than the differences between the scenarios in the year 2016,.

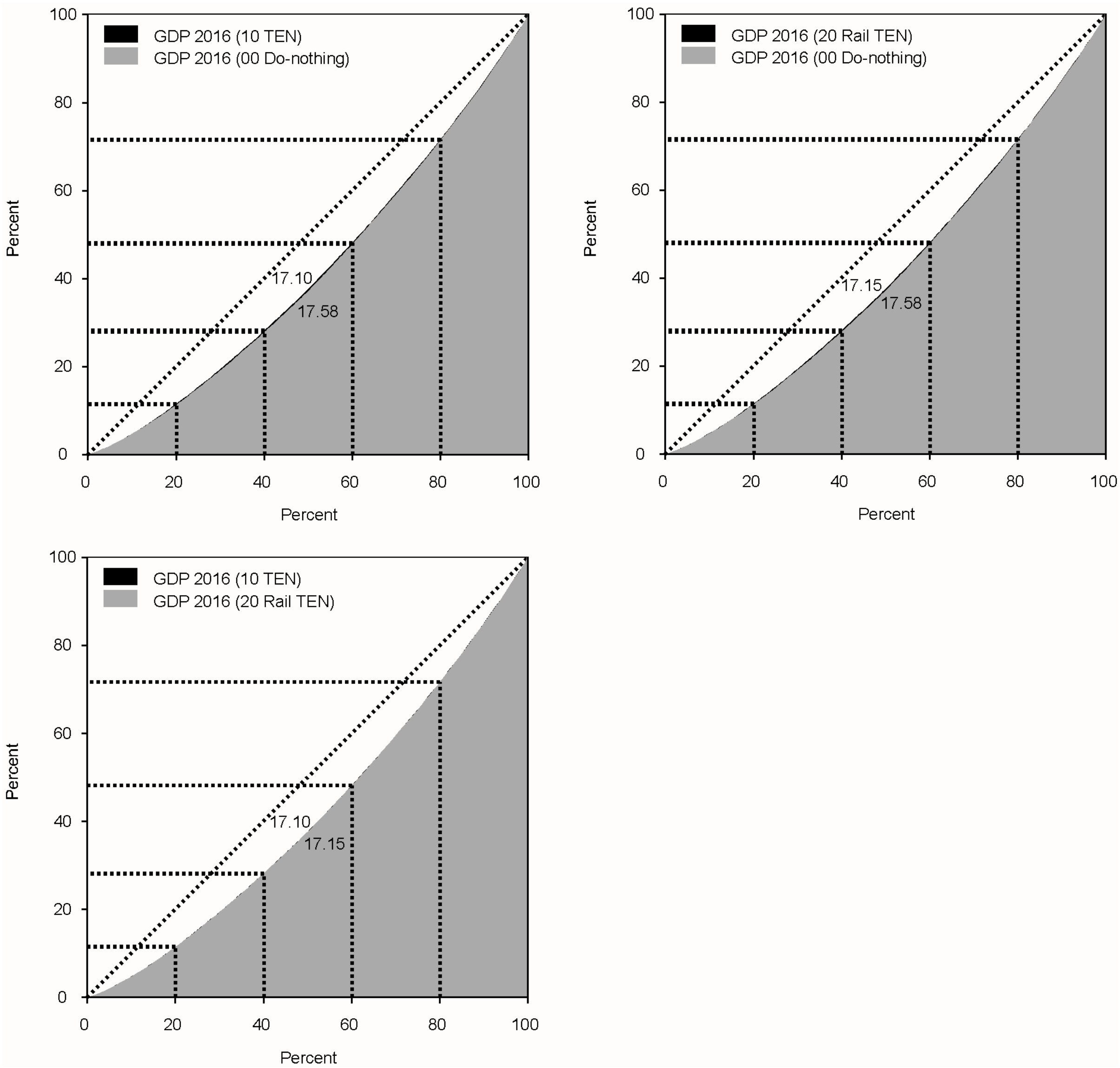


Figure 5.28. Scenarios 00, 10 and 20, Lorenz curves of regions for GDP, 2016

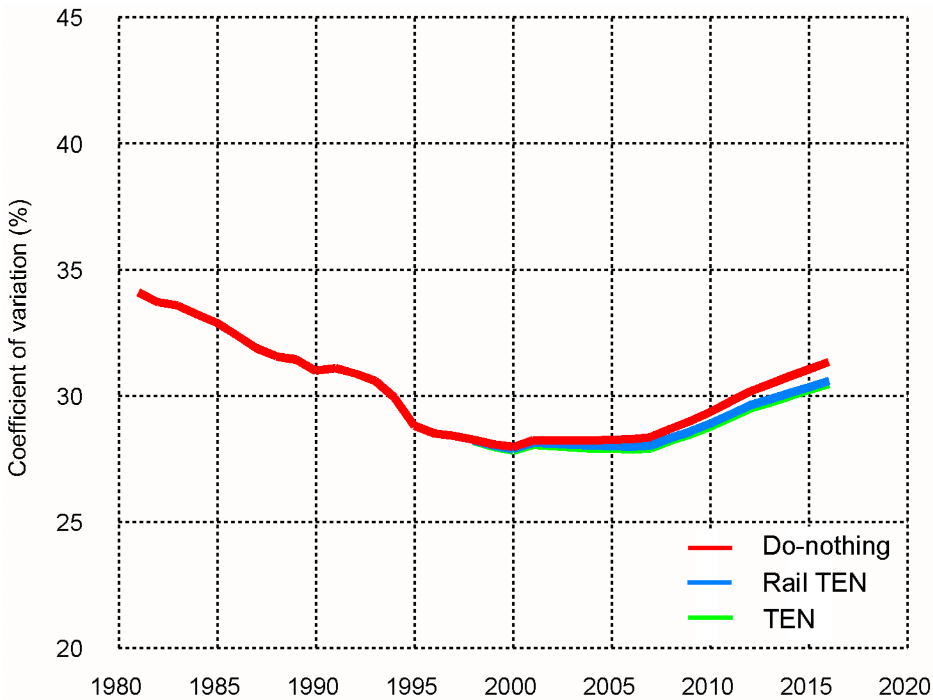


Figure 5.29. Scenarios 00, 10, and 20, coefficient of variation for GDP/capita, 1981-2016

6. The Øresund Link

The scenarios and their respective results described in the previous chapter comprise a variety of infrastructure projects of different types, sizes, investment volumes, transport modes and geographical locations. In order to demonstrate that the SASI model is sensitive not only with regard to evaluating the combined effects of a multitude of projects, the results of evaluating the impact a single project are described in this section.

Out of many possible projects, the example of the Øresund bridge project is illustrated in detail here. The Øresund bridge is especially suitable for assessing the impact of an individual project because it connects two previously physically separated countries with a fixed link. It is expected to open in July 2000 and connects the Danish region of Copenhagen and the Swedish region of Malmö. This link is important because it is one of the main infrastructure bottlenecks for all passenger and goods transports from and to the Scandinavia, thus being an important infrastructure endowment for the 3.5 million inhabitants who live within a radius of 100 km from the link and a considerably higher number of transit passengers in this region.

Figure 6.1 shows a comparison of Scenarios 09 and 10 where Scenario 09 includes all the links contained in Scenario 10 with the exception of the Øresund bridge which is replaces again by current ferry services. It is apparent that in the regions of Copenhagen (CP) and Malmö (ML) differences in the accessibility trajectories are brought about while there are no visible accessibility effects for the more distant region of Stockholm (ST). Figure 6.2 shows that marginal gains in accessibility are to be expected mainly in Scandinavia and not so much on the European mainland. It is also obvious that the accessibility impact of the link weakens with a region's distance from the link. While Malmö's and Copenhagen's accessibility increases by 1.9 and 1.6 percent respectively, the effect for all other regions is below 1 percent.

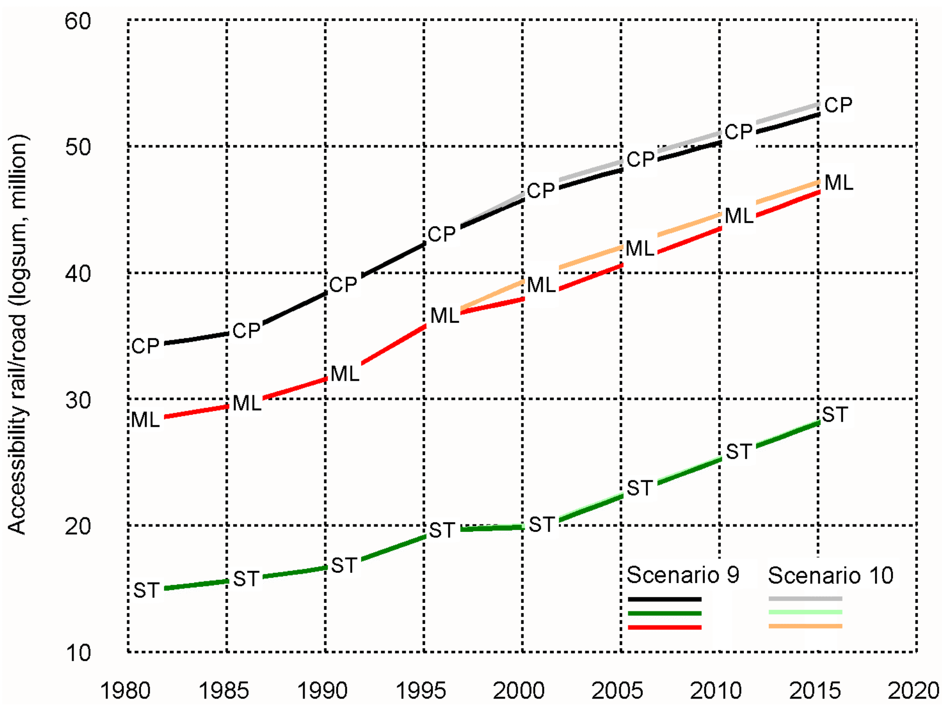


Figure 6.1. Scenario 09 (TEN with Øresund ferry) and Scenario 10 (TEN with Øresund bridge), selected regions, relative differences in accessibility, 1981-2016

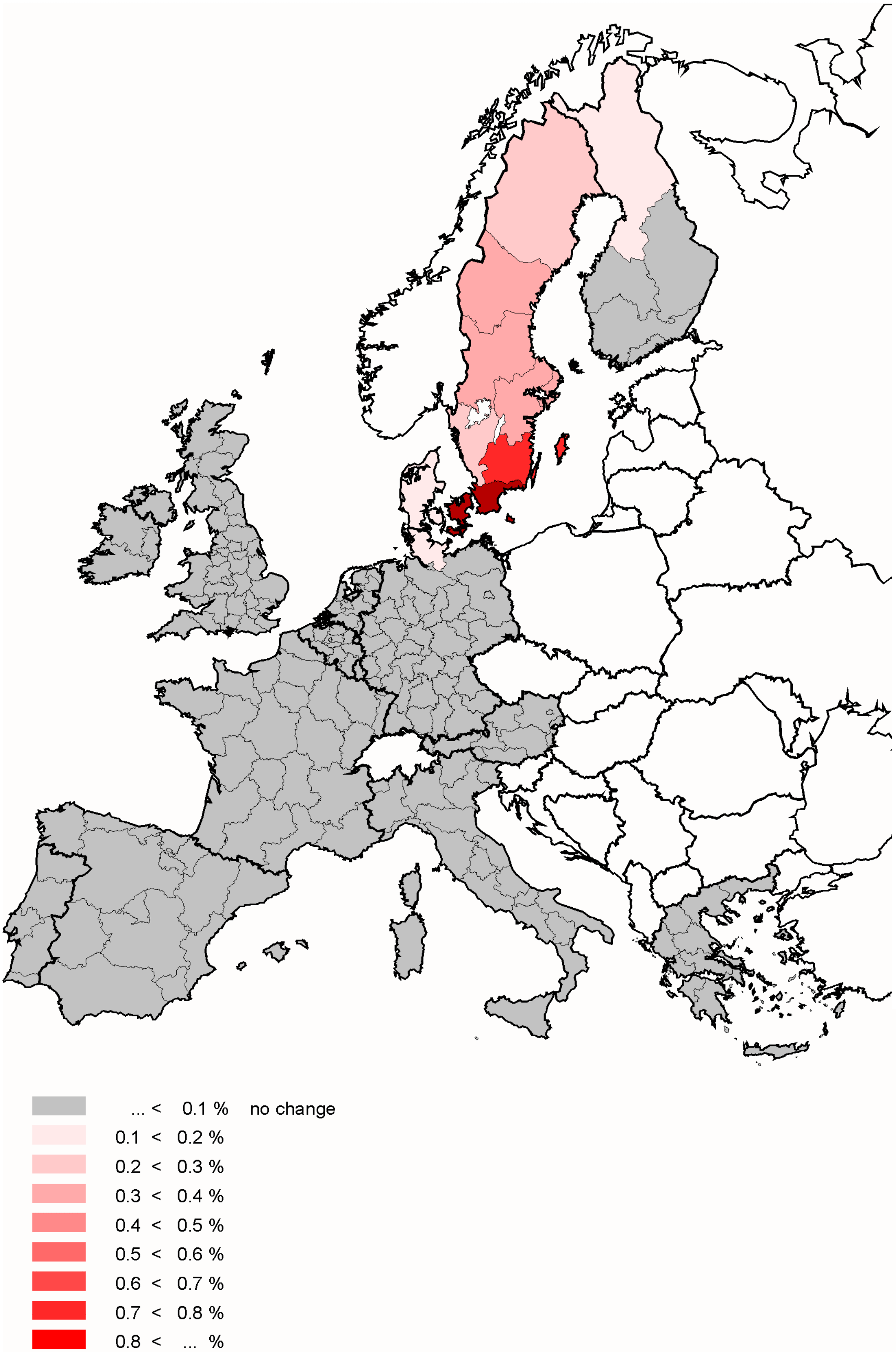


Figure 6.2. Scenario 09 (TEN with Øresund ferry) and Scenario 10 (TEN with Øresund bridge), relative differences in accessibility, 2016

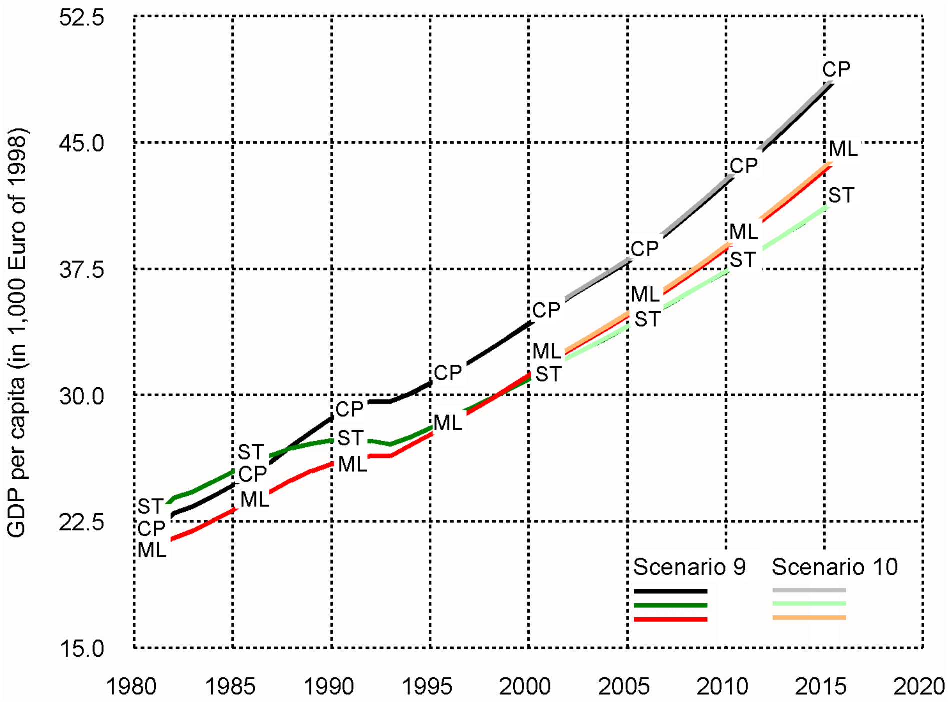


Figure 6.3. Scenario 09 (TEN with Øresund ferry) and 10 (TEN with Øresund bridge), selected regions, relative differences in GDP, 1981-2016

Figure 6.3 shows an equivalent comparison of the scenarios with respect to differences in GDP. It can be observed that the increased accessibility generated by the Øresund bridge results in less friction in the movement of persons and goods between the regions and consequently in higher economic performance per capita. Effects for the more distant region of Stockholm are again not visible in this diagram. Mapping the differences between Scenarios 9 and 10 reveals that the number of regions experiencing gains of over 0.1 percent in GDP is even smaller than for accessibility (Figure 6.4). The difference amounts to 0.81 percent in the region of Malmö and 0.6 percent in the region of Copenhagen. The region of Jönköping increases its GDP by about 0.23 percent through the link.

The demonstration example of the Øresund link proves that the SASI model is sufficiently sensitive to assess individual infrastructure projects with regard to their impact on accessibility and regional economic development. The results are plausible on the regional level even in a range of below one percent of the respective total indicator value.

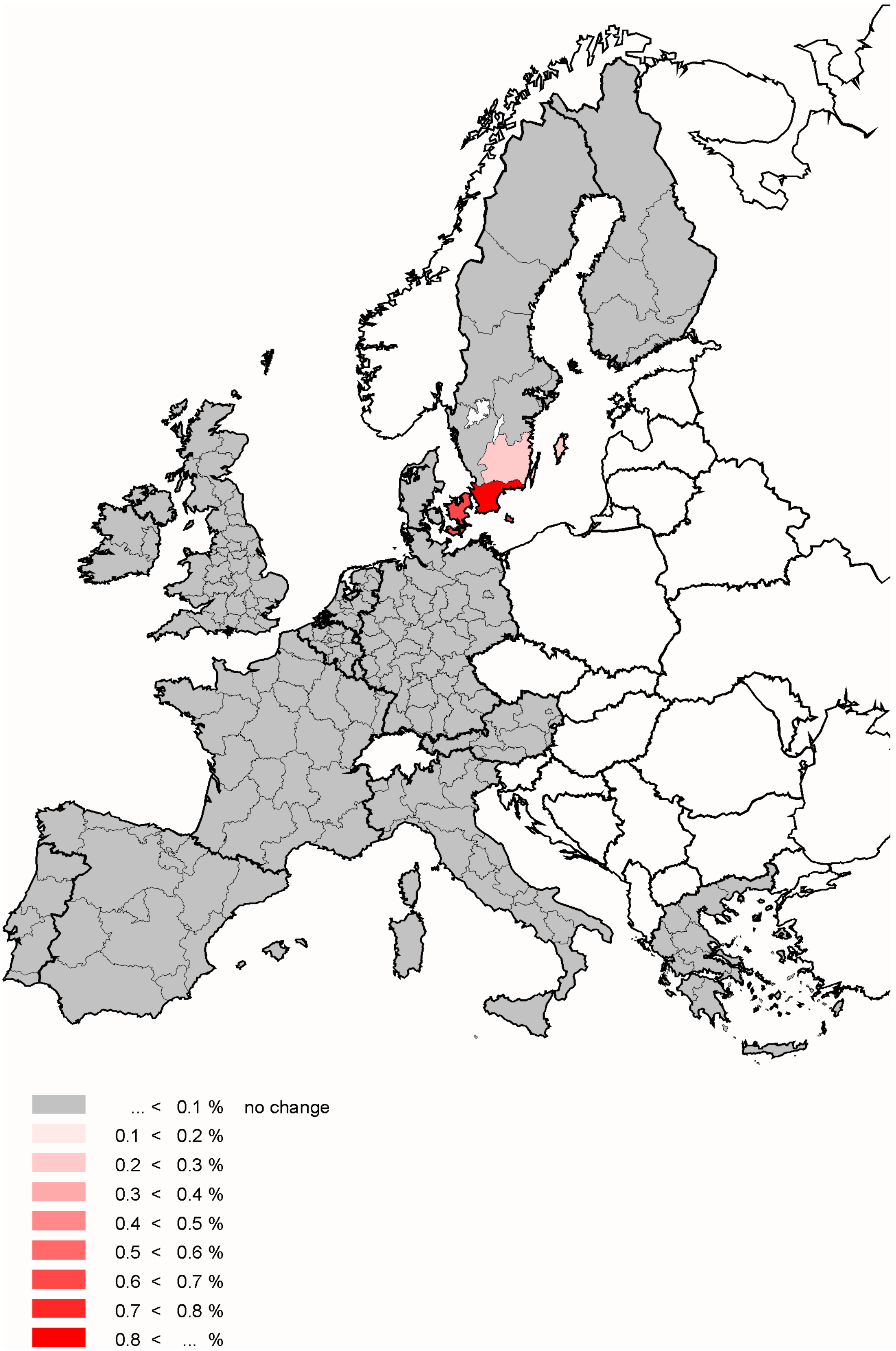


Figure 6.4. Scenario 09 (TEN with Øresund ferry) and Scenario 10 (TEN with Øresund bridge, relative differences in GDP, 2016

7. Conclusions

This report presented demonstration examples of the SASI model based on the results of the previous six SASI deliverables.

After a description of the overall project objectives, first the design principles and structure of the SASI model as developed in the previous deliverables were summarised. In the main part of the report, four scenarios designed to test the central research questions of the SASI project were presented. They include a reference scenario, two network policy scenarios exploring the impact of full TEN and railway TEN implementation and a scenario to demonstrate the sensitivity of the SASI model to individual TEN projects. The results of the model runs were presented and interpreted, with particular emphasis on their implications for socio-economic cohesion between the European regions.

In this concluding chapter, the following sections assess the strengths and weaknesses of the SASI model revealed during its design, development and application, summarise the main project results and discuss further work.

Strengths and weaknesses of the model

The SASI model differs from other approaches to modelling the impacts of transport on regional development by modelling not only regional production (the demand side of regional labour markets) but also regional population (the supply side of regional labour markets). This makes the model capable of predicting regional unemployment. As full employment is one of the major policy objectives of the European Union, this is an important advantage.

A second major advantage of the model is its comprehensive geographical coverage. Its study area are all regions of the fifteen member states of the European Union at NUTS-2 level. In addition, the other European countries, including the European part of Russia, are included as external regions. This makes the model especially suited to model spatial redistribution effects of the TETN within the European Union. Accordingly, this is the major focus of the model. Although in principle it would be possible to model aggregate macroeconomic multiplier effects of transport investments on the European economy as a whole, this is not presently intended because of the many factors and uncertainties related to global economic developments that would have to be considered. Therefore all model results are constrained by exogenous forecasts of economic development, immigration and outmigration of the European Union as a whole.

A third distinct feature is its dynamic network database. Based on a 'strategic' subset of the highly detailed pan-European road and rail networks developed by IRPUD and licensed to Eurostat and DG VII, the model is associated with one of the most sophisticated transport network representations available in Europe today. Moreover, these networks have recently been given a dynamic dimension by backcasting major historical network changes as far back as 1981 and forecasting expected network changes according to the most recent EU documents on the future evolution of the trans-European transport networks (European Communities, 1995; 1996; European Commission,1998).

A fourth unique feature of the model is the way impacts of transport infrastructure investments and transport system improvements on regional production are modelled. The model uses regional production functions in which transport infrastructure is represented by accessibility. Accessibility is measured by spatially disaggregate accessibility indicators which take into account that accessibility within a region is not homogenous but rapidly decreases with increasing distance from the nodes of the networks (Schürmann et al., 1997).

A fifth significant feature of the model is its flexibility in incorporating 'soft' non-transport factors of regional economic development beyond the economic factors traditionally included in regional production functions. These may be indicators describing the spatial organisation of the region, i.e. its settlement structure and internal transport system, or institutions of higher education, cultural facilities, good housing and a pleasant climate and environment. In addition to these tangible endowment indicators, regional residuals taking account of intangible factors not considered are included in the production functions.

A sixth important characteristic of the model is its dynamic character. Regional socio-economic development is determined by interacting processes with a vast range of different dynamics. Whereas changes of accessibility due to transport infrastructure investments and transport system improvements become effective immediately, their impacts on regional production are felt only two or three years later as newly located industries start operation. Regional productivity and labour force participation are affected even more slowly. The sectoral composition of the economy and the age structure of the population change only in the course of many years or even decades. A model that is to capture these dynamics cannot be an equilibrium model but has to proceed in time increments shorter than the time lags of interest.

A characteristic important for the policy relevance of the model are the cohesion indicators calculated. As the model predicts accessibility, GDP per capita and unemployment of each region for each year of the simulation, it can also calculate cohesion indicators measuring the convergence (or divergence) of these indicators in the regions over time. These measures indicate whether transport infrastructure investments or transport system improvements contribute to the achievement of the cohesion goals of the Union or whether they tend to reinforce the existing disparities between rich and poor regions.

A final property of the model are its relatively moderate data requirements. The model does not require a highly disaggregate classification of industries nor an input-output table. The population and migration model works with minimum input data such as five-year age groups and net migration. Due to the method used to calculate disaggregate accessibility indicators, the road, rail and air networks do not need to be coded with excessive detail. The data requirements for calibrating the model are also moderate because many model equations are validated against a long period of the past.

Compared with these significant advantages of the modelling approach chosen, its few limitations seem acceptable. As total economic and population development are exogenous, it does not predict the macroeconomic multiplier effects of transport infrastructure investments and transport system improvements such as elasticity of demand. Direct effects of transport infrastructure investment during the construction period are not considered. Labour productivity is linked to changes of accessibility but not to other factors in the production function, so no substitution between factors are modelled. The migration model based only on net migration is simplistic as is the labour force participation model, which may affect the validity of the unemployment forecasts. Finally, as the model does not contain a full transport submodel, it cannot take account of network congestion or intermodality.

Main project results

The main task of the SASI project has been to identify the way transport infrastructure contributes to regional socio-economic development in different regional contexts. To this end, an interactive and transparent modelling system has been designed for forecasting the impacts of transport infrastructure investments and transport system improvements, in particular of the trans-European transport networks, on socio-economic activities and developments in Europe. The choice of indicators to measure and describe these impacts was carried out with the intention that the results of this project can be related to the policy goals of the European Union. These are the main characteristics and findings of the project:

- Accessibility indicators are central to the task of linking infrastructure projects to regional economic development. For this purpose it was necessary to investigate different types of accessibility indicators and their relevance for different aspects of modelling regional development. The more complex accessibility indicators which are used here are a construct of two functions, one representing the activities or opportunities to be reached and the other representing effort, time, distance or cost needed to reach them (Schürmann et al., 1997).

- The indicators accessibility, GDP and unemployment were selected from many other possible indicators as indicators of socio-economic development because they provide a picture of a region's socio-economic profile and its development over time and can be used to assess the impact of European Union policies.

- 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 (Fürst et al., 1999).

- 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.

- Four network scenarios were simulated to assess the socio-economic impacts of infrastructure development: a do-nothing scenario, a TEN scenario, a rail-only TEN scenario and a scenario assessing only one large transport project

The examination of the results of the four transport scenarios simulated yielded the following main results:

- An important general finding is that the development trajectories of the European regions are rather similar for all scenarios thus confirming the assumption that socio-economic and technical macro trends, such as ageing of the population, shifting labour force participation and increases in labour productivity are the most powerful driving forces of regional development and have a much stronger impact on cohesion indicators than different transport infrastructure scenarios.

- The results suggest that in all network policy scenarios most European regions will improve their accessibility and economic performance in absolute terms. However, differences in relative terms reveal, that numerous changes in the relative positions of regions and countries are to be expected. This implies that there may be relative losses of some regions, which can lead to absolute losses in the increasing economic competition between regions in the long run.

- The full TEN scenario leads to a slightly less polarised distribution of accessibility and GDP among European regions than the rail-only TEN and do-nothing scenario. This slight cohesion effect of the TEN will, however, not be able to reverse the general trend towards economic polarisation in the European Union.

- The cohesion effect of the TEN scenarios are only visible if cohesion indicators measuring relative differences between spatial distributions are applied. If absolute differences are considered, the results are ambiguous or may even indicate divergence in accessibility and economic development. Moreover, testing different statistical measures of dispersion yielded different results with regard to the distinctness and volume of the observed trends. This confirms the importance of the selection of appropriate cohesion indicators.

- The model proved to be resilient and robust with respect to 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. The example of the Øresund bridge project was selected to demonstrate this. The main result of the Øresund case study is that accessibility and economic performance impacts are strongest in the regions adjacent to the project site and that benefits occur mainly in southern Sweden as a consequence of the removal of a general transport bottleneck. The results of the case study, though small, are plausible even at the regional level.

Further work

Work on the SASI model will continue after the completion of the present SASI project. The research team hopes to find the resources needed to address weaknesses of the current model implementation, to continue the validation of model results, to improve the database of the model and in the medium term to further develop the model in terms of spatial resolution, spatial scope and substance. The following list contains tasks presently considered by the research team as being particularly promising and relevant:

- More time needs to be invested into a thorough validation of the model with time-series data of regions and countries, also with respect to model variables not considered as output indicators in this report. In this context, the poor state of the art of calibrating and validating dynamic models of the kind of SASI *over time* needs to be improved.

- To reduce heterogeneity in the data, the socio-economic database needs to be refined. This includes the disaggregation of the economic sectors into a number of industries and a better representation of human capital.

- To reduce errors implied by spatial aggregation, the spatial resolution of the model should be improved by disaggregating the model regions from NUTS-2 to NUTS-3.

- As a consequence of these refinements, the GDP and population submodels will have to be re-calibrated. In this revision, the possibility to explicitly consider wage levels and production costs in the GDP model and to convert the migration model from net migration to migration flows should be examined.

- The cohesion indicators used for assessing the impacts of transport policies should be expanded and critically assessed with respect to their possible implicit bias towards convergence and divergence.

- To enable the model to address issues related the future enlargement of the European Union, the geographical scope of the model should be expanded to include the potential accession countries and the related extensions of the trans-European networks known as TINA.

- A further aim is to make the model a standard policy evaluation tool by developing the user interface so that users not familiar with the internal structure of the model are able to modify key variables and scenarios and generate model results.

- It would also be desirable to make the model more responsive to non-transport policies, such as regional economic policies or immigration policies, and to a broader range of transport policies, such as policies addressing intermodality and congestion.

- Another interesting experiment would be to abandon the present exogenous control totals of total European GDP and migration in favour of endogenously determined European aggregates.

- In order to facilitate the evaluation of the long-term impacts of transport infrastructure investments the forecasting period might be extended from 2016 to 2030 or beyond.

8. References

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.

European Commission (1997): *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 (1998): *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 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.

Fürst, F., Hackl, R., Holl, A., Kramar, H., Schürmann, C., Spiekermann, K., Wegener, M. (1999): *The SASI Model: Model Implementation.* SASI Deliverable D11. Report to the European Commission. Dortmund: Institute of Spatial Planning.

IRPUD (1999): *European Transport Networks. Number of network elements.* Dortmund: Institute of Spatial Planning, http://irpud.raumplanung.uni-dortmund.de/irpud/pro/ten/counts_e.htm.

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.

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

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

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

Wegener, M., Schürmann, C., Spiekermann, K. (2000): *The SASI Model: Model Software.* SASI Deliverable D13. Report to the European Commission. Dortmund: Institute of Spatial Planning.