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Integrated Spatial Scenarios until 2050

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Urban and Regional Research (S&W)

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Integrated Spatial Scenarios until 2050

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1. Introduction

The objective of the ESPON project ET2050 (Territorial Scenarios and Visions for Europe) was to support policy makers in formulating a long-term integrated and coherent vision for the development of the EU territory. In a participatory process different groups of stakeholders were involved in developing the vision to widen thematic, temporal and territorial horizons by imagining a future that transcends sector-based, short-term and domestic policy considerations. The following key questions were to be answered:

- (1) What is the current state of the European territorial structure?
- (2) What will be the future European territorial structure if development trends and policies remain unchanged?
- (3) What could be feasible future states of the European territorial structure in three territorial exploratory scenarios?
- (4) What is the room for manoeuvre to politically steer the development of the future territorial development in Europe and what is the range in which a realistic territorial vision can be formulated?
- (5) What could be midterm targets in order to steer territorial development towards the desired long-term vision, and what policy actions are required to meet these midterm targets?

The methodology applied in the project combined qualitative and quantitative approaches. The qualitative work was based on the project partners' expertise, expert surveys and workshops, surveys during internal and open ESPON seminars, workshops with the ESPON Monitoring Committee, presentations to the European Parliament and the Committee of the Regions and consultations with the European Commission. The quantitative work applied demographic, regional economic, transport and land-use models to provide a better understanding of the likely impacts of dominant long-term trends in political and economic framework conditions and strategic European policy decisions, in particular reforms of the EU cohesion policy. The main focus of the modelling exercise was therefore to investigate the possible evolution of social, economic and territorial cohesion under different scenarios and policy-assumptions from 2010 to 2030 and 2050.

In the project scenarios until 2030 were modelled with the MULTIPOLES (demography), MASST (economy), MOSAIC (transport) and Metronamica (land use) models. These mid-term simulations were complemented by long-term integrated simulations until 2050 using the integrated model of spatial and socio-economic development SASI. This report presents methodology, assumptions and results of the long-term simulations with the SASI model.

The SASI model is being used to investigate the likely economic, social and environmental impacts of different EU and EU member states strategies to influence the spatial development of the European territory, i.e. to assess these impacts with respect to the major European Union goals competitiveness, cohesion and sustainability. The core question investigated with the SASI simulations is whether after the recent economic crisis the trend of the last thirty years towards reduction of the economic disparities between the more advanced and the economic lagging regions in Europe will continue.

2. The SASI Model

The SASI model is a recursive simulation model of socio-economic development of regions in Europe subject to exogenous assumptions about the economic and demographic development of the European Union as a whole and transport and other spatial policies.

The SASI model differs from other approaches to model regional development by modelling not only production (the demand side of regional labour markets) but also population (the supply side of regional labour markets). The model was developed at the University of Dortmund in co-operation with the Technical University of Vienna (Wegener, Bökemann, 1998) and has since been applied in several EU projects, among them IASON (Integrated Appraisal of Spatial Economic and Network Effects of Transport Investments and Policies), ESPON 2.1.1 (Territorial Impacts of EU Transport and TEN Policy) of the European Spatial Planning Observation Network (ESPON), the Interreg-IIIb project AlpenCors (Alpen Corridor South) and the RTD 6th Framework Programme project STEPs (Scenarios for the Transport System and Energy Supply and their Potential Effects).

The spatial dimension of the model is established by the subdivision of the European territory into NUTS-3 or equivalent regions and by connecting these by road, rail and air networks. For forecasting regional economic development the SASI model applies an extended production function with regional economic structure, regional productivity, accessibility, availability of labour, R&D investments, population density and availability of developable land as explanatory variables. In addition it uses a migration function in which net migration is forecast with regional wage level and quality of life as explanatory variables. A detailed documentation of the SASI model is contained in Wegener (2008) and S&W (2013).

Figure 1 visualises the structure of the SASI model.

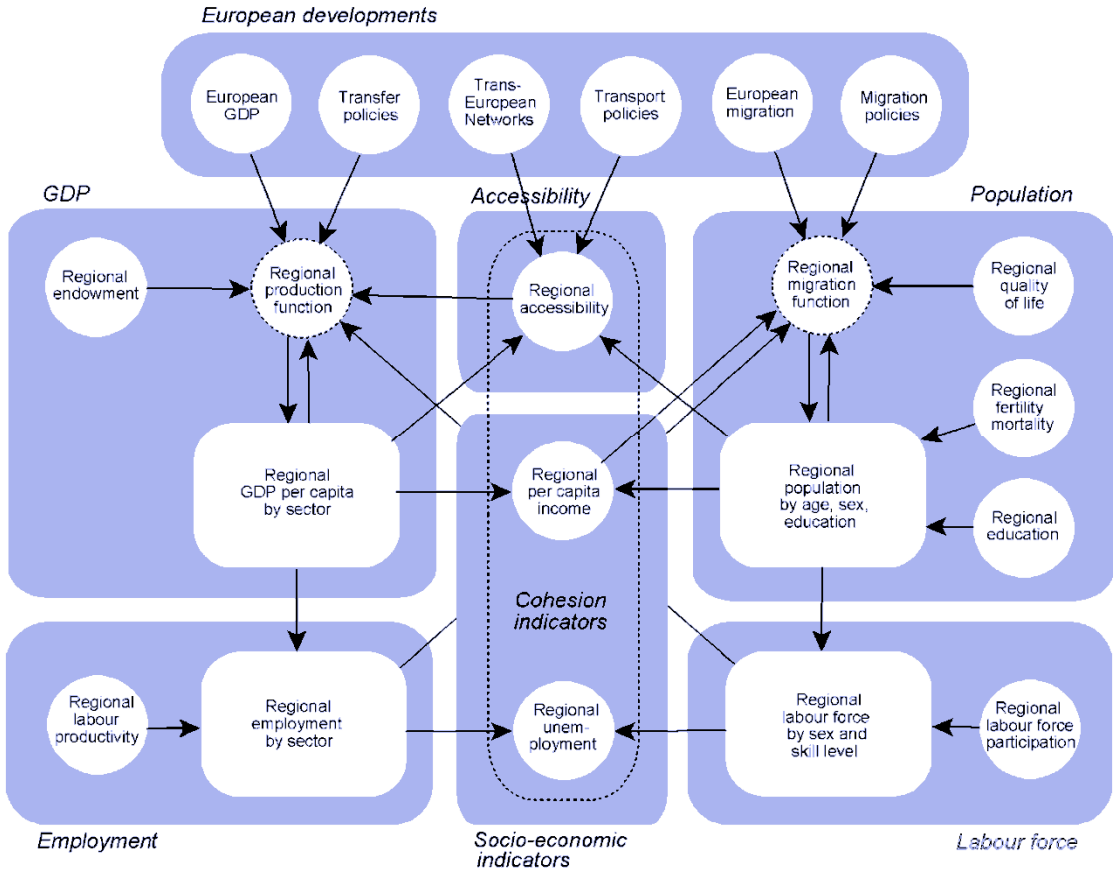


Figure 1. The structure of the SASI model

The SASI model has seven forecasting submodels (see Figure 1):

- (1) The *European developments* submodel prepares exogenous assumptions about the wider economic and policy framework of the simulations.
- (2) The *Accessibility* submodel calculates accessibility indicators expressing the locational advantage of each region with respect to relevant destinations.
- (3) The *GDP* submodel calculates regional GDP by industrial sector based on sector-specific quasi-production functions.
- (4) The *Employment* submodel calculates regional employment by industrial sector from regional GDP and labour productivity.
- (5) The *Population* submodel forecasts regional population through natural change (fertility, mortality) and net migration.
- (6) The *Labour force* submodel calculates regional labour force from regional population and labour force participation.
- (7) The *Socio-economic indicators* submodel calculates cohesion and polycentricity indicators.

The temporal dimension of the model is established by dividing time into periods of one year duration. 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.

For application in the ET2050 project, the SASI model was updated and extended in order to as much as possible meet the scenario specifications in the ET2050 First Interim Report. The adjustments required many trial-and-error runs. In particular the following adjustments to the model and its database were made:

- The model database was updated using the most recent available regional data and converted to the system of NUTS-3 regions of 2006.
- The forecasting horizon of the model was extended to 2050 to see how the assumptions made for the period until 2030 would work out in the twenty years thereafter. This extension required the extrapolation of model input parameters.
- The study area of the model was extended to the larger study area EU27+4, the so-called ESPON Space (EU27 plus Iceland, Liechtenstein, Norway, Switzerland). In addition, the Western Balkan countries Albania, Bosnia and Herzegovina, Croatia, Kosovo, Former Yugoslav Republic of Macedonia (FYROM), Montenegro and Serbia were included in the analysis. The recent accession of Croatia to the European Union could not yet be considered.
- The exogenous assumptions of the model were adjusted to match as much as possible the exogenous assumptions made in the MASST and MULTIPOLES models.
- The NUTS-2 typology of regions proposed for the exploratory scenarios in the MASST model was translated to NUTS-3 regions (see Section 5) .
- The development of the transport networks after 2016 was updated to support the three exploratory scenarios (see Section 5).
- The model was re-calibrated with the updated regional data for the new region system and the more recent data.
- In addition to the three exploratory scenarios modelled in MULTIPOLES, MASST, MOSAIC and Metronamica, each exploratory scenario was combined with three different assumptions about extreme possible framework conditions.

All simulations with the SASI model start from 1981 to demonstrate that the model is able to re-produce the past development and how the future development continues or deviates from the past development. Because the database of the SASI model is largely based on census data, it ends with the year 2051 instead of 2050.

3. Model Calibration

For the project the SASI model was re-calibrated with the updated regional data for the new region system and the more recent data. The parameters of the new regional production function predicting gross domestic product (GDP) by sector are as follows:

Table 1. SASI model: calibration results (2006)

Variable	Regression coefficients					
	Agriculture	Manufacturing	Construction	Trade, tourism, transport	Financial services	Other services
<i>sgd_{pn}</i>	0.678524	0.893175	0.973386	1.099938	1.177336	0.999325
<i>gdp_{wn}</i>	0.341488	0.612451	0.521618	0.687285	0.531100	0.603967
<i>acctr</i>				0.092569	0.026030	0.062745
<i>acctr_{ra}</i>	0.150137		0.056099			
<i>accfrr</i>		0.081128				
<i>rlmp</i>				0.029001	0.036534	0.035755
<i>pdens</i>	-0.119823		0.077598			
<i>devld</i>	-0.120504			-0.223148		
<i>rdinv</i>		0.145465			0.053178	0.145935
Constant	0.767319	0.213326	0.419835	0.119600	1.157029	0.394670
r^2 log	0.861	0.822	0.735	0.838	0.850	0.842
r^2	0.679	0.694	0.579	0.657	0.714	0.671

where

<i>sgd_{pn}</i>	Share of GDP of sector <i>n</i> (%)
<i>gdp_{wn}</i>	GDP per worker in sector <i>n</i> (1,000 Euro of 2010)
<i>acctr</i>	Accessibility of GDP travel road/rail
<i>acctr_{ra}</i>	Accessibility of GDP travel road/rail/air
<i>accfrr</i>	Accessibility of GDP freight road/rail
<i>rlmp</i>	Regional labour market potential (accessibility to labour)
<i>pdens</i>	Population density (pop/ha)
<i>devld</i>	Developed land (%)
<i>rdinv</i>	R&D investment (% of GDP)

To take account of the slow process of economic structural change, independent variables *sgd_{pn}* and *gdp_{wn}* are lagged by five years; all other independent variables are lagged by one year, i.e. the most recent available value is used. Because no data are available for years before 1981, no lags are applied for 1981.

Because it is not the purpose of the model to predict the economic crisis of the years 2008-2009, total GDP of the countries most affected by the crisis (Cyprus, Estonia, Spain, Greece, Lithuania, Latvia, Portugal and Slovenia) was exogenously entered into the model for the years 2005-2013 plus a recovery period until 2020.

4. The SASI Baseline Scenario

The SASI Baseline Scenario is a business-as-usual scenario, i.e. it assumes that current policies are continued in the future. However, it is much more optimistic than that assumed for the MASST model. It assumes that the consequences of the recent economic crisis affecting the most crisis-stricken countries, in particular Greece, Italy, Spain and Portugal, will soon have been overcome by EU solidarity transfers and stricter fiscal regulation and that the new EU member states in eastern Europe will continue to catch up through productivity convergence, though at lower speeds than before the crisis ("sluggish recovery").

The kinds of spatial policies considered in SASI, EU subsidies and transport policies, are the same as those applied in the other models in their simulations until 2030, but are treated in a slightly different manner:

- (1) *Structural Funds subsidies* consist of EU regional policy expenditures from the European Regional Development Fund (ERDF), the European Agricultural Fund for Rural Development (EAFRD), the European Social Fund (ESF) and the Cohesion Fund (CF). It is assumed that the relative share of these funds of the total EU budget will stay the same as in the funding period 2007-2013, and that the total EU budget will grow like the expected growth of the economy of the European Union. As allocation rule an inverse exponential function of GDP per capita empirically derived from the allocation estimates for the funding period 2007-2013 in the SFC database (European Commission, 2008) was used:

$$b_i = \exp [-0.035 \times (y_i - 51.0)] \times 3.0$$

where b_i is Cohesion policy expenditure as per cent of GDP in region i , and y_i is GDP per capita in region i as per cent of the average GDP per capita of the European Union (EU27=100). Figure 2 shows how this function was derived from data of the funding period 2007-2013. Cohesion policy expenditures are treated as transfers, i.e. are paid by all regions in proportion to their GDP per capita.

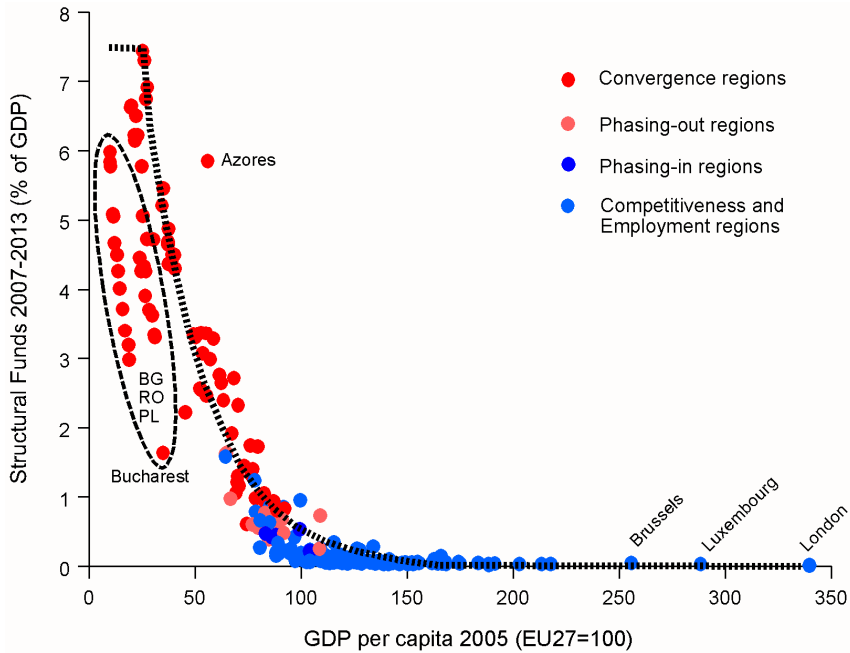


Figure 2. Structural Funds of regions as % of GDP v. GDP per capita (EU27=100)

(2) *Transport policies* consist of time-sequenced network improvements and assumed changes of the generalised costs of passenger and goods transport through energy price increases and advances in energy efficiency of vehicles. In addition, perceived energy costs of transport are calculated as a combination of energy prices, energy efficiency and household incomes. If transport costs increase by the same rate as GDP per capita, no change in accessibility is assumed. This is the case in the Baseline Scenario.

The specification of the SASI Baseline Scenario is a combination of (a) the specifications suggested in the ET2050 First Interim Report, (b) information about the Baseline Scenario simulated with the MULTIPOLES, MASST and MOSAIC models and (c) the most recent forecasts by Eurostat, the European Commission and the International Energy Agency.

Table 2 summarises the specification of the SASI Baseline Scenario between 1981 and 2051: The numbers in the table refer to the European Union (EU27) and the ESPON Space consisting of the EU plus Iceland, Liechtenstein, Norway and Switzerland (EU27+4), respectively.

Table 2. SASI Baseline Scenario specification 1981-2051

Year	Population EU27 (million)	Population EU27+4 (million)	Net migration EU27 (1,000)	GDP EU27 (billion Euro of 2010)	GDP EU27+4 (billion Euro of 2010)	Structural Funds (billion Euro of 2010)	Oil price per barrel (Euro of 2010)
1981	460	471	77	7,067	7,472	6.7	39
1986	464	475	285	8,045	8,496	12.7	19
1991	471	483	1078	9,476	9,979	23.9	18
1996	478	490	748	10,221	10,762	34.0	20
2001	482	494	654	11,591	12,133	39.0	25
2006	491	504	1578	12,697	13,273	44.0	55
2011	501	514	929	12,407	12,981	49.4	63
2016	514	528	1239	13,381	14,020	54.3	98
2021	526	540	1327	15,318	16,010	60.9	107
2026	535	549	1300	16,922	17,685	67.2	112
2031	541	556	1290	18,418	19,248	73.2	118
2036	543	558	1265	19,740	20,635	78.4	124
2041	540	556	1217	20,848	21,797	82.8	130
2046	535	550	1163	21,682	22,683	86.2	136
2051	526	542	1094	22,228	23,253	88.3	142

Population:

1995-2010: Eurostat. <http://epp.eurostat.ec.europa.eu>. Table tps00001

2015-2050: Eurostat population projections. <http://epp.eurostat.ec.europa.eu/> Table tps00002

Net migration:

European Commission (2012a, b)

GDP:

1995-2013: <http://sdw.ecb.europa.eu>

1995-2014: <http://epp.eurostat.ec.europa.eu/> Table tec00115

2015-2050: http://ec.europa.eu/economy_finance/publications/european_economy/2012/pdf/ee-2012-2_en.pdf

Structural Funds:

Eurostat, DG Regio

Oil price:

IEA (2012)

The population totals indicated are no fixed constraints but targets to be achieved by the demographic submodel. The assumed oil price development is only indicative of generally rising energy costs – the exact way how perceived energy cost increases are calculated as a combination of energy prices, energy efficiency gains and rising incomes will be explained later.

In the following Figures 3-6 the four main columns of Table 2 are visualised showing the time period for which empirical data were available and the remaining period until the forecasting horizon for which assumptions had to be made.

Figure 3 shows the assumed population development with its peak around 2035 and subsequent slow decline until 2050. This assumption is in contrast to the assumption of continued growth until 2050 of the MULTIPOLES model based on the ESPON DEMIFER project but supported by the EU Ageing Report and EUROPOP projections (European Commission 2012a, 2012b).

Figure 4 shows the assumption made for total EU27 net migration, i.e. the balance between total immigration and outmigration into and out of the European Union, also adopted from the Ageing Report and EUROPOP (European Commission 2012a, 2012b).

Figure 3. Baseline assumptions for total population in EU27+4 1981-2051. Source: European Union (2012)

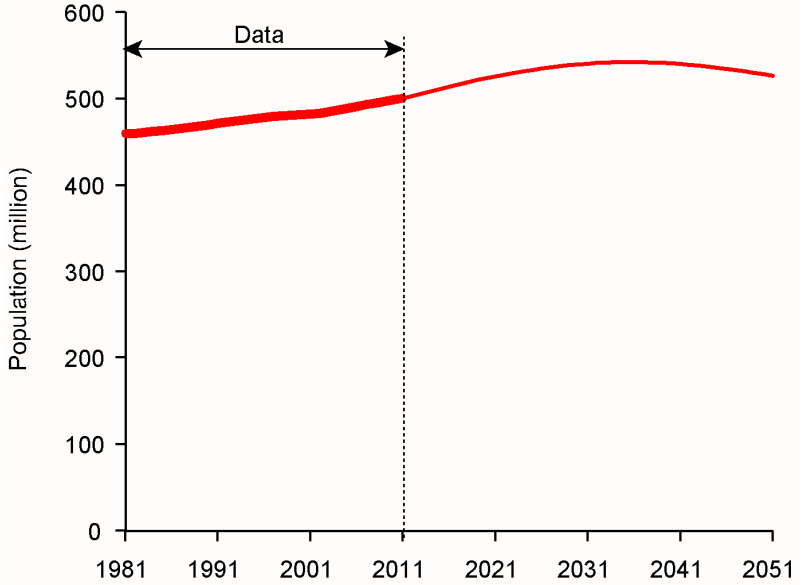
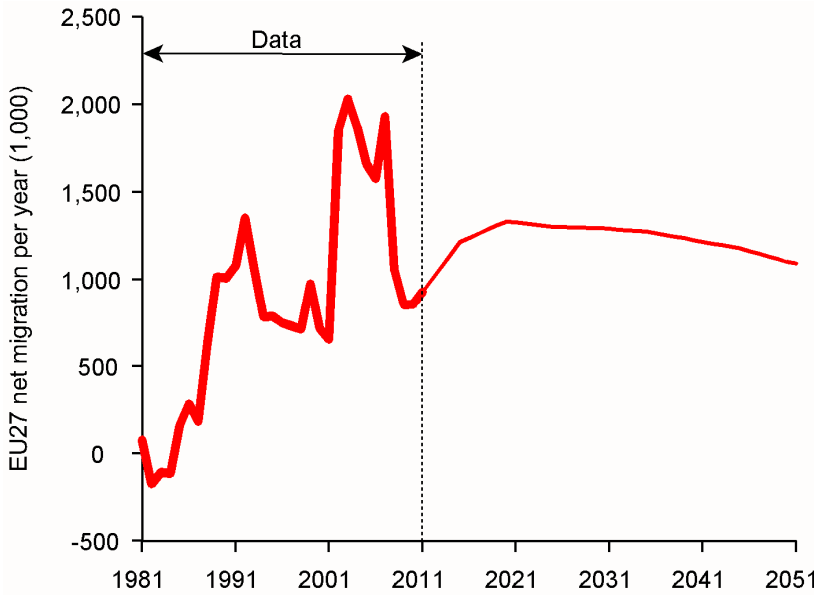


Figure 4. Baseline assumptions for total EU27 net migration 1981-2051. Source: European Union (2012)



The EU net migration assumed for the years until 2030 is significantly higher than that assumed in MULTIPOES and MASST. The wide fluctuation of annual net migration in the past shows the difficulty of projecting future migration flows. Even this assumption may be too conservative and be exceeded by the future immigration of refugees from countries in Africa and the Middle East.

Figure 5 shows the projection of gross domestic product (GDP) of the countries in the ESPON Space (EU27+4) in the Baseline Scenario. The assumption represents the "sluggish recovery" hypothesis suggesting that after the crisis of 2008-2010 total GDP of all countries including those countries most affected by the crisis will return to the previous growth path but at a lower level and with slightly less dynamics. Moreover, it can be seen that after 2030 a gradual decline of the economic growth rate is assumed, in accordance to the position suggested by the recent report to the Club of Rome (Randers, 2012) that exponential economic growth cannot continue forever.

Figure 6 shows the assumption for total EU regional policy Structural Funds expenditures through the European Regional Development Fund (ERDF), the European Agricultural Fund for Rural Development (EAFRD), the European Social Fund (ESF) and the Cohesion Fund (CF). That the curve looks similar to that for GDP is intentional, reflecting the assumption that Structural Funds annual expenditures will continue to amount to roughly 0.4 per cent of total annual EU27 GDP.

Figure 5. Baseline assumptions for total GDP (billion Euro of 2010) in EU27+4 1981-2051. Source: European Union (2012)

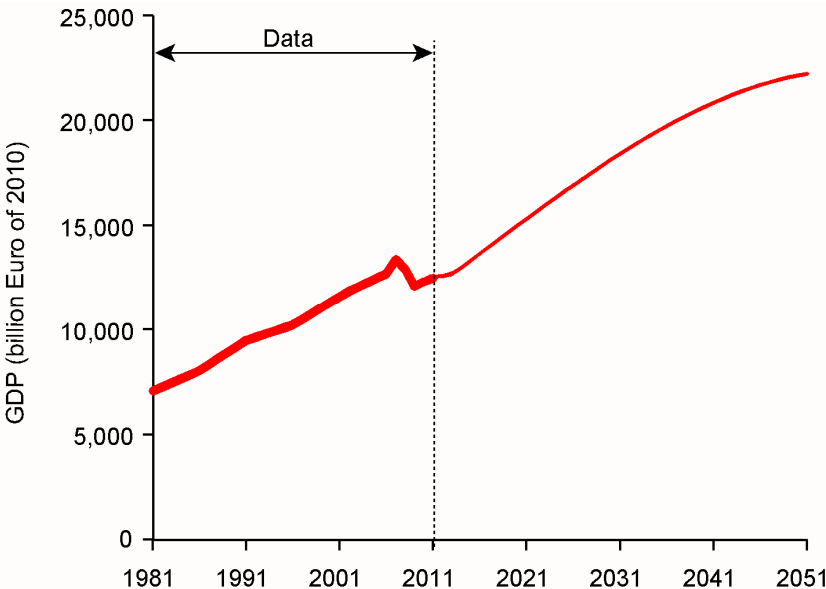
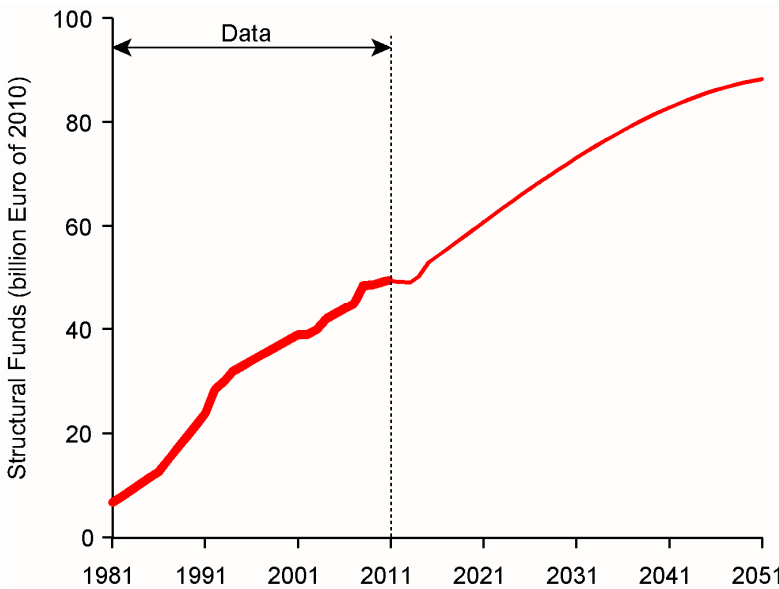


Figure 6. Baseline assumptions for total Structural Funds expenditures of the European Union 1981-2051. Source: European Union (2012)



Figures 7-10 show additional assumptions for the SASI European transport model and energy consumption and CO₂ emission of transport not included in Table 2.

Figure 7 shows the Baseline assumption for total person-km travelled per year in EU27 by road and rail. This assumption is used to calibrate the travel part of the SASI transport model. The travel part of the SASI transport model calculates trips between NUTS-3 regions as a function of population weighted by income as origins, population as destinations and perceived generalised costs of travel by road and rail between NUTS-3 regions. The figure shows the assumed Baseline development of modal shares with slowly growing rail and stabilising road travel.

Figure 8 shows the same assumptions for freight transport in tonne-km per year in EU27 used to calibrate the SASI freight transport model. The freight part of the SASI transport model calculates freight flows between NUTS-3 regions as a function of GDP as origins and destinations and generalised cost by freight transport by road or rail between NUTS-3 regions. The figure shows the assumed Baseline development of modal shares with freight transport by road growing by 60 per cent until 2050, significantly faster than freight transport by rail. The diagram makes it clear that curbing the excessive growth of freight transport by road is one of the major challenges of planning for sustainability in Europe.

Figure 7. Baseline assumptions for total person-km travel per year in EU27 1981-2051. Source: European Union (2012)

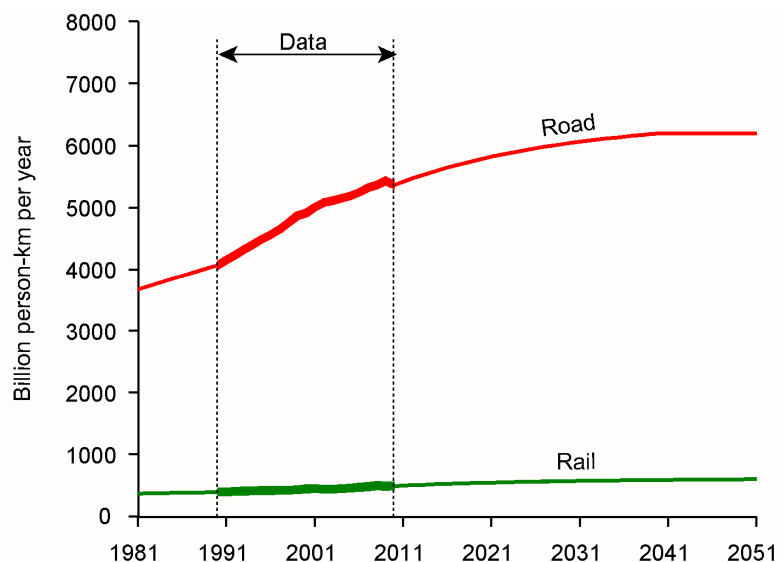
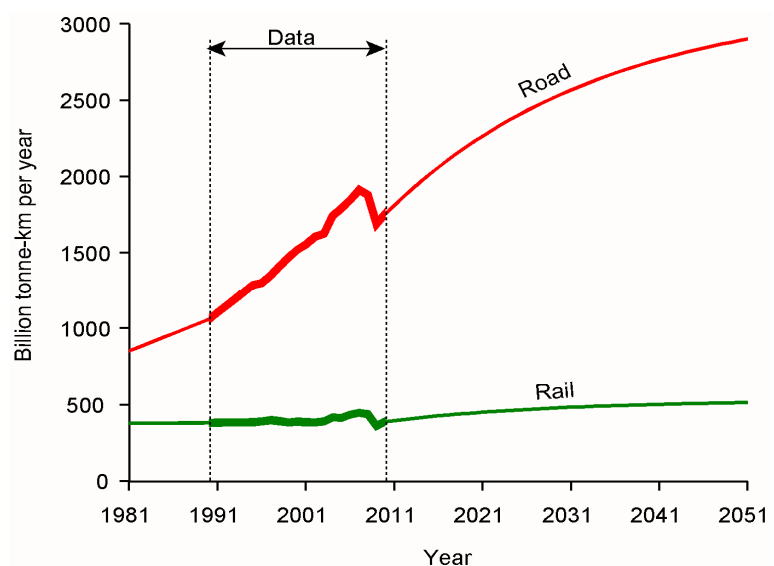


Figure 8. Baseline assumptions for total tonne-km freight per year in EU27 1981-2051. Source: European Union (2012)



The next two diagrams show the assumptions used to calculate energy consumption and CO₂ emission by ground transport (road and rail) within Europe. These two indicators were selected as measures of sustainability because they are more affected by the different spatial scenarios than other environmental indicators, such as intercontinental aviation or maritime transport, and because land-use effects are addressed by the Metronamica model.

Figure 9 shows energy consumption (MJ) per person-km of travel and tonne-km of freight transport, by road and rail, respectively, based on data published by the German Energy Agency (dena, 2012) for the period 1990-2010. The extrapolation of the four lines until 2051 assumes that the gains in energy efficiency observed in that period will continue but will eventually level off.

Figure 10 shows the CO₂ emission per unit of energy consumption (MJ) estimated for the period 1990-2010 for road and rail, respectively, based on data of total energy consumption and total CO₂ emission of transport published by the European Union (2012). The extrapolation of both lines until 2051 reflects the assumptions about the potential further substitution of fossil energy by renewable energy in road and rail transport.

Figure 9. Baseline assumptions for energy consumption per person-km (travel) and tonne-km (freight) 1981-2051. Source: dena (2012)

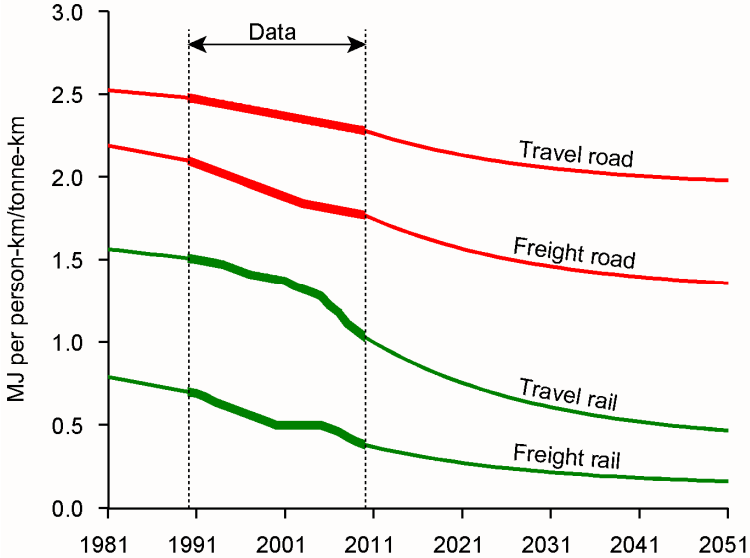
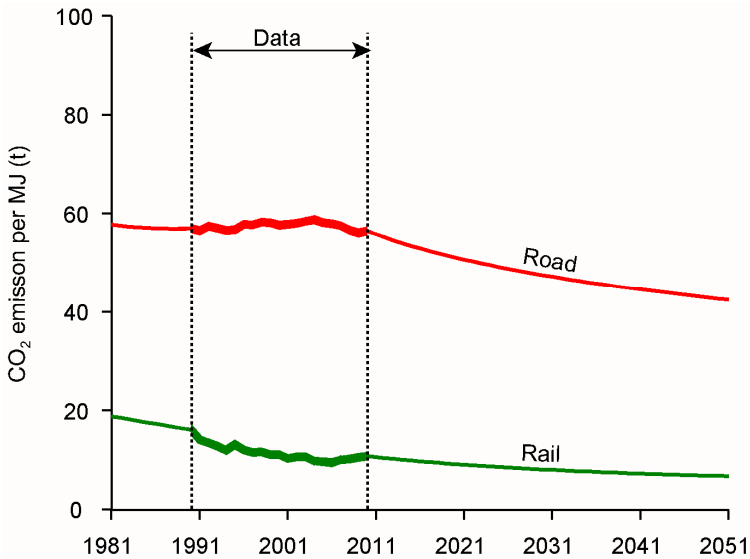


Figure 10. Baseline assumptions for CO₂ emission per MJ for rail and road transport, 1981-2051. Source: European Union (2012)



5. The SASI Exploratory Scenarios

In the three exploratory scenarios A, B and C the framework conditions (see Table 2) are assumed to be the same as in the Baseline Scenario, and only policies, i.e. the allocation of EU subsidies and transport policies are changed after 2013.

The definition of the three exploratory scenarios used the region typology based on ESPON 1.1.1 (2005) developed for the MASST model (POLIMI, 2014) but translated to NUTS-3 regions:

- In the *MEGAs Scenario A* large European metropolitan areas are promoted in the interest of global competitiveness and economic growth.
- In the *Cities Scenario B* secondary European cities are promoted in order to strengthen the balanced polycentric spatial structure of the European territory.
- In the *Regions Scenario C* rural and peripheral regions are promoted to advance territorial cohesion between affluent and economically lagging regions.


For comparability the total volume of EU Structural Funds expenditures is kept across all scenarios as 0.4 per cent of total EU27 GDP, and only the allocation of expenditures to regions is changed according to the scenario objectives: in Scenario A in proportion to GDP of MEGAs, in Scenario B in proportion to population of the promoted cities and in Scenario C as in the Baseline Scenario as an inverse function of GDP per capita of the regions to be promoted. In all cases a short period of transition to the new allocation is allowed for.

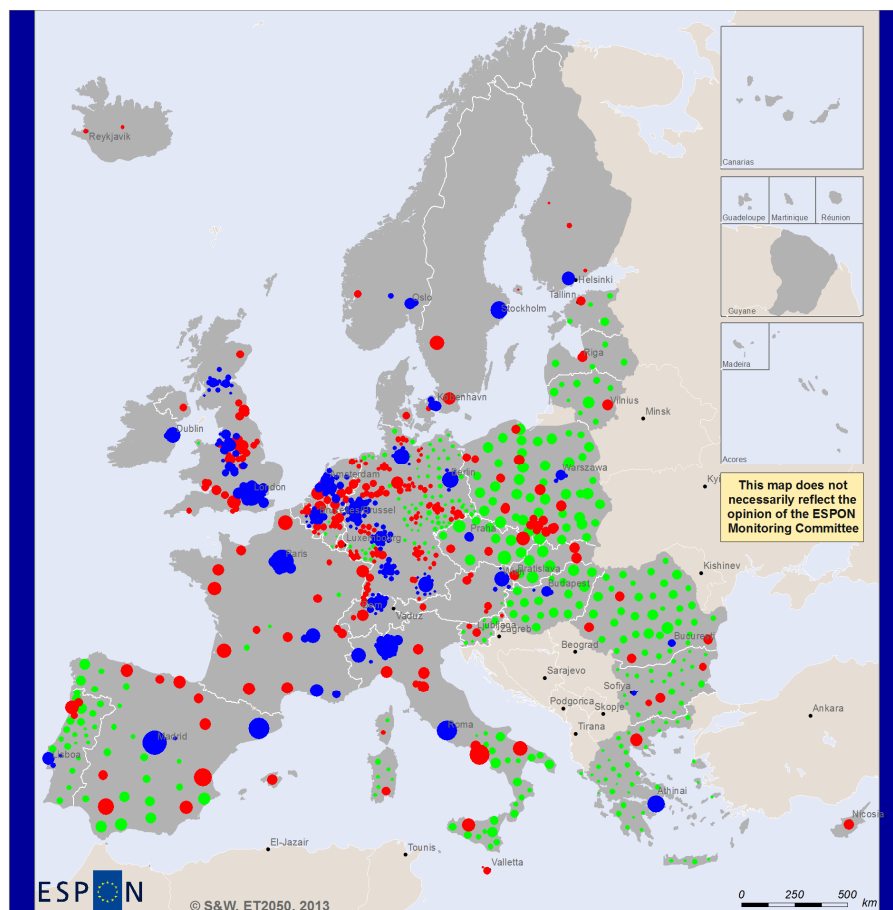
The map in Figure 11 shows the resulting allocation of EU Structural Funds expenditures in the three exploratory scenarios A, (blue), B (red) and C (green). The size of the circles in the map corresponds to the volume of Structural Funds expenditures allocated to each region in per cent of EU funds. Like the Baseline Scenario, each exploratory scenario assumes the implementation

Figure 11. EU Structural Funds expenditures in SASI exploratory scenarios A, B and C

Regional level: NUTS3
Source: S&W (2013)
Origin of data: SASI model 2013

- MEGAs (A scenarios)
 - Cities (B scenarios)
 - Regions (C scenarios)
- 1.0 %
 ● 0.5 %
 ● 0.25% } of EU funds


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of the trans-European transport core network until 2050. In addition each exploratory scenario assumes specific additional road and rail network improvements to support its objectives:

- In the MEGAs Scenario A it is assumed that all MEGAs not more than 500 km apart will be linked by road and rail connections with 90 km/h airline speed for cars and 200 km/h for rail, and that the metropolitan areas will improve their intra-regional transport system.
- In the Cities Scenario B it is assumed that cities not more than 300 km apart will be linked by connections with 80 km/h airline speed for cars and 160 km/h for rail, and that they will improve their intra-regional transport system.
- In the Regions Scenario C it is assumed that regions will be linked with the metropolitan areas and cities of the A and B Scenarios not more than 200 km apart by connections with 65 km/h for cars and 80 km/h for rail, and that they will improve their regional transport system.

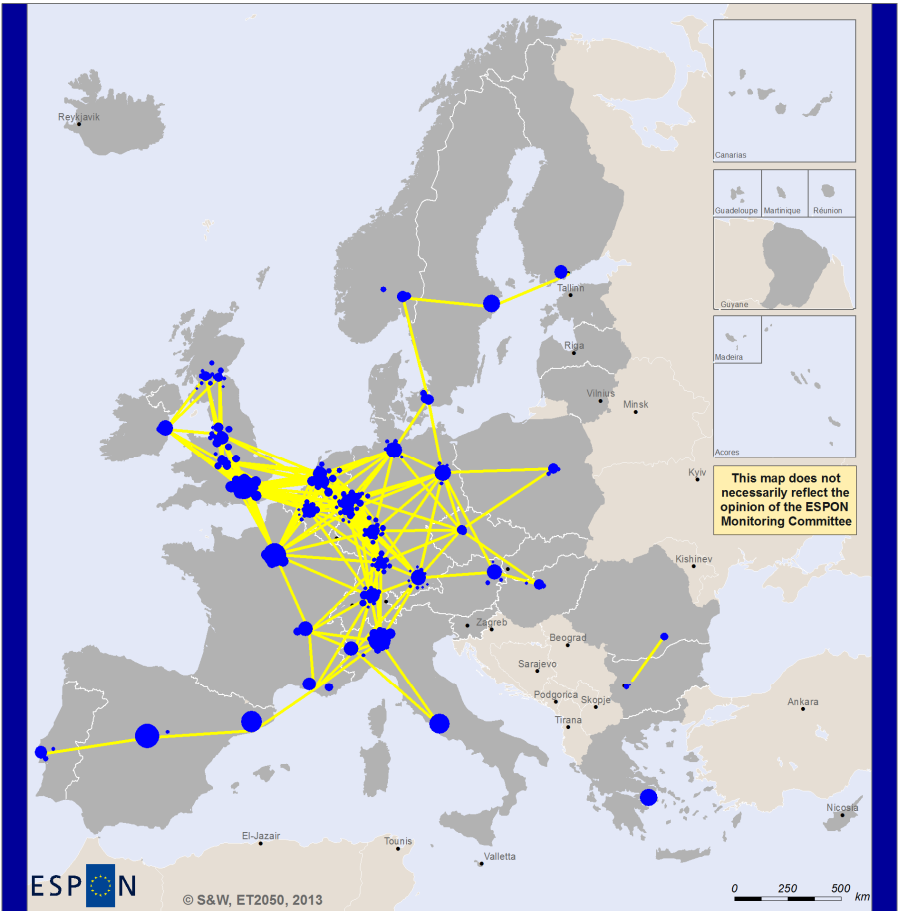
These assumptions are understood as minimum levels. If the transport infrastructure of the Base-line Scenario offers already connections of at least that quality, for instance through existing high-speed trains, no further improvements are introduced.

Figures 12-14 show the additional network improvements of each exploratory scenario A, B and C in schematic form as links between MEGAs, cities and regions. Remarkably, because of Germany's polycentric urban system, the number of network improvements in Scenario C in Germany is particularly dense, although the number of regions receiving subsidies from the Structural Funds is only low because of Germany's high GDP per capita.

Figure 12. Scenario A:
Network improvements
(if necessary)
2011-2051

Regional level: NUTS3
Source: S&W (2013)
Origin of data: SASI model 2013

- MEGAs
- Connections between MEGAs not more than 500 km apart
- Minimum speed:
Road: 90 km/h
Rail: 200 km/h

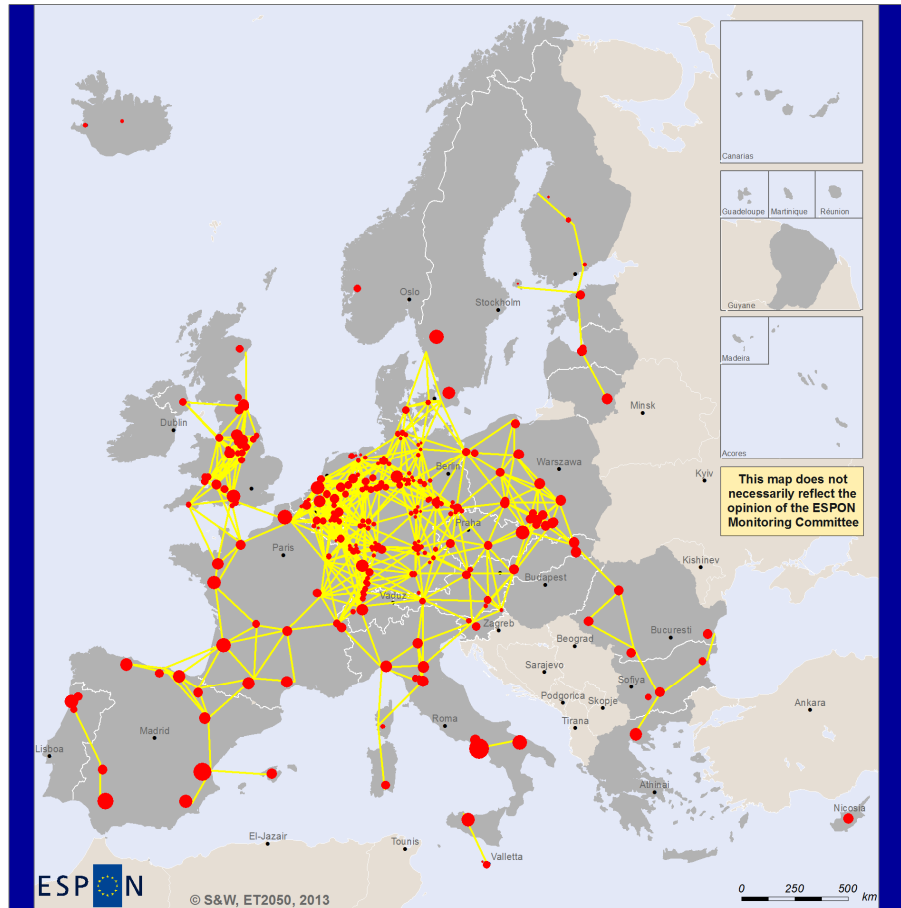


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Figure 13. Scenario B:
Network improvements
(if necessary)
2011-2051

Regional level: NUTS3
Source: S&W (2013)
Origin of data: SASI model 2013

- Cities
- Connections between cities not more than 300 km apart
- Minimum speed:
Road: 80 km/h
Rail: 160 km/h

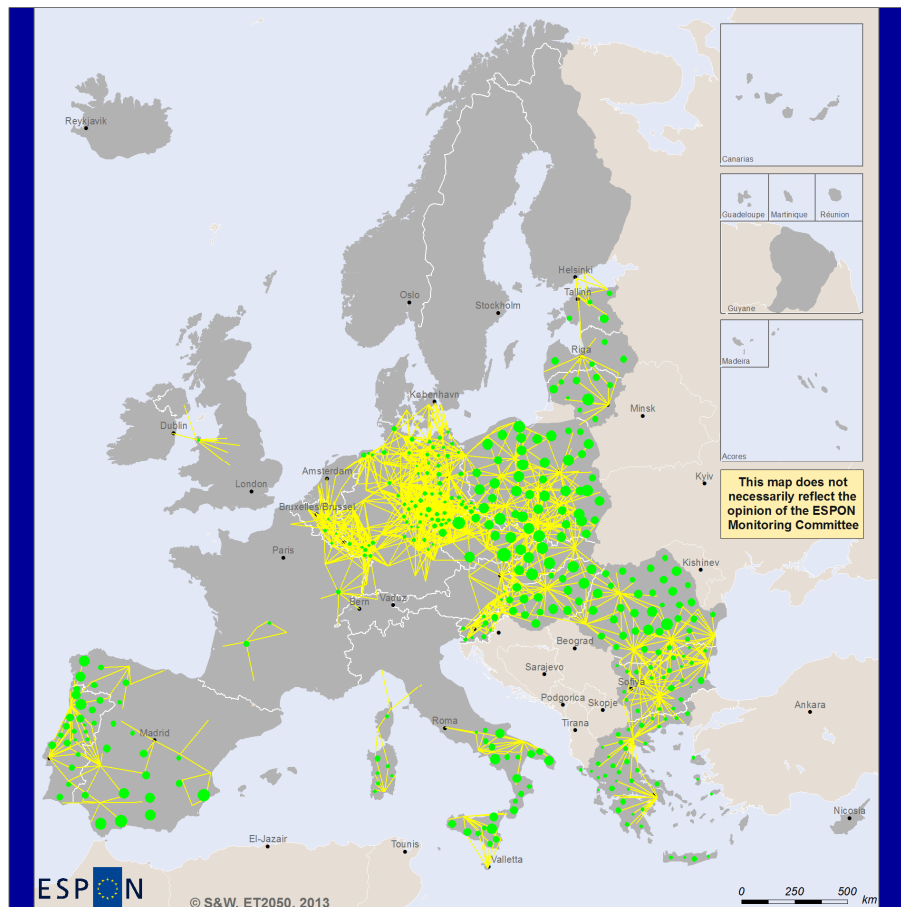


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Figure 14. Scenario C:
Network improvements
(if necessary)
2011-2051

Regional level: NUTS3
Source: S&W (2013)
Origin of data: SASI model 2013

- Regions
- Connections between regions not more than 200 km apart
- Minimum speed:
Road: 65 km/h
Rail: 80 km/h



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6. Results of the SASI Exploratory Scenarios

Figures 15-33 show results of the SASI Baseline Scenario and the three exploratory scenarios A, B and C in map form.

6.1 Accessibility

The maps in Figures 15-18 show the distribution of multimodal accessibility (road/rail) in Europe in the Baseline Scenario and in the exploratory scenarios A, B and C in 2051.

Although in the SASI model also accessibility by air is considered, this bi-modal accessibility is presented here because air accessibility is kept the same in all scenarios.

Unlike in earlier applications of the SASI model, economic activity in terms of GDP is taken as destination activity because of its higher explanatory power in the SASI production function (see Section 3). Already in the map of the Baseline Scenario (Figure 15) it can be seen that accessibility in Europe is heavily centralised in western Europe in the corridor between Zürich and Amsterdam along the Rhine river (formerly called the "Blue Banana").

It is also apparent that, although, as it will be shown later (see Figure 34), the relative changes in accessibility in the exploratory scenarios A, B and C are substantial, they are not sufficient to fundamentally change this centralised pattern. Nevertheless it is obvious that in Scenario A (Figure 16) the high-accessibility area is largest, whereas it is smallest in Scenario C (Figure 18).

6.2 GDP

Table 3 and the maps in Figures 19-23 show the development of GDP and GDP per capita in the SASI Baseline Scenario and the three exploratory scenarios A, B and C.

Table 3 shows the development of GDP and GDP per capita over the different time periods between 1981 and 2051 for all four scenarios. It is apparent that after the decline due to the economic crisis, the MEGAs Scenario A produces the highest generative effects as public investment is concentrated in the largest metropolitan areas with the highest productivity. As expected, the Regions Scenario C scores last as subsidies are directed primarily at peripheral regions with low productivity. The Cities Scenario B takes a middle position.

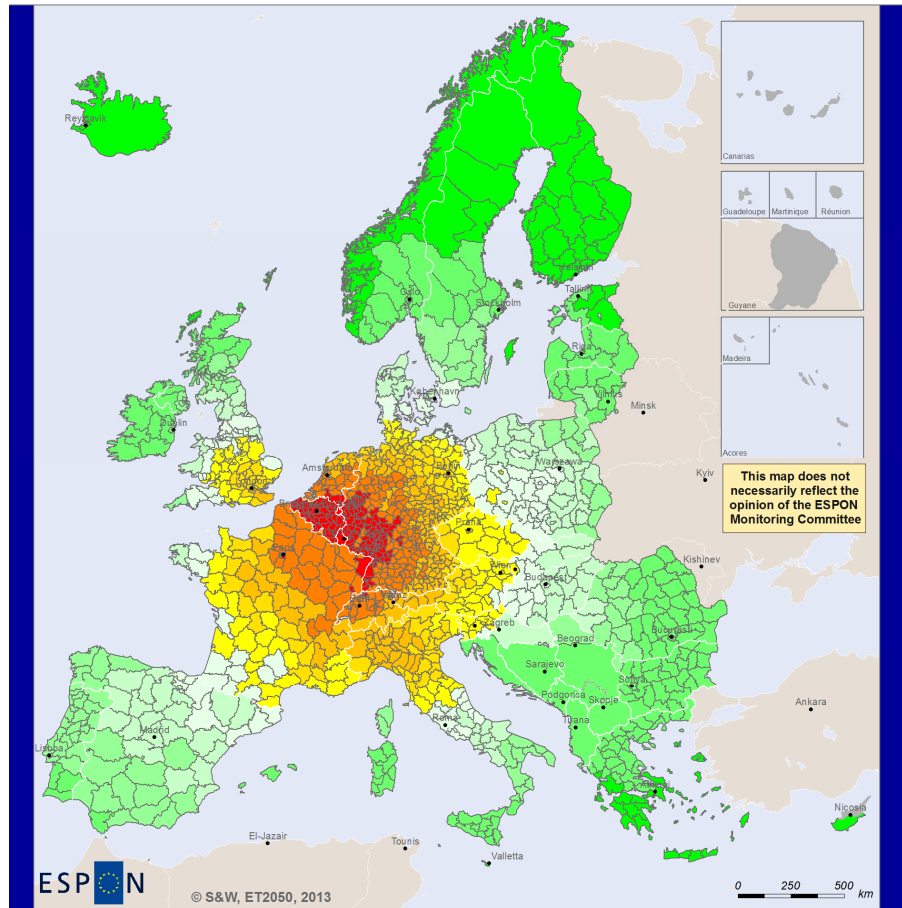
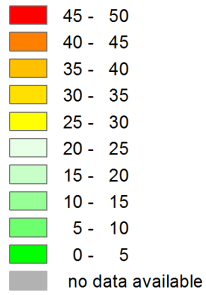
The table also shows that for all scenarios a general slowing down of material economic growth is projected in the period between 2013 and 2051. This is in line with the assumptions for the whole of Europe in Table 2 based on the conviction based on the recent report to the Club of Rome (Randers, 2012) that exponential economic growth cannot continue forever, in particular not in the more economically advanced and more affluent continents.

Table 3. Development of GDP and GDP per capita by period: average annual change (%)

Period	GDP				GDP per capita			
	Base	A	B	C	Base	A	B	C
1981-2007	+2.43	+2.43	+2.43	+2.43	+2.15	+2.15	+2.15	+2.15
2007-2013	-1.21	-1.21	-1.21	-1.21	-1.65	-1.65	-1.65	-1.65
2013-2031	+2.22	+2.33	+2.28	+2.24	+1.84	+1.95	+1.89	+1.85
2031-2051	+0.95	+0.97	+0.97	+0.96	+1.08	+1.10	+1.09	+1.08

Figure 15.
Baseline Scenario:
Accessibility road/rail
to GDP 2051

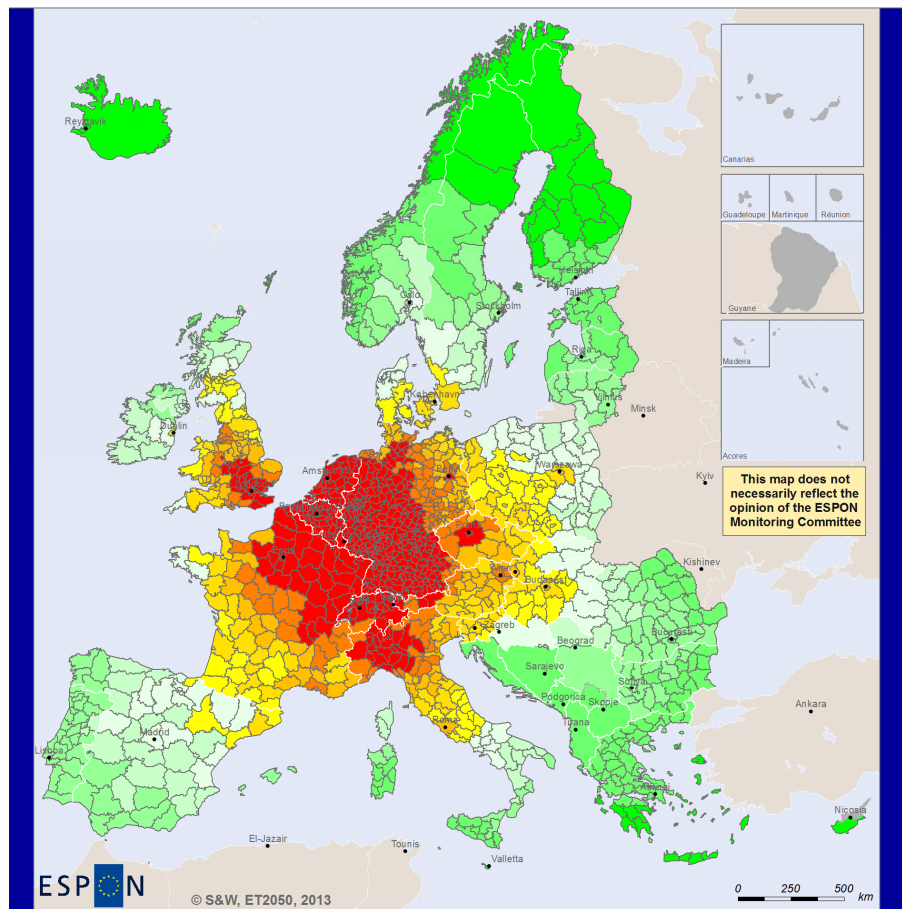
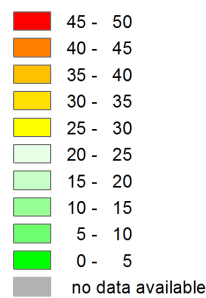
Regional level: NUTS3
Source: S&W (2013)
Origin of data: SASI model 2013



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Figure 16. Scenario A:
Accessibility road/rail
to GDP 2051

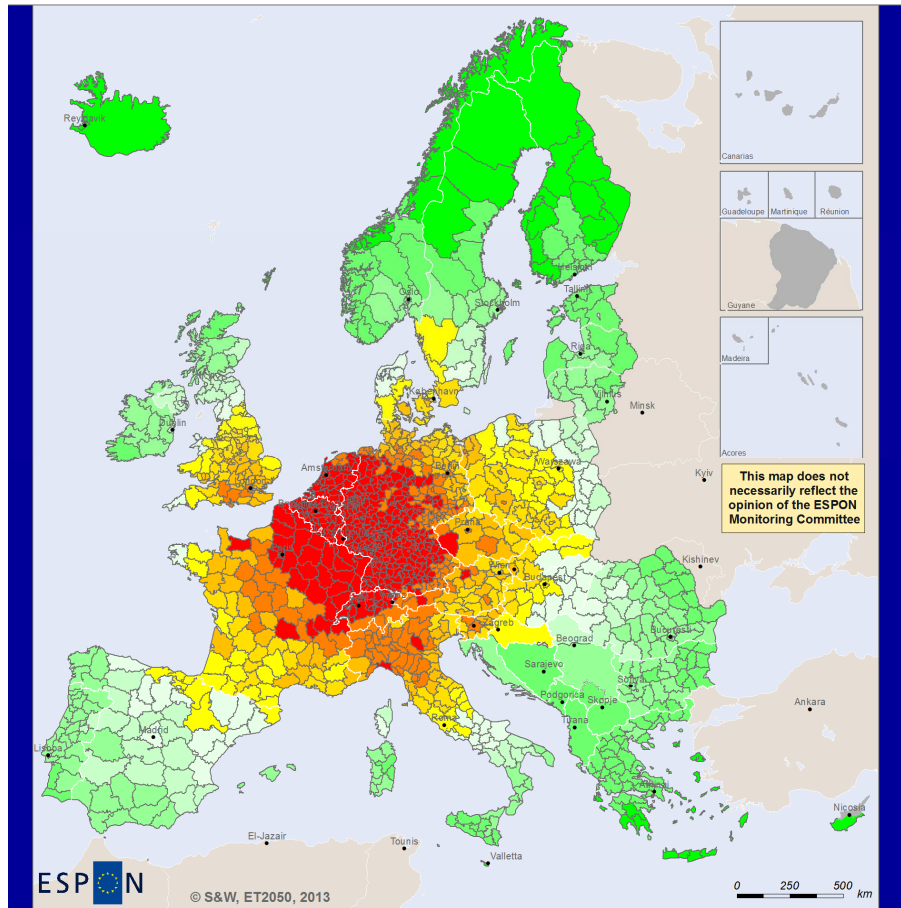
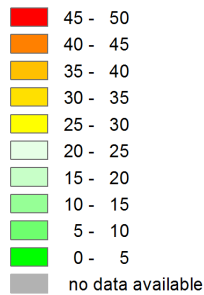
Regional level: NUTS3
Source: S&W (2013)
Origin of data: SASI model 2013



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Figure 17. Scenario B:
Accessibility road/rail
to GDP 2051

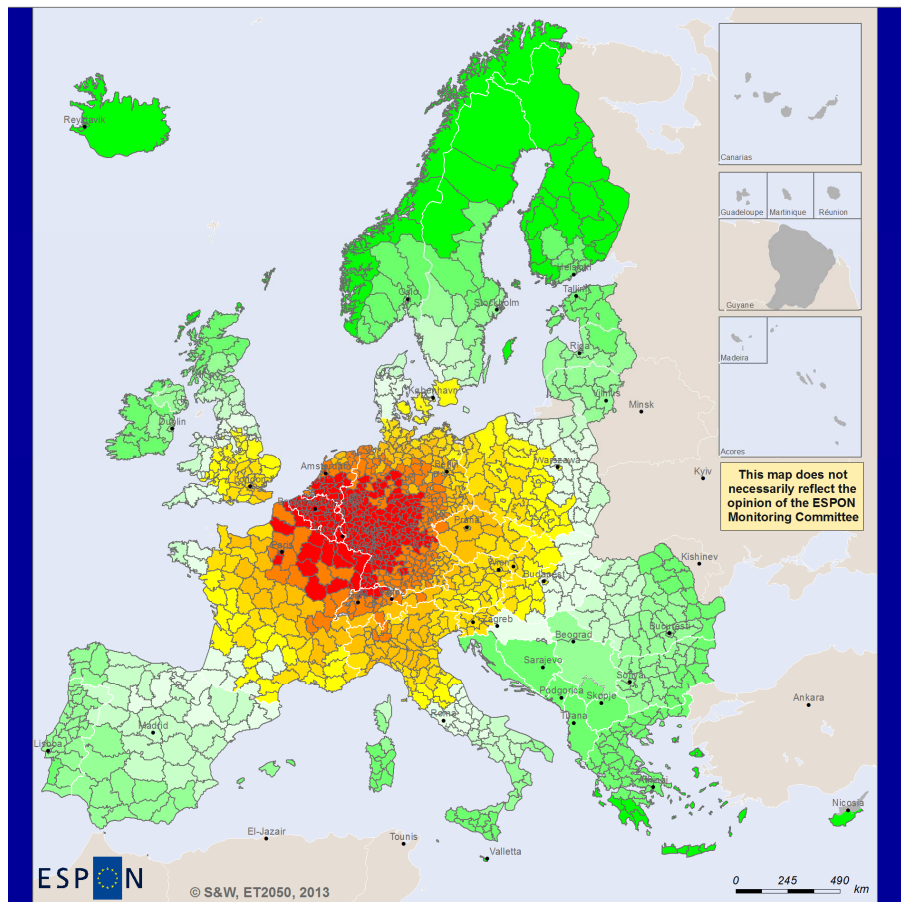
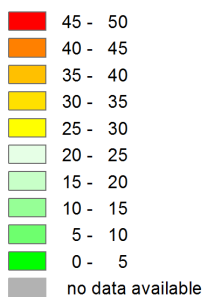
Regional level: NUTS3
Source: S&W (2013)
Origin of data: SASI model 2013



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Figure 18. Scenario C:
Accessibility road/rail
to GDP 2051

Regional level: NUTS3
Source: S&W (2013)
Origin of data: SASI model 2013



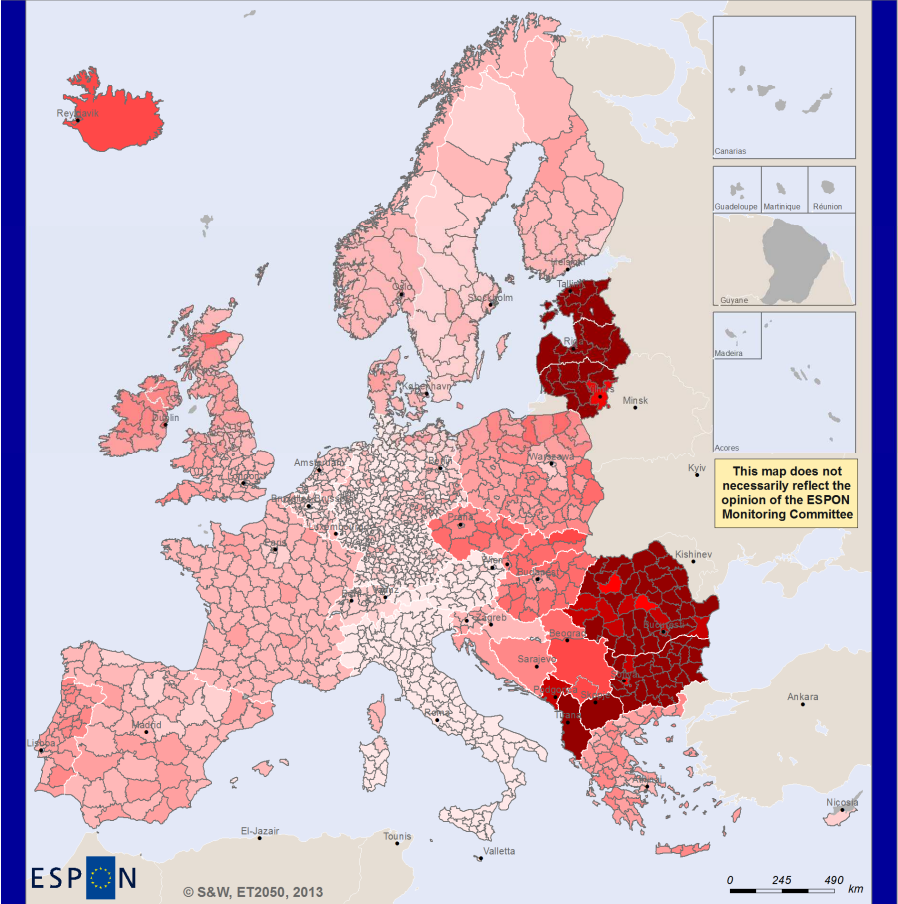
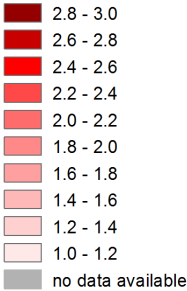
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The maps in Figures 19-23 show the spatial distribution of the economic growth projections summarised in Table 3.

The map in Figure 19 visualises the spatial dynamics of economic development in the European territory projected in the SASI Baseline Scenario. According to this optimistic perspective, the catching-up process of the new EU member states in central and eastern Europe will continue, though with lower speed as before the economic crisis. In particular the Baltic States, Estonia, Latvia and Lithuania, and Romania and Bulgaria are expected to significantly improve their economic situation compared to the northern, western and even central European member states.

Figure 19.
Baseline Scenario:
Mean annual change
of GDP 2011-2051
(%)

Regional level: NUTS3
Source: S&W (2013)
Origin of data: SASI model 2013



However, it has also kept in mind that even this catching up in relative terms will not fundamentally change the existing economic decline from north to south and from west to east.

This is illustrated by the map in Figure 20 which shows the distribution of GDP per capita in the Baseline Scenario in the year 2051. It can be seen that many regions in the new member states that joined the European Union in 2004 and 2007, but also in parts of Portugal, Spain, southern Italy and Greece, will still have a GDP per capita far below the European Union average

The map illustrates the sobering prospect that even in this optimistic scenario, in 2051, after forty years of economic convergence, there will continue to exist a significant gap in income between the prosperous old EU member states in western and northern Europe and the new member states in eastern Europe, but also in parts of Portugal, Spain, southern Italy and Greece, even though these regions will on average more than double their GDP per capita in these forty years – a demonstration of the inherent long-term persistence of economic structures and the fundamental political challenge it represents for the European Union.

As expected, the pattern of GDP per capita in the western and northern Europe remains more or less as today with higher GDP per capita in the economically more successful metropolitan areas and capital cities and the traditional high values in Switzerland, Luxembourg and the north-European countries Norway, Sweden and Denmark. It is remarkable that Ireland and Iceland seem to have completely overcome their severe recessions.

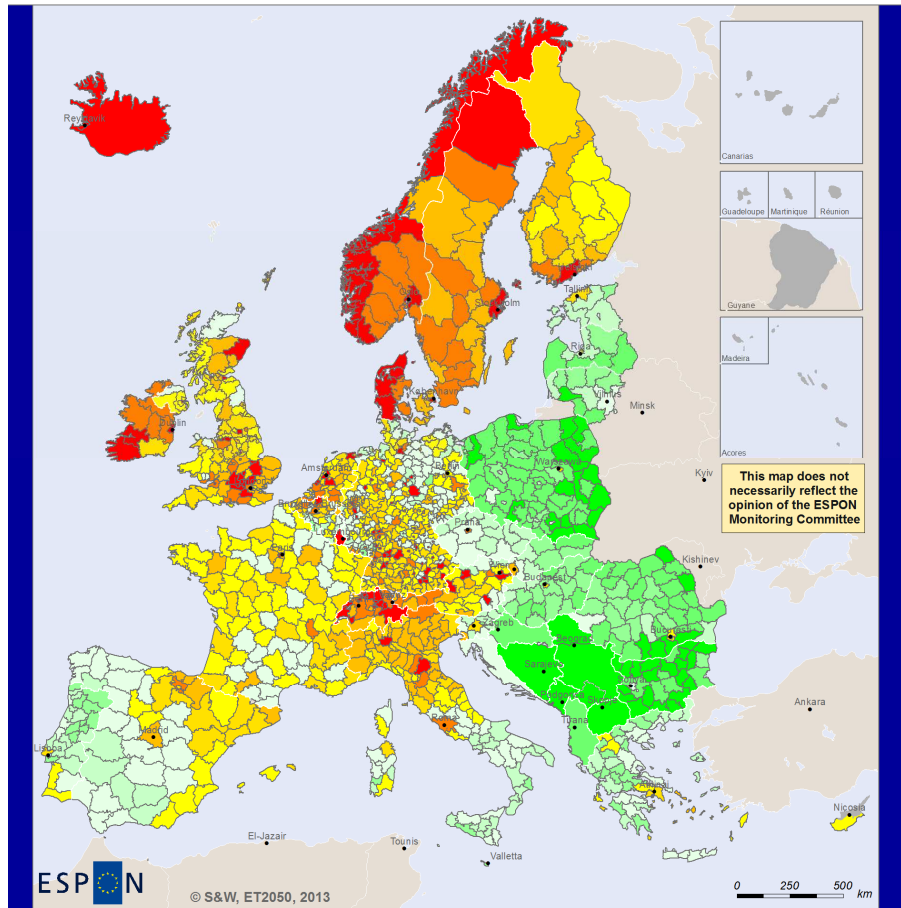
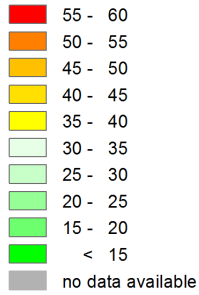
The maps in Figures 21-23 show how GDP per capita in the three exploratory scenarios A, B and C deviate from the Baseline Scenario in the year 2051. The three maps reflect the spatial orientation of the policies of the three scenarios:

- The MEGAs Scenario A (Figure 21) reinforces the already dominant position of the major metropolitan areas in the 'Pentagon' through GDP-oriented Structural Funds subsidies, high-speed oriented transport network improvements and better links between long-distance and local transport, such as better access to high-speed rail terminals. The new member states in eastern and southern Europe, except some of their capitals classified as MEGAs, lose most in terms of GDP per capita compared with the Baseline Scenario, in the most severe cases more than ten per cent. The already dominant largest metropolitan areas and their immediate surroundings gain most, up to ten per cent compared with the Baseline Scenario. Whether this policy of making the strongest players even stronger will result in increased overall European growth, as the Lisbon strategy claims, will be discussed in Sections 8 and 9 below.
- The Cities Scenario B (Figure 22) emphasises the polycentric urban system of Europe already proposed as desirable by the European Spatial Development Perspective (ESDP) of 1999 (European Commission, 1999) and further articulated in the Territorial Agenda of 2007 (European Commission, 2007) and the Territorial Agenda 2020 (European Commission, 2011). It strengthens the position of large European cities by education-oriented EU subsidies, medium-speed oriented transport network improvements and better links between regional and local transport networks. This polycentricity orientation is clearly reflected in the results shown in the map: The secondary cities selected as well as their immediate hinterlands in both eastern and western Europe grow significantly faster than the remaining regions. However, the imbalance between the affluent western and northern regions in Europe and the disadvantaged regions in eastern and southern Europe not classified as secondary cities to be promoted remains. This imbalance is most visible in the growing disparity between the promoted capitals and other large cities and other regions in the new member states in eastern Europe. It becomes apparent here that polycentricity at the European level tends to be in contradiction with polycentricity at the national or regional level. It will be discussed in Sections 8 and 9 below how the polycentric Cities Scenario B scores in terms of the EU goals of competitiveness, territorial cohesion and sustainability compared to the MEGAs Scenario A and the Regions Scenario C.
- The Regions Scenario C (Figure 23) strengthens the still economically lagging regions in eastern and southern Europe and so clearly pursues the territorial cohesion objective. As also in this scenario the allocation of Structural Funds subsidies follows the inverse function of GDP per capita (as in the Base Scenario), the results are similar to the Baseline Scenario in northern and western Europe, but the promotion of rural and peripheral regions in the new member states in eastern Europe and Portugal, Spain, southern Italy and Greece is stronger, as the number of regions eligible for Structural Funds support is smaller, 355 compared to the total of 1,290 EU regions in the Baseline Scenario. But nearly all regions, except the MEGAs and secondary cities promoted in Scenarios A and B, benefit from the policies applied in the Regions Scenario C, though only to a small degree. Whether the scenario really scores better in terms of territorial cohesion and sustainability will be discussed in Sections 8 and 9 below.

In summary, the economic impacts of the three exploratory scenarios reflect their policy orientations and result in significantly different spatial futures of Europe. In how far these differences will contribute to the achievement of the three overarching goals of the European Union, competitiveness, territorial cohesion and sustainability will be discussed in Sections 8 and 9 below.

Figure 20.
Baseline Scenario:
GDP per capita
(1,000 Euro of 2010)
2051

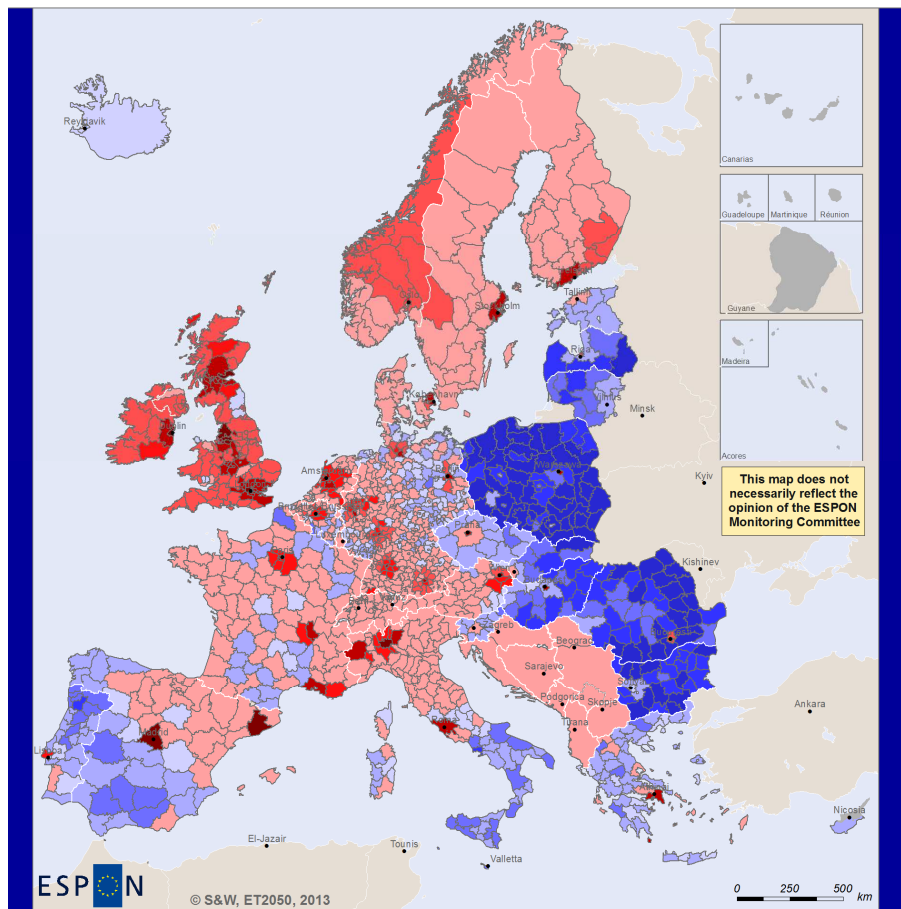
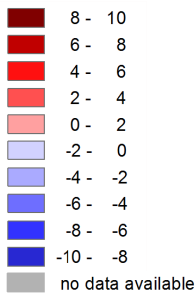
Regional level: NUTS3
Source: S&W (2013)
Origin of data: SASI model 2013



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Figure 21. Scenario A:
Difference in GDP per capita to Baseline Scenario (%)
2051

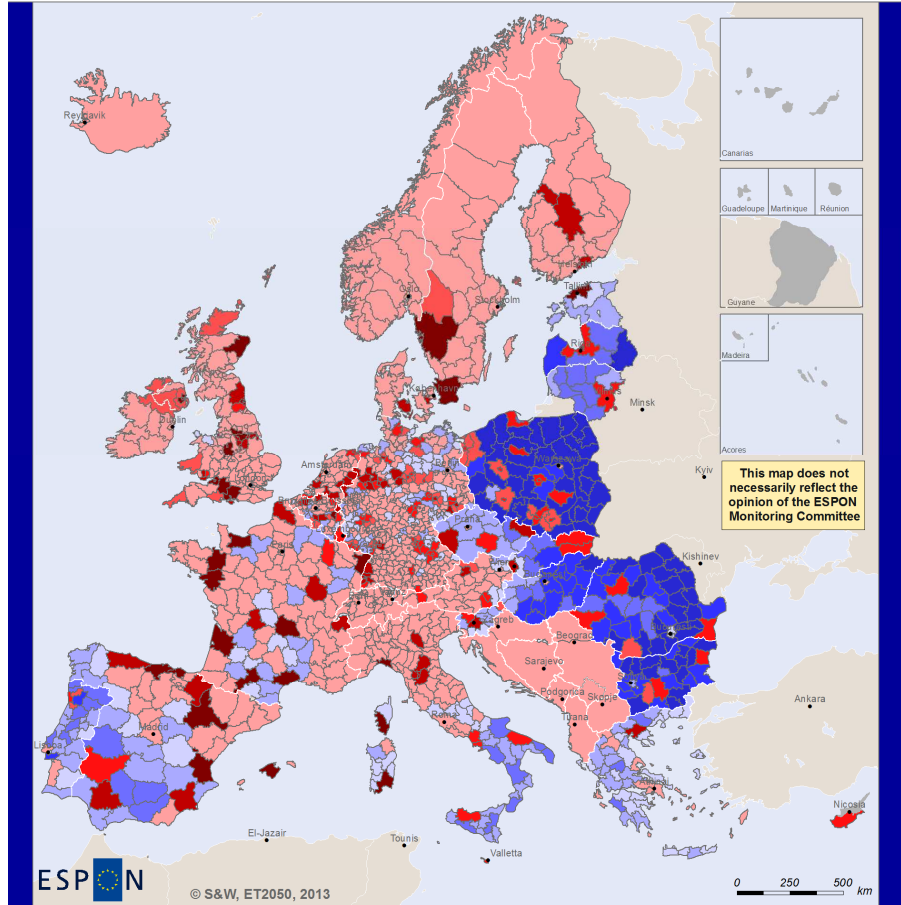
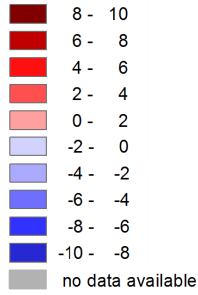
Regional level: NUTS3
Source: S&W (2013)
Origin of data: SASI model 2013



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Figure 22. Scenario B:
Difference in GDP per
capita to Baseline
Scenario (%)
2051

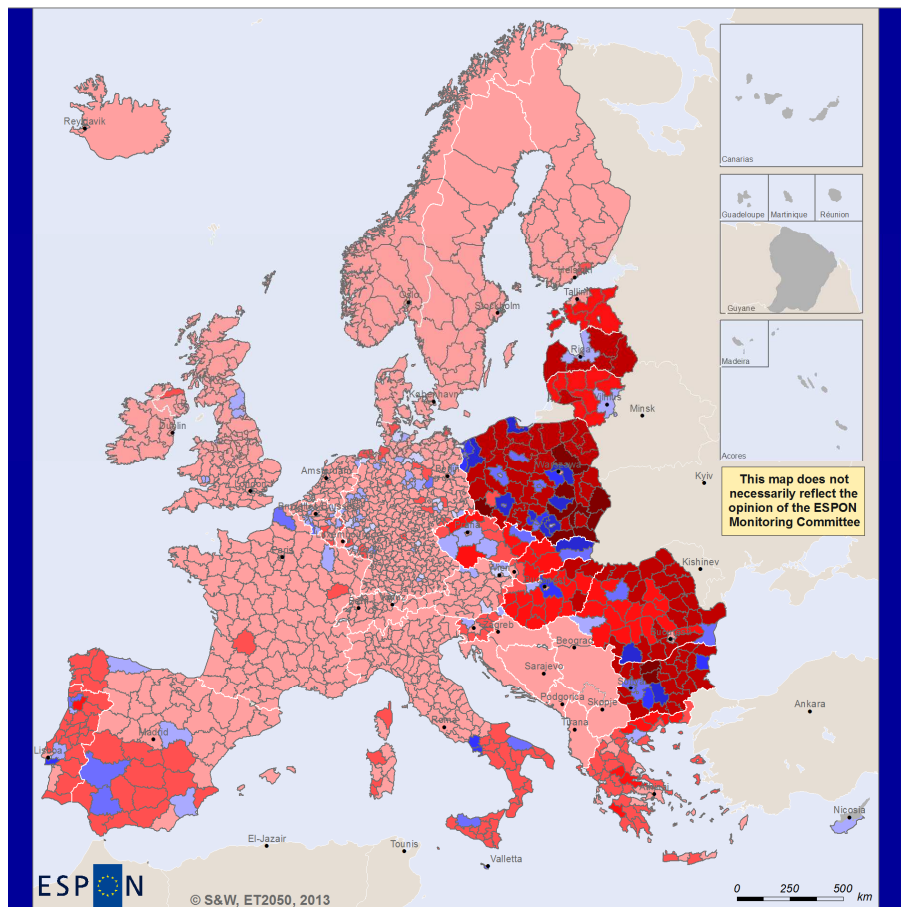
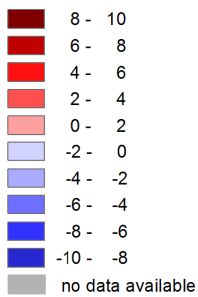
Regional level: NUTS-3
Source: S&W (2013)
Origin of data: SASI model 2013



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Figure 23. Scenario C:
Difference in GDP per
capita to Baseline
Scenario (%)
2051

Regional level: NUTS-3
Source: S&W (2013)
Origin of data: SASI model 2013



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6.3 Population

The maps in Figures 24-29 show the results of the Baseline Scenario and the exploratory scenarios A, B and C with respect to population and net migration.

The map in Figure 24 visualises the spatial population dynamics in the European territory projected by the SASI model. Despite the assumed continuing high total net migration of the European Union, most European countries face declining populations, except the Nordic and Baltic countries, Great Britain and Ireland, the Benelux countries, France, Switzerland and Austria due to their higher birth rates. This together with progressive ageing of the population will confront the countries with declining populations with serious social problems. As assumed for the Baseline Scenario, the total population of the European Union will peak with about 540 million people between 2030 and 2040 and decline to about 526 million in 2051.

The maps in Figures 25-28 show the spatial distribution of population in the Baseline Scenario and the changes in population in the exploratory scenarios A, B and C. The differences between the population distributions of the three exploratory scenarios and the Baseline Scenario are due to the different degrees of attractiveness of cities and regions in the scenarios: In the MEGA or A Scenario, the increased wage earning opportunities in the large metropolitan areas attract even more job-seeking migrants both from within and outside the EU, creating stronger population decline in the more peripheral both southern and eastern regions. In the Cities or B Scenario, the pattern of attractor cities is more dispersed, but the depopulation trend in the peripheral regions continues. Only in the Regions or C Scenario the trend is reversed, though not sufficiently to stop the process of depopulation of peripheral regions.

Figure 24.
Baseline Scenario:
Mean annual change
of population (%)
2011-2051

Regional level: NUTS-3
Source: S&W (2013)
Origin of data: SASI model 2013

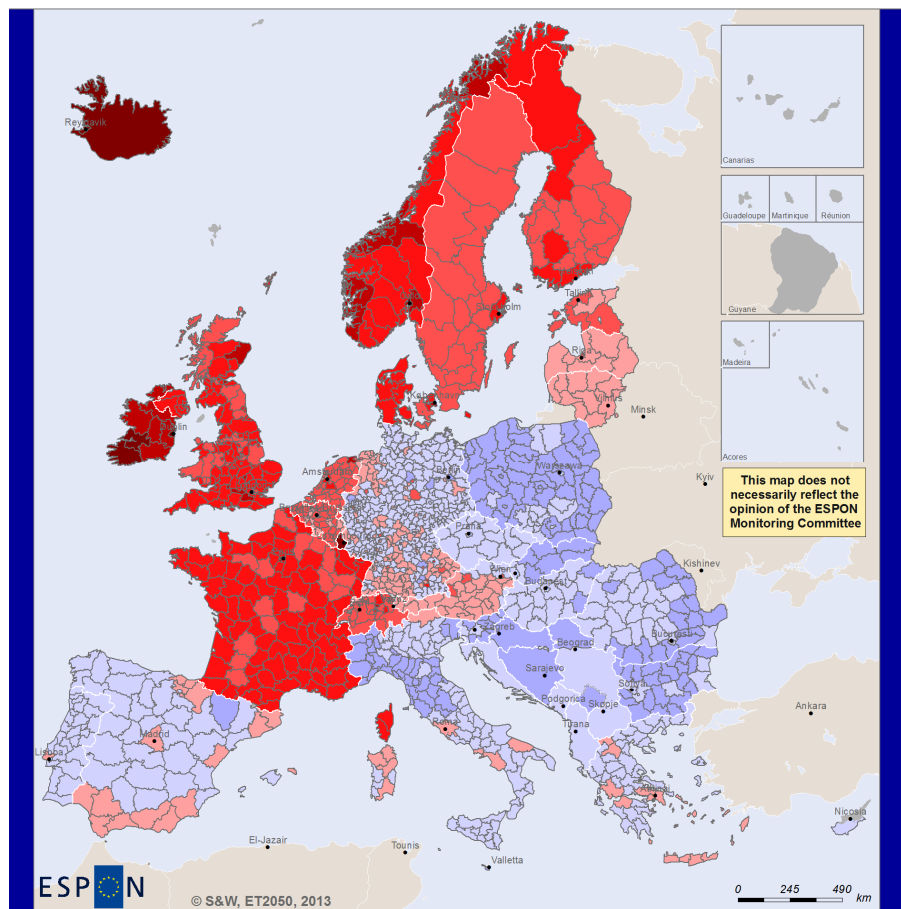
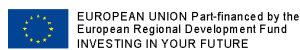
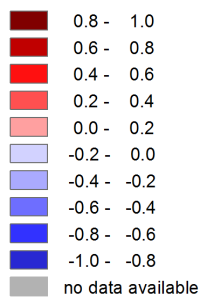
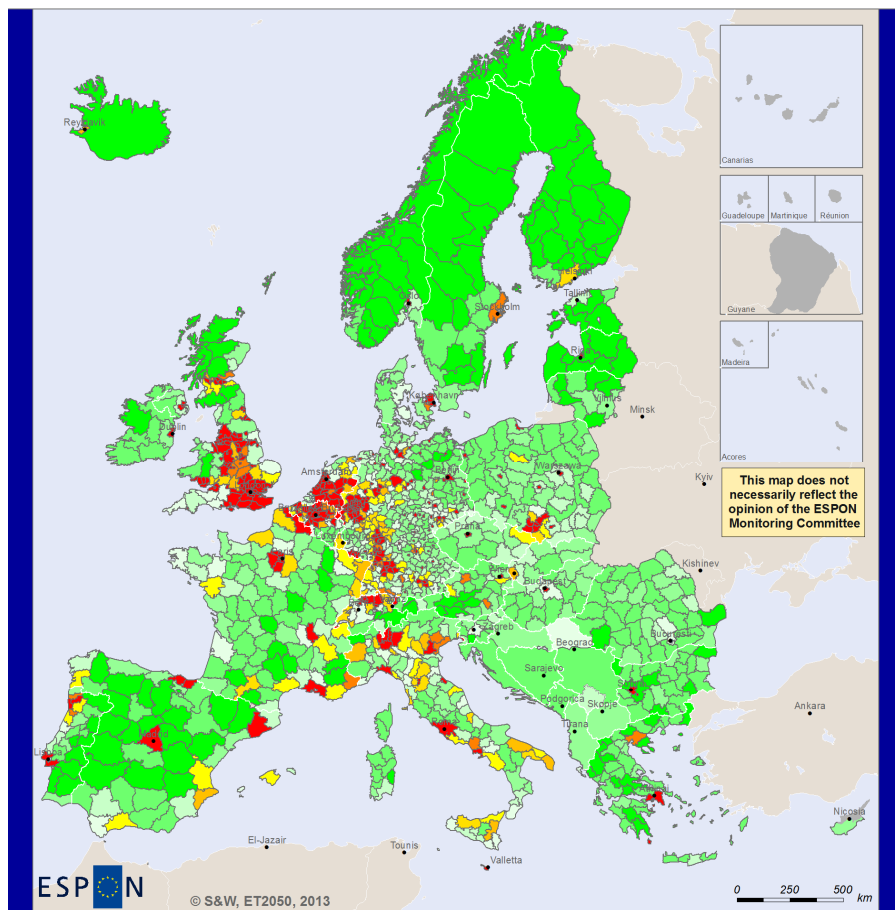
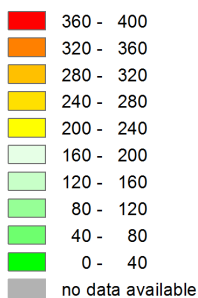


Figure 25.
Baseline Scenario:
Population density
(population/sqkm)
2051

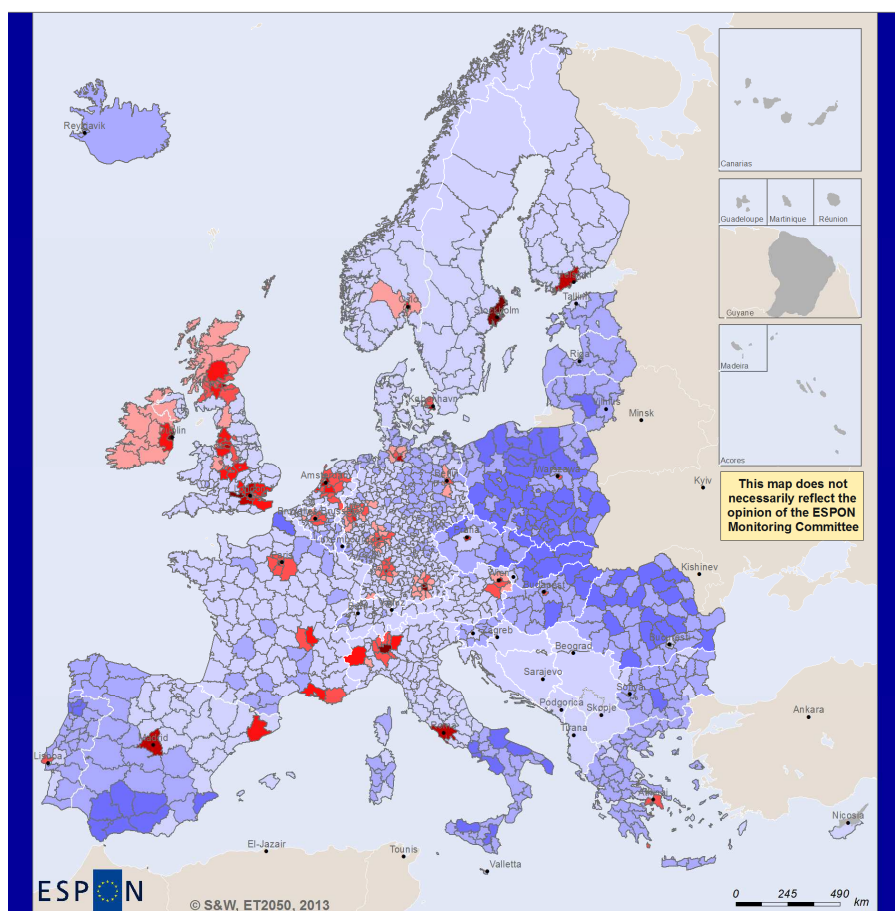
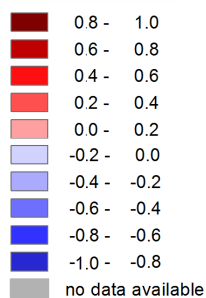
Regional level: NUTS-3
Source: S&W (2013)
Origin of data: SASI model 2013



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Figure 26. Scenario A:
Difference in population
to Baseline Scenario
(%) 2051

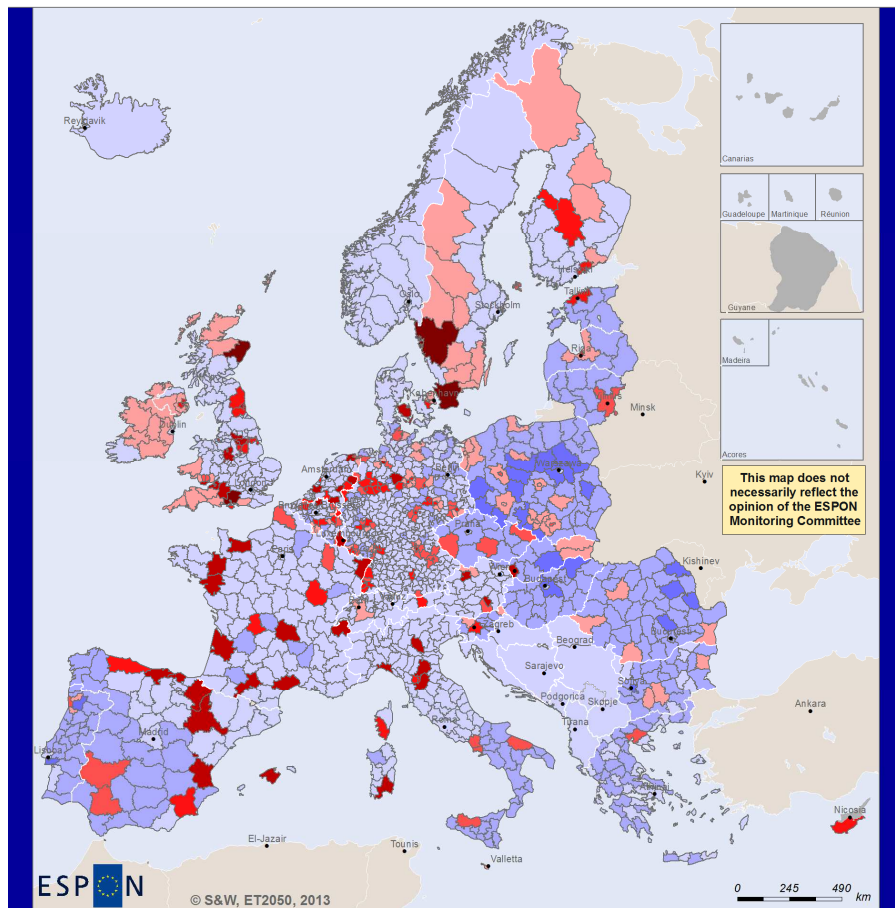
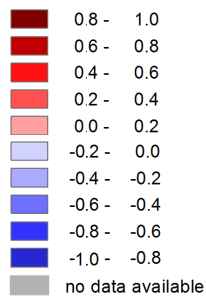
Regional level: NUTS-3
Source: S&W (2013)
Origin of data: SASI model 2013



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Figure 27. Scenario B:
Difference in population
to Baseline Scenario
(%) 2051

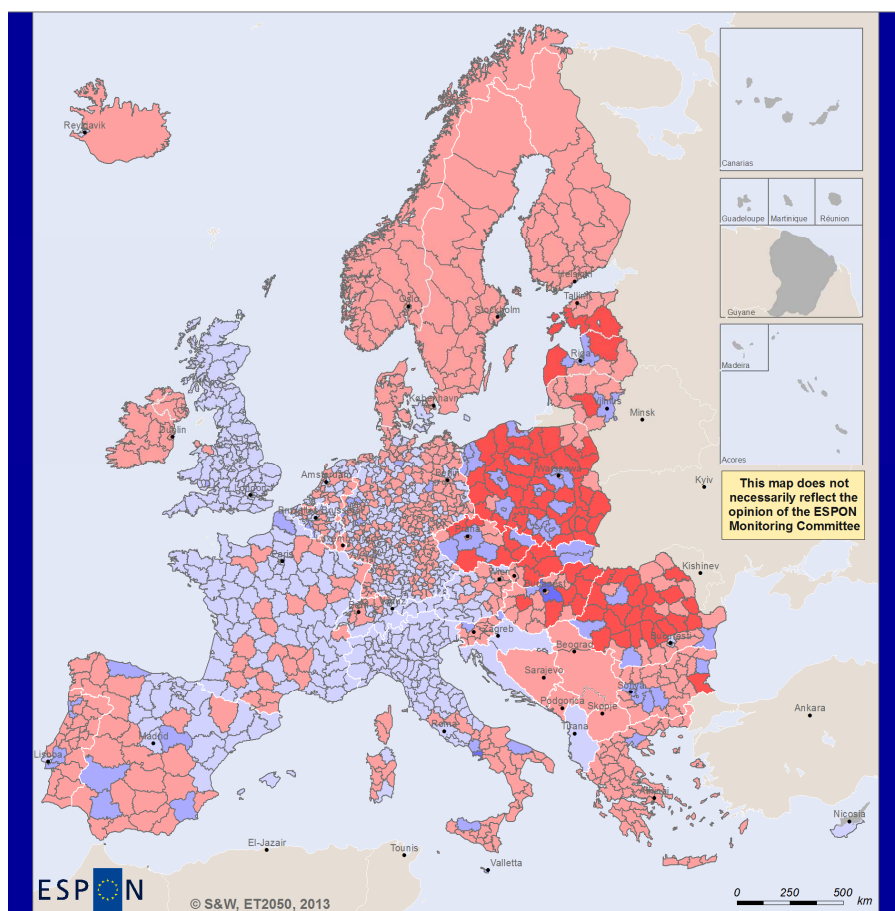
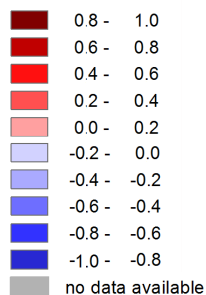
Regional level: NUTS-3
Source: S&W (2013)
Origin of data: SASI model 2013



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Figure 28. Scenario C:
Difference in population
to Baseline Scenario
(%) 2051

Regional level: NUTS-3
Source: S&W (2013)
Origin of data: SASI model 2013



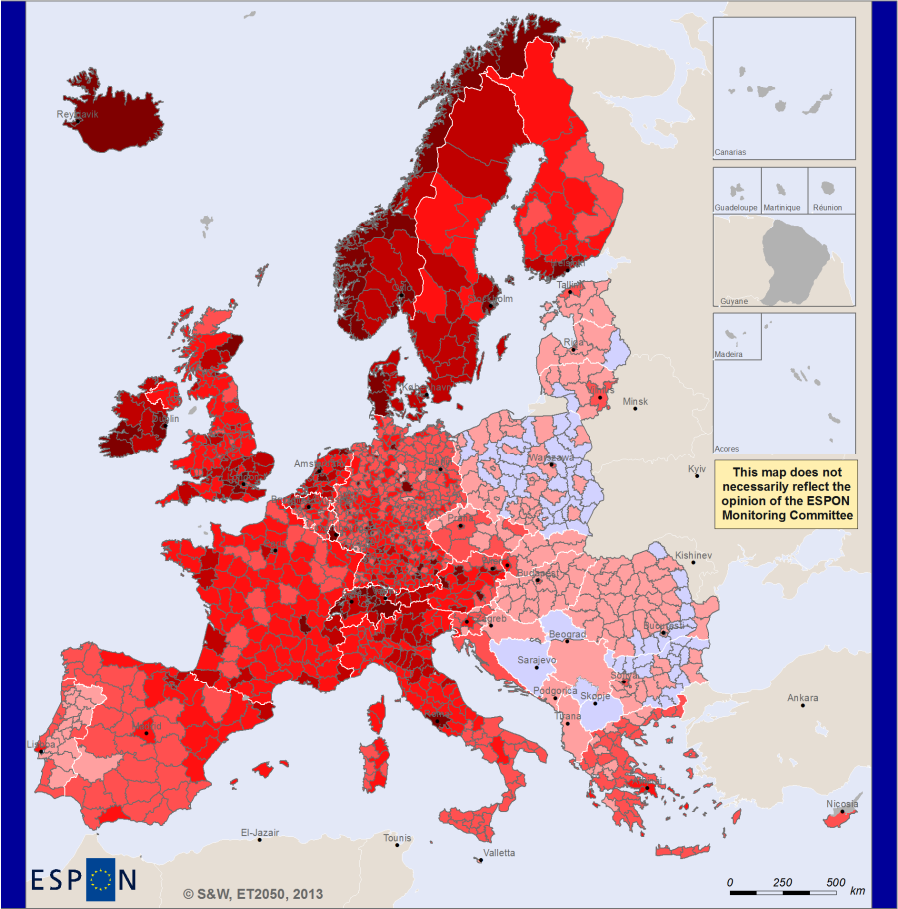
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The map in Figure 29 shows the migration component of the population dynamics. Because of the assumed high total EU net migration, almost all regions have a positive migration balance, i.e. they attract more immigrants than they lose outmigrants. It is also apparent that due to their catching-up economically, even eastern and southern EU member states with below-average GDP per capita have positive net migration balances as they attract immigrants from neighbouring Asian and African countries. The main result is that the changes in population caused by immigration from outside the EU and inter-regional migration are small compared to the changes in GDP per capita, indicating a general low degree of mobility in response to changing income opportunities.

Figure 29.
Baseline Scenario:
Cumulative
net migration
2011-2051 (%)

Regional level: NUTS-3
Source: S&W (2013)
Origin of data: SASI model 2013

- 16 - 20
- 12 - 16
- 8 - 12
- 4 - 8
- 0 - 4
- < 0
- no data available

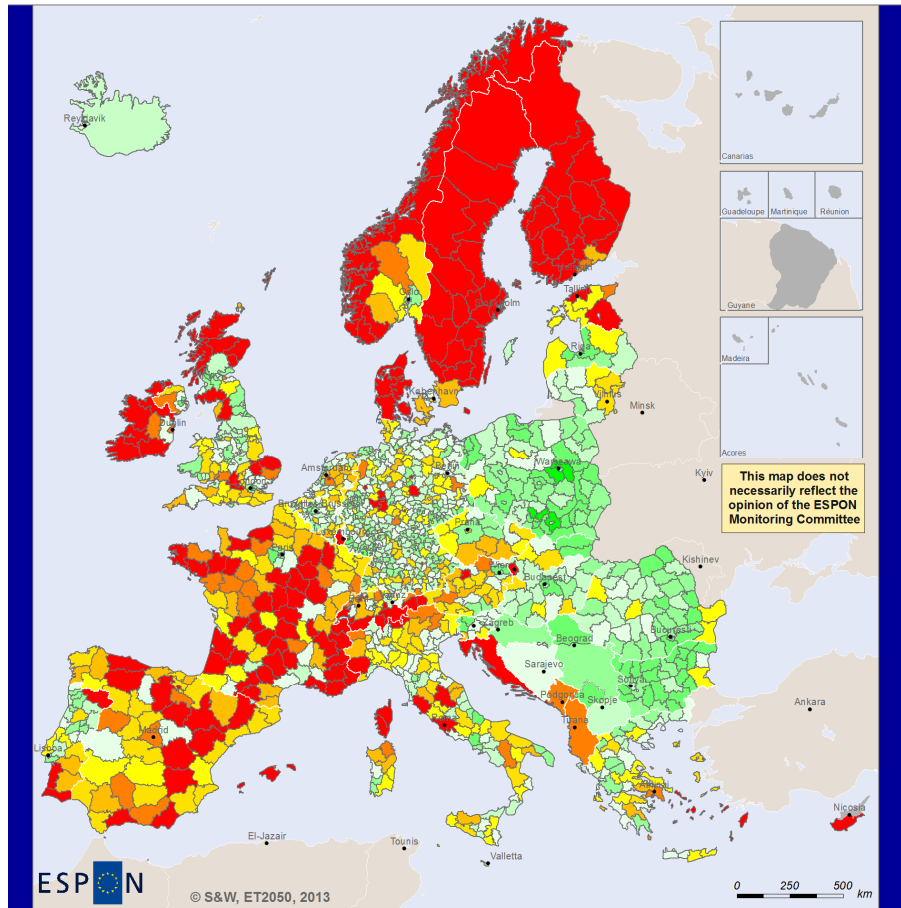
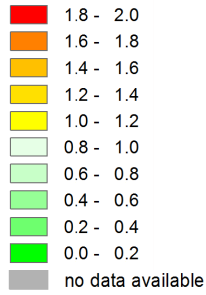


6.4 Transport

The transport submodel recently added to the SASI model predicts freight transport and person travel and the energy consumption and CO₂ emission resulting from them. The maps in Figures 30-33 show CO₂ emission of transport as one of the sustainability indicators selected because of its responsiveness to different spatial configurations. Here the effects of two drivers are visible: The most affluent regions travel more and generate more freight traffic than the poorer peripheral regions. On the other hand the peripheral regions have to make longer journeys and to ship their goods over longer distances. This leads to higher emissions in the central regions and lower emissions in the peripheral regions in Scenario A and to the reverse effect in the Scenario C, with Scenario B taking a middle position.

Figure 30.
Baseline Scenario:
CO₂ emission by
transport (t/capita/y)
2051

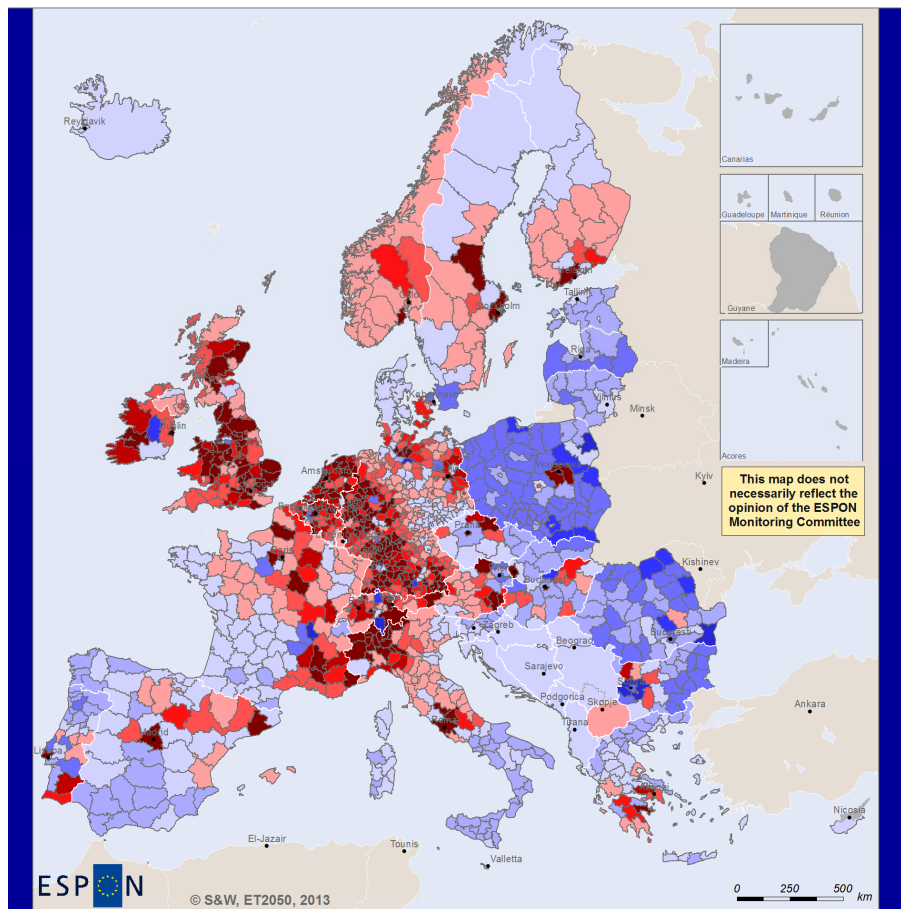
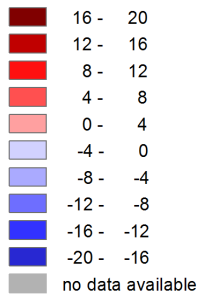
Regional level: NUTS3
Source: S&W (2013)
Origin of data: SASI model 2013



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Figure 31. Scenario A:
Difference in CO₂
emission by transport
to Baseline Scenario
(%) 2051

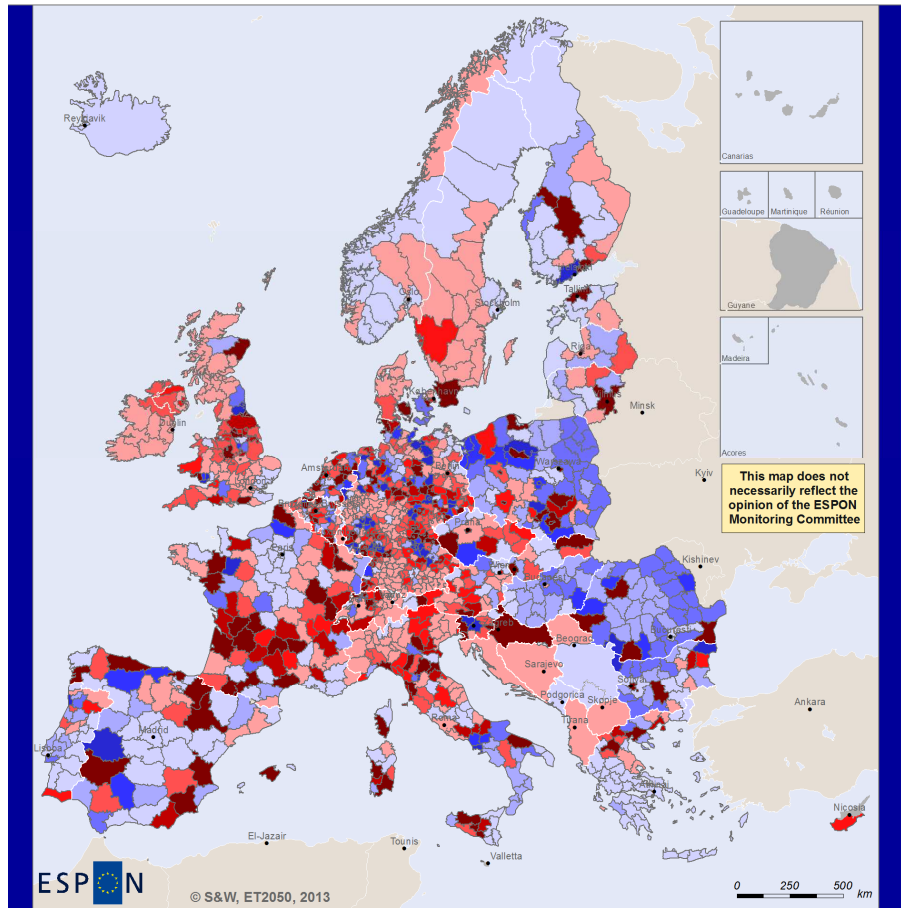
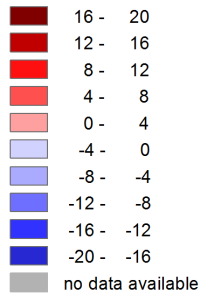
Regional level: NUTS-3
Source: S&W (2013)
Origin of data: SASI model 2013



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Figure 32. Scenario B:
Difference in CO₂
emission by transport
to Baseline Scenario
(%) 2051

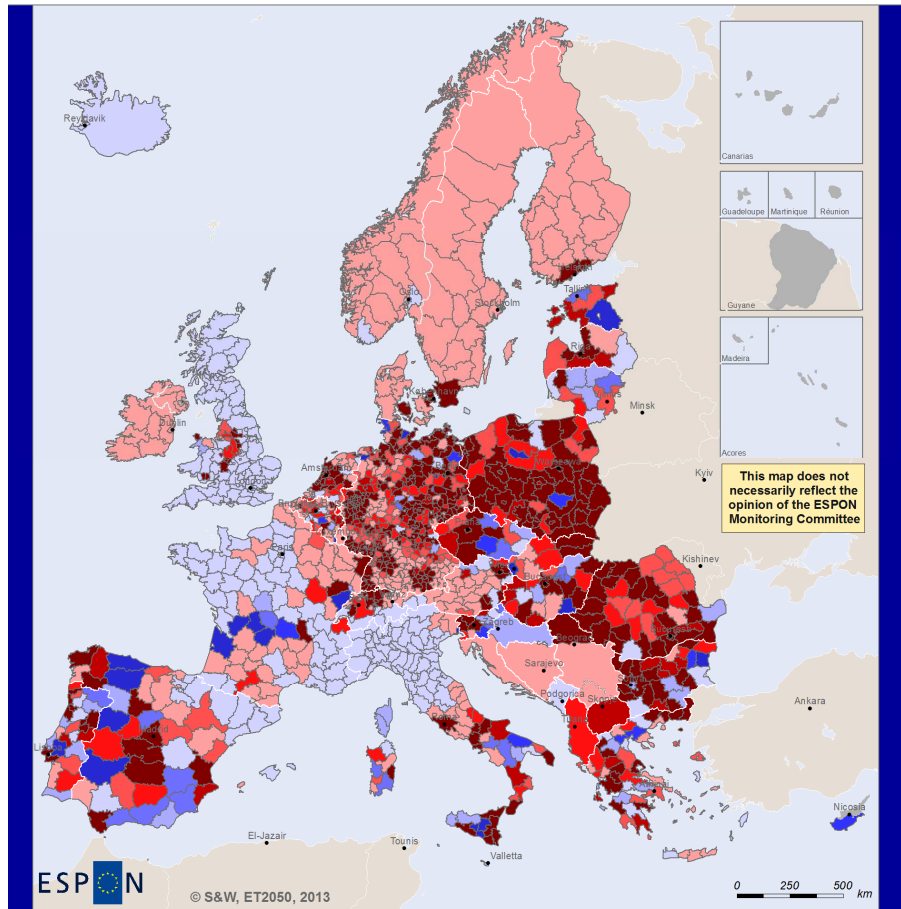
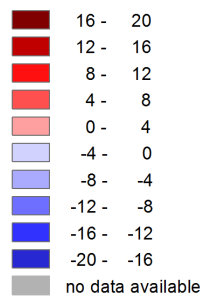
Regional level: NUTS-3
Source: S&W (2013)
Origin of data: SASI model 2013



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Figure 33. Scenario C:
Difference in CO₂
emission by transport
to Baseline Scenario
(%) 2051

Regional level: NUTS-3
Source: S&W (2013)
Origin of data: SASI model 2013



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7. The SASI Scenario Variants

In addition to the Baseline Scenario and the exploratory scenarios A, B and C, nine scenario variants in which the three exploratory scenarios were combined with alternative framework conditions were tested with the SASI model:

- 1 *Economic recession*: Globalisation and growth of emerging economies lead to significant slowing down of the growth of the European economy.
- 2 *Technology advance*: New innovations in labour productivity and transport technology result in significant increases in labour and transport system productivity.
- 3 *Energy/climate*: Rising energy costs and/or greenhouse gas emission taxes lead to strong increases of production and transport costs.

Table 4 shows combinations of the three exploratory scenarios and the three different framework conditions resulting in nine scenario variants:

Table 4. Exploratory scenarios and their variants

Spatial orientation of the scenarios	Framework conditions			
	As in the Baseline Scenario	1 Economic recession	2 Technology advance	3 Energy/ climate
Promotion of large metropolitan areas	A	A1	A2	A3
Promotion of secondary European cities	B	B1	B2	B3
Promotion of peripheral regions	C	C1	C2	C3

Table 5 shows the assumptions made to specify the nine scenario variants.

Table 5. Assumptions for the scenario variants

Assumptions	Framework conditions			
	Baseline Scenario	Scenarios A1, B1, C1 Economic recession	Scenarios A2, B2, C2 Technology advance	Scenarios A3, B3, C3 Energy/ climate
Population 2051 (million)	542	542	542	542
GDP 2051 (billion Euro of 2010) ¹	23,253	16,722	23,253	23,253
GDP 2013-2051 (% p.a.) ¹	+1.50	+0.62	+1.50	+1.50
GDP/worker 2051 (Euro of 2010) ¹	99,400	99,400	145,500	99,400
GDP/worker 2013-2051 (% p.a.) ¹	+0.94	+0.94	+1.94	+0.94
Energy efficiency of transport (% p.a.)	+0.45	+0.45	+0.75	+0.45
EU Subsidies (% of GDP)	0.4	0.4	0.4	0.4
Fuel price/litre (Euro of 2010 per litre)	3.00	3.00	3.00	10,20
Fuel price 2013-2051 (% p.a.)	+1.50	+1.50	+1.50	+5.00

¹ without generative effects

- 1 *Economic recession*: It is assumed that in Scenarios A1, B1 and C1 total GDP of EU31 grows by only 0.62 per cent p.a. on average between 2011 and 2051 compared to 1.50 per cent in the Baseline. Also here it is assumed that growth rates will gradually decrease after 2030.
- 2 *Technological advance*: It is assumed that in Scenarios A2, B2 and C2 labour productivity, i.e. GDP per worker, grows by 1.94 per cent p.a. on average between 2013 and 2051 compared to 0.94 per cent in the Baseline Scenario. It is assumed that productivity will gradually converge between countries towards 2051.
- 3 *Energy/climate*: Rising energy costs and greenhouse gas emission taxes lead to strong increases of production and transport costs. It is assumed that in Scenarios A3, B3 and C3 fuel costs of road vehicles will increase by 5 per cent p.a. on average between 2013 and 2051 compared to 1.50 per cent in the Baseline Scenario. This will result in an average fuel price of 10.20 Euro of 2010 in 2051 compared with 3.00 Euro in the Baseline Scenario. Energy cost of rail transport is assumed to increase by 2 per cent p.a. between 2013 and 2051.

8. Results of the Scenario Variants

Figures 34-42 on the following pages show selected results of the SASI scenario variants compared with the Baseline Scenario and the exploratory scenarios A, B and C. Because of the number of variants, no maps of results for regions in individual variants can be shown. Instead time-series diagrams showing all scenarios and their variants together are used. Each diagram shows trajectories of all 13 scenarios (Baseline Scenario, A, A1, A2, A3, B, B1, B2, B3, C, C1, C2, C3) as coloured lines each representing one scenario. The heavy black line represents the development in the Baseline Scenario (00). The thinner coloured lines represent the exploratory scenarios and their variants in blue (A scenarios), red (B scenarios) and green (C scenarios).

Figure 34 shows the average development of multimodal accessibility (road/rail) of the NUTS-3 regions in the 13 scenarios. Clearly the significant increase of accessibility due to transport network investments, faster trains and shorter border waiting times through European integration and the Schengen accord becomes visible. After 2016 the exploratory scenarios and their variants depart from the Baseline Scenario leading to the differences in accessibility shown in the maps of Figures 16-18. The exploratory scenarios A, B and C and their variants A1, A2, B1, B2 and C1 and C2 show increased average accessibility. In particular the A scenarios with their massive extension of high-speed rail lines serving the major corridors, achieve the largest gain in overall accessibility, with the B and C scenarios following. However, the strong price increases in the energy and climate scenarios A3, B3 and C3 lead to large reductions of accessibility.

Figure 35 shows the development of average GDP per capita (in Euro of 2010) of NUTS-3 regions over time. To better understand why even in 2051 the regions in eastern and southern Europe continue to lag behind, average GDP per capita in the old EU member states in western and northern Europe (EU15) and the new EU member states in eastern Europe (EU12) are shown separately. It is apparent that although the regions in EU12 grow faster in relative terms, they grow less in absolute terms so that the gap between EU15 and EU12 continues to grow. Scenarios A2, B2 and C2 with accelerated technological innovation lead to economic growth, whereas Scenarios A1, B1 and C1 for which economic recession is assumed fall behind. The exploratory scenarios A, B and C and Scenarios A3, B3 and C3 with significant price increase due to energy scarcity and climate change remain in a middle course. In all three groups of scenarios the effects of the assumed declining growth rates towards 2050 can be observed.

The situation is different with labour productivity (Figure 36), which is determined endogenously from productivity growth in previous years except in the technological innovation scenarios A2, B2 and C2. Here only the technological innovation scenarios stand out.

Figure 34. All scenarios:
Accessibility road/rail travel
(million) 2051

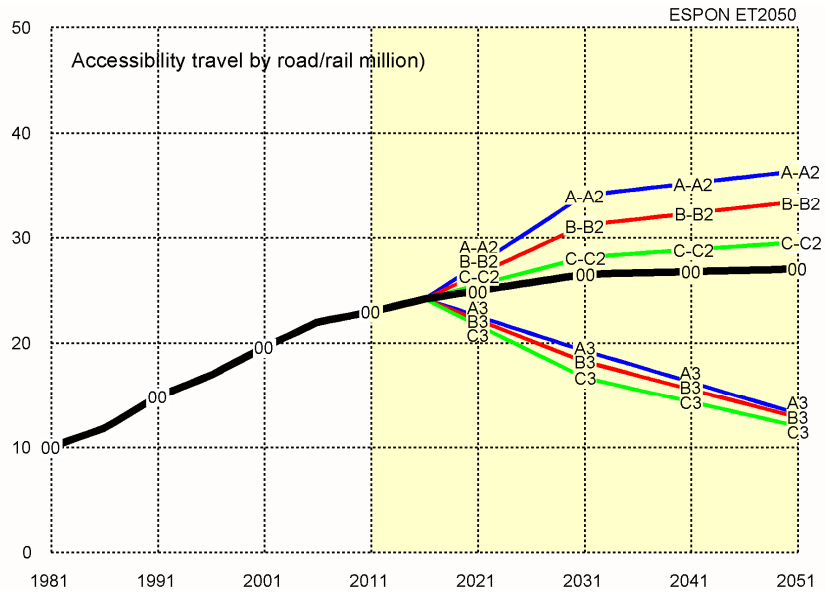


Figure 35. All scenarios:
GDP per capita (1,000 Euro of 2010), EU15 and EU12 1981-2051

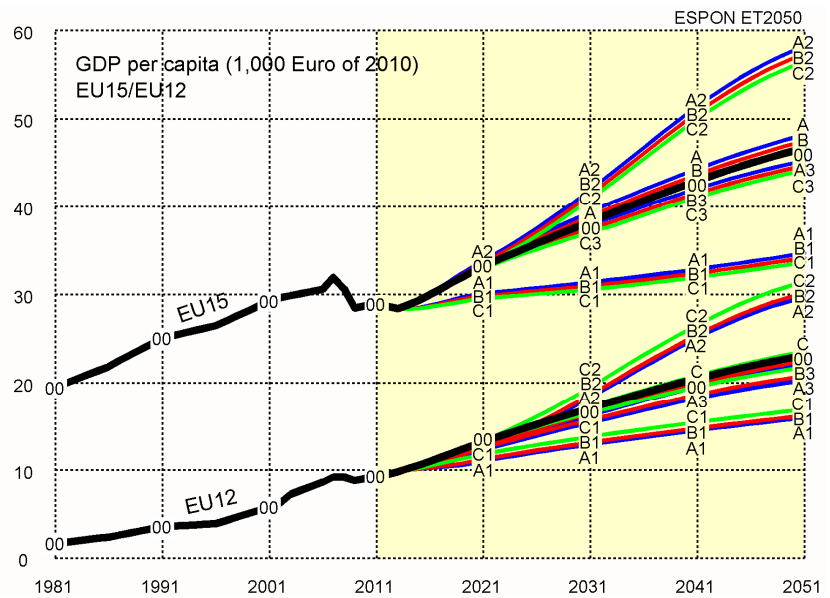
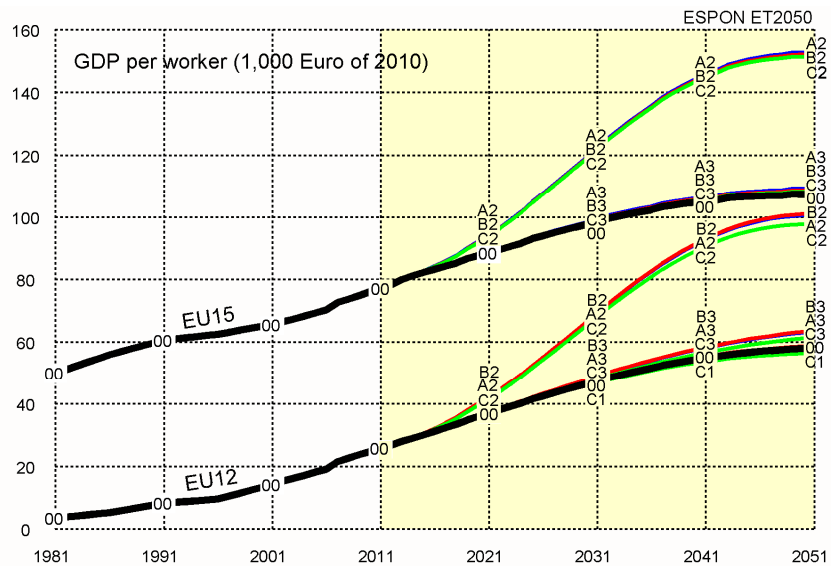


Figure 36. All scenarios:
GDP per worker (1,000 Euro of 2010), EU15 and EU12 1981-2051



What the trajectories presented so far do not show is whether spatial development in Europe in the next decades will lead to further convergence of economic conditions or, after the recent economic crisis, to economic divergence.

This is analysed by the two most common indicators of spatial cohesion, the coefficient of variation of GDP per capita in Figure 37 and the Gini index of GDP per capita in Figure 38. Both indices measure the degree of disparities between objects of observation, in this case 1,347 NUTS-3 regions of the ESPON Space. The higher the indicator values, the greater are the disparities.

The figures show that, according to the SASI model, convergence in economic development between regions in Europe indeed comes to a halt during the economic crisis but that after the crisis convergence continues, though more slowly than before the crisis. The reason is that in most new member states in eastern and southern Europe technology, i.e. labour productivity, will continue to catch up with that in the more advanced member states in western and northern Europe, although not as fast as in the years 1991-2011 after the fall of the Iron Curtain. Convergence continues in all scenarios. It is fastest in the Cities and Regions scenarios, in particular in the Technology Advance Scenarios B2 and C2. As to be expected, convergence is weakest in the MEGAs or A scenarios and even changes into divergence at the end of the forecasting period.

Figure 37. All scenarios: Coefficient of variation of GDP per capita 1981-2051.

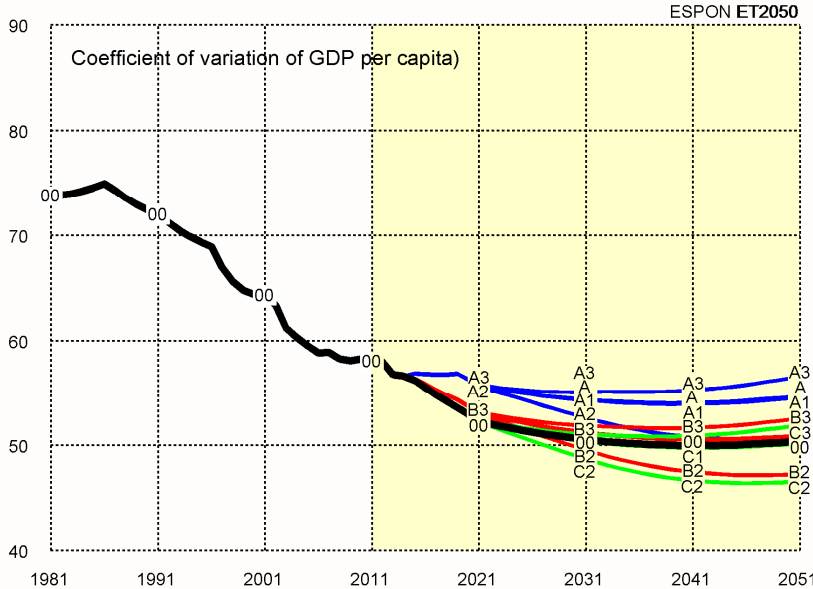
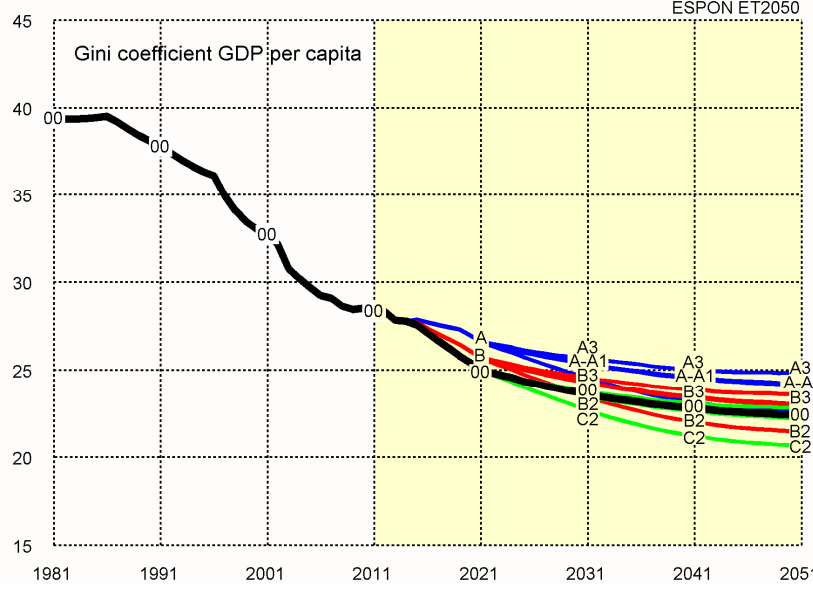


Figure 38. All scenarios: Gini coefficient of GDP per capita 1981-2051.



A final level of analysis addresses polycentricity, the stated goal of the European Spatial Development Perspective of 1999 and the Territorial Agenda of 2007 and the Territorial Agenda 2020. Figures 39 and 40 show national polycentricity calculated with the Polycentricity Index developed in ESPON 1.1.1. The index goes beyond conventional measures of polycentricity by considering three dimensions of polycentricity (see ESPON 1.1.1, 2005, 60-84):

- (1) *Size*: Population and GDP: not one too dominant city,
- (2) *Location*: Service areas: as equal as possible and
- (3) *Connectivity*: Accessibility: also secondary cities

Figures 39 and 40 show that there are great differences in the development of polycentricity between western and eastern Europe. While only small changes are observed in EU15 (Figure 39), polycentricity in the new member states of eastern Europe (EU12) declines dramatically because of the massive concentration of population and economic activity in their capital cities (Figure 40). The exploratory scenarios A and B and the economic decline and technological advance scenarios A1, A2, B1 and B2 reduce polycentricity in these countries, whereas the energy/climate scenarios A3, B3 and C3, which make long distances less affordable, and all C scenarios, which promote decentralisation, improve polycentricity.

Figure 39. All scenarios:
National polycentricity index
EU15 1981-2051

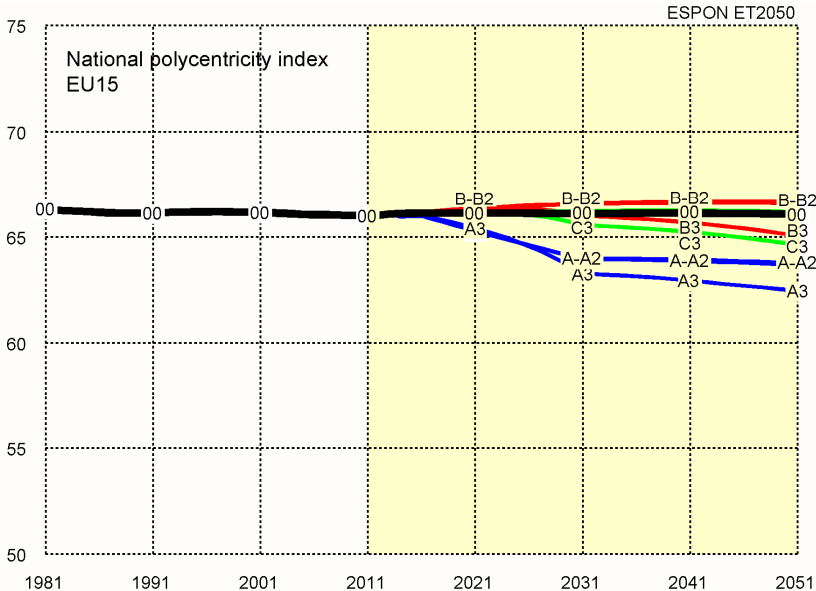
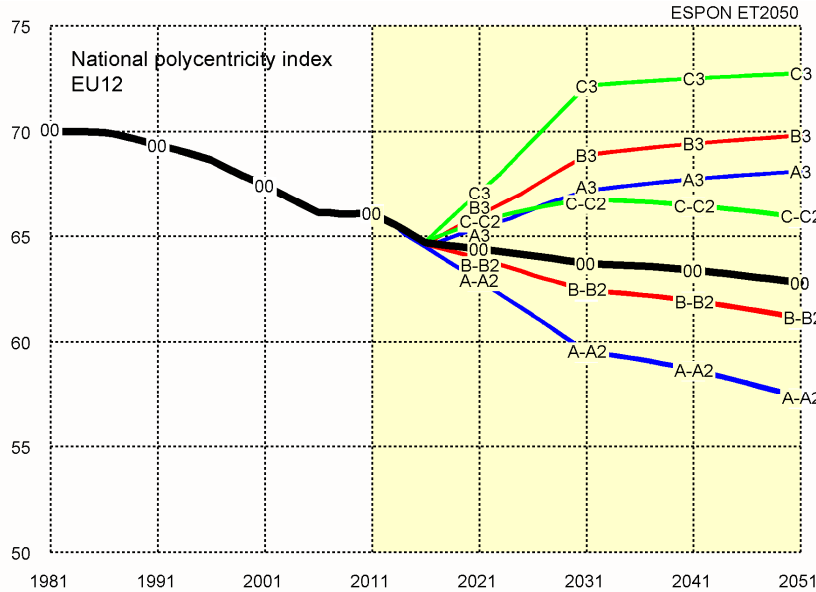


Figure 40. All scenarios:
National polycentricity index
EU12 1981-2051



The diagrams in Figures 41 and 42 show energy consumption and CO₂ emission of transport as possible indicators of the sustainability of the scenarios.

Figure 41 shows the vast difference in energy consumption per capita between road and rail transport. This is due to much larger share of road transport (see Figures 7 and 8) but also to the superior energy efficiency of rail (see Figure 9). The figure also shows the growth in energy consumption of road transport in the past due to rising transport volumes (see Figures 7 and 8) and the assumed stabilisation of energy consumption of road transport due to expected further increases of energy efficiency (see Figure 9). It is also apparent that the three exploratory scenarios lead to more traffic and hence more energy consumption, whereas the technology advance scenarios A2, B2 and C2 and the energy/climate scenarios A3, B3 and C3 lead to lower energy use per capita.

Figure 42 shows that this, in conjunction with a growing share of renewable energy leads to a reversal of the past trend of growing CO₂ emission of transport. By far the greatest energy saving effect have the fuel price increases in the energy/climate scenarios A3, B3 and C3 leading to less travel and goods transport by road and a decrease of CO₂ emission of transport by 50 per cent compared to 1990.

Figure 41. All scenarios:
Energy consumption by transport per capita per year (MJ) 1981-2051

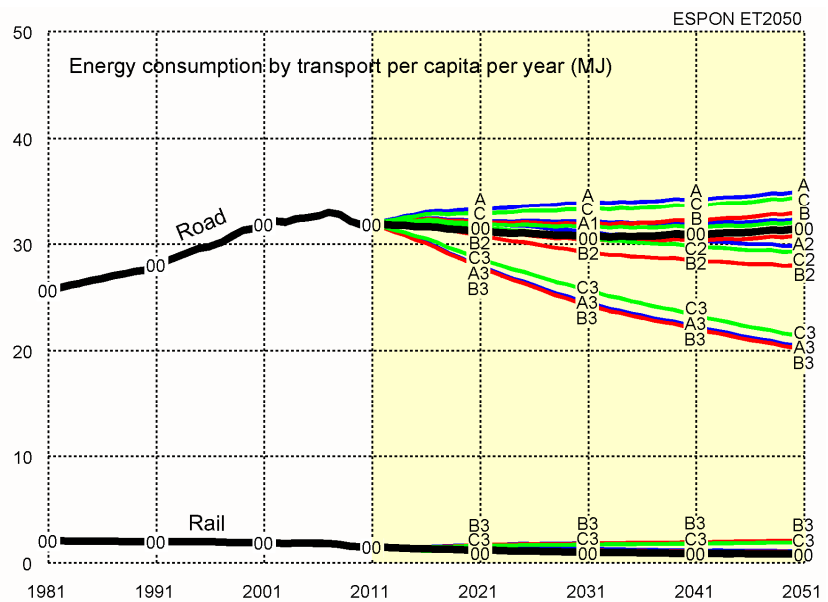
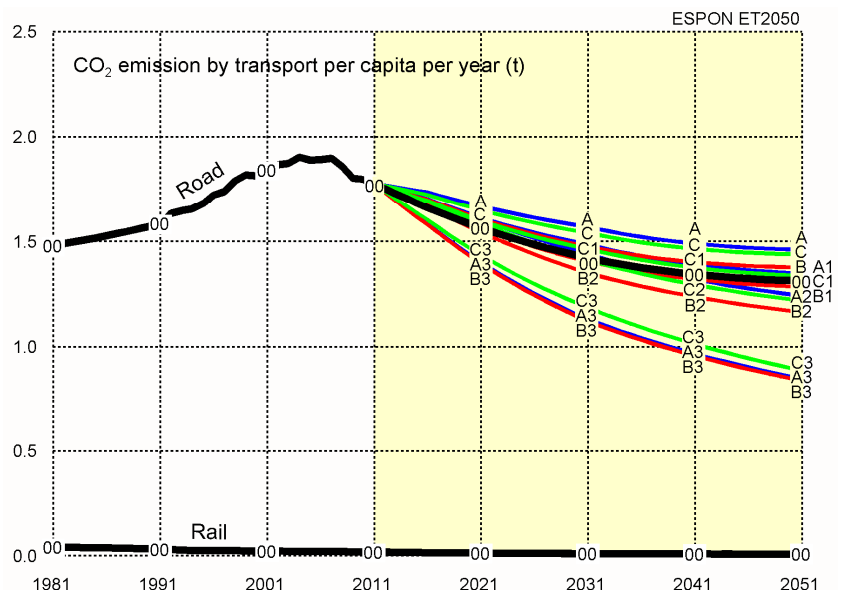


Figure 42. All scenarios:
CO₂ emission by transport per capita per year (t) 1981-2051



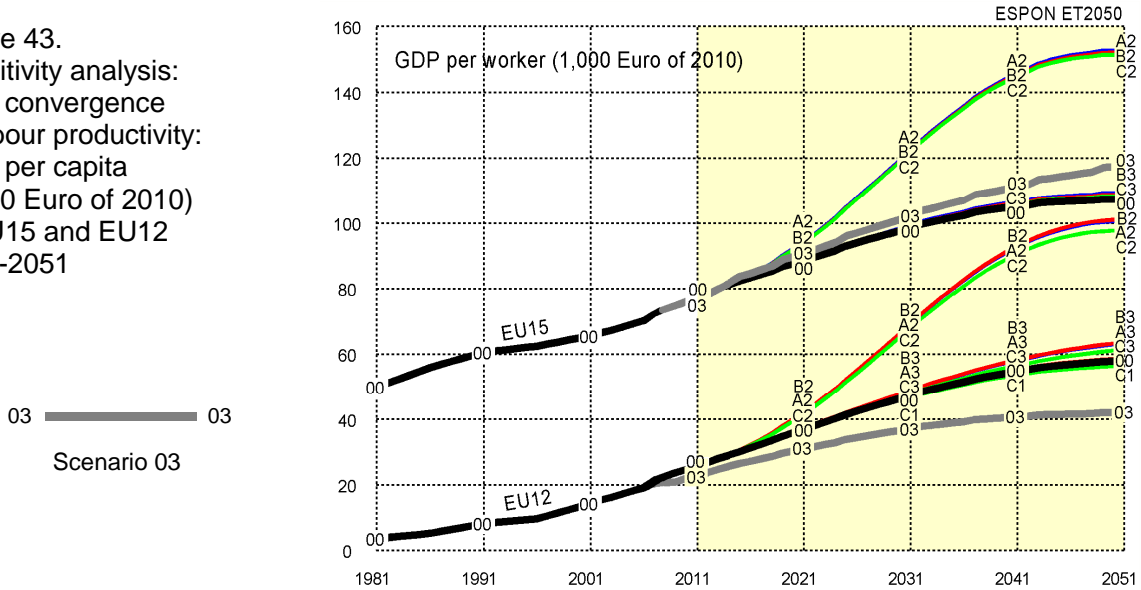
9. Sensitivity Analysis

The simulation results presented on the previous pages present an optimistic view of the future of the European project. It is built on the lessons from the past crisis and the confidence that efficient regulation of financial markets plus continuing solidarity transfers between EU member states will prevent a prolongation of the crisis. This implies the assumption that after the crisis traditional drivers of economic development, innovation, technological advance and hence productivity growth, will become again dominant. In addition, it is assumed that, as the majority of economists agree, through globalisation, free trade and open markets existing differences in productivity between countries are likely to converge – asymptotically, i.e. with decreasing speed as productivity becomes more similar.

To guard the simulations against possible doubts whether the assumptions about the future growth and convergence of productivity may be too optimistic, a sensitivity analysis was performed how the model results would be affected by more conservative assumptions about productivity convergence.

Figure 43 shows one example of several variants examined. In this example an additional Scenario 03 was simulated, in which productivity (GDP per worker) was assumed to converge only little. Advanced technologies remain concentrated in the technologically more advanced northern and western (EU15) countries with the effect of faster rising productivity there, whereas in the less advanced countries in central and eastern Europe (EU12) productivity is growing less. The heavy grey lines show the development of productivity in EU15 and EU12, respectively, compared with that in the other scenarios and scenario variants (cf. Figure 36).

Figure 43.
Sensitivity analysis:
Slow convergence
of labour productivity:
GDP per capita
(1,000 Euro of 2010)
in EU15 and EU12
1981-2051



Figures 44 and 45 show the impacts of the slower convergence of productivity. As to be expected, GDP per capita grows faster in the EU15 countries and more slowly in the EU12 countries, and this has negative consequences on territorial cohesion, as the Gini coefficient shows. What is more disturbing is that the *absolute* gap in GDP income or per capita (the grey area in Figure 43), which already grows with the more optimistic assumption about productivity convergence, opens up even more widely (cf. Figure 35). Therefore the assumptions about productivity convergence were left unchanged.

Figure 44.
Sensitivity analysis:
Slow convergence
of labour productivity:
GDP per worker
(1,000 Euro of 2010)
in EU15 and EU12
1981-2051.

03 ——— 03
Scenario 03

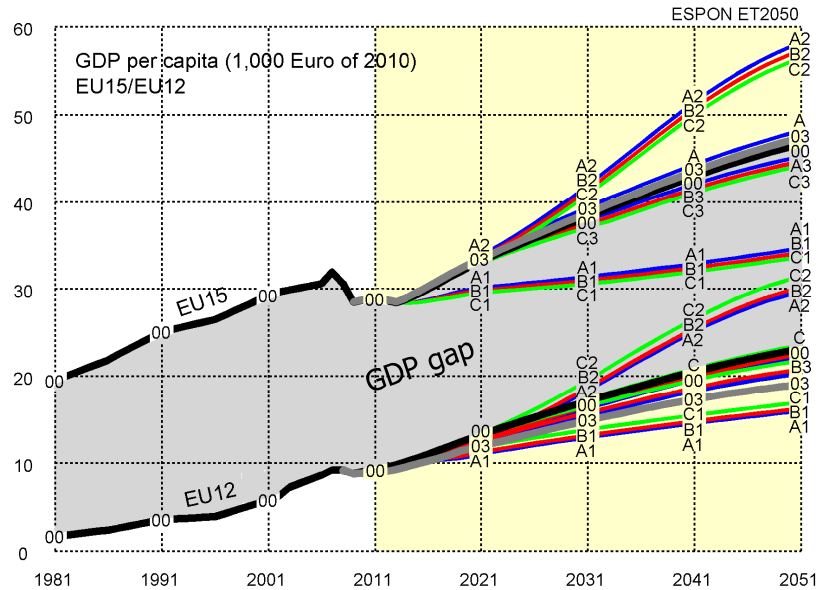
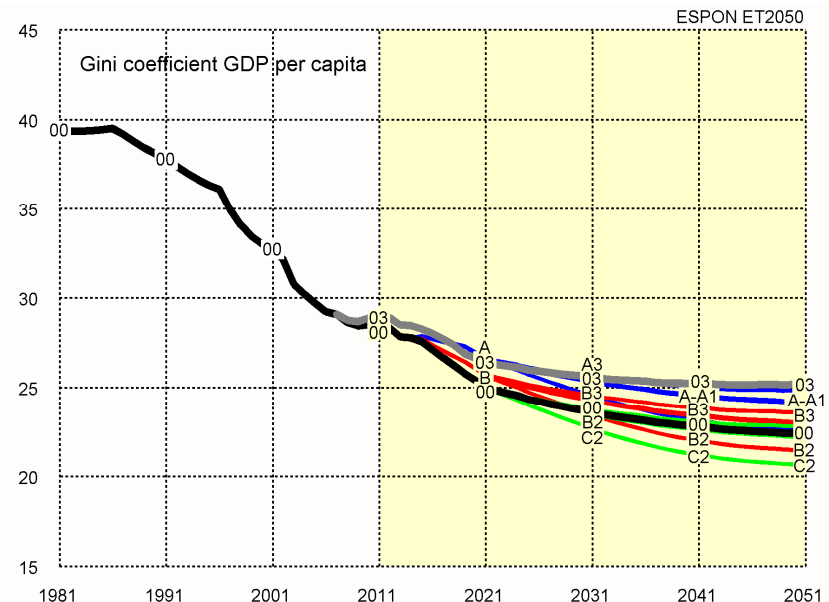


Figure 45.
Sensitivity analysis:
Slow convergence
of labour productivity:
Gini coefficient of GDP
per capita 1981-2051

03 ——— 03
Scenario 03



9. Conclusions

To summarise the results of the scenario simulations, relevant indicators of all scenarios relating to the EU goals competitiveness, cohesion and sustainability are compared in Table 6.

Obviously the comparison can only be performed within each group of framework conditions as the interest lies primarily in the impacts of EU spatial policies, i.e. subsidies and transport policies. But it is remarkable that the differences in competitiveness and cohesion are much larger between the different framework conditions than between the different spatial policies.

The spatial policies of the EU investigated make a difference of not more than 1.5 to 2.0 per cent of average GDP per capita per year. If one considers that this amounts to between 600 and 1,100 Euro per capita per year that may not be totally irrelevant. But, as the relatively low cohesion indicator shows, these benefits will not be distributed evenly but may be much larger in the regions being promoted and much lower in the remaining regions.

The comparison of indicators with respect to the three goals competitiveness, cohesion and sustainability within each group of framework conditions gives a straightforward result:

- *Competitiveness*: In each group the A scenarios (MEGAs) produce the largest generative effects in terms of GDP (the table cells shaded in blue). The C scenarios (Regions) perform worst in terms of overall European growth, and the B scenarios (Cities) lie in between.
- *Cohesion*: The performance of the scenarios in terms of cohesion is the opposite: The C scenarios (Regions) are more successful in cohesion and polycentricity (the table cells shaded in green), the A scenarios (MEGAs) score worst, and the B scenarios (Cities) lie in between.
- *Sustainability*: With respect to sustainability of transport, the B scenarios (Cities) are most successful (the table cells shaded in red). Under all framework conditions the A scenarios (MEGAs) and the C scenarios (Regions) use more energy for transport and produce more CO₂ emission of transport.

Table 6. Summary of SASI scenario results

Scenario	Competitiveness		Cohesion		Sustainability	
	GDP/capita (Euro of 2010) 2051	Change in GDP/capita 2013-2051 % p.a.	Coefficient of variation GDP/capita 2051	National polycentricity 2051	Energy use of transport (MJ/capita/y) 2051	CO ₂ emission by transport (t/capita/y) 2051
Baseline	42,897	+1.43	50.3	65.1	32.2	1.31
MEGAs A	43,988	+1.50	54.4	62.1	36.0	1.46
Cities B	43,463	+1.47	50.7	65.2	33.9	1.38
Regions C	43,078	+1.45	50.1	65.7	35.3	1.44
Economic recession A1	31,636	+0.63	54.6	62.1	33.2	1.35
B1	31,254	+0.59	50.8	65.2	31.6	1.28
C1	30,978	+0.57	50.2	65.7	32.8	1.34
Technology advance A2	53,548	+2.03	50.7	62.1	30.6	1.24
B2	52,922	+2.00	47.2	65.3	28.7	1.16
C2	52,436	+1.97	46.5	65.8	29.9	1.22
Energy/climate A3	41,190	+1.33	56.5	63.2	22.1	0.86
B3	40,810	+1.30	52.5	65.6	22.1	0.85
C3	40,571	+1.29	51.8	65.8	23.1	0.89

The simulated economic development over time (Figures 35 and 36) supports the hypothesis that the forces moving towards economic convergence are robust and will remain in effect after the economic crisis under a wide range of framework conditions. However, they will not be strong enough to remove the gap in income between the prosperous old member states in western and northern Europe and the economically lagging new member states in eastern and southern Europe (Figures 37 and 38). In this respect the A scenarios (MEGAs) performs worst and the C scenarios (Regions) best, with the B scenarios (Cities) in between.

The same holds for polycentricity at the national level, with remarkable differences between the old and new member states (Figures 39 and 40). In the old member states in western and northern Europe the impacts are modest, but in the new member states in eastern Europe they are large because of the growing centralisation of economic activities in their capital cities. As expected, the A scenarios and B scenarios lead to more spatial polarisation, except the energy/climate variants A3 and B3, whereas all C scenarios lead to more polycentricity.

In terms of sustainability all scenarios reflect the positive effects of rising energy efficiency and rising shares of renewable energy. But the most important message is that the political targets of the European Union and national governments to reduce CO₂ emission of transport can only be achieved if transport, in particular road transport, becomes more expensive, be it by rising energy prices, user fees or taxation. Under all framework conditions the B scenarios are more successful in reducing energy consumption and CO₂ emission of transport than the A and C scenarios.

In summary the scenario simulations point to the great importance of the framework conditions and policy scenarios in which the spatial scenarios are embedded. But within those contexts they confirm the importance of which regions are promoted with priority:

- Promotion of large metropolitan areas will maximise economic growth but increase spatial disparities and environmental damage.
- Promotion of rural and peripheral regions will increase spatial cohesion but reduce economic growth and sustainability.
- Promotion of large and medium-sized cities is a rational trade-off between competitiveness and cohesion and will be most successful in terms of sustainability.

This is one of the first studies confirming the claim of the European Spatial Development Perspective (ESDP) and the Territorial Agenda of 2007 and the Territorial Agenda 2020 that a polycentric spatial system of Europe would comply in a balanced way with the three major goals of the European Union, competitiveness, cohesion and sustainability.

These results strongly support the promotion of a balanced polycentric spatial organisation as proposed by the European Spatial Development Perspective and the two Territorial Agendas and suggest to take the B scenarios (Cities) as point of departure for the Territorial Vision.

A Territorial Vision for the European Union along these lines would be a unique and future-oriented alternative to the world-wide mainstream towards mega cities and ever more material growth, resource use and exploitation of the environment.

10. Further Research

Every modelling exercise is permanent work in progress Therefore the SASI team looks forward to using the experience of the ET2050 model application as a lesson to think about further model extensions and refinements. There are many possibilities of complementing and improvement of the SASI model. Only few can be listed here:

- (1) The collaboration with the authors of the MULTIPOLES model showed the utmost importance of the assumptions about future migration both into and out of the EU and inter-regional within the EU. This suggests to replace the current net migration submodel of SASI by the migration flow submodel developed in the ESPON Preparatory Study on the Feasibility of Flows Analysis (ESPON 1.4.4, 2007). This would include the explicit modelling of the barriers to immigration executed by many countries.
- (2) The collaboration with the authors of the MASST model taught the lesson that national policies are as least as important for the spatial development of Europe as European policies. This suggests to think about ways to incorporate into the SASI model assumptions about fiscal, regulatory and spatial policies.
- (3) The scenarios presented so far differ only in two types of policies, EU regional policy subsidies and transport policies, with everything else kept the same as in the Baseline Scenario. But there are other possible futures that may have a significant impact on the performance of the European spatial system, such as new social movements and new life styles.

- (4) In the energy and climate scenarios so far only transport prices were increased. It might be tested whether also generally rising energy costs and renewable energy aspects and building energy might be considered.
- (5) It might also be worthwhile to explore the impact of assumptions about the growth and decline of specific economic sectors beyond the six sectors agriculture, manufacturing, construction, trade/tourism/transport, financial services and other services presently addressed in the SASI model.
- (6) The work in the project revealed that the selection of secondary cities for the Cities (B) scenarios needs to be re-examined, in particular with respect to the representation of second-level cities in some of the new member states, such as Hungary, Estonia and Lithuania.
- (7) In addition results for the Western Balkan countries Albania, Bosnia and Herzegovina, Croatia, Kosovo, Former Yugoslav Republic of Macedonia (FYROM), Montenegro and Serbia, including the new EU member state Croatia, which are part of the total model region, might be included in the published results.

References

dena - Deutsche Energie-Agentur (2012): *Verkehr. Energie. Klima. Alles Wichtige auf einen Blick*. Berlin: dena,

ESPON 1.1.1 (2005): *Potentials for Polycentric Development in Europe*. ESPON 1.1.1 Final Report. http://www.espon.eu/main/Menu_Projects/Menu_ESPON2006Projects/Menu_ThematicProjects/polycentricity.html.

ESPON 1.4.4 (2007): *Study on the Feasibility of Flows Analysis*. ESPON 1.4.4 Final Report. http://www.espon.eu/main/Menu_Projects/Menu_ESPON2006Projects/Menu_StudiesScientificSupportProjects/flows.html

European Commission (1999): *ESPD – European Spatial Development Perspective: Towards Balanced and Sustainable Development of the Territory of the European Union*. Luxembourg: Office for Official Publications of the European Communities. http://ec.europa.eu/regional_policy/sources/docoffic/official/reports/pdf/sum_en.pdf

European Commission (2007): *Territorial Agenda of the European Union: Towards a More Competitive and Sustainable Europe of Diverse Regions*. Lisbon: Cooperation for Territorial Cohesion of Europe. <http://www.eu-territorial-agenda.eu/Reference Documents/Territorial-Agenda-of-the-European-Union-Agreed-on-25-May-2007.pdf>

European Commission (2008): SFC2007 Database: System for Fund Management in the European Community: Structural Funds Allocations Estimates NUTS-2 2007-2013. http://ec.europa.eu/employment_social/sfc2007/index_en.htm

European Commission (2011): *Territorial Agenda 2020 – Towards an Inclusive, Smart and Sustainable Europe of Diverse Regions*. Budapest: Hungarian Presidency of the Council of the European Union. <http://www.eu2011.hu/files/bveu/documents/TA2020.pdf>

European Commission (2012a): *The 2012 Ageing Report. Economic and Budgetary Projections for the 27 Member States (2019-2060)*. European Economy 2/2012. Brussels: DG Economic and Financial Affairs and Economic Policy Council. http://ec.europa.eu/economy_finance/publications/european_economy/2012/pdf/ee-2012-2_en.pdf.

European Commission (2012b): *Eurostat Population Projections 2010-based (EUROPOP 2010): Methodology and results of demographic convergence*. Luxembourg: Publications Office of the European Union.

European Commission (2012c): TREMOVE: an European-wide Transport Model. <http://www.tremove.org>.

European Union (2012): EU Transport in Figures. Statistical Pocketbook 2012. Luxembourg: Publications Office of the European Union

IEA – U.S. Energy Information Administration (2012): *Annual Energy Outlook Early Review Overview*. http://205.254.135.7/forecasts/aeo/er/early_prices.cfm

Randers, J. (2012): *2052: A Global Forecast for the next Forty Years*. White River Junction, VT: Chelsea Green Publishing.

POLIMI (2014): *Economic Trends and Scenarios*. ESPON ET2050 Scientific Report, Volume 3. Milan: Politecnico di Milano.

S&W (2013): SPQR: SASI. Integrated Spatial Development Model. http://www.et2050.eu/forecast/SASI_Model_SPQR_040613_V5.doc

Wegener, M. (2008): *SASI Model Description*. Working Paper 08/01. Dortmund: Spiekermann & Wegener Urban and Regional Research. http://www.spiekermann-wegener.de/mod/pdf/AP_0801.pdf.

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

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