# A high-speed train scenario for central Europe: Some long-term regional growth forecasts

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## Abstract

The implementations of high-speed train networks (HST) in Europe have stimulated new traffic planers as how to connect the new accession states of the EU to the existing networks in the EU-15. But the costs of new traffic infrastructure is high and will be only justified if there are wide spread and long ranging economic advantages associated with such investments.

We develop a multi-country regional model to forecasts growth for the year 2002 if a HST corridor is implemented between Berlin and Budapest. We estimate a dynamic panel model with spatial effects and spatial explanatory variables. The spatial dimension is based on distances between 227 regions in central Europe and the travel time matrix reflects the travel time improvements between regions when the HST network will be in place. Several traffic induced regressor variables are driving the forecasts: a) average past growth rates, weighted by travel times, b) average travel times across regions (made comparable by index construction), c) potential variables based on GDP per capita, employment, productivity and population and finally d) dummy variables plus other socio-demographic variables will control for country differences.

We find that HST accessibility will improve regional growth in the majority of the regions for the year 2020 along the HST corridor and the cone around it. But there are regional differences as what regions will benefit and the response is different for GDP, employment, and population.

Keywords: Dynamic panel models, long-term regional growth forecasts, BMA inference, traffic sensitivity analysis, accessibility and train travel times.

# 1. Introduction

In the last decades, Europe has seen an increasing network of high-speed trains (HST), with rather independent networks in France, Germany, Italy and Spain[1]. There exist only a few - and then mainly national - studies how transportation infrastructure and economic activities are linked or co-develop. A backbone for this co-development of economic activities and traffic in the early EU-6 was the so-called blue banana, stretching from Amsterdam to Milan. Now with the east expansion of the European Union traffic planers have come up with the idea to develop a second “banana”, i.e. a traffic backbone in Central Europe, extending from Berlin to Budapest (which could even extended later to Saloniki, Greece)[2], If such a project would be realized by a HST corridor what would be the effect on economic growth in these countries? This paper tries to answer this question by developing a multi-country regional econometric model emphasizing traffic and accessibility.

Long-term forecasting in Central Europe is a big challenge for traffic planning, since usually only a few years of panel data are available since the fall of the iron curtain and the economic growing together of east and west in Europe. Furthermore, traffic dependent models must be developed to explore the sensitivity of traveling times on the socio-demographic variables of a region. Using the sophisticated model choice procedure BMA (Bayesian model averaging, see Raftery et al. 1997) for the entire regional data set we have successfully reduced the pool of variables and we are able concentrate solely on demo-economic variables with traffic related backgrounds.

We consider two types of forecasts (with or without country-wise adjustments) and 2 railway travel time (TT) scenarios: scenario 3 assumes that a high-speed project will be realized between Berlin and Budapest. Scenario 4 assumes a best compromise between conventional and high-speed projects for the decade from 2010 to 2020: The best cost effective high-speed project is combined with the best conventional projects from Scenario 1 and 2.

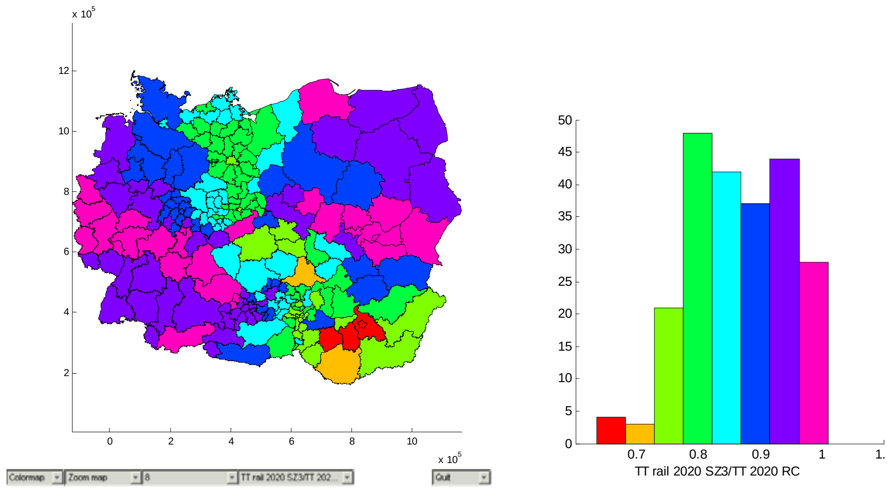
We will forecast the 3 main economic characteristic variables of a region, namely the GDP growth rates, the employment rate and the population growth rate.

[1] France’s TGV was extended to Switzerland, and Germany’s ICE to Switzerland and Austria in the 1990s.

[2] The new central European accession countries that joined the EU on May 1st 2004 are: Poland, Czech Republic, Slovakia, and Hungary. Note that the extension of the corridor to Greece would include the countries Croatia, Serbia, and the Macedonian Republic, which are not currently members of the EU, while Slovenia would be reached not directly.

In the remaining Section 1 we introduce the regional modeling approach and in Section 2 describe the traffic dependent GDP growth model. We define all the "spatial" related regressor variables that pick up the space and traffic interactions between all regions. Then we present the sensitivity analysis based on the long range forecast and the traffic improvement scenarios 3 and 4. Section 3 and 4 extends this approach to the modeling and forecasting of the employment growth rate (EMPL%) and the population growth rate (POP%). A final section concludes.

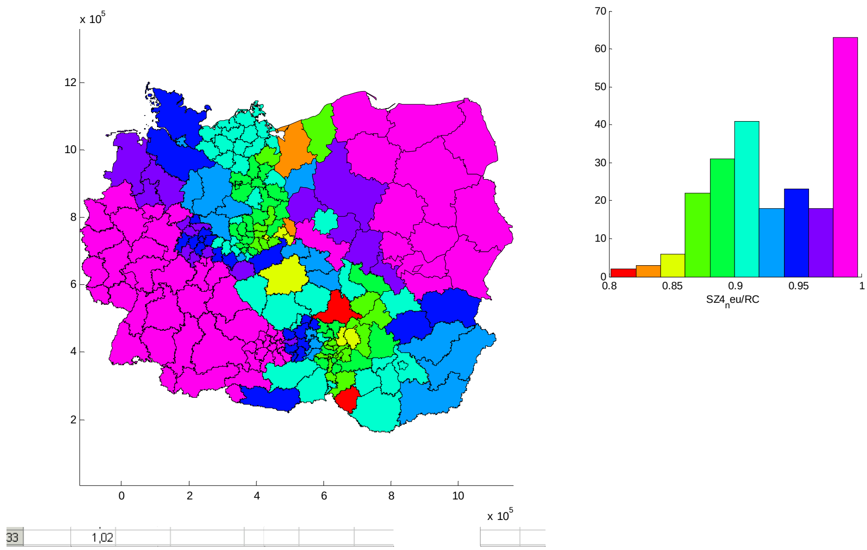
*Chart 1.1: The percentage of travel time reduction between the two train TT scenarios, i.e. TT3/TT1*




*Note: Scenario 1 (TT1 or "reference case") and Scenario 3 (TT3 or high speed train). Legend of the histogram: 5 classes of reduction from 0.9 (10% reduction in red) to 0.98-1.0 (small reduction, dark blue).*

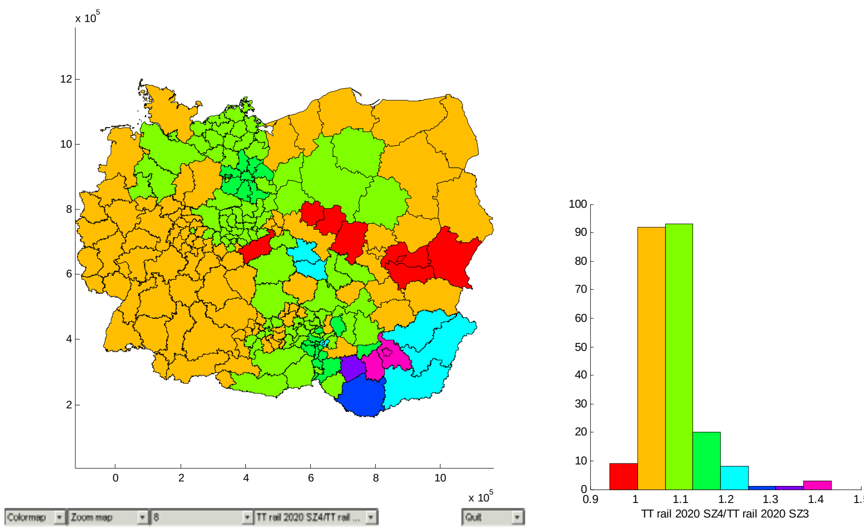
Chart 1.1 shows the potential travel time reductions for the high-speed scenario (TT3) over the reference scenario (TT1). Now the corridor between Berlin and Budapest becomes clearly visible. Left and right off the corridor the TT improvements will be small. The highest TT reduction can be seen for Budapest and the surrounding regions, which improve by more than 30%.

*Chart 1.2: The percentage of travel time reduction between the two train TT scenarios, i.e. TT4/TT1*




*Note: Scenario 1 (TT1 or "reference case") and Scenario 4 (TT4 or "high speed light scenario"). Legend of the histogram: 5 classes of reduction from 0.9 (10% reduction in red) to 0.98 - 1.0 (small reduction, dark blue).*

*Chart 1.3: The percentage of travel time reduction between the two high-speed train TT scenarios, i.e. TT4/TT3*




Note that the "high-speed light" scenario will not bring many time improvements, except for some regions along the "via regia to Kiev" in Upper Silesia and Southern Poland, because of a cross connection between Dresden (the high speed node) and Krakow.

Two types of forecasting methods were used: a) adjusted forecasts: growth in all regions of a country was restricted so that an average predicted growth was maintained in each country and b) unadjusted forecasts: growth prediction without country-specific restrictions.

## 1.1 The regional growth model

The econometric model uses a dynamic panel model and data set for period 1995-2001 in 227 regions of 6 countries, where the main focus regions are located between Berlin and Budapest and consists of NUTS-3-regions, while most of the regions outside this proposed new traffic corridor are measured at NUTS–2-level. We use a Barro and Sala-i-Martin (1995) type growth regression model allowing for convergence, and the convergence term in the regression consists of the levels of the dependent focus variables, i.e. GDP, employment (EMPL) and population (POP) in the year 1995 (i.e. the first year of the data base of the present study). The dependent variable is the growth rates for the 3 focus variables: (real) regional GDP growth (GDP%, discounted by the national inflation rate), the employment rate (EMPL%) and the population growth rate (POP%).

We started with a traditional spatial model with up to 6 nearest neighbors, but we soon found out that - for traffic purposes - the transformation to special (= spatial) regression variables has more explanatory power. These linear and non-linear transformations are possible in our case since we obtained travel time (TT) matrices for train and road networks between all 227 regions. In the BMA analysis all the newly created TT and traffic variables were selected more often than traditional spatial variables, based on neighborhood (continuity) or distance (or nearest neighbors).

The following groups of explanatory variables were used in the forecasting model and in the preceding model choice procedure (BMA, see Raftery et al. 1997):

Traveling times (TT) between 227 regions for the year 2000 (in the matrix TT1) and the year 2020 (in the matrix TT2).

Average travel times: a) average TT, b) weighted TT: with distance ("Far index") and with inverse distance ("Near index"), c) harmonic means, d) speed averages.

Accessibility indices: Based on the TT on road and on train we calculated an index with minimum 0 and maximum 1. This index is constructed either for the whole area (all) or the normalization in each country.

Potential indices: based on the gravity formula of Newton A*B/ D, where A and B denote the variables for the origin region and destination regions, and D is a distance measure. The following variables were used: GDP, GDP per capita (GDPpc), employment, population, productivity: GDP per worker (GDPpw)[3].

Infrastructure variables: a) the number of highway entrances per highway (Autobahn) km, b) the number of railway stations per rail km, c) the length of highway net per square-km and the length of railway net per square-km.

TT adjusted growth rates: Only past average weighted growth rates were calculated where we used the train TT or the road TT as weights.

## 1.2 The sensitivity analysis

The sensitivity analysis is needed to show the dependence of the regional growth rates on the TT of the variables on the right hand side that enter in linear and non-linear form. For the sensitivity analysis we use the models estimated by the BMA method since we selected trough this method the best regressor variables

[3] The exact formula is $x_i = \Sigma_j \, a_i b_j / d_{ij}$

using the Scenario 1 rail travel times. With this model we calculate iteratively the future growth rates and the level of the dependent variable in the model until the year 2020. (Note that the model is specified in a causal way, i.e. no contemporaneous regressor variables are allowed.) The alternative forecasts for Scenario 2 are calculated in the same way. Finally, we compare both forecasts for the year 2020 and calculate the difference as percent of the Scenario 1 forecasts. These differences are plotted by geographical maps to see where the strongest positive and negative effects can be expected. This approach is called the unadjusted sensitivity analysis.

We derived also an "adjusted" sensitivity analysis, by looking at the country averages of forecasts and then we demand that the pattern of changes of the forecast model is zero over all regions within a country. This approach shows a special sensitivity pattern without international boundary spill-overs that means all push and pull effects of growth rates are equalized in each country.

## 1.3 Caveats

To make the results of the sensitivity analysis visible we have employed statistical maps as a graphical visualization technique for the 227 regions. The advantage is that a large amount of data information can be understood faster than studying tables, but the disadvantage is that graphics stir up many more questions of the type "Why do we see these differences?" Thus, we have to warn the reader that not all of these questions can be answered satisfactory. Some differences will be due to occasional bad regional observations or data quality, some due to misfits of the model and some will be just unexplainable. We have followed the rule that the total graph has to reflect and present a sensible picture to justify our modeling approach.

Furthermore we want to emphasize that we focus on a regional model where the regressor selection was done in such a way as to maximize the possible influence of train TT. This approach was chosen, since it was clear that traffic impacts, especially for train travel times on growth will be generally small. Thus, an "optimal regional growth model" will probably give slightly different results; also a model that will be based solely in road travel times or both. (Note that the interaction between the road TT and train travel times needs also some special studies).

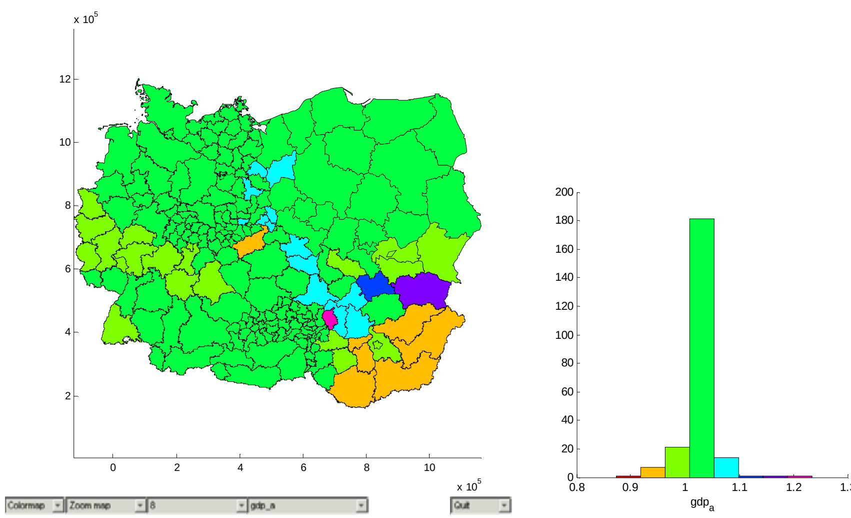
Therefore we recommend regarding our study as a magnifying glass of train TT on regional growth patterns, while the other (observed and non-observed) factors are more or less kept constant.

## 2. The GDP growth (GDP%) model with spatial traffic interactions

The sensitivity analysis of the travel time induced GDP forecasts for the year 2020 is shown in Charts 2.1.a to 2.3.a for the adjusted model and for the un-adjusted model in Charts 2.1.b to 2.3.b.

*Chart 2.1.a The adjusted model: The differences between GDP levels for the TT3 and TT1scenarios is computed in ratios.*

Ich habe Zweifel dass diese Grafik stimmt WP14..8.



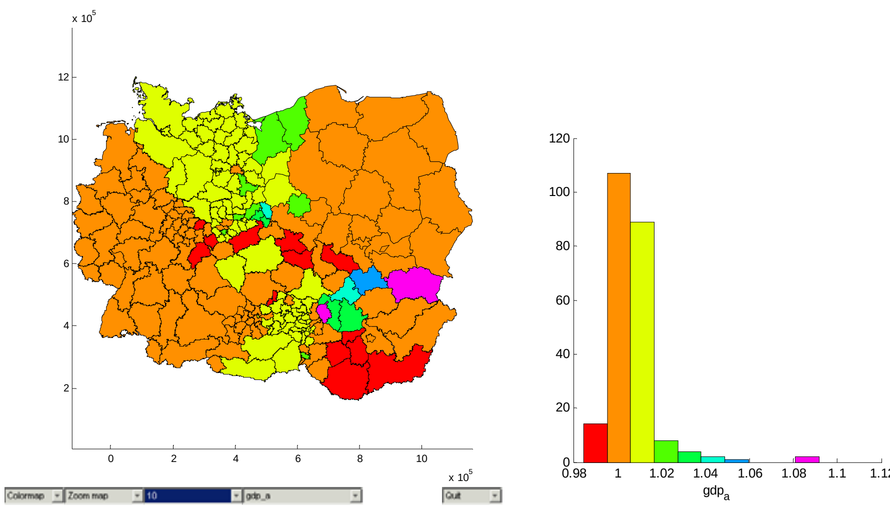

*Color legend: green: no growth, orange/red: negative growth, blue: positive growth.*

*Summary of the sensitivity analysis for the adjusted model:* We see that the GDP levels between the reference scenario and scenario 3 is …….

A regional map of the sensitivity analysis is shown in Chart 2.1.a for the scenario “high speed trains” (i.e. from Berlin to Budapest) given by the matrix TT3 in comparison with the present (planned and realized 2000-2010) rail travel times, given by the matrix TT1. Let us denote by GDP2020(TT1) the GDP forecasts for the year 2020 by the TT1- matrix and GDP2020(TT3) for the TT3 matrix. We have plotted the Ratio_GDP variable, i.e. the relative change of the GDP levels for 2020 based on 2 train travel time matrices, according to the formula:

Ratio_GDP = GDP2020(TT3)/GDP2020(TT1).

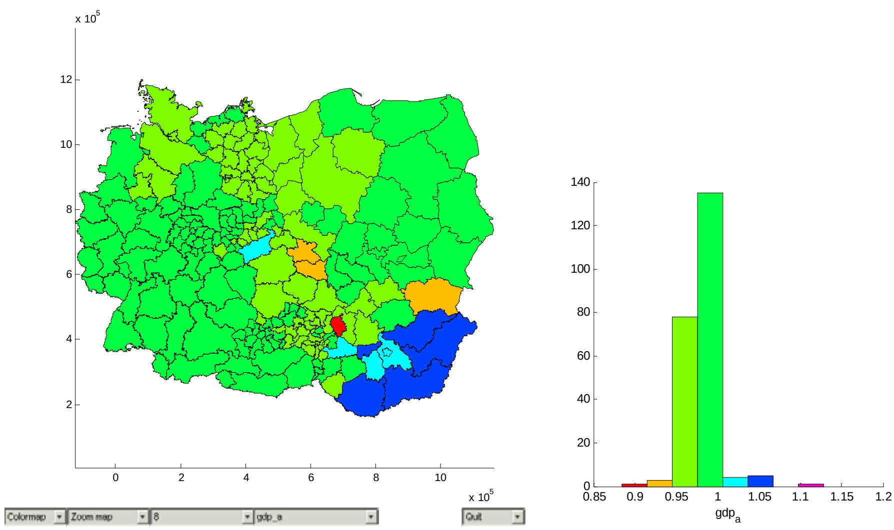
*Chart 2.2.a The adjusted model: The differences between GDP levels for the TT4 and TT1 scenarios is computed in ratios of the levels for 2020*




*Color legend: orange: no growth, red: negative growth, green/blue: positive growth.*

Chart 2.2.a shows that across the corridor we will see an increase in GDP in the regions between Hamburg and Bratislava. Interestingly, we see that southern Hungary might not be on the winning side, but instead, the north-south regions in Austria starting from Vienna will benefit.

*Chart 2.3.a The adjusted model: The differences between GDP levels for the TT4 and TT3 scenario is computed in ratios.*



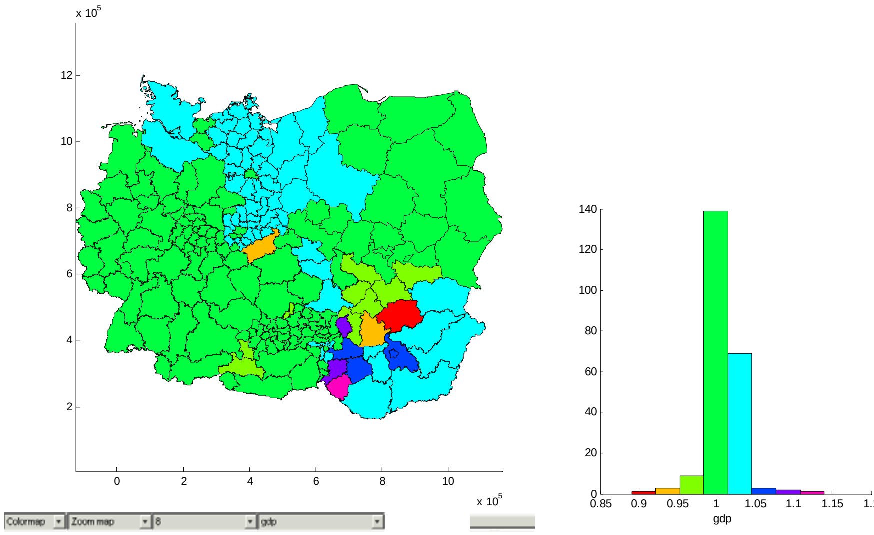

*Colour legend: green: no growth, red: negative growth, blue: positive growth.*

*Table 2.1: Scenario sensitivities: The top and low region of GDP growth rate differences 2020*

a) From the adjusted models

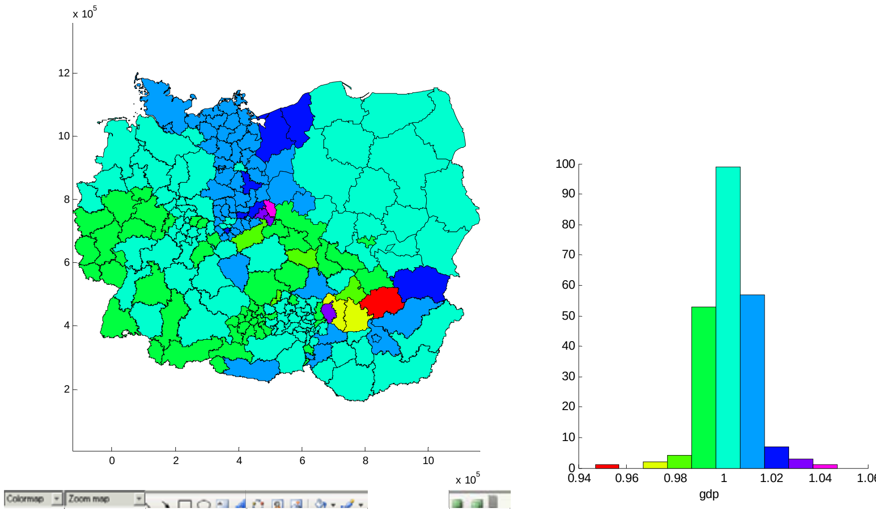
b) From the unadjusted model

*Chart 2.1.b Scenario 3/1 differences of the unadjusted GDP model: The ratios between TT3 and TT1 GDP levels.*



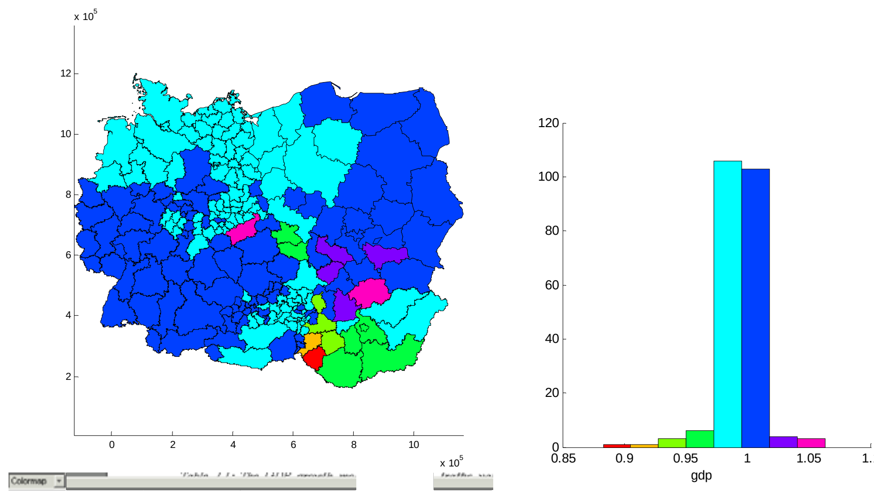

*Color legend: green: no growth, red: negative growth, blue: positive growth.*

*Chart 2.2.b Scenario 3/4 differences of the **un**adjusted GDP model: The ratios between TT4 and TT1 scenario GDP levels.*




*Color legend: green: slight negative growth, red: strong negative growth, blue: zero and positive growth.*

*Chart 2.3.b  Scenario 3/4 differences of the **un**adjusted model: The ratios between TT4 and TT3 scenario GDP levels.*




*Color legend. green: slight negative growth, red: strong negative growth, blue: zero and positive growth.*

*Summary of the sensitivity analysis for the unadjusted model: From* Chart 2.3.b we see that the Hungarian regions will be most affected while the regions in the shadow of the cone (SW and West Germany, NE Poland and East Slovakia) will no benefit.

The next Table 2.1 summarizes the BMA estimates for the GDP% model.

*Table 2.1: The GDP growth model and spatial traffic variables (BMA estimates)*

| | | | |
|---|---|---|---|
| Bayesian Model Averaging Estimates | Nobs= 227, | Nvars = 20 | |
| Dependent Variable GDP%: | Average GDP | growth rates | (1995-2001) |
| R-squared = 0.886 | | | |
| nu,lam,phi = (4, 0.25, 3)) | ndraws = 25000 | | |
| # models visited | = 2249 | | |

| ****************************** Posterior Estimates | | | |
|---|---|---|---|
| Variable | Coefficient | t-statistic | t-probability |
| const | -0.017 | -0.9 | 0.35 |
| Lgdp.1995 | -0.011 | -8.4 | 0.00 |
| Lgdp.giTT.rail.96 | -2.289 | -5.5 | 0.00 |
| Lgdp.giTT.rail.97 | -0.024 | 0.0 | 0.98 |
| Lgdp.giTT.rail.98 | 0.059 | 0.3 | 0.74 |
| Lgdp.giTT.rail.99 | -0.003 | 0.0 | 1.00 |
| Lgdp.giTT.rail.00 | 0.086 | 0.3 | 0.76 |
| Lpop.95 | 0.009 | 7.6 | 0.00 |
| Lempl.00.95 | 0.388 | 7.7 | 0.00 |
| Lpop.00.95 | 0.289 | 4.2 | 0.00 |
| nodes.per.highway.km | 0.015 | 2.9 | 0.00 |
| TT.train.far | 0.176/1000 | 11.7 | 0.00 |
| acc.all.bahn.dist.avg | 0.048 | 12.2 | 0.00 |
| potential.gdp.empl.00.95.rail | 0.123 | 9.0 | 0.00 |
| potential.all.empl.95.rail | 0.015 | 5.4 | 0.00 |
| potential.all.gdp.cap.00.95.rail | 0.153 | 11.3 | 0.00 |
| d.aut | 0.000 | 0.0 | 0.96 |
| d.sk | -0.021 | -7.2 | 0.00 |
| d.hu | 0.000 | 0.0 | 0.97 |
| d.ger | 0.000 | -0.2 | 0.81 |
| d.pl | -0.001 | -0.4 | 0.71 |

From Table 2.1 we see that the BMA estimate for the constant is not significant, and the Slovakia dummy variable is the only fixed effect that is negative (-2.1%). That means that Slovakia has a -2.1% base line handicap for regional growth, on average in our model. Slovakia needs strong positive impulses from other variables to overcome this GDP growth handicap compared with the other 5 countries. The convergence effect for the log GDP level is negative (Lgdp.1995: -.011), but the level effect of (log) population is positive (Lpop.95: .01).

The coefficients of the past POP and EMPL growth rates are both positive and between 0.29 and 0.39: this implies that a 3 % growth rate in either employment or population will result in a 1 % larger GDP growth rate.

Three out of the 5 inverse-travel-time weighted past EMPL growth rates are negative, and all of them are rail TT effects. The sum of these effects is – 2.2 that show a strong negative time dynamic component that was observed for GDP growth in the late 90s. The long distance weighted TT variable for railways and the accessibility index based on train TT (acc.all.bahn.dist.avg: 0.048) have a positive influence and might be interpreted as a good transportation proxy variable (TT.far.train: 0.176). All potential variables have a positive effect, and all are based on rail TT. A significant potential effect is found for the change of the GDP per capita (potential.all.gdp.cap.00.95.rail), for productivity changes (GDP/ employment: potential.gdp.empl.00.95.rail), and for the employment potential (potential.all.empl.95.rail).

# 3. The employment growth (EMPL%) model with spatial traffic interactions

The Bayesian model averaging estimates for the EMPL% model are given in Table 3.1.

*Table 3.1 EMPL growth model and spatial traffic variables (BMA estimates)*

| | | | |
|---|---|---|---|
| Bayesian Model Averaging | Estimates | | |
| Dependent Variable: EMPL%, | Average GDP | growth rate | (1995-2001) |
| R-squared | = 0.849 | | |
| Nobs= 227 | Nvars = 23 | | |
| ndraws | = 25000 | | |
| nu,lam,phi | = (4., 0.25, 3) | | |
| # models visited | 589 | | |
| ********************************* | Posterior Estimates | | |
| Variable | Coefficient | t-statistic | t-probability |
| const | 0.020 | 1.6 | 0.11 |
| Lempl.95 | -0.010 | -9.8 | 0.00 |
| Lempl.gTT.road.99 | -1.019 | -2.8 | 0.00 |
| Lempl.giTT.rail.00 | -2.206 | -4.4 | 0.00 |
| Lempl.giTT.road.00 | 0.798 | 2.4 | 0.02 |
| Lgdp.95 | 0.011 | 9.9 | 0.00 |
| Lgdp.01.95 | 0.486 | 10.6 | 0.00 |
| Lpop.00.95 | 0.481 | 8.1 | 0.00 |

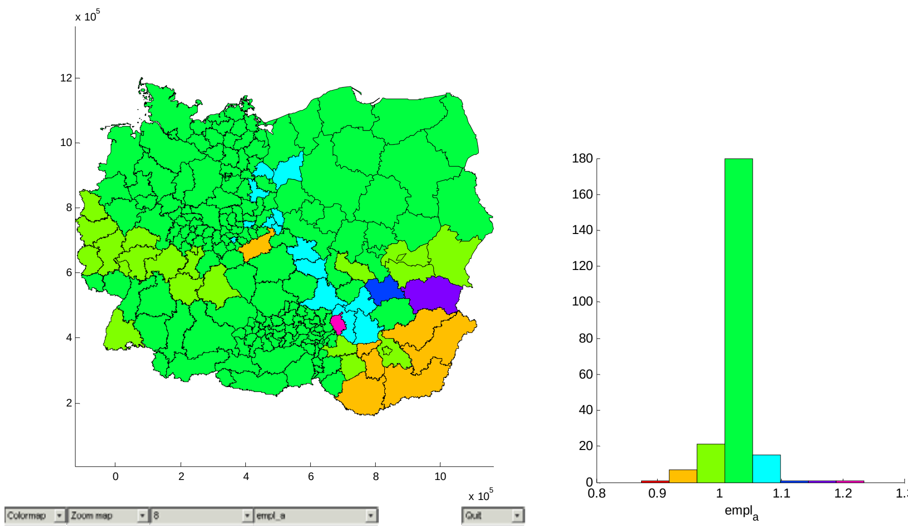
| | | | |
|---|---|---|---|
| TT.train.far | -0.000075/1000 | -5.2 | 0.00 |
| acc.all.bahn.dist.avg | -0.023 | -5.5 | 0.00 |
| potential.gdp.cap.95.rail | 0.012 | 4.9 | 0.00 |
| potential.empl.95.road | -0.007 | -3.3 | 0.00 |
| potential.gdp.00.95.rail | -0.298 | -5.3 | 0.00 |
| potential.gdp.cap.00.95.rail | 0.310 | 8.7 | 0.00 |
| potential.gdp.cap.00.95.road | -0.101 | -3.6 | 0.00 |
| potential.gdp.empl.00.95.rail | -0.247 | -14.8 | 0.00 |
| potential.gdp.empl.00.95.road | 0.140 | 6.2 | 0.00 |
| potential.all.gdp.00.95.rail | 0.187 | 3.9 | 0.00 |
| potential.all.gdp.cap.00.95.rail | -0.143 | -5.2 | 0.00 |
| d.aut | -0.001 | -0.2 | 0.85 |
| d.sk | 0.024 | 9.6 | 0.00 |
| d.hu | 0.000 | 0.1 | 0.91 |
| d.ger | -0.001 | -0.4 | 0.70 |
| d.pL | 0.001 | 0.3 | 0.76 |

From Table 3.1 we see that the $R^2$ is 0.85 and quite high. The intercept is 2% and not different from zero: this shows that the regressors of the model are able to explain much of the GDP growth variation (and a little insignificant constant is present). Concerning the country fixed effects; only Slovakia is significant and has on average a 2.4% higher growth in employment. The convergence coefficient of the log employment level (Lempl.95) is significant and negative as expected, while the level effect of log GDP (Lgdp.95) is positive and about the same size as the initial employment (Lempl.95) coefficient. The coefficients on the GDP and population growth rates (Lgdp.01.95 and Lpop.00.95) are both positive and almost 0.5: This implies that a 2% growth rate in GDP or population will result in a 1% larger EMPL growth rate.

Surprisingly, the inverse rail TT weighted past EMPL growth rates are negative, also the coefficient of the road TT effects, although the sum of the effects of the growth rates on roads (short and long distance weighted) for the years 2000 and 1999 is small negative (Lempl.gTT.road.99 and Lempl.giTT.road.00).

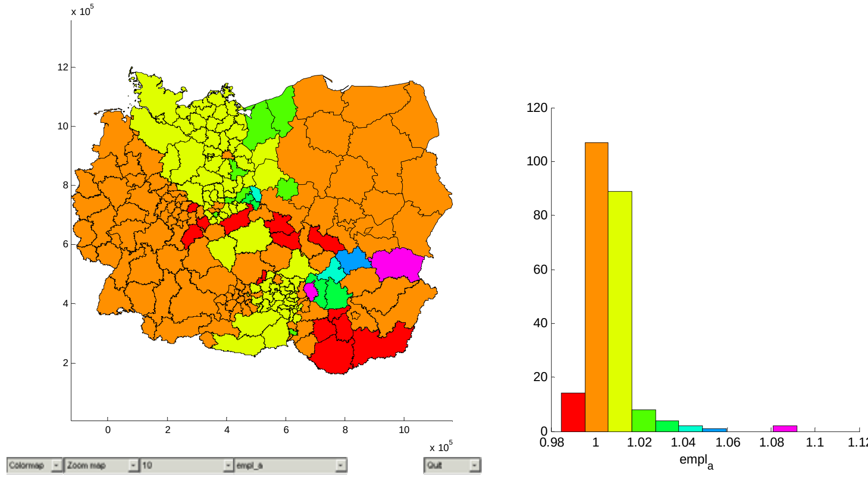
The, long distance weighted travel time for railways (TT.far.train) has a positive influence and might be interpreted as a good transportation proxy variable, while the effects of the 9 potential variables is quite mixed. The potential variables of GDP per capita (potential.gdp.cap.95.rail) have a positive effect, surprisingly many negative potential effects are found for rail TT potentials. But the highest positive potential effect is found for the change of the GDP per capita potentials for trains (potential.gdp.cap.00.95.rail: 0.31). This reflects some kind of complex interactions in the potential variables and furthermore, that the rail and road travel times have different effects on the regional growth rates when combined with macro economic indicators.

*Chart 3.1.a Scenarios 3/1 differences of the adjusted employment model: The between TT1 and TT3 employment levels.*



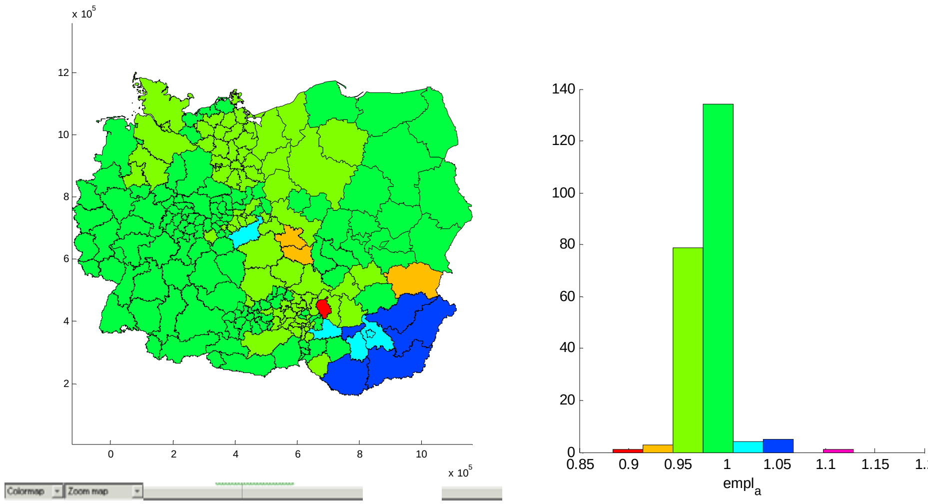

*Color legend. red and orange: strong negative growth, ligthgreen: slight negative growth or zero growth, green and ligthblue : slight positive growth, dark blue, purple and pink: strong positive growth.*

*Chart 3.2.a Scenario 4/1 differences of the adjusted employment model: The ratios between TT1 and TT4 scenario employment levels.*




*Colour legend: red: -2-3%-points, yellow –1-2%-points, green: -1 to 0 % points, blue 0 to 1%-points, and violet 1 to 2%-points.*

*Chart 3.3.a Scenarios differences of the adjusted employment model: The ratio between TT3 and TT4 employment levels.*




*Color legend: red: -2-3%-points, yellow –1-2%-points, green: -1 to 0 % points, blue 0 to 1%-points, and violet 1 to 2%-points.*

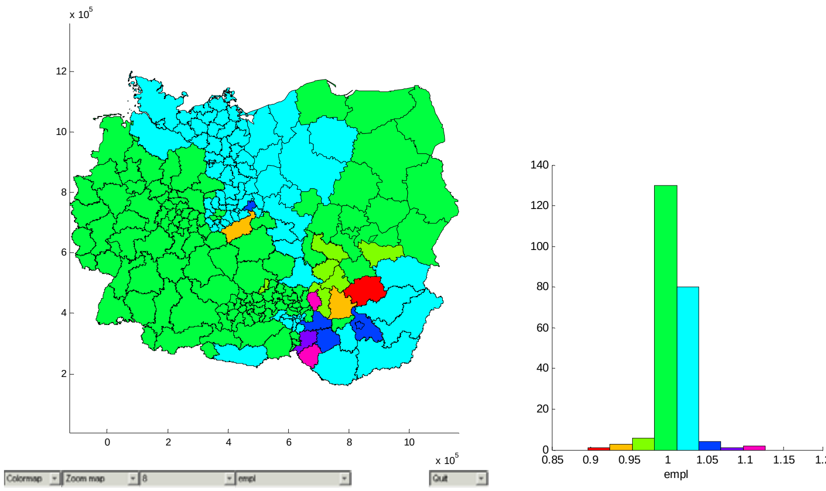
Summary of the sensitivity analysis for the adjusted model: We see again that the southern Hungarian regions will be mainly affected by the HST and the HST light scenario.

## *Table 3.2 Scenarios sensitivities: The top and low EMPL growth differences for 2020*

a) The adjusted model

b) The unadjusted model

*Chart 3.1.b Scenario 3 differences of the **un**adjusted employment model: The ratio between TT1 and TT3 employment levels.*

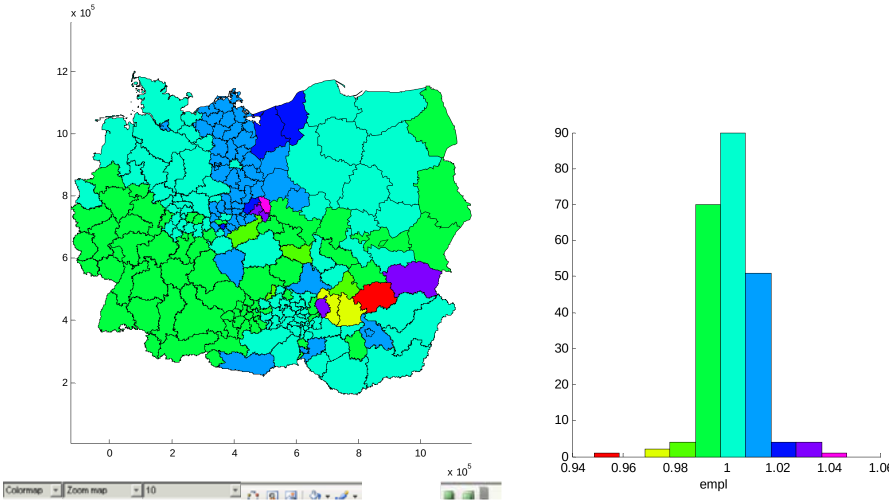



*Color legend: red: -2-3%-points, yellow –1-2%-points, green: -1 to 0 % points, blue 0 to 1%-points, and violet 1 to 2%-points.*

*Summary of the sensitivity analysis for the unadjusted model:*

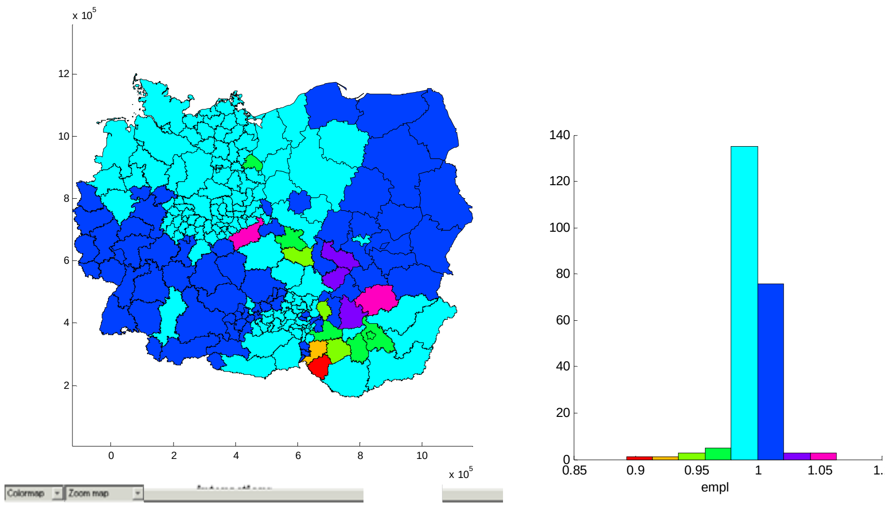
*The high speed cone is rather thin for the employment level in the Czech Republic, but the influence is clearly seen in the both ends of the cone, namely in the South of Hungary and in the North Eastern Germany until Hamburg.*

*Chart 3.2.b Scenario 1/4 sensitivities of the* ***un****adjusted model: The differences between TT1 and TT4 employment levels.*




*Color legend: red: -2-3%-points, yellow –1-2%-points, green: -1 to 0 % points, blue 0 to 1%-points, and violet 1 to 2%-points.*

*Chart 3.3.b Scenario 3/4 sensitivities of the unadjusted model: The ratio between TT3 and TT4 scenario employment levels.*




*Color legend: red: -2-3%-points, yellow –1-2%-points, green: -1 to 0 % points, blue 0 to 1%-points, and violet 1 to 2%-points.*

Along the corridor axis we see only a few reductions of the final employment levels, only the region along the orthogonal axis of the high-speed corridor will suffer an employment loss.

Summary: The regions along the high-speed cone (with center Prague) will benefit while the regions in the “high speed shadow” will not benefit.

# 4. The population growth (POP%) model with spatial traffic interactions

The following Table 4.1 summarizes the BMA estimation results.

*Table 4.1 POP growth model and spatial traffic variables (BMA estimates)*

| Bayesian | Model | Averaging | Estimates |
|---|---|---|---|
| Dependent Variable: POP%, | (Average | Population | Growth) |
| R-squared = 0.7675 | | | |

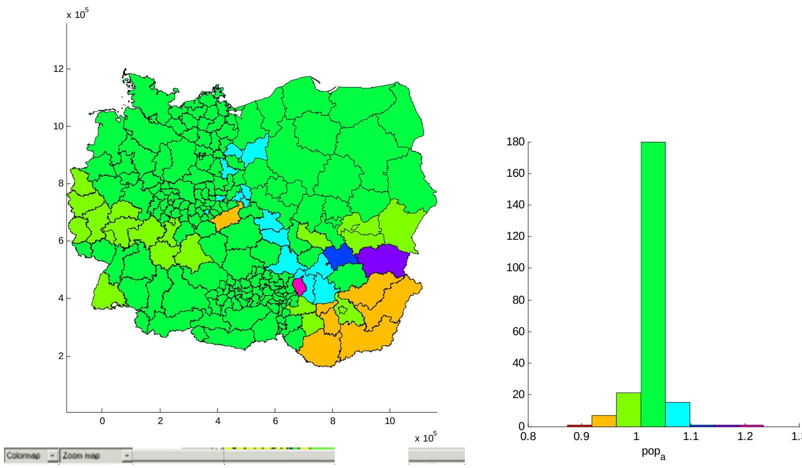
| | | | |
|---|---|---|---|
| Nobs = 227, | Nvars = 23, | Ndraws | = 25000 |
| (nu,lam,phi) = (4., 0.25, 3) | # models | = 927 | |
| ******************************************** Posterior Estimates | | | |
| Variable | Coefficient | t-statistic | t-probability |
| const | -0.01 | -1.1 | 0.28 |
| Lpop.gTT.rail.96 | -74.65 | -7.5 | 0.00 |
| Lpop.gTT.rail.97 | 87.98 | 6.4 | 0.00 |
| Lpop.gTT.rail.98 | -110.03 | -11.4 | 0.00 |
| Lpop.gTT.road.97 | -62.44 | -6.1 | 0.00 |
| Lpop.gTT.road.99 | 29.27 | 9.1 | 0.00 |
| Lpop.giTT.rail.97 | -8.79 | -3.3 | 0.00 |
| Lpop.giTT.rail.98 | -13.86 | -7.8 | 0.00 |
| Lpop.giTT.road.96 | -4.52 | -4.9 | 0.00 |
| Lpop.giTT.road.97 | 4.56 | 3.4 | 0.00 |
| Lgdp.01.95 | 0.14 | 3.9 | 0.00 |
| Lempl.01.95 | 0.20 | 4.7 | 0.00 |
| TT.road.far | 0.00 | -4.4 | 0.00 |
| TT.road.harm | 0.00 | 2.8 | 0.01 |
| potential.gdp.cap.00.95.rail | -0.15 | -8.5 | 0.00 |
| potential.gdp.cap.00.95.road | 0.09 | 4.2 | 0.00 |
| potential.gdp.empl.00.95.rail | 0.11 | 6.8 | 0.00 |
| potential.gdp.empl.00.95.road | -0.10 | -5.3 | 0.00 |
| potential.all.pop.00.95.rail | 0.21 | 3.9 | 0.00 |
| d.aut | 0.00 | 1.1 | 0.26 |
| d.sk | 0.00 | 0.0 | 1.00 |
| d.hu | 0.00 | -0.1 | 0.91 |
| d.ger | 0.00 | -0.6 | 0.53 |
| d.pl | 0.00 | -0.4 | 0.72 |

From Table 4.1 we see that the R2 is again quite high (0.77) but less than the previous 2 models. The intercept is -1% and not different from zero. No country fixed effects is significant. We conclude that population growth seems to follow a rather similar pattern in these 6 countries. The convergence coefficient of the log population level could not be significantly estimated and there are no level effects except the changes of potential variables. Interestingly, the GDP per capita and the GDP per worker potential variable enter the regression in pairs.

The productivity pair for road TT and train TT almost cancel (the sum of the coefficients of potential.gdp.empl.00.95.rail and potential.gdp.empl.00.95.road is -.01), while for the GDP per capita pair, we find a negative combined effect for the changes (-0.06 for potential.gdp.cap.00.95.road and ~rail). That means that differences in potential growth in high growing regions are less favorable for population growth. Note that there is a fifth variable with a positive growth effect based on population potential differences, and it has the largest positive coefficient (potential.all.pop.00.95.rail: 0.21). This is an indication that regions benefit from a positive population growth feed back loop, based on population potentials and discounted by train travel times.

Note that dynamic time pattern for the TT weighted population growth rates is characterized by diversity and rather strong: 5 past TT weighted growth rate variables are far distance weighted (gTT), and 4 variables are short distance weighted (giTT). The effects of road based growth rates for the year 1996 and 1997 almost cancel (the sum is -4.52 + 4.56 = 0.04) while the combined effects of the short-term effects from the year 1997 and 1998 are negative. Surprisingly, in the long run the combined effects of TT weighted past population growth rates are also negative (Lpop.gTT.road.97 and Lpop.gTT.road.99: -33) for road, and -100 (the sum of Lpop.gTT.rail.96, for the years 96, 97, and 98) for train. This implies that regional train related growth is about 3 times as important than road related population growth. These estimates imply that the auto-projected population growth dynamics works negatively for all regions and will lead to depressed forecasts in the long run.

*Chart 4.1.a Scenario 3 sensitivities of the adjusted model: The differences between TT1 and TT3 scenario of POP forecasts.*




*Summary of the sensitivity analysis for the adjusted model*: Chart 4.1.a: The cone of the TT improvement does not carry over to a similar cone type improvement for population growth. At the best we see the SW part of the cone, since some Hungarians regions will benefit from the high-speed cone (including Bratislava) while the NW part of the cone is not visible.

In Chart 4.2.a that compares scenario 4 with 1, we see a clearer manifestation of the nigh speed cone. Southern Hungarian regions and some “via regia” regions will benefit while in the northern part of the cone we hardly see any population improvements.

*Chart 4.2.a Scenario 4/1 sensitivities of the adjusted model: The differences between TT1 and TT4 scenario POPulation forecasts.*

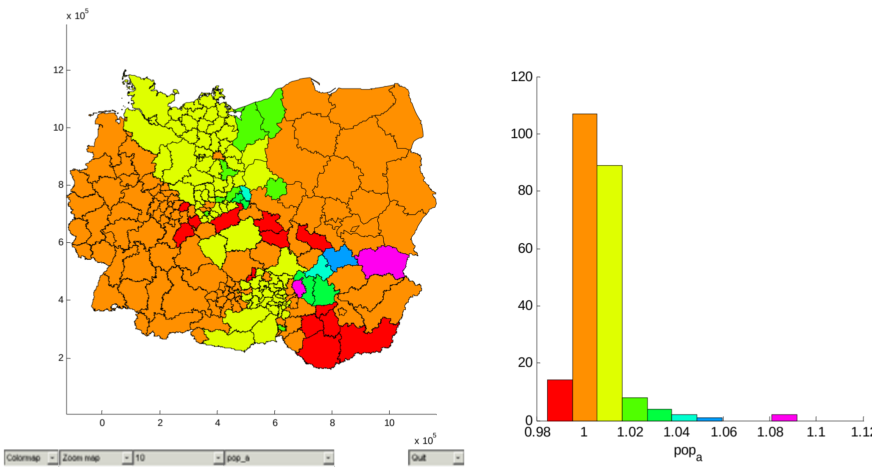
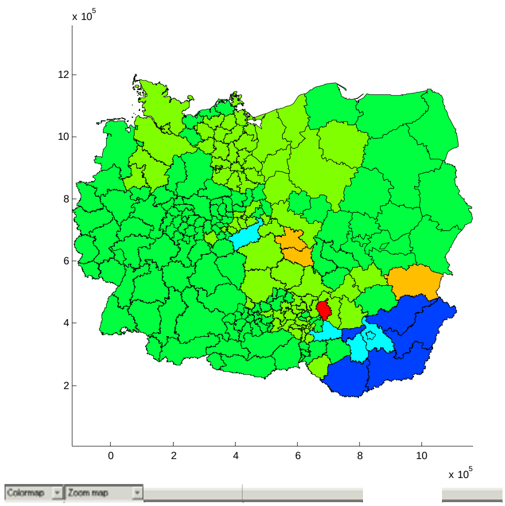


*Chart 4.3.a The adjusted population model: The ratios between TT3 and TT4 scenario POPulation level forecasts.*



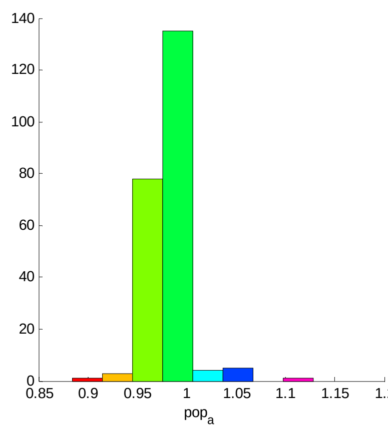



*Table 4.3 TT Scenarios sensitivities: The top and low POPulation growth differences.*

a) The adjusted model:

b) The unadjusted model:

*Chart 4.1.b Scenario 3/1 differences of the unadjusted population model: The ratio between TT1 and TT3 POPulation forecasts 2020.*

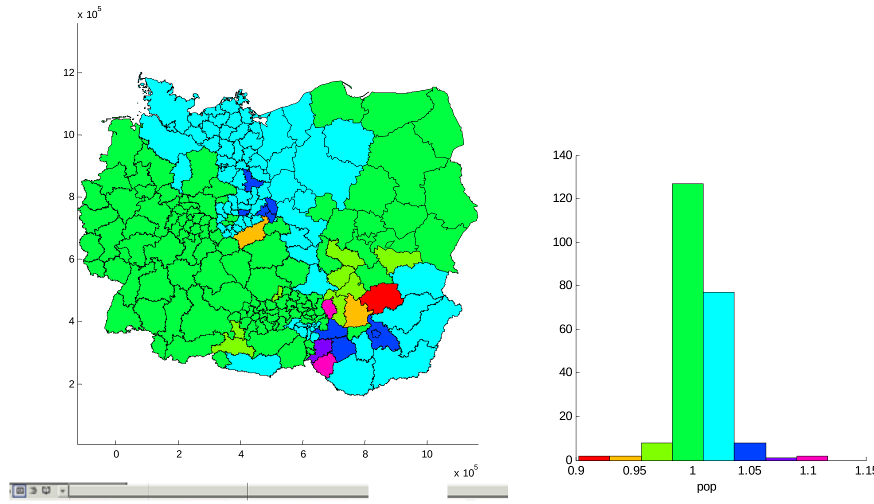


*Chart 4.2.b Scenario 4/1 sensitivities of the unadjusted population model: The ratio between TT1 and TT4 scenario POP forecasts 2020.*

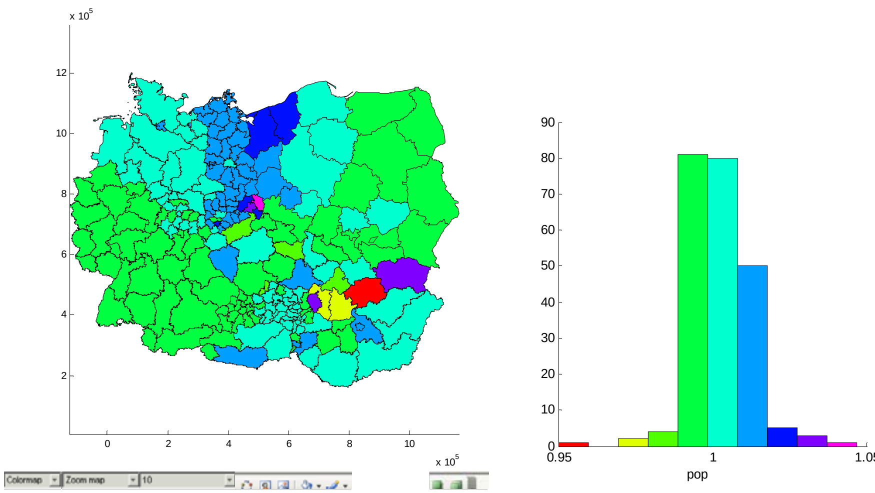
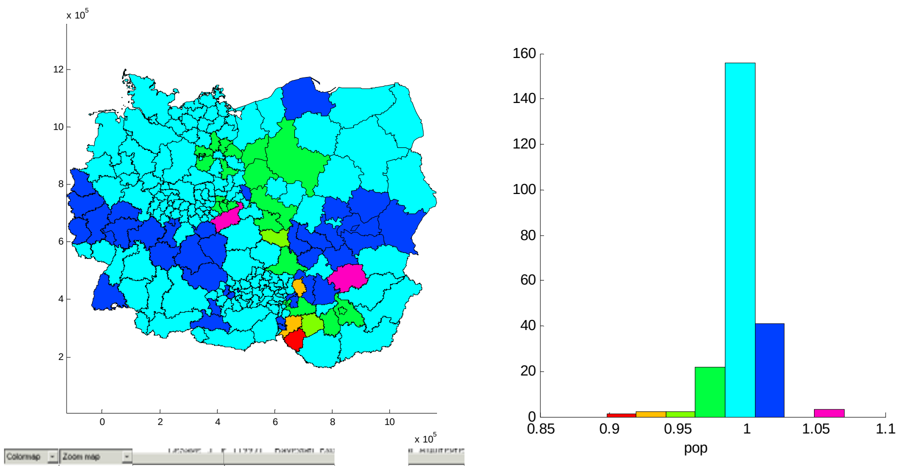


*Chart 4.3.b Scenario 3/4 differences of the unadjusted population model: The ratio between TT3 and TT4 POP scenario forecasts 2020.*




*Summary of the sensitivity analysis for the unadjusted model: .*

*Chart 5.1 Scenario sensitivities of the unadjusted model: The ratios between TT3 and TT1 GDP forecasts 2020.*

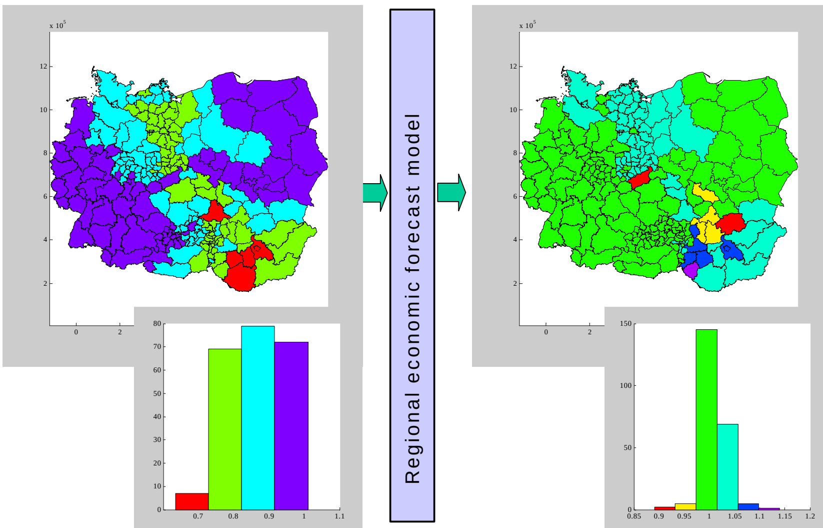
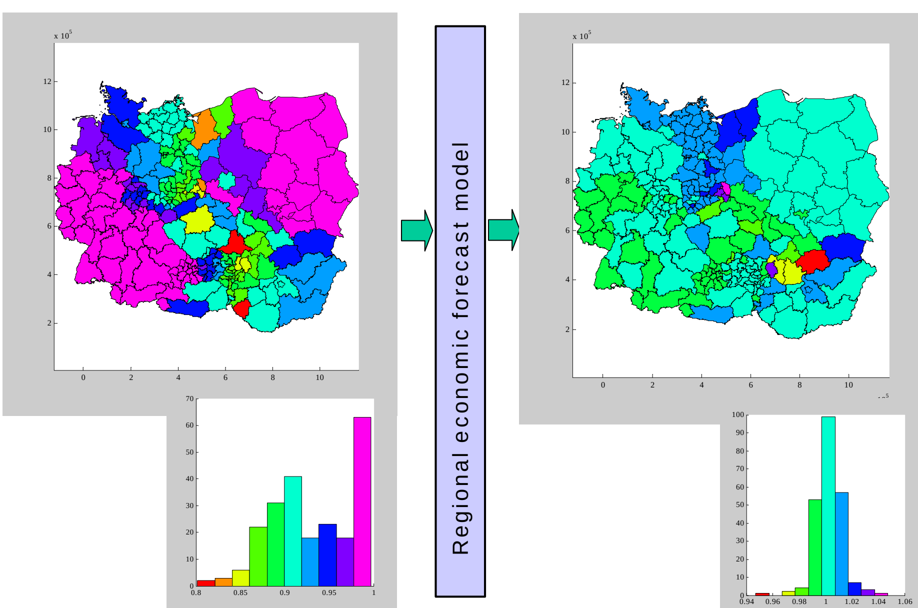



*Chart 5.2 Scenario sensitivities of the unadjusted model: The ratios between TT4 and TT1 GDP forecasts 2020.*



# 4. Conclusions

The long term forecast implications of a high-speed train scenario in Central Europe would create a cone type improvement pattern along the high-speed corridor with center Prague. Regions in the shadow of this high-speed corridor, i.e. region along the SW-N E axis will not benefit. This pattern is not visible for the 3 focus variables in equal strength but is stronger for the pure high-speed scenario 3 than for the “high-speed light” scenario 4. The high-speed light scenario 4 will break the strong cone pattern especially for southern Poland (the via regia) since a cross-segment will connect to the high-speed corridor in Dresden with connection to Krakow.

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# Appendix A: List of variable abbreviations

| | |
|---|---|
| Lgdp.1995 | Logarithm real GDP |
| Lgdp.gTT.rail.96 | average GDP growth rates 1996, weighted by rail TT |

| | |
|---|---|
| Lgdp.gTT.rail.97 | average GDP growth rates 1997, weighted by rail TT |
| Lgdp.gTT.rail.98 | average GDP growth rates 1998, weighted by rail TT |
| Lgdp.gTT.rail.99 | average GDP growth rates 1999, weighted by rail TT |
| Lgdp.gTT.rail.00 | average GDP growth rates 2000, weighted by rail TT |
| Lgdp.gTT.road.96 | average GDP growth rates 1996, weighted by road TT |
| Lgdp.gTT.road.97 | -”- 1997 |
| Lgdp.gTT.road.98 | -”- 1998 |
| Lgdp.gTT.road.99 | -”- 1999 |
| Lgdp.gTT.road.00 | -”- 2000 |
| Lgdp.giTT.rail.96 | average GDP growth rates 1996, weighted by inverse rail TT |
| Lgdp.giTT.rail.97 | average GDP growth rates 1997, weighted by inverse rail TT |
| Lgdp.giTT.rail.98 | average GDP growth rates 1998, weighted by inverse rail TT |
| Lgdp.giTT.rail.99 | average GDP growth rates 1999, weighted by inverse rail TT |
| Lgdp.giTT.rail.00 | average GDP growth rates 2000, weighted by inverse rail TT |
| Lgdp.giTT.road.96 | average GDP growth rates 2000, weighted by inverse road TT |
| Lgdp.giTT.road.97 | -”- 1997 |
| Lgdp.giTT.road.98 | -”- 1998 |
| Lgdp.giTT.road.99 | -”- 1999 |
| Lgdp.giTT.road.00 | -”- 2000 |
| Lempl.95 | Logarithm of employment 1995 |
| Lpop.95 | Logarithm of population 1995 |
| Lpop.dichte.95 | Logarithm of population density 1995 |
| Lempl.00.95 | % changes of employment 1995-2000 |
| Lpop.00.95 | % changes of population 1995-2000 |
| youth.dep.ratio | percentage of 0-20 years old in the population |
| old.dep.ratio | percentage of 60+ years old in the population |
| nodes.per.highway.km | highway access points per highway km |
| highway.per.km2 | highway density in a region |
| Roads.per.km2 | road density in a region |
| Railstation.per.km | Rail station density per rail net km |
| Railnet.per.km2 | railway density in a region |
| TT.train.ave | average train TT |
| TT.train.far | average train TT, weighted by distance |
| TT.train.near | average train TT, weighted by inverse distance |
| TT.train.harm | harmonic average train TT |
| TT.train.speed | average speed for rail ways |
| TT.road.ave | average road TT |
| TT.road.far | average road TT, weighted by distance |
| TT.road.near | average road TT, weighted by inverse distance |
| TT.road.harm | harmonic average road TT |
| TT.road.speed | average speed on road |
| potential.gdp.95.rail | within country potential index based on GDP and rail TT 1995 |
| potential.gdp.95.road | within country potential index based on GDP and road TT 1995 |
| potential.gdp.cap.95.rail | within country potential based on GDP per capita and rail TT 1995 |
| potential.gdp.cap.95.road | within country potential based on GDP per capita. and road TT 1995 |
| potential.pop.95.rail | within country potential based on population and rail TT 1995 |
| potential.pop.95.road | within country potential based on population and road TT 1995 |
| potential.empl.95.rail | within country potential based on employment and rail TT 1995 |
| potential.empl.95.road | within country potential based on employment and road TT 1995 |
| potential.gdp.empl.95.rail | within country potential based on productivity and rail TT 1995 |
| potential.gdp.empl.95.road | within country potential based on productivity and road TT 1995 |
| potential.gdp.00.95.rail | % change of potential index based on GDP and rail TT 1995-2000 |
| potential.gdp.00.95.road | % change of potential index based on GDP and road TT 1995-2000 |
| potential.gdp.cap.00.95.rail | % change of potential index based on GDP_pc and rail TT 1995-2000 |
| potential.gdp.cap.00.95.road | % change of potential index based on GDP_pc and road TT 1995-2000 |
| potential.pop.00.95.rail | % change of potent. index based on population and rail TT 1995-2000 |
| potential.pop.00.95.road | % change of potent. index based on population and road TT 1995-2000 |
| potential.empl.00.95.rail | % change of pot. index based on employment and rail TT 1995-2000 |

| | |
|---|---|
| potential.empl.00.95.road | % change of pot. index based on employment and road TT 1995-2000 |
| potential.gdp.empl.00.95.rail | % change of pot. index based on productivity and rail TT 1995-2000 |
| potential.gdp.empl.00.95.road | % change of pot. index based on productivity and road TT 1995-2000 |
| potential.all.gdp.95.rail | -“- as above but for all 6 countries (227 regions) |
| potential.all.gdp.95.road | -“- as above |
| potential.all.gdp.cap.95.rail | -“- as above |
| potential.all.gdp.cap.95.road | -“- as above |
| potential.all.pop.95.rail | -“- as above |
| potential.all.pop.95.road | -“- as above |
| potential.all.empl.95.rail | -“- as above |
| potential.all.empl.95.road | -“- as above |
| potential.all.gdp.empl.95.rail | -“- as above |
| potential.all.gdp.empl.95.road | -“- as above |
| potential.all.gdp.00.95.rail | -“- as above |
| potential.all.gdp.00.95.road | -“- as above |
| potential.all.gdp.cap.00.95.rail | -“- as above |
| potential.all.gdp.cap.00.95.road | -“- as above |
| potential.all.pop.00.95.rail | -“- as above |
| potential.all.pop.00.95.road | -“- as above |
| potential.all.empl.00.95.rail | -“- as above |
| potential.all.empl.00.95.road | -“- as above |
| potential.all.gdp.empl.00.95.rail | -“- as above |
| potential.all.gdp.empl.00.95.road | -“- as above |
| d.aut, d.sk, d.hu, d.ge, d.cr, d.pl. | Dummy variables for countries |