TEN-T Corridors – Stairway to Heaven or Highway to Hell?

Kathrin Goldmann*
Jan Wessel*†

October 18, 2018

Abstract

The European Union coordinates and co-finances supra-national transport infrastructure investments in the Trans-European Transport Network (TEN-T) which consist of road, rail, airport, and port infrastructure. To the best of our knowledge, we are the first to quantify the direct and indirect economic growth effects of newly created TEN-T core corridor roads in Eastern European countries. Both the panel data and the spatial analyses show that regional GDP growth at the NUTS3 level is between 0.4 and 2.4 percentage points higher, if a region has direct access to a newly built road. The analyses with a spatial Durbin model (SDM), for which we use three differently specified spatial weight matrices, show that the new construction of a TEN-T core road also causes positive spillover effects on adjacent regions, as well as on regions that are connected by the same corridor section. The results thus indicate that the TEN-T policy, which aims to alleviate transport bottlenecks, can help to increase cohesion between central and peripheral regions and consequently to enhance regional welfare in Eastern Europe.

JEL: R42, O18, O47.
Keywords: transport infrastructure, TEN-T corridors, supra-national infrastructure investment, spatial Durbin model.

---

[*] University of Münster, Institute of Transport Economics, Am Stadtgraben 9, 48143 Münster, Germany

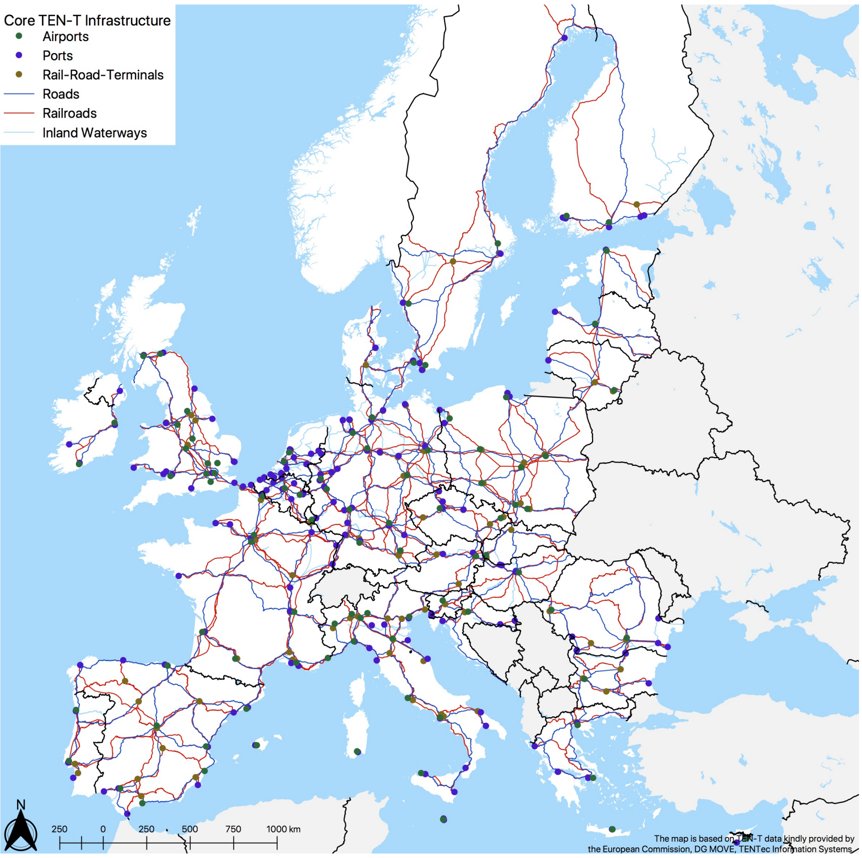
[†] Corresponding author: E-Mail: jan.wessel@uni-muenster.de

1 Introduction

The assessment of wider economic benefits of transport infrastructure investment has received considerable attention in the economic literature. Those economic impacts caused by increased accessibility can result in market expansions to achieve gains from trade and to promote inter-regional integration, as well as to enhance factor market performance (Lakshmanan, 2011). However, Romp and de Haan (2007) point out that, especially in developed countries, the effect of new infrastructure crucially depends on the extent to which new investments remove bottlenecks within existing networks. Through the Trans-European Transport Network (TEN-T) corridors, the European Union (EU) aims directly at alleviating such bottlenecks in the Trans-European transport infrastructure.

When evaluating investment in and the performance of transport networks, large spillover effects on other countries can be expected. These spillover effects increase with the number of users from other countries. For this reason, the country-wide gains from infrastructure investment are likely to be smaller than the total effect, including positive spillover effects on other countries. Proost et al. (2011) point out that infrastructure is likely to be undersupplied on a national level when there are spillover effects, and that this can be considered as the key motivation for supra-national subsidies for transport infrastructure.

The European Union provides supra-national subsidies for the TEN-T network, consisting of nine core corridors which should be completed by 2030. An overview of these corridors and the related TEN-T infrastructure can be seen in Figure 1. TEN-T policy should enhance the supra-national coordination of transport infrastructure investment. Transport infrastructure is regarded as the major means of enhancing economic and social cohesion and of strengthening the internal market. The TEN-T policy is designed to close gaps, remove bottlenecks, and eliminate technical barriers that hamper the interoperability of the member state sub-networks (European Commission, 2018a). To achieve these goals, several EU funding instruments are available which comprise, among others, the Connecting Europe Facility (CEF), the European Structural and Investment Funds (ESI) and the European Fund for Strategic Investments (EFSI). In connection with the eastern enlargement of the EU, the 12 new Member States have already invested more than 40 billion Euros in TEN-T projects between 2007 and 2013 (European Commission, 2018b). Between 2014 and



The map is based on TEN-T data kindly provided by the European Commission, DG MOVE, TENTec Information Systems

Figure 1: TEN-T Core Infrastructure

2016, approximately 600 projects with a total volume of 21 billion Euros were co-funded by the CEF, while 34 billion Euros have been programmed for TEN-T infrastructure during the period 2014-2020 (European Commission, 2017). As huge investments are made in these transport corridors, it is important to look carefully at the outcome in order to evaluate whether the investments are justified.

However, the economic impacts of the TEN-T policies have not received much attention in the economic literature. Research on different aspects of the TEN-T corridors has been conducted by Gutiérrez and Urbano (1996), Vickerman et al. (1999), Papadaskalopoulos et al. (2005), Köhler et al. (2008), and Bröcker et al. (2010).

Gutiérrez and Urbano (1996) analyze the Trans-European Road Network plans that were formulated in the 1990s to generate higher accessibility of remote regions by 2002. They show that the area of the EU that lies within 40 km of the closest road corridor increases from 70 % to 85 % through these plans.

They also state that the more distant regions can benefit most from the accessibility increases. Vickerman et al. (1999) analyze changes in high-speed rail accessibility due to TEN-T investments by the EU. They find that, in contrast to the policy objective of cohesion, the development of the high-speed rail network widens rather than narrows the differences in accessibility between central and peripheral regions. Papadaskalopoulos et al. (2005) investigate the spatial impact of TEN-T corridors in the Balkan area. They investigate 185 urban centers and construct a spatial weight matrix based on direct land transport connections. They find that TEN-T corridors are a significant factor in the spatial reallocation of economic activities and that there are both winning and losing regions.

Köhler et al. (2008) calculate the indirect economic effects of different EU transport policies. They combine an integrated European Passenger and Freight Transport Model with an EU macroeconomic model to calculate indirect economic effects. They analyze different policy scenarios that involve, for instance, fuel tax increases, the implementation of social marginal cost pricing and a faster completion of major TEN-T core projects. They show that social marginal cost pricing, implemented as a revenue-neutral fiscal reform, has a positive impact on economic growth and employment. The earlier completion of TEN-T infrastructure projects has only a small impact at the national macroeconomic level. The authors argue that this small effect is plausible, because the policy change from the business-as-usual case would be relatively small if the TEN-T projects were completed a few years earlier. They do not, however, include the scenario of not completing the TEN-T infrastructure projects at all.

Bröcker et al. (2010) investigate whether spillover effects or the contribution to spatial cohesion justify EU subsidies for the TEN-T network. They use a spatial computable general equilibrium model to calculate changes in the welfare of households in different regions caused by new TEN-T infrastructure and the resulting transport cost reductions. Their analysis builds on the fact that cost-benefit analyses do not account for benefit spillovers to countries that are not involved in the financing of a project. Their results suggest that only 12 of 22 projects are profitable regarding their direct and indirect economic effects captured by their model, and only five projects have spillovers large enough to justify EU subsidies. Therefore, they conclude that subsidies are not justified.

In general, the spatial impacts of transport infrastructure have been investigated in various papers, for instance by Holtz-Eakin and Schwartz (1995), Boarnet (1998), Bo and Florio (2012), Crescenzi and Rodríguez-Pose (2012), Alvarez-Ayuso and Delgado-Rodriguez (2012), Chen and Haynes (2015), or Li and Whitaker (2018).

Bo and Florio (2012) analyze the economic contribution of disaggregated infrastructure capital to European NUTS2 regions' Gross Domestic Products (GDPs) in a spatial model. Their results underline the positive impact of investment in the quality and quantity of infrastructure on GDP. They find negative spatial spillovers effects which might, however, be driven by infrastructure types other than transport infrastructure.

Crescenzi and Rodríguez-Pose (2012) investigate the spatial impact of regional motorways on regional growth in the EU. They use data on NUTS1 and NUTS2 regions of the EU 15 countries and use the kilometers of motorways as a proxy of transport infrastructure endowment. Their results indicate that infrastructure endowment is a poor indicator of economic growth. However, they state that their proxy for transport infrastructure has weaknesses because, for instance, it does not adequately indicate removed bottlenecks.

Alvarez-Ayuso and Delgado-Rodriguez (2012) incorporate the monetary capital stock of high capacity roads in a regional production function for Spanish regions. They find a small positive impact on private production. This positive impact increases when adjacent regions are taken into account. Therefore, they conclude that there are positive spillovers for high-capacity road infrastructure.

Chen and Haynes (2015) investigate the impact of transportation infrastructure on regional growth using a spatial panel approach. They find that transport infrastructure has a positive impact on regional growth in the US eastern metropolitan region. They also find high positive spillover effects to adjacent regions. Including highway, public rail, public transit, and public airport infrastructure, they find that highway infrastructure outweighs the effects of other transport modes. In contrast to Chen and Haynes (2015), Li and Whitaker (2018) only find limited influence of highway infrastructure on regional growth in Texas. They conclude that transportation is only one of many factors contributing to economic growth.

The regional impacts of transport or economic corridors have been investigated for instance by Chandra and Thompson (2000), Michaels (2008), and Athukorala and Narayanan (2018).

Chandra and Thompson (2000) use a panel data approach to show for the U.S. that the regional growth effects of a new interstate highway are positive for certain industries, but that they can be ambiguous for other industries. Furthermore, they estimate that U.S. highways can raise the level of economic activity in a county that this highway passes directly through, but that it can reduce economic activity in adjacent regions. Michaels (2008) also uses a panel data approach to show that counties can experience a gain in trade-related activities like trucking and retail sales, if they are crossed directly by a U.S. interstate highway. Athukorala and Narayanan (2018) analyze the Malaysian experience of economic corridors on regional development. In their qualitative analysis, the authors observe positive growth and employment effects. They state, however, that it is unclear to what extent the corridor initiatives contribute to the improvements.

The majority of papers find positive regional growth impacts of road infrastructure. Spatial spillover effects of roads are often positive, while rail infrastructure and other infrastructure types may induce negative spillover effects. In this context, road infrastructure is often proxied by the length or density of road or motorway networks. This infrastructure indicator, however, does not adequately indicate removed bottlenecks or improved connectivity due to new connections to transport networks. For this reason, we use an indicator variable that shifts from 0 to 1 when a TEN-T core corridor road segment is completed in a given NUTS3 region. Through this variable, we account for the above-mentioned bottleneck-removing and accessibility-improving effects of newly constructed road segments. These features are also proclaimed by the EU as the main goals of the TEN-T policy. To the best of our knowledge, we are the first to quantify the direct and indirect economic effects of newly gained access to the TEN-T core network. Consequently, we directly address the targets of the TEN-T policy and state whether it contributes to regional growth and might therefore contribute to cohesion.

Our analysis deals with the TEN-T corridor policies, its regional growth impacts and its spatial spillover effects. In order to shed more light on these effects, we use a panel data approach as well as a spatial Durbin model (SDM). With these approaches, we estimate whether the new construction of a core corridor road segment can enhance regional economic growth at the NUTS3 level. As there are barely any new TEN-T core road constructions in the Western European countries, where infrastructure has instead often only been upgraded, we focus on Eastern European countries where there are many new constructions for the TEN-T road network. In order to isolate the effect of the road transport corridor, we incorporate various fixed effects and control variables in the sensitivity analysis. Since we know the years in which corridor segments were completed, we can also estimate contemporary, lagged and leading effects on regional growth. By incorporating three different spatial weight matrices, we can distinguish between spillover effects on adjacent regions, on those that lie on the same corridor section, and on regions for which both conditions hold. The adjacency matrix can therefore account for the effects on the hinterland of the transport corridors, while the corridor matrices capture spillover effects along the corridor.

The remainder of this paper is organized as follows. Section 2 describes the data used for the panel data analysis outlined in Section 3, as well as for the spatial analysis presented in Section 4. We conduct various sensitivity analyses in Section 5 before discussing the results in Section 6. Section 7 concludes.

2 Data

In order to estimate the different economic effects of TEN-T corridors on NUTS3 regions, we collected data from various sources. All in all, our data sample consists of 3,615 observations that were obtained for 241 NUTS3 regions of the EU Eastern Enlargement countries between 2001 and 2015.[1]

In our analysis, the economic variable of interest is GDP growth of a NUTS3 region. Accordingly, we take GDP level values from Eurostat and construct annual growth rates.

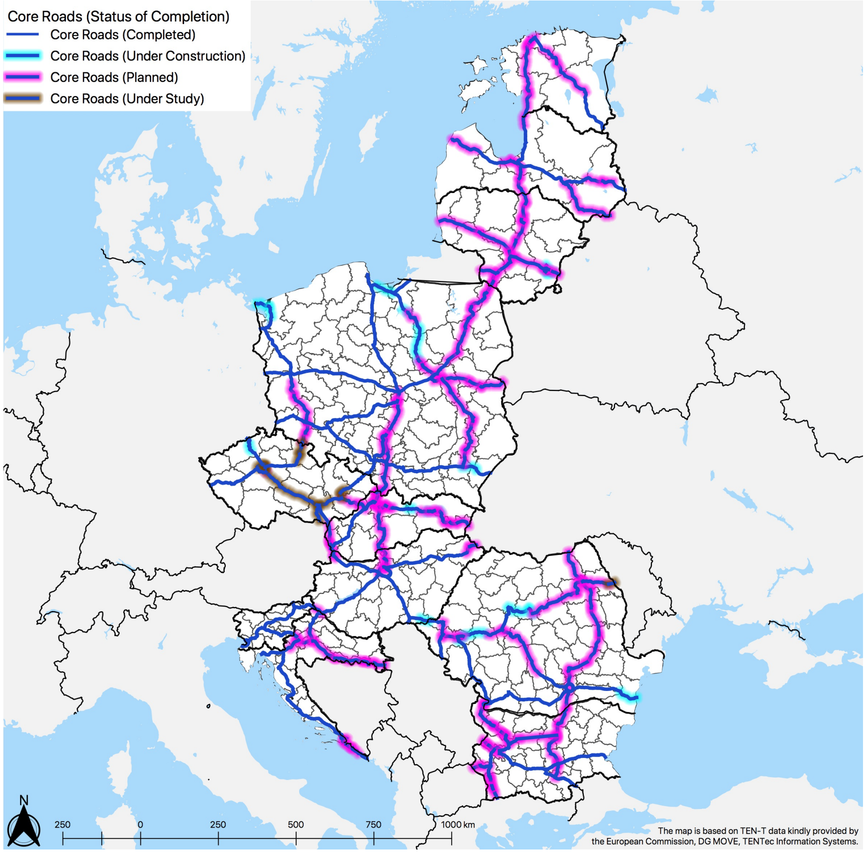
The data on the TEN-T corridors were kindly provided by the European Commission, DG MOVE, TENTec Information System. This dataset offers information on the infrastructure types of roads, railroads, inland waterways, seaports, airports, and rail-road terminals of the TEN-T initiative. The dataset differentiates between 3,539 road segments, 3,712 railroad segments, 883 inland waterway segments, 554 seaports, 353 airports, and 220 rail-road terminals. All of these infrastructure segments or sites can be assigned to either the comprehensive network or the core network. An overview of the core network can be seen in Figure 1.

For roads, railroads, and inland waterways, the dataset offers further information on whether a certain infrastructure segment was completed, planned,

---

[1] These countries include Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovenia, and Slovakia

under construction/ongoing, or under study/preparation. This differentiation is displayed in Figure 2.



The map is based on TEN-T data kindly provided by the European Commission, DG MOVE, TENTec Information Systems.

Figure 2: TEN-T Core Roads by Status of Completion

Furthermore, it is specified whether the construction of a specific segment was a new construction, an upgrade, a rehabilitation, or whether this information was not measured. An overview of these differently categorized, already completed road segments can be seen in Figure 3.

For the panel data analysis of the economic impacts of TEN-T corridors, we focus on newly constructed segments of the road network that have already been completed.[2] This is due to the availability of information on the completion of TEN-T corridor segments; while this information could be obtained from various sources for the road network, similarly detailed information was not available for the railroad network. However, as can be seen in Figure 1, railroads often run parallel to road corridors and therefore through the same NUTS3 regions as

---

[2] It should be noted that this data is based on the information provided by the European Commission and dated 9th March of 2018.

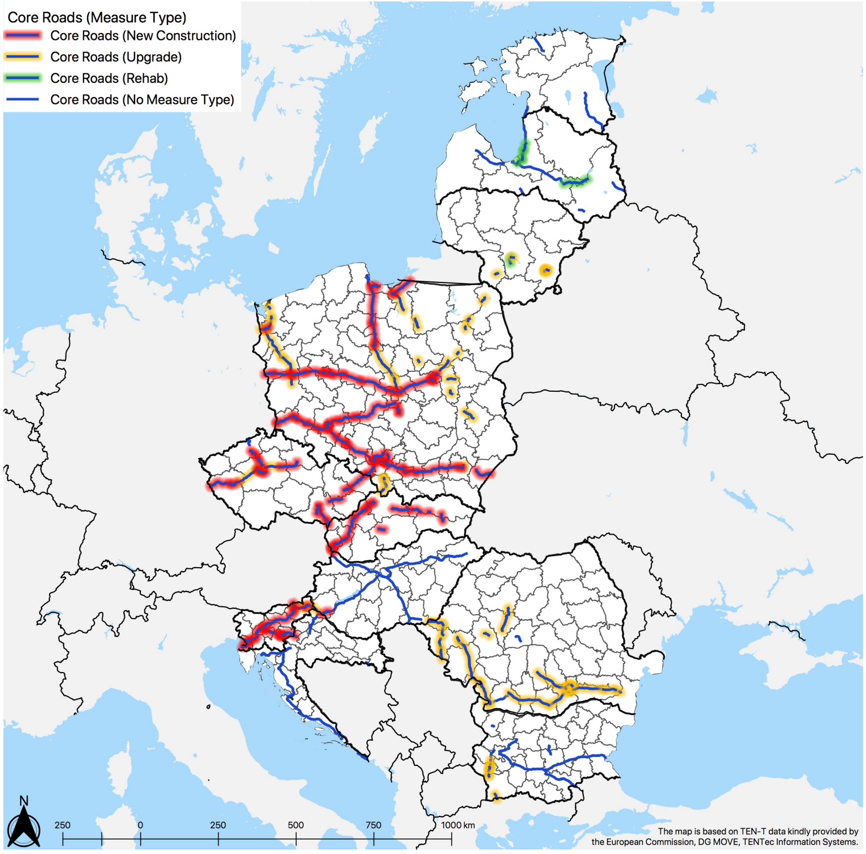


Figure 3: Completed TEN-T Core Roads by Type of Measurement

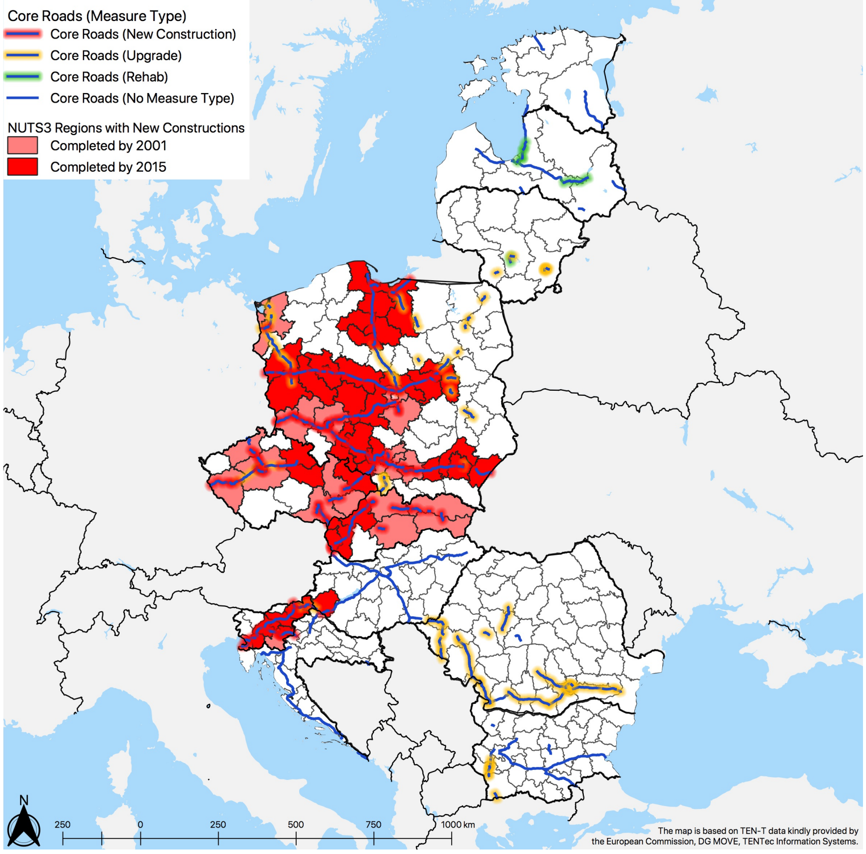
the TEN-T core roads. Additionally, the ports, airports, and rail-road terminals are often in close proximity to the core road network. Thus, the geographical dimensions of the TEN-T core corridor network should be similar for different infrastructure types, and the focus on the road network should not cause any serious disturbances in the estimation results.

To estimate infrastructure growth effects on a NUTS3 region, we check whether there was a newly constructed TEN-T core corridor road segment built in this NUTS3 region during the considered time period. If this was the case, the panel dummy variable for this NUTS3 region takes on the value 0 in years prior to completion, and the value 1 if the newly constructed TEN-T core corridor road segment had already been completed and could be used at the beginning of the year.[3] NUTS3 regions where a new TEN-T core corridor road segment

---

[3] Thus, our indicator variable bears close resemblance to the indicator variable used in Michaels (2008). One notable difference, however, is that our indicator variable can change over time.

was built can be seen in Figure 4.[4] For the NUTS3 regions colored in light red, the new core road segment was already completed before 2001, while for NUTS3 regions colored in dark red, the new core road segment was completed between 2001 and 2015. This information on the time of completion helps us to estimate the growth effects in the next Section.



The map is based on TEN-T data kindly provided by the European Commission, DG MOVE, TENTec Information Systems.

Figure 4: NUTS3 Regions where a new TEN-T core corridor road segment is built

3 Panel Data Analysis

3.1 Theory

As our data has a cross-sectional dimension with the 241 NUTS3 regions, and a longitudinal dimension with observations from 2001 to 2015, we use a panel

---

[4] If two or more road segments were built within one NUTS3 region, the dummy variable shifts from 0 to 1 after the first segment has been completed.

data approach. In order to account for unobservable influences, we include different types of fixed effects in the regression model. As Gormley and Matsa (2014) point out, fixed effects are the best way to control for unobserved group heterogeneity. Furthermore, a Hausman test suggests that fixed effects are preferred over random effects for our panel data set.

The four different regression models that we apply are presented in Equations 1 to 4:

$$gdp\_growth_{cit} = core\_corridor_{cit} + \lambda_t + \mu_c + \varepsilon_{cit} \tag{1}$$
$$gdp\_growth_{cit} = core\_corridor_{cit} + \lambda_t + \nu_i + \varepsilon_{cit} \tag{2}$$
$$gdp\_growth_{cit} = core\_corridor_{cit} + \xi_{ct} + \varepsilon_{cit} \tag{3}$$
$$gdp\_growth_{cit} = core\_corridor_{cit} + \nu_i + \xi_{ct} + \varepsilon_{cit}. \tag{4}$$

In these equations, gdp_growth_{cit} denotes the growth of the GDP of region i in country c and year t. The dummy variable $core\_corridor_{cit}$ indicates whether a newly constructed road segment in region i was (already) completed in year t.[5] The error term is denoted by ϵ_{ict}.

In Equation 1, we include country fixed effects (μ_c) and time fixed effects (λ_t). Thus, this regression model captures the specific characteristics of a country that are fixed over time. Time fixed effects capture time trends or cyclical aspects that affect all NUTS3 regions equally within one year. In Equation 2, we substitute the country fixed effects with NUTS3 fixed effects (ν_i), consequently allowing NUTS3 regions within a country to systematically differ from each other with respect to their fixed effects. This approach is also used by Michaels (2008). As a third option, we include country-year fixed effects (ξ_{ct}) in Equation 3. They capture the unique idiosyncrasies of one country in a specific year, thus time trends might differ from one country to another country. The regression model that is presented in Equation 4 features country-year fixed effects as well as NUTS3 fixed effects. Consequently, the regression model structure is similar to those in Dell et al. (2014) or Gormley and Matsa (2014), where similarly structured problems are analyzed.

In order to manage the large number of multi-way fixed effects, we employ the Stata command “reghdfe” from Correia (2016). One advantage of this command is the careful estimation of the degrees of freedom in a multi-way

---

[5] Only road projects that were completed between 2001 and 2015 are considered in this analysis.

Table 1: Results of the Panel Data Analysis

	Dependent Variable: gdp_growth			
	(1)	(2)	(3)	(4)
core_corridor	0.011*** (0.002)	0.024*** (0.005)	0.005*** (0.002)	0.004* (0.002)
Observations	3615	3615	3600	3600
R^2	0.543	0.559	0.772	0.787
Year Fixed Effects	Yes	Yes	No	No
Country Fixed Effects	Yes	No	No	No
NUTS3 Fixed Effects	No	Yes	No	Yes
Country-Year Fixed Effects	No	No	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Own calculation.

fixed effects setting that accounts for nesting within clusters, as well as possible sources of collinearity within fixed effects. Thereby, the significance levels of our estimates are calculated more accurately.

Error terms are clustered at the NUTS3 level, as we believe that the observations for a given NUTS3 region are not independent over time. This clustering procedure makes standard errors, and thus inferences, robust to serial correlation and heteroskedasticity (Wooldridge, 2016, p. 433).

3.2 Results of the Panel Data Regression

The results of these regression analyses are presented in Table 1. The effect of a newly created TEN-T core corridor road segment on the GDP growth of a NUTS3 region is positive in all four specifications. When we use year and country fixed effects in the regression model (Column 1), the construction of a TEN-T core corridor road segment increases GDP growth by 1.1 percentage points. When employing year and NUTS3 fixed effects (Column 2), this effect even increases to 2.4 percentage points. This increase in the growth effect magnitude might indicate that there is substantial variation between NUTS3 regions of the same country.

If we allow for cyclical effects to vary across different countries (Column 3), the usual year fixed effects can no longer be included in the regression due to perfect multicollinearity issues. In this specification, the GDP growth effect of a newly created TEN-T core corridor road segment declines to 0.5 percentage points. When NUTS3 fixed effects are considered additionally (Column 4), the effect even drops to 0.4 percentage points. In the next section, we test whether the results hold when spatial spillover effects are accounted for.

4 Spatial Analysis

4.1 Theory of Spatial Analysis

The first law of geography is, according to Tobler (1970, p. 236), that "everything is related to everything else, but near things are more related than distant things." Accordingly, LeSage (2008) states that in empirical studies, it is often observed that regions close to each other observe similar values. Thus, they are not independent from each other, but spatially dependent. This may be due to externalities of physical and human capital, technological interdependence (Ertur and Koch, 2007), cultural influences, infrastructure, and other reasons (LeSage, 2008).

The spatial effects of public infrastructure have been analyzed by various researchers with varying results. While Chen and Haynes (2015) find positive spillover effects of public transportation infrastructure on regional economic growth for the U.S. Northeast Megaregion, Holtz-Eakin and Schwartz (1995) find that there are no productivity spillovers from state highways within the U.S. Boarnet (1998) even finds evidence of negative output spillovers for monetary public infrastructure capital in Californian counties.

In our context, we are interested in the regional spillover effects of access to newly constructed TEN-T core corridor roads on growth in neighboring countries. To estimate these spillover effects, we employ the spatial Durbin model (SDM), which can account for spatial dependence of the dependent variable y on the dependent variable itself, as well as for spatial dependence on other independent variables. This controls for unobservable regional factors and can thereby mitigate omitted variable bias.

To achieve these features, spatial lag terms are added to the regression. These are linear combinations of the variable values from all neighboring regions. The spatial lag term of the dependent variable y for region i can consequently be written as $\sum_{j=1}^{n} w_{ij} y_j$, where w_{ij} is an element that describes the relationship between regions i and j. In most cases, w_{ij} is a dummy variable that takes on the value 1 if regions i and j are contiguous, and 0 otherwise. Switching to matrix notation, we can create a $n \times n$ spatial weight matrix W_C for contiguity, which has the elements w_{ij} (LeSage and Pace, 2009).

Then, an SDM that includes spatial lags of the dependent variable y and spatial lags of a set of explanatory variables X, thereby accounting for externalities of these variables, can be written as follows (LeSage and Pace, 2009):

$$\begin{aligned} y &= \alpha\iota_n + \rho W_C y + X\beta + W_C X\gamma + \varepsilon \\ \varepsilon &\sim N(0, \sigma^2 I_n), \end{aligned} \tag{5}$$

where α is a parameter and ι_n is a vector of ones. Thus, the first term on the right allows for situations where the mean of vector y is different from zero. The scalar parameter ρ reflects the strength of spatial dependence. Note that if $\rho = 0$, there is no spatial dependence on the dependent variable y. In general, the matrix X represents the set of independent variables, which reduces to the indicator variable *core_corridor* for our estimation setup. Vectors β and γ are the regression coefficients in which we are interested. Furthermore, we also include NUTS3 and year fixed effects to control for unobserved factors that are constant for NUTS3 regions and for different time periods.

LeSage and Pace (2009) show that when using ordinary least squares (OLS), the estimates of the spatial parameters, of regression parameters for models with spatially lagged dependent variables, and of error terms, can be inconsistent. We therefore follow Lee (2004) and LeSage and Pace (2009) and use a maximum likelihood estimation technique, implemented via the "xsmle" command in Stata (Belotti et al., 2016).

4.2 Creation of Spatial Weight Matrices

The spatial weight matrix W_C that gives the contiguity relations for the NUTS3 regions of our sample was created with GeoDa from a Eurostat map of the EU and its NUTS3 regions. Contiguity was defined following the *rook* criterion. The main diagonal consists of zeros to prevent regions from being neighbors to themselves. Furthermore, the spatial weight matrix W_C was row-standardized, so that the sum of each row would equal unity.

In addition to the contiguity-indicating spatial weight matrix W_C, we create two more weight matrices. For the first matrix, we depart from the stricter notion of Tobler's 1970 first law of geography. The matrix should thus no longer indicate spatial proximity, but focus on whether two regions are connected through a TEN-T core road network section, and is denoted as W_N. Therefore, we define 30 sections of the TEN-T core corridor road network in countries of the Eastern Enlargement. These 30 sections are mostly constructed as parts of the core corridor network that (*i*) lie on the same national or international E-road network (and can thus be driven without switching to another road), and (*ii*) form a fairly straight connection between two distant points. Next, because the weights of the matrix do not have to reflect contiguity, but can rather indicate any kind of potential interaction, connection, or otherwise defined nearness (Anselin, 1988; Anselin and Bera, 1998; Leenders, 2002), we declare two regions i and j to be connected with each other, if the same corridor section runs through both regions. The elements of the weight matrix W_N then take on the following values:

$$w_{ij} = \begin{cases} 1 & \text{if NUTS3 regions } i \text{ and } j \text{ are connected through} \\ & \text{one of the 30 corridor sections,} \\ 0 & \text{otherwise.} \end{cases} \tag{6}$$

An example of this procedure is presented in Figure 5 in Appendix A.1 for the A2 highway in Poland.

The second additional matrix, W_{CN}, combines information from the two previously outlined matrices. Two regions are now declared to be connected if they are contiguous and if they are also penetrated by the same corridor section. Thus, the created spatial weight matrix is similar to the one used by LeSage and Polasek (2008). This matrix can be calculated as the Hadamard product of matrices W_C and W_N:

$$W_{CN} = W_C \circ W_N. \tag{7}$$

Hence, the matrix contains the intersecting set of information of the first two information sets and identifies regions that are contingent and connected by the corridor.

4.3 Results of the Spatial Analysis

The three weighting matrices outlined above can be used in the SDM, in order to estimate spatial autocorrelation and spatial dependence of economic growth on the explanatory variables. The results of regressions with these three differently specified weighting matrices can be found in Table 2.

Table 2: Results of the Spatial Analysis

	Dependent Variable: gdp_growth		
	Contiguity (1)	Corridor (2)	Corridor-Contiguity (3)
Explanatory Variables			
core_corridor	0.006	0.016***	0.011**
	(0.004)	(0.004)	(0.005)
Spatial Lags			
core_corridor	0.020***	0.045***	0.021***
	(0.006)	(0.009)	(0.006)
Spatial Dependence			
ρ	0.608***	0.468***	0.378***
	(0.020)	(0.032)	(0.023)
Variance			
σ^2	0.003***	0.003***	0.003***
	(0.000)	(0.000)	(0.000)
Direct Effect			
core_corridor	0.011***	0.018***	0.015***
	(0.004)	(0.004)	(0.004)
Indirect Effect			
core_corridor	0.056***	0.071***	0.027***
	(0.012)	(0.012)	(0.006)
Total Effect			
core_corridor	0.067***	0.088***	0.042***
	(0.013)	(0.013)	(0.006)
Observations	3615	3615	3615
R^2	0.470	0.420	0.460
Year Fixed Effects	Yes	Yes	Yes
NUTS3 Fixed Effects	Yes	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Own calculation.

Note: The first part of the regression table contains the actual regression output. The second part of the regression output contains the direct, indirect, and total effects that were calculated as in Belotti et al. (2016) and LeSage (2008). These effects account for feedback effects and are thus more relevant for the interpretation of the results.

The estimated regression coefficients of the SDM do not account for feedback loops, which represent situations where region i affects region j and region j also has an impact on region i (or even longer paths). In order to account for these feedback loops, we compute and analyze the direct effects (DE), indirect effects (IE), and total effects (TE), as outlined in LeSage and Pace (2009). The direct effect gives the impact of a unit change in the explanatory variable of region i on the dependent variable of region i, averaged over all regions. The total effect represents the impact of a unit change in the explanatory variable of all regions on the dependent variable of region i, averaged over all regions. As $TE = DE + IE$, the indirect effect is thus the impact of a unit change in the explanatory variable of all regions except region i on the dependent variable in region i, averaged over all regions (LeSage, 2008; Belotti et al., 2016). The hereinafter presented direct, indirect, and total effects of our static SDM should be compared to the short-run effects of the dynamic SDM (Belotti et al., 2016; Ojede et al., 2018).

The underlying spatial weight matrix W_C in Column 1 of Table 2 indicates contiguity between two regions. In this regression specification, the direct effect of a newly created TEN-T core corridor road segment on the region itself is 0.011, which implies that GDP growth is 1.1 percentage point higher in regions that have access to a newly created TEN-T core corridor road segment than in regions without such a road segment. Following the interpretation from LeSage (2008), the indirect effect, that is, if a new TEN-T core corridor road segment was built in all NUTS3 regions that share a border with region i, amounts to 0.056. Consequently, the GDP growth of this region i would increase by 5.6 percentage points. It should be noted, however, that the average number of contiguous neighbors in the data sample is 4.91, so that the growth effect of creating a TEN-T core corridor road segment in one neighboring region would be proportionally smaller, that is $0.056/4.91 \approx 0.011$, if we assume a linear relationship between the number of neighboring regions and the regional growth effect. As for the total effect, that is, if in the NUTS3 region itself and in all neighboring regions a TEN-T core corridor road segment was built, the GDP growth of the NUTS3 region would increase by 6.7 percentage points.

Next, we look at spatial interdependencies that exist between regions connected through the same corridor segment. Both the direct effect (0.018) and the indirect effect (0.071) are slightly higher than in the first specification. While the interpretation of the direct effect is the same as before, the indirect effect now

indicates the GDP growth increase in region i if all regions that lie on the same corridor section as region i, except region i itself, gained access to a newly created TEN-T core corridor road segment. It should be borne in mind, however, that the corridor sections that we defined, consist on average of 12.27 NUTS3 regions. Consequently, the impact of a newly created TEN-T core corridor road segment in one single NUTS3 region on GDP growth of another NUTS3 region lying the same corridor section is proportionally smaller. The indirect growth effect of a single region would amount to roughly $0.071/12.27 \approx 0.0058$, and thus 0.58 percentage points.
The third specification accounts for spatial interdependencies between neighboring regions that also lie on the same corridor section. Here, the direct effect is 0.015 and the indirect effect is 0.027. The indirect effect is smaller than in the two previous specifications, but considering that a given NUTS3 region has on average 1.99 regions that qualify as a connected region, the proportionally adjusted indirect effect of TEN-T core corridor access in one single region on the GDP growth of a connected region is, at $0.027/1.99 \approx 0.014$, even higher than for the two previous specifications.

To check the robustness of these results, we conduct several sensitivity analyses in the next section.

5 Sensitivity Analysis

5.1 Additional Control Variables

Besides the access to the TEN-T core corridor road network and the different fixed effects, the GDP growth could of course be influenced by a variety of other factors. If possible, we attempt to generate information on such factors at the NUTS3 level. One variable controls for the population at the NUTS3 level and six different variables control for the employment in different economic sectors at the NUTS3 level.[6] Furthermore, a dummy variable indicates whether the NUTS3 region is already part of the EU. If, on the other hand, the information is not available at the NUTS3 level, we use information at the NUTS2 level. This includes the length of motorways, the length of other roads, the length of total railway lines, as well as six variables on the gross fixed capital formation

---

[6] The six economic sectors that are considered are: A, B-E, F, G-J, K-N, O-U of the NACE Revision 2 classification.

and six variables on the compensation of employees in the aforementioned six different economic sectors of the NUTS2 regions.[7]

The results of this sensitivity analysis can be found in Table 3 in Appendix A.2. They indicate that our basic results are robust to the inclusion of additional control variables. In the first two specifications, we have a slightly smaller growth effect, whereas the growth effect of the third specification is very similar to the basic results. In the last specification with country-year and NUTS3 fixed effects, the growth effect is even stronger than in the basic regression model. Due to some missing values in the additional control variables, we cannot conduct this sensitivity analysis for our SDM.

5.2 Beyond New Constructions

So far, we have restricted our analysis to TEN-T core corridor road segments that have been classified as "New Construction".[8] One concern with this approach is that we disregarded previously constructed infrastructure that only needed upgrades or rehabilitation in order to qualify as a TEN-T core corridor. It could be argued that NUTS3 regions with these preexisting road infrastructure types already have better connectivity levels than regions without these infrastructure types. Thus, the growth effects of newly constructed TEN-T core road segments could differ between those two types of regions.

In order to check the robustness of earlier results, we now include road segments from all four classifications in our analysis. As there is no reliable information on when upgrades or rehabilitations took place (or on how to deal with "No Measure Type"-segments), we perform a worst-case analysis and assume that all road segments except new constructions were already in use since the beginning of the observational period. Thus, the TEN-T core dummy variable only jumps from 0 to 1 in NUTS3 regions where two conditions are satisfied: (*i*) a new TEN-T core corridor road segment was built in the NUTS3 region, and (*ii*) there are no TEN-T core corridor road segments of the other three classifications in this NUTS3 region. For regions that contain road infrastructure of one of the three other classifications, the dummy variable is set to 1 for the

---

[7] The variables described in this section are from Eurostat. Only the EU dummy variable was created by ourselves, based on the years of accession to the EU.

[8] The dataset provided by the *European Commission, DG MOVE, TENTec Information System* labels road segments as either "New Construction", "Upgrade", "Rehabilitation", or "No Measure Type".

complete observation period.

The results of these analyses can be found in Tables 3 and 4 in Appendix A.2. For the panel data analysis without spatial aspects (Table 3), the results for the first two regression specifications remain almost unchanged when using the new TEN-T core dummy variable. In the third Column with country-year fixed effects, there is a pronounced increase for the new dummy variable. The estimated coefficient increases from 0.005 to 0.009. When employing NUTS3 and country-year fixed effects in Column 4, the effect of newly constructed TEN-T core corridor road segments on GDP growth becomes insignificant.

The results of the regression analysis with spatial features (Table 4) are highly robust to the new specification of the TEN-T core corridor dummy variable. All coefficients that were significant in the earlier regressions are still significant under the new dummy variable. Furthermore, the effect magnitude does not change greatly, with the only notable differences lying in the higher indirect effects for specifications 1 and 2. These results confirm the notion of positive growth impacts of newly constructed TEN-T core road segments.

5.3 Lags and Leads

In our initial regression setup, we assume that there is an immediate growth effect of the TEN-T core corridor road completion. This, however, might not always be true as growth effects could also occur after the completion, thus signifying a phase-in effect. On the other hand, the effects might also emerge prior to the final completion due to economic agents' expectations and their subsequently adapted behavior. We therefore add a one year lag and a one year lead of the TEN-T core corridor dummy variable to the initial model.

The results of a regression setup that includes a leading, a contemporaneous, and a lagging variable can be found in Tables 3 and 4 in Appendix A.2. All specifications of the panel data analysis show that there are no leading effects, which implies that economic agents do not change their behavior prematurely. The first two regression models indicate that there is a positive growth effect which emerges rather close to the completion of the new TEN-T core corridor road segment. The results in Columns 3 and 4 support this notion, but also suggest that there is a negative growth effect roughly one year after the completion. The net effect of the immediate and the lagged effect, however, is still positive.

The spatial analysis shows a positive contemporaneous direct growth effect that is higher than in our basic regressions setup, a result which holds for all three weight matrices. The contemporaneous indirect effect is insignificant for all three specifications. For Specifications 2 and 3 with the spatial weight matrices W_N and W_{CN}, however, there is a significant positive indirect effect that is lagged by one year. The magnitude of this effect lies within similar ranges to our standard regression setups. Thus, the spatial effects seem to emerge to a later date, whereas the direct growth effects emerge closer to the finalization of the road segment.

5.4 Effect on GDP per capita

In addition to the GDP growth effect of TEN-T corridor access, we also analyze the effect on Gross Domestic Product per capita (GDPPC) growth in order to test whether individuals benefit in a similar fashion to the regional economy as a whole.[9] The results of this analysis can be found in Tables 3 and 4 in Appendix A.2.

A new TEN-T core corridor road segment impacts on GDP and GDPPC in an almost identical manner. The only difference is that there is no longer a significant impact when NUTS3 and country-year fixed effects are included simultaneously in the regression model (Column 4). When spatial effects are included in the regression model, it appears that the direct and indirect effects of a newly constructed TEN-T core corridor road segment are almost identical for GDP growth as well as for GDPPC growth.

6 Discussion

Both the panel data and the spatial analysis yield significant and positive NUTS3 regional GDP growth effects of a newly constructed TEN-T core corridor road segment. Depending on the specification, this effect lies between 0.4 and 2.4 percentage points for the panel data analysis and between 1.1 and 1.8 for the spatial analysis. Thus, the TEN-T corridors can increase economic growth at the NUTS3 level.

By reviewing the literature on growth effects of transport infrastructure investments, Romp and de Haan (2007) find that the growth effect crucially

---

[9] Information on GDPPC are taken from Eurostat.

depends on the extent to which bottlenecks are removed. We cannot explicitly determine whether our positive growth effects are due to the removal of bottlenecks or caused by generally improved accessibility in Eastern European regions. However, as we focus on the EU TEN-T policy which aims especially at removing bottlenecks, we incorporate the effects of bottleneck-removing infrastructure in our analysis. Thus, our results are in line with the findings of Romp and de Haan (2007).

Our results contrast with Crescenzi and Rodríguez-Pose (2012), who conclude that there is no significant evidence that a good endowment of roads can contribute to GDP growth of the own or of neighboring regions.[10] There are, however, some important differences to our analysis. While we estimate growth effects at the NUTS3 level, Crescenzi and Rodríguez-Pose (2012) resort to effects on the larger NUTS2 or NUTS1 regions. Our deeper level of disaggregation comes at the cost of fewer available control variables, which we try to circumvent through the use of various fixed effect specifications. Also, Crescenzi and Rodríguez-Pose (2012) use kilometers of motorway standardized by regional population as their infrastructure measurement. Our focus, on the other hand, is not on the quantity of infrastructure, but rather on access to the TEN-T core corridor network. Thus, the positive direct growth effects that we estimate can be attributed to an increase in the connectivity of a region.

Elburz et al. (2017) employ a meta-analysis on 912 observations from 42 studies and find that public infrastructure in the United States is more likely to have negative regional growth effects, whereas public infrastructure in the EU is more likely to have positive regional growth effects. Our own study is thus in line with these findings.

A study by Bo and Florio (2012), for example, finds positive direct effects as well as negative indirect effects for investments in infrastructure on GDP for European NUTS2 level regions. Our results, on the other hand, indicate that the positive spillover effects of newly constructed roads of the TEN-T core corridor project, such as a better connectivity between regions, exceed negative spillover effects caused by increased competition. Since we use data at a lower level of aggregation, we are better able to isolate and estimate spillover effects. Moreover, they use a broadly defined infrastructure measure which,

---

[10] It should be noted that Crescenzi and Rodríguez-Pose (2012) find a significant and positive spatial impact of infrastructure in one region on GDP growth in a neighboring region for their fixed effects within regressions.

besides transport infrastructure, also includes telecommunications and broadband infrastructure. As negative spillovers of the latter two infrastructure types seem plausible due to higher competitive effects, their results of overall negative spatial spillovers therefore seem to be dominated by telecommunications and broadband infrastructure.

Vickerman et al. (1999) show that improvements in the earlier rail corridor network widened the differences in accessibility between central and peripheral regions. Therefore, they conclude that the earlier rail corridor network was unable to achieve stronger convergence in accessibility and economic performance of European countries. We show that increases in accessibility by road transport corridors can cause economic growth in the Eastern European NUTS3 regions, which were, generally speaking, lagging behind Western European NUTS3 regions in economic terms. Hence, the TEN-T road projects might contribute to economic growth and convergence after all.

In conclusion, we can state that the extent and sign of direct and indirect effects seem to depend on the type of infrastructure analyzed. It seems plausible that road infrastructure, which can also be accessed easily from the periphery, has positive spatial impacts, whereas rail corridors and especially the high-speed rail network rather benefits central regions and therefore could widen differences in accessibility between central and peripheral regions. While growth effects from investments in broadband infrastructure seem to be very local, road transport TEN-T-corridors seem to provide benefits for a larger catchment area.

We also show that these positive spillover effects not only accrue to neighboring regions, but also to regions on the same corridor section. When breaking down the indirect effects to an average NUTS3 region, it can be seen that regions which are both directly adjacent to and also lie on the same corridor section can benefit most.[11] Further, the positive spillover effects on NUTS3 regions lying on the same corridor section underline the importance of the network structure of the TEN-T project. Newly created access to this planned network can increase the connectivity of a NUTS3 region, thereby eliminating transport bottlenecks and enhancing economic performance.

As our infrastructure dummy variable only takes on the value 1 if, within a given region, a TEN-T core corridor road segment was already completed on

---

[11] The calculation of average effects on regions on the same corridor section implicitly assumes that the growth effect is of similar magnitude for all regions. It might, however, also be reasonable to assume that distant regions gain less than closer regions, in which case the calculation of averages would be not perfectly adequate.

January 1st of the considered year, we consequently estimate the *ex post* impact of TEN-T core corridor access on regional GDP growth. The sensitivity analysis with lagged and leading variables indicates that the direct effects appear shortly after the completion of the core road segment, whereas the indirect spillover effects are lagged by one year. This suggests that the growth effects spread outward from the point of origin over time.

The positive direct effects of access to the TEN-T core corridor network underline that the TEN-T project helps to remove bottlenecks, increases a NUTS3 region's connectivity and thus contributes positively to economic performance. The elimination of bottlenecks and improved access to important transport networks are consequently a viable way to support distant regions in their endeavors to participate in national and international economic activities. This can also have further positive impacts on the hinterland. Moreover, our results indicate that TEN-T policy indeed succeeds in fostering economic cohesion, since the construction of new corridor road segments, for which our positive growth effects are calculated, is concentrated mainly in Eastern European countries that need to catch up with the Western European countries.

7 Conclusion

We use a panel data approach to estimate the regional NUTS3 GDP growth effects accruing from the creation of a new TEN-T core corridor road segment within regions in EU Eastern Enlargement countries. This growth effect is positive and ranges, depending on the specification, between 0.4 and 2.4 percentage points.

The spatial analysis confirms that this direct GDP growth effect is between 1.1 and 1.8 percentage points. Moreover, we calculate indirect effects of the creation of TEN-T core road segments using three different spatial weight matrices. We find positive spillover effects on adjacent regions, where GDP increases by 1 percentage point on average. There are also positive spillover effects for regions on the same corridor section. The spillover effect, however, appears to be the strongest on regions that are adjacent and also on the same corridor section. Given that our results show that not only regions where EU-funded corridor infrastructure is built, but also adjacent regions and those on the same corridor section benefit from these investments, EU TEN-T policy might indeed contribute to economic cohesion between central and peripheral regions, as well as between Eastern and Western European countries.

The results are robust to various fixed effects specifications, additional control variables, a specification with lagged and leading infrastructure variables, as well as to a more pessimistic modelling of the infrastructure variable. Moreover, the results can be upheld if GDPPC serves as the dependent variable. Our paper could be extended in various ways. As indicated by Figure 2, more corridor segments will be completed by 2030. Future research should expand our analysis to these corridor segments. As the data on the TEN-T also indicate upgrades of existing infrastructure, future research should also analyze these upgrades to determine whether they lead to significant growth effects for NUTS3 regions.

Although our results cannot be regarded as an exhaustive analysis of the complete EU TEN-T transport policy program, they nonetheless provide evidence that, apart from improved conditions for transit traffic, infrastructure investments also have positive effects on regional GDP growth along the corridor. For this reason, TEN-T policy contributes to economic cohesion and a stronger internal market. Thus, the EU should continue working on the highways of European countries in order to advance their cohesion policy.

References

Alvarez-Ayuso and Maria Jesus Delgado-Rodriguez (2012). “High-capacity Road Networks and Spatial Spillovers in Spanish Regions”. In: *Journal of Transport Economics and Policy* 46.2, pp. 281–292.

Anselin, Luc (1988). *Spatial Econometrics: Methods and Models.* Kluwer Academic Publisher.

Anselin, Luc and Anil K Bera (1998). “Spatial Dependence in Linear Regression Models with an Introduction to Spatial Econometrics”. In: *Statistics Textbooks and Monographs* 155, pp. 237–290.

Athukorala, Prema chandra and Suresh Narayanan (2018). “Economic Corridors and Regional Development: The Malaysian Experience”. In: *World Development* 106, pp. 1–14.

Belotti, Federico, Gordon Hughes, and Andrea Piano Mortari (2016). *Spatial Panel Data Models Using Stata.* CEIS Research Paper 373. Tor Vergata University, CEIS.

Bo, Chiara F. Del and Massimo Florio (2012). “Infrastructure and Growth in a Spatial Framework: Evidence from the EU Regions”. In: *European Planning Studies* 20.8, pp. 1393–1414.

Boarnet, Marlon G. (1998). “Spillovers and the Locational Effects of Public Infrastructure”. In: *Journal of Regional Science* 38.3, pp. 381–400.

Bröcker, Johannes, Artem Korzhenevych, and Carsten Schürmann (2010). “Assessing Spatial Equity and Efficiency Impacts of Transport Infrastructure Projects”. In: *Transportation Research Part B* 44, pp. 795–811.

Chandra, Amitabh and Eric Thompson (2000). “Does Public Infrastructure Affect Economic Activity? Evidence from the Rural Interstate Highway System”. In: *Regional Science and Urban Economics* 30.4, pp. 457–490.

Chen, Zhenhua and Kingsley E. Haynes (2015). “Regional Impact of Public Transportation Infrastructure”. In: *Economic Development Quarterly* 29.3.

Correia, Sergio (2016). *Linear Models with High-Dimensional Fixed Effects: An Efficient and Feasible Estimator*. Tech. rep. Working Paper.

Crescenzi, Riccardo and Andrés Rodríguez-Pose (2012). "Infrastructure and Regional Growth in the European Union". In: *Papers in Regional Science* 91.3, pp. 487–513.

Dell, Melissa, Benjamin F Jones, and Benjamin A Olken (2014). "What Do We Learn From The Weather? The New Climate-economy Literature". In: *Journal of Economic Literature* 52.3, pp. 740–98.

Elburz, Zeynep, Peter Nijkamp, and Eric Pels (2017). "Public Infrastructure and Regional Growth: Lessons from Meta-Analysis". In: *Journal of Transport Geography* 58, pp. 1–8.

Ertur, Cem and Wilfried Koch (2007). "Growth, Technological Interdependence and Spatial Externalities: Theory and Evidence". In: *Journal of Applied Econometrics* 22.6, pp. 1033–1062.

European Commission (2017). *Delivering TEN-T - Facts and Figures September 2017*. Tech. rep. Directorate General for Mobility and Transport.

European Commission (2018a). *About TEN-T*. URL: https://ec.europa.eu/transport/themes/infrastructure/about-ten-t_en.

European Commission (2018b). *Linking East and West*. URL: https://ec.europa.eu/transport/themes/infrastructure/ten-t-policy/linking_en.

Gormley, Todd A. and David A. Matsa (2014). "Common Errors: How to (and Not to) Control for Unobserved Heterogeneity". In: *The Review of Financial Studies* 27.2, pp. 617–661.

Gutiérrez, Javier and Paloma Urbano (1996). "Accessibility in the European Union: The Impact of the Trans-European Road Network". In: *Journal of Transport Geography* 4.1, pp. 15–25.

Holtz-Eakin, Douglas and Amy Schwartz (1995). “Spatial Productivity Spillovers from Public Infrastructure: Evidence from State Highways”. In: *International Tax and Public Finance* 2.3, pp. 459–468.

Köhler, Jonathan, Ying Jin, and Terry Barker (2008). “Integrated Modelling of EU Transport Policy”. In: *Journal of Transport Economics and Policy* 42.1, pp. 1–21.

Lakshmanan, T.R. (2011). “The Broader Economic Consequences of Transport Infrastructure Investments”. In: *Journal of Transport Geography* 19.

Lee, Lung-Fei (2004). “Asymptotic Distributions of Quasi-Maximum Likelihood Estimators for Spatial Autoregressive Models”. In: *Econometrica* 72.6, pp. 1899–1925.

Leenders, Roger Th. AJ. (2002). “Modeling Social Influence Through Network Autocorrelation: Constructing the Weight Matrix”. In: *Social Networks* 24.1, pp. 21–47.

LeSage, James P. (2008). “An Introduction to Spatial Econometrics”. In: *Revue d’Économie Industrielle* 0.3, pp. 19–44.

LeSage, James P. and Robert Kelley Pace (2009). *Introduction to Spatial Econometrics*. Chapman and Hall/CRC.

LeSage, James P. and Wolfgang Polasek (2008). “Incorporating Transportation Network Structure in Spatial Econometric Models of Commodity Flows”. In: *Spatial Economic Analysis* 3.2, pp. 225–245.

Li, Jianling and Elizabeth Whitaker (2018). “The impact of governmental highway investments on local economic outcome in the post-highway era”. In: *Transportation Research Part A* 113, pp. 410–420.

Michaels, Guy (2008). “The Effect of Trade on the Demand for Skill: Evidence from the Interstate Highway System”. In: *The Review of Economics and Statistics* 90.4, pp. 683–701.

Ojede, Andrew, Bebonchu Atems, and Steven Yamarik (2018). "The Direct and Indirect (Spillover) Effects of Productive Government Spending on State Economic Growth". In: *Growth and Change* 49.1, pp. 122–141.

Papadaskalopoulos, Athanasios, Anastasios Karaganis, and Manolis Christofakis (2005). "The Spatial Impact of EU Pan-European Transport Axes: City Clusters Formation in the Balkan Area and Developmental Perspectives". In: *Transport Policy* 12, pp. 488–499.

Proost, Stef et al. (2011). "When are Subsidies to Trans-European Network Projects Justified?" In: *Transportation Research Part A* 45, pp. 161–170.

Romp, Ward and Jakob de Haan (2007). "Public Capital and Economic Growth: A Critical Survey". In: *Perspektiven der Wirtschaftspolitik* 8, pp. 6–52.

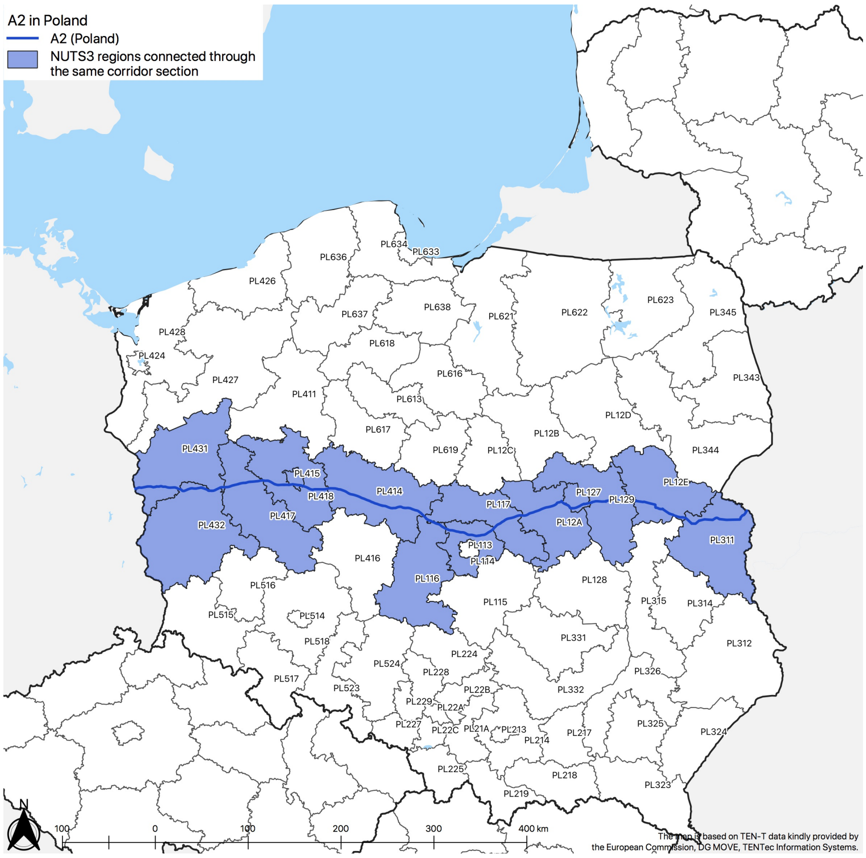
Tobler, W. R. (1970). "A Computer Movie Simulating Urban Growth in the Detroit Region". In: *Economic Geography* 46, pp. 234–240.

Vickerman, Roger, Klaus Spiekermann, and Michael Wegener (1999). "Accessibility and Economic Development in Europe". In: *Regional Studies* 33.1, pp. 1–15.

Wooldridge, J.M. (2016). *Introductory Econometrics: A Modern Approach.* 6th ed. Cengage Learning.

A Appendix

A.1 Creation of the Spatial Weight Matrix W_N



The map is based on TEN-T data kindly provided by the European Commission, DG MOVE, TENTec Information Systems.

Figure 5: Creation of the Spatial Weight Matrix W_N. Example: A2 in Poland

NUTS3 regions along the same corridor section are declared to be connected to each other. Figure 5 shows the pathway of the Polish highway A2, which is one of our 30 considered corridor sections. Consequently, all NUTS3 regions through which the corridor section passes, that is, all blue NUTS3 regions in Figure 5, are declared to be connected to each other.

A.2 Sensitivity Analyses

Table 3: Overview of the Panel Data Sensitivity Analyses

	Dependent Variable: gdp_growth			
	(1)	(2)	(3)	(4)
Basic Regression Setup				
core_corridor	0.011***	0.024***	0.005***	0.004*
	(0.002)	(0.005)	(0.002)	(0.002)
Additional Control Variables				
core_corridor	0.006**	0.013**	0.004*	0.010***
	(0.003)	(0.006)	(0.002)	(0.004)
Beyond New Constructions				
core_corridor	0.010***	0.023***	0.009***	0.005
	(0.002)	(0.006)	(0.002)	(0.003)
Lags and Leads				
core_corridor_lead1	−0.007	−0.001	−0.001	−0.005
	(0.008)	(0.008)	(0.005)	(0.005)
core_corridor	0.024**	0.025**	0.017**	0.017**
	(0.011)	(0.011)	(0.007)	(0.007)
core_corridor_lag1	−0.006	0.004	−0.011**	−0.014**
	(0.008)	(0.010)	(0.006)	(0.007)
Effect on GDPPC				
core_corridor	0.011***	0.025***	0.004**	0.004
	(0.002)	(0.005)	(0.002)	(0.003)
Year Fixed Effects	Yes	Yes	No	No
Country Fixed Effects	Yes	No	No	No
NUTS3 Fixed Effects	No	Yes	No	Yes
Country-Year Fixed Effects	No	No	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Own calculation.

Note: The different columns represent the four different fixed effects specifications also applied in the baseline regression. Note that only the regression coefficients for the *core_dummy* variables are presented here. The complete regression tables for each sensitivity analysis are available upon request.

Table 4: Overview of the Spatial Sensitivity Analyses

	Dependent Variable: gdp_growth		
	Contiguity (1)	Corridor (2)	Corridor-Contiguity (3)
Basic Regression Setup			
Direct Effect			
core_corridor	0.011***	0.018***	0.015***
	(0.004)	(0.004)	(0.004)
Indirect Effect			
core_corridor	0.056***	0.071***	0.027***
	(0.012)	(0.012)	(0.006)
Total Effect			
core_corridor	0.067***	0.088***	0.042***
	(0.013)	(0.013)	(0.006)
Beyond New Constructions			
Direct Effect			
core_corridor	0.011**	0.019***	0.016***
	(0.004)	(0.005)	(0.005)
Indirect Effect			
core_corridor	0.065***	0.091***	0.024***
	(0.015)	(0.021)	(0.007)
Total Effect			
core_corridor	0.076***	0.110***	0.040***
	(0.017)	(0.022)	(0.009)
Lags and Leads			
Direct Effect			
core_corridor_lead1	−0.006	−0.006	−0.003
	(0.006)	(0.007)	(0.007)
core_corridor	0.019**	0.021**	0.021**
	(0.009)	(0.009)	(0.009)
core_corridor_lag1	−0.005	−0.002	−0.006
	(0.008)	(0.009)	(0.008)
Indirect Effect			
core_corridor_lead1	−0.011	0.043	0.001
	(0.026)	(0.030)	(0.008)
core_corridor	0.057	−0.009	0.013
	(0.039)	(0.039)	(0.013)
core_corridor_lag1	0.026	0.079***	0.023**
	(0.026)	(0.030)	(0.009)
Total Effect			
core_corridor_lead1	−0.017	0.037	−0.002
	(0.030)	(0.032)	(0.012)
core_corridor	0.076*	0.013	0.034**
	(0.042)	(0.043)	(0.016)
core_corridor_lag1	0.021	0.078**	0.017
	(0.029)	(0.034)	(0.013)
Effect on GDPPC			
Direct Effect			
core_corridor	0.011***	0.018***	0.015***
	(0.004)	(0.004)	(0.004)
Indirect Effect			
core_corridor	0.060***	0.074***	0.028***
	(0.012)	(0.013)	(0.006)
Total Effect			
core_corridor	0.070***	0.092***	0.043***
	(0.014)	(0.014)	(0.006)
Year Fixed Effects	Yes	Yes	Yes
NUTS3 Fixed Effects	Yes	Yes	Yes

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Source: Own calculation.

Note: Note that only the regression coefficients for the *core_dummy* variables are presented here. The complete regression tables for each sensitivity analysis are available upon request.