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Title:

Regional economic impacts of trans-European transport networks

Abstract:

The paper presents results of a recent research project which was set up to identify the way transport infrastructure contributes to regional economic development in different regional contexts. The main goals of the project were to design an interactive and transparent modelling system for forecasting the impacts of transport infrastructure investments and transport system improvements, in particular of the trans-European transport networks (TETN), on socio-economic activities and developments in Europe, including spatial and temporal distribution and uncertainty/probability of impacts, and to demonstrate the usability of the modelling system by applying it to a number of relevant case studies in the framework of various scenarios of political, social and economic developments.

The paper will give explanation of the theoretical foundation and internal structure of the simulation model developed as well as its input and output. The focus of the paper will be on the presentation of results of demonstration scenario simulations, i.e. the application of the model to a set of different assumptions on TETN infrastructure investments and the presentation of its likely socio-economic impacts on the European regions.

Key words: Trans-European transport networks, infrastructure and regional development, spatial impacts, simulation model

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Regional Economic Impacts of Trans-European Transport Networks

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1. INTRODUCTION

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.

In this situation, the European Union expects to contribute to reducing the socio-economic disparities between its regions by the development of the trans-European transport networks (TETN). The TETN 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. However, the TEN 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. 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 the face of this uncertainty, the consistent prediction and the rational and transparent evaluation of likely socio-economic impacts of major transport infrastructure investments has become of great political importance. A comprehensive and transferable model for forecasting socio-economic and spatial impacts of large transport investments in Europe, in particular of different scenarios of TETN development, was developed in the project "Socio-Economic and Spatial Impacts of Transport Infrastructure Investments and Transport System Improvements" (SASI). SASI was conducted for DG VII (Transport) of the European Commission as part of the 4th Framework Programme for Research and Technological Development by the Institute of Urban and Regional Research of the University of Vienna, the Department of Town and Regional Planning of the University of Sheffield and the Institute of Spatial Planning of the University of Dortmund (Wegener and Bökemann, 1998; Fürst et al., 1999; Fürst et al., 2000).

The main goals of the SASI project were 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, including spatial and temporal distribution and uncertainty/probability of impacts, and to demonstrate the usability of the modelling system by applying it to a number of relevant case studies in the framework of various scenarios of political, social and economic developments.

The SASI model developed to meet these objectives 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.

With respect to the cohesion objective of the European Union, the model is to answer the question whether the TEN will lead to a reduction of regional disparities and which regions of the European Union are likely to benefit from the TEN and which regions are likely to be disadvantaged.

The paper will show that the model is capable to model the development of the interaction between infrastructure and regional development in the past and to forecast the regional effects of different infrastructure network scenarios. The paper will start with an explanation of the theoretical foundation and internal structure of the simulation model developed as well as its input and output. The focus of the paper will be on the presentation of results of demonstration scenario simulations, 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.

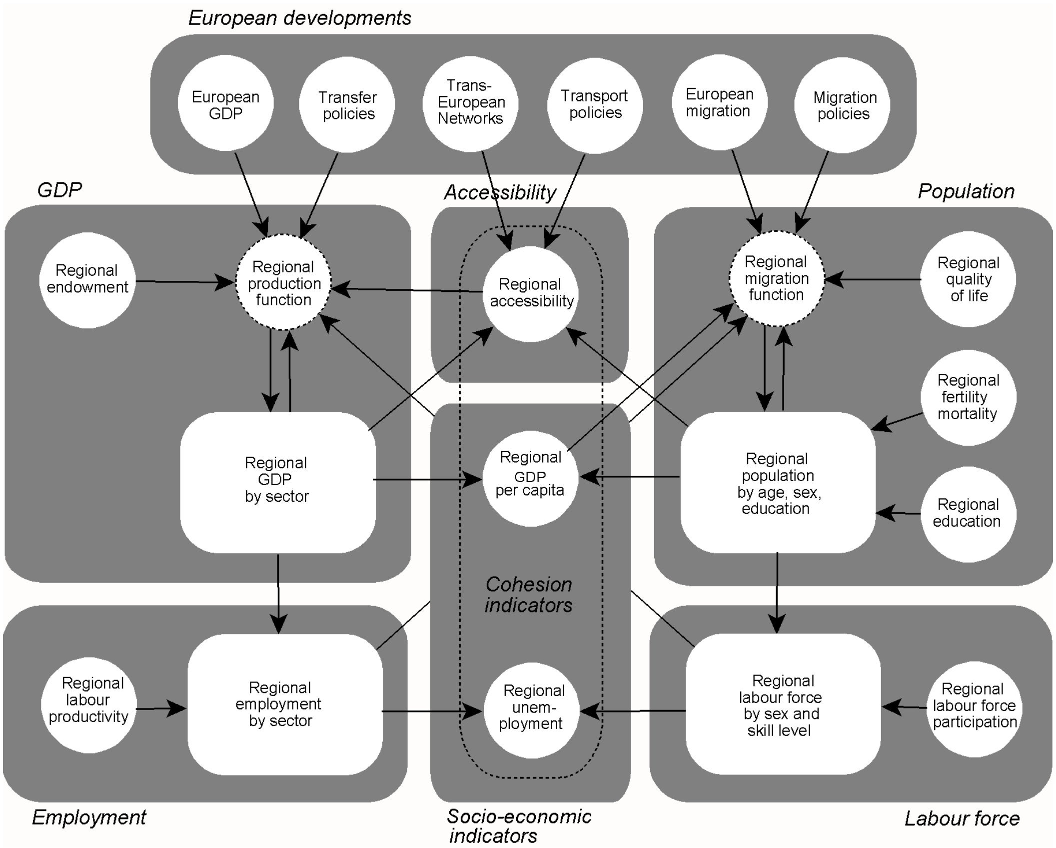
2. MODEL OVERVIEW

The SASI model is innovative in that it is based on measurable indicators derived from advanced location theory to explain and predict the locational behaviour of investment capital, manufacturing and services and population. It is pragmatic in that it does not require massive 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 and open for new indicators and issues that may become relevant in the future.

2.1 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 (Figure 1).

Figure 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 TEN scenarios reflecting different investment programmes for the road, rail or air networks were 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. From a variety of accessibility indicators, potential accessibility expressed as logsum of road, rail and air networks were selected as most relevant for explaining the locational behaviour of firms. Schürmann et al. (1997) present the method of calculating accessibility indicators; the choice of accessibility indicators for the model is explained in Fürst et al. (1999).

Regional GDP

This is the core submodel of the SASI model. It forecasts 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 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 in 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. It is assumed that labour productivity grows by an average sector-specific growth rate and is co- determined by historical conditions in the region, i.e. by its composition of industries and products, technologies and education and skill of labour.

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 in 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. It is assumed that labour force participation grows by an average country-specific rate and is co- determined by historical conditions in the region, i.e. by cultural and religious traditions and education, and that it is positively affected by availability of jobs (or negatively by 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.

2.2 Space and time

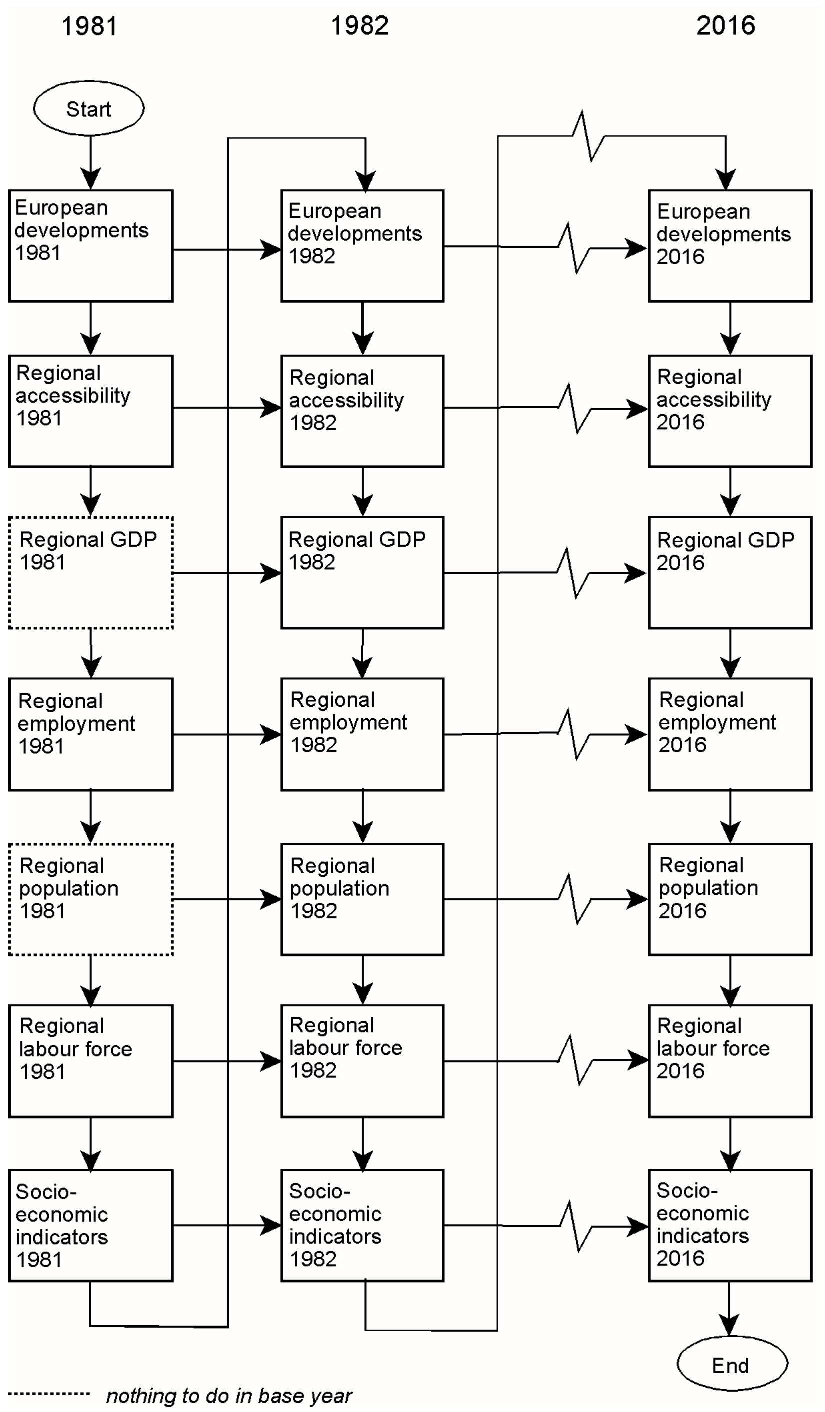
The SASI model forecasts socio-economic development for 201 regions at the NUTS-2 level for the fifteen EU countries. These are the 'internal' regions of the model. 27 regions defined for the rest of Europe are the 'external' regions used as additional destinations when calculating accessibility indicators.

The spatial dimension of the model is established by the connection of the regions 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 (1999) and adopted by Eurostat for the GISCO spatial reference database. The strategic road and rail networks contain all TEN 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 Pan-European Transport Conference in Crete in 1994 (European Communities, 1995) as well as additional links selected for connectivity reasons.

The temporal dimension of the model is established by dividing time into discrete time intervals 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 is 2016.

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 2 illustrates the recursive organisation of the model.

Figure 2. The recursive organisation of the SASI model



2.3 Network scenarios

As the purpose of the SASI model is to forecast impacts of TETN policy decision, several policy scenarios were defined to demonstrate the application of the model. The 'backbone' of these scenarios is the network evolution over time from 1981 to 2016. All scenarios are based on assumptions about the development of trans-European transport networks. The implementation of these assumptions starts from 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.

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 air lines, 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.

Currently four scenarios are implemented for the SASI model: a 'do-nothing scenario', two scenarios based on assumptions about the overall development strategy for the TEN and one scenario involving a single project (Table 1):

Table 1. Scenarios

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 the TEN programme
Scenario 20	Rail TEN	Evolution of rail network according to the 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

In the *Do-nothing Scenario* (00) no development of the trans-European transport infrastructure is foreseen, i.e. the networks 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 purpose of the Do-nothing Scenario is to serve as reference and benchmark for the other scenarios.

The *TEN Scenario* (10) assumes that all road and rail links of the TEN network will be implemented until 2016. In the *Rail TEN Scenario* (20) it is assumed that only the rail links of the TEN programme are implemented and that nothing happens with respect to road. All TEN projects are applied to these two scenarios with respect to their estimated completion times as laid down in the TEN implementation report (European Commission, 1998). If no completion year is available, the projects are first introduced in the 2011 networks. Figure 3 shows as an example for the network scenarios the evolution of planned TEN railway links for the TEN Scenario with respect to their estimated completion year.

Figure 3. Evolution of the strategic rail network in the TEN Scenario (10)

In Figure 3 those TEN projects are highlighted which will be newly constructed or result in changing network capacities on existing links (e.g. adding a second track) or changing speeds, whereas other projects such as removing level crossings and links without improvements are displayed with thin lines.

3. RESULTS OF DEMONSTRATION EXAMPLES

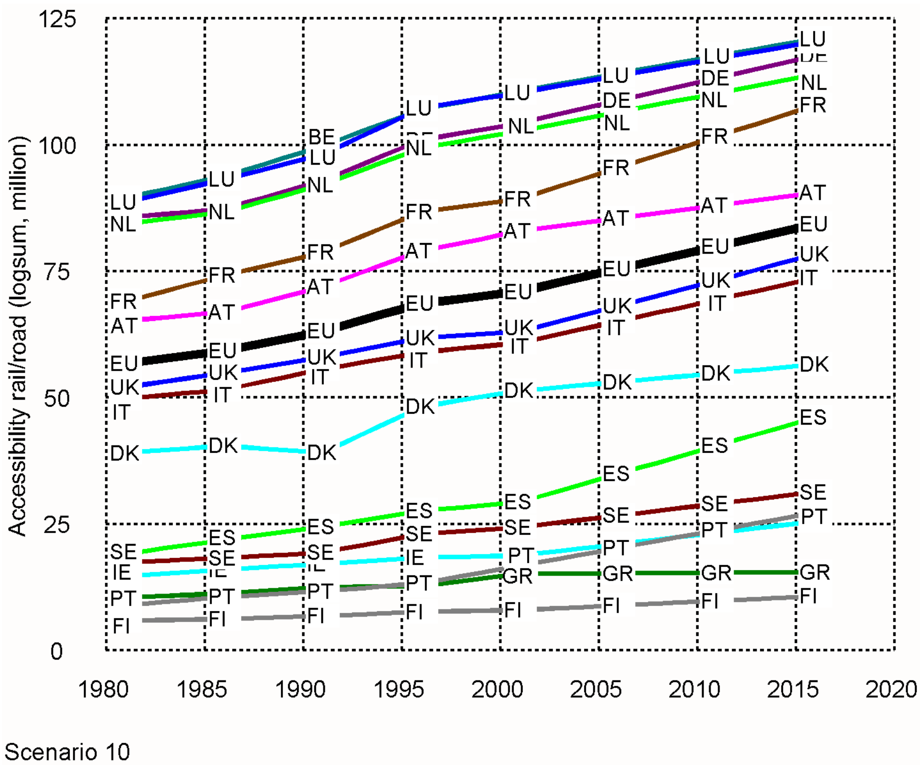
The four scenarios defined above were simulated with the SASI model and analysed using tools developed for comparison, cohesion effects and mapping. A detailed report on these results is contained in Fürst et al. (2000a). There, first the results of each scenario are presented separately and then compared with respect to the main SASI indicators accessibility, GDP per capita and unemployment using the *Do-Nothing Scenario* (00) as reference. Finally, the cohesion, or equity, consequences of each scenario are presented.

For space reasons, here only a small selection of these results can be presented. The focus is on the *TEN Scenario* (10), i.e. the implementation of the full TETN outline plans, and its comparison with the other scenarios with respect to cohesion effects.

3.1 Regional impacts of the *TEN Scenario* (10)

The *TEN Scenario* (10) envisions the implementation of all road and railway links laid down in the trans-European Transport Outline Plan (European Communities, 1996). Figure 4 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.

Figure 4. TEN Scenario (10), accessibility rail, road (logsum) by country, 1981-2016



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 left). However, when differences in percentage points of the European Union's averages are considered (Figure 5 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 on 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 6 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 6 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.

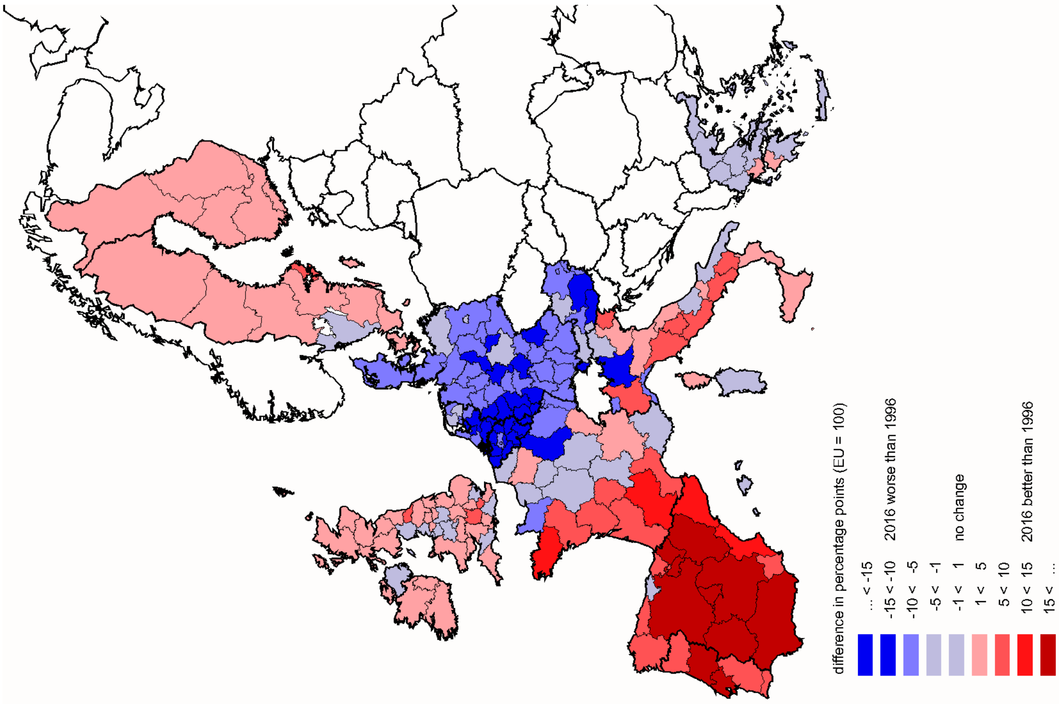
3.2 Comparison *TEN Scenario* (10) versus *Do-Nothing Scenario* (00)

For determining the socio-economic impact of TETN 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 TETN investment from other political, economic and demographic variables contributing to regional development. Figure 7 (left) shows a comparison of changes in accessibility for the *TEN Scenario* (10)and *the Do-Nothing Scenario* (00)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 TETN investment through increased accessibility.

Figure 7 (right) shows how TETN investments translate into changes in regional economic performance by considering regional differences in GDP per capita in percent for both scenarios. Most regions in the European core and the northern European regions encounter absolute and relative losses in GDP per capita from TETN investment, while most regions at the periphery are characterised by considerable gains. This distribution pattern hints at a convergence effect of TETN 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.

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. 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.

Figure 5. TEN Scenario (10), accessibility road, rail (logsum) by region, 2016 (left), change 1996-2016 (right)



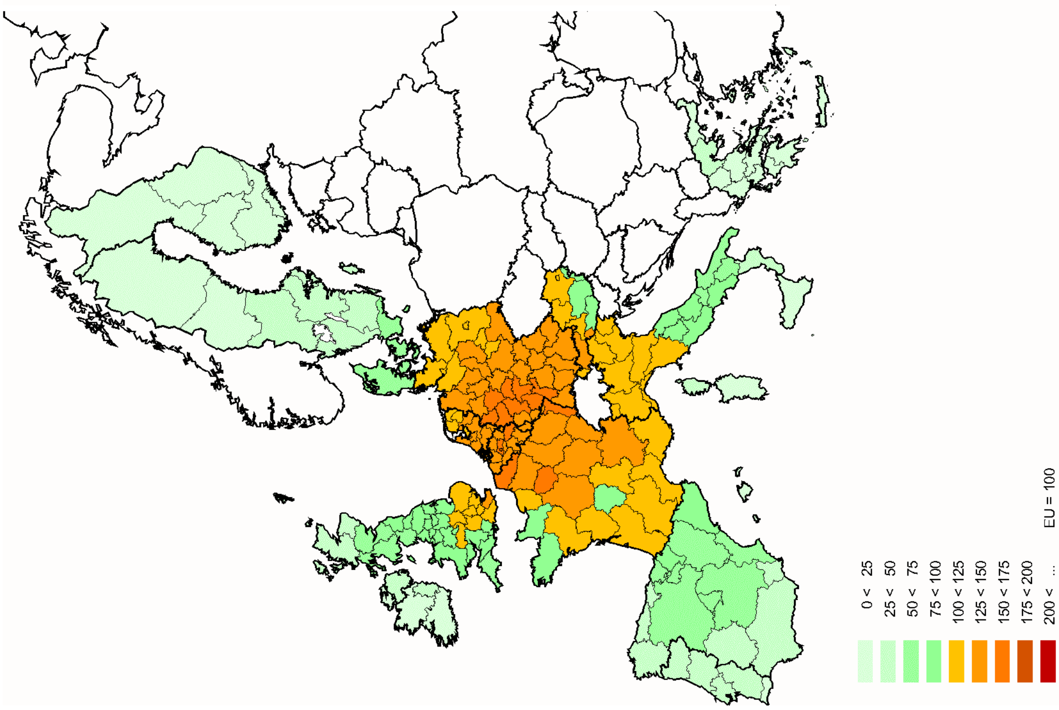
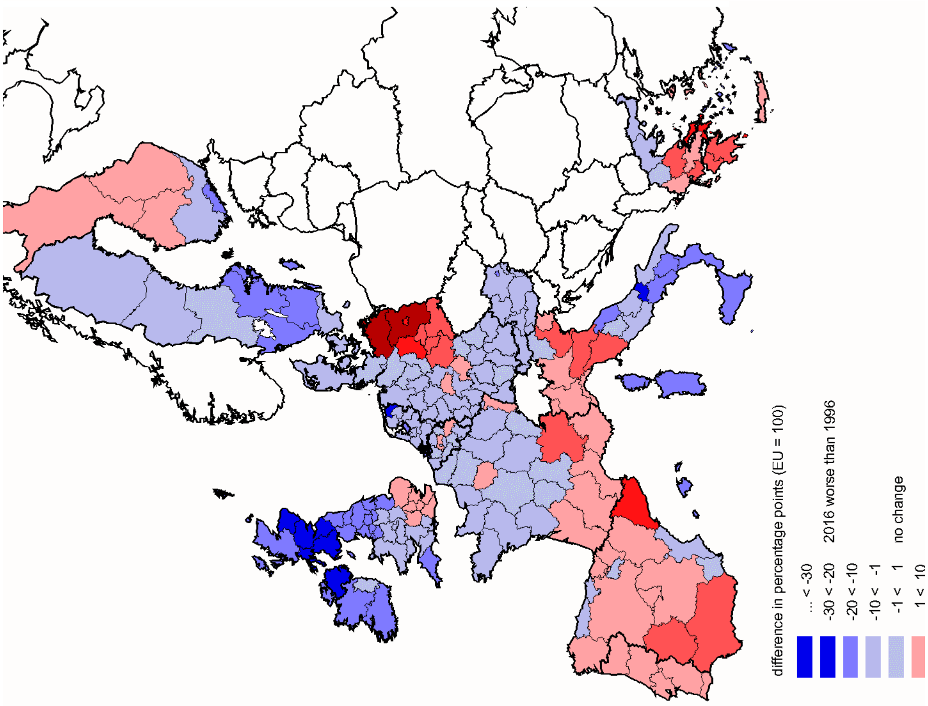


Figure 6. TEN Scenario (10), GDP per capita by region, 2016 (left), change 1996-2016 (right)



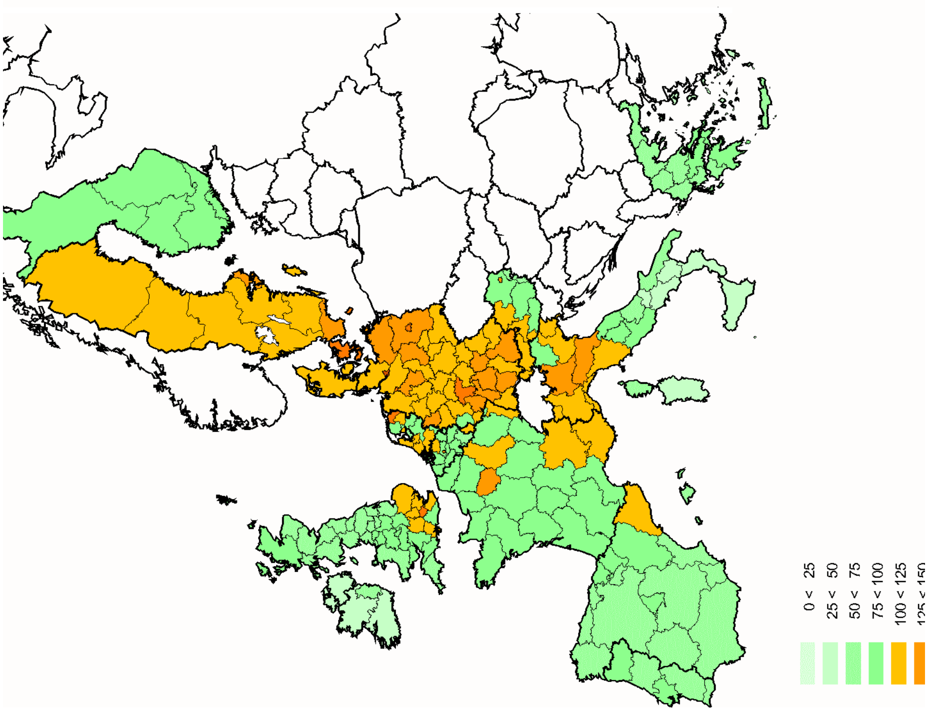
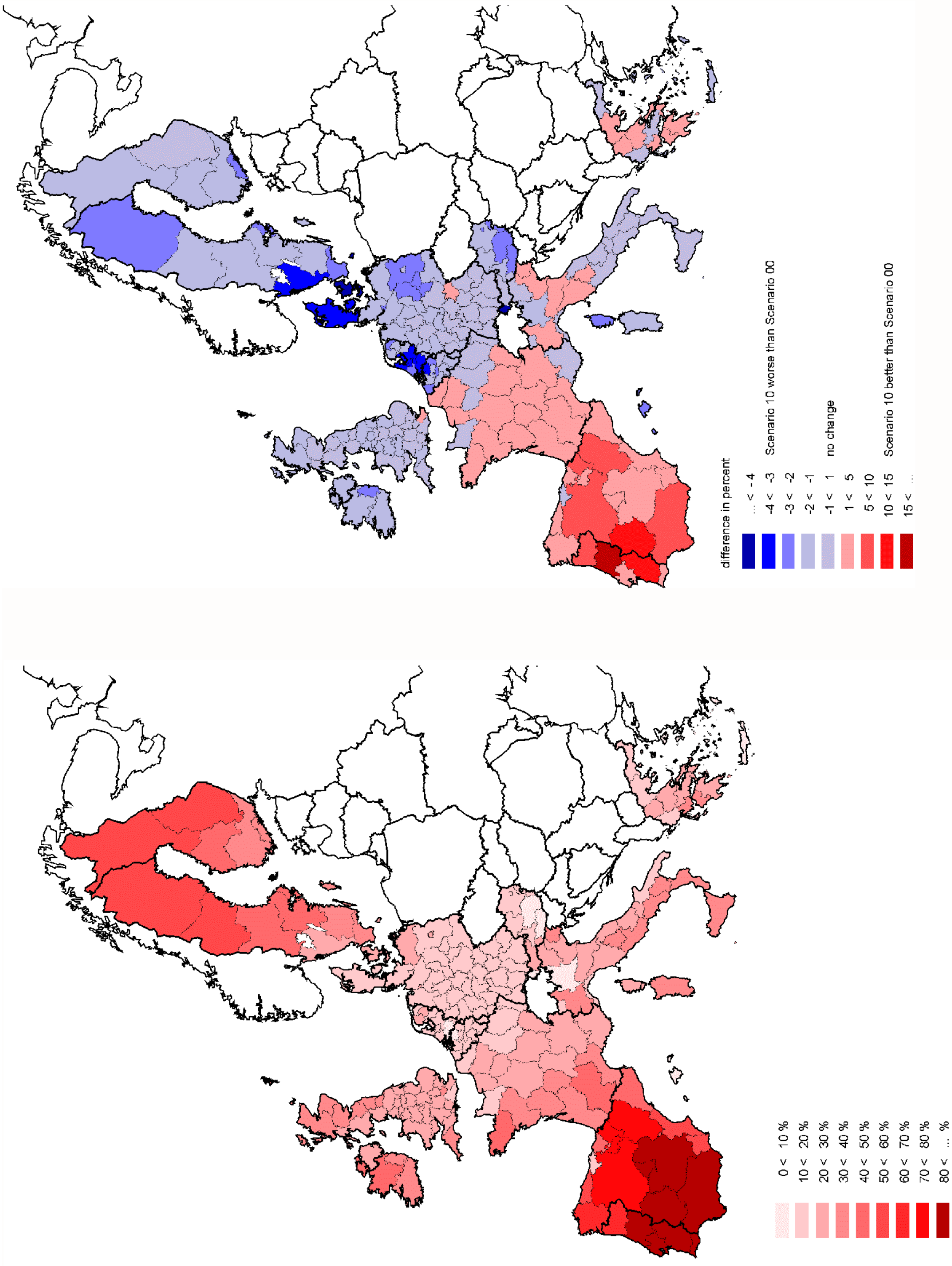


Figure 7. TEN Scenario (10) v. Do-Nothing Scenario (00), accessibility (left) and GDP per capita (right), relative difference, 2016



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.

3.3 Scenario implications for cohesion

One fundamental aim of establishing and developing TETN 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 TETN projects to this aim is not a straightforward tasks in the presence of a variety of possible aspects, indicators and methodologies.

Figure 8 shows coefficients of variation for accessibility from 1981 to 2016 which indicates the spread of a set of data as a proportion of its mean in percentage points. 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 TETN.

Figure 9 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 to the previous one. 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 Scenario* (10) and the *Rail TEN Scenario* (20) can be observed. The previously reported moderate convergence effect of the TEN scenarios compared to the *Do-Nothing Scenario* (00) 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 8. Scenarios 00, 10 and 20, coefficient of variation for accessibility, 1981-2016

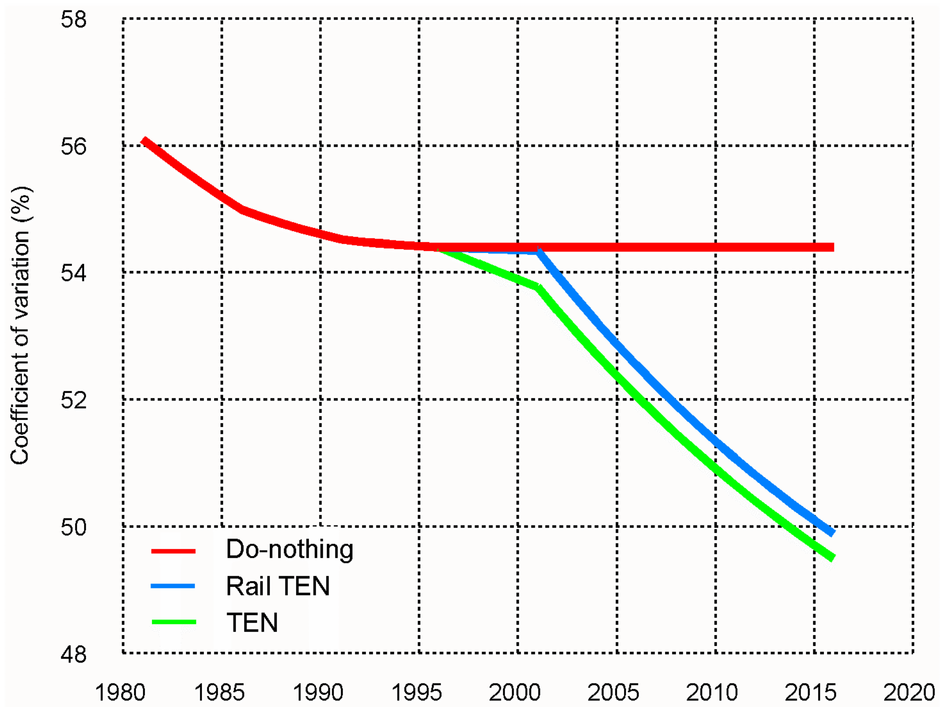
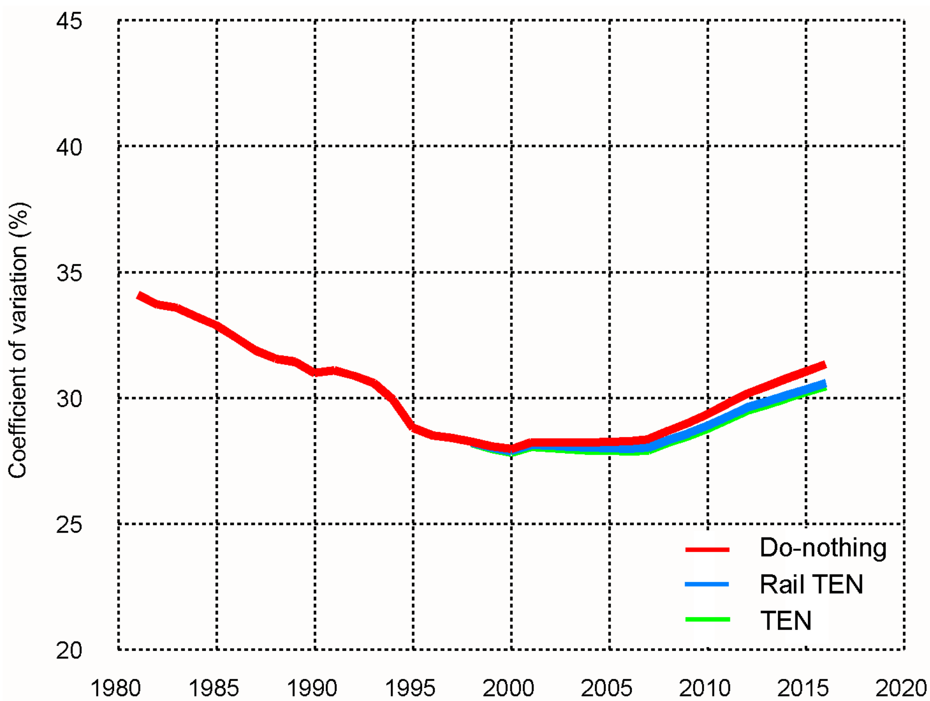


Figure 9. Scenarios 00, 10 and 20, coefficient of variation for GDP/capita, 1981-2016



4. CONCLUSIONS

This concluding section assesses the strengths and weaknesses of the SASI model revealed during its design, development and application and summarises the main project results.

4.1 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, 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, 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; Spiekermann and Wegener, 1996; 1999).

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 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.

4.2 Main 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 results of this project can be related to 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.
- 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 (Fürst et al., 1999).
- 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 demonstration example of the Øresund link proves that the SASI model is sufficiently sensitive to assess individual infrastructure projects with regard to impacts 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.

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 TETN 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.

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