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Road Connectivity and the Border Effect: Evidence from Europe

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ABSTRACT / RÉSUMÉ

Road connectivity and the border effect: evidence from Europe

Several studies have reported a large negative effect of national borders on the volume of trade. We provide new estimates of the border effect for continental Europe using road rather than great circle – or "as-crows-fly" – distance. Road distances for 48 180 European city pairs have been extracted from Bing Maps Routing Services. As our dataset also has information on travel time, we are able to consider costs related to time in addition to those depending on distance. We find that for the same great circle distance and the same city size, the road distance between two cities located in the same country is around 10% shorter than that between cities located in different ones. Travel speed is also higher between cities in the same country. We find that by using measures based on the actual road distance rather than the great circle distance, the negative effect of international borders on goods trade in a standard gravity equation is lowered by around 15%. Time-related trade costs account for an additional 10% reduction in the border effect. Overall these results point to the importance of road networks – and road transport policy in general – to enhance market integration.

JEL classification codes: F14; F15; R49

Keywords: road transport; international trade; distance; travel time; gravity

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La connectivité routière et l'effet frontière : données concernant l'Europe

Plusieurs études font état d'un effet négatif très prononcé des frontières nationales sur le volume des échanges. Nous livrons de nouvelles estimations de l'effet frontière en Europe continentale en utilisant les distances routières au lieu des distances orthodromiques – c'est-à-dire « à vol d'oiseau ». Les distances routières de 48 180 paires de villes européennes sont issues du service de calcul d'itinéraires de Bing Cartes. Étant donné que notre ensemble de données comporte aussi des informations sur les temps de trajet, nous sommes en mesure de prendre en compte les coûts liés au temps, en plus de ceux qui dépendent de la distance. Nous constatons qu'à distance orthodromique et taille d'agglomération égales, la distance routière entre deux villes d'un même pays est inférieure de 10 % environ à celle qui sépare des villes situées dans des pays différents. De même, la distance est parcourue plus rapidement lorsque les villes se trouvent dans le même pays. Nous observons qu'en utilisant des mesures établies sur la distance routière effective, plutôt que sur la distance orthodromique, l'effet négatif des frontières internationales sur les échanges de marchandises dans une équation de gravité standard diminue d'environ 15 %. Les coûts des échanges liés à la durée des trajets sont à l'origine d'une réduction supplémentaire de 10 % de l'effet frontière. Dans l'ensemble, ces résultats font ressortir l'importance des réseaux routiers – et de la politique du transport routier en général – pour renforcer l'intégration des marchés.

Classification JEL : F14 ; F15 ; R49

Mots-clés : transport routier ; échanges internationaux ; distance ; temps de trajet ; gravité

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ROAD CONNECTIVITY AND THE BORDER EFFECT: EVIDENCE FROM EUROPE

Henrik Braconier and Mauro Pisu[1]

Introduction

A large literature has documented a large negative impact of national borders on the volume of trade. McCallum (1995) was the first to provide evidence on this phenomenon. Using data on Canadian provinces and US states, McCallum found that the trade volume among Canadian provinces was more than 20 times larger than that with US states, even after controlling for economic importance and distance. Subsequent studies on North America, Europe or OECD countries, employing improved methodologies, found lower but still sizeable border effects. Estimates, however, range widely from two to above ten.[2]

Previous studies have used different distance metrics, but virtually all of them were based on the great circle (i.e. geodesic or "as-crows-fly") distance. Distances between countries (i.e. external distances) have often been computed using capitals or alternatively the most populous city in each country. The choice of cities is not important when countries are small and/or far from each other (in comparison with their size) or when the country's economic centre is close to the selected city. However, if these conditions are not met, between-country distances computed in this way may not accurately reflect the actual distance between economic centres. Calculations of internal distance have relied on even rougher approximations, such as taking one quarter of the distance to the nearest trading partner or assigning it a value as a function of the country's area.

Head and Mayer (2002; 2010) proposed alternative within- and between-country distance metrics. These are based on the population-weighted average distance between a number of cities in each country. They show that using population-weighted distance measures lowers the border effect significantly with respect to the one estimated using traditional distance measures, as the latter systematically underestimate the internal-to-external distance ratio.

The contribution of this paper is twofold. First, it provides new evidence on the border effect in Europe using road distance rather than great circle distance. Second – in addition to trade costs attributable to geographical distance – we also consider time-related trade costs as our data provide information on travel time. To our knowledge, road distance and travel time measures have not been used before to analyse transport costs.

1. We would like to thank Jorgen Elmeskov, Peter Hoeller, Jean-Luc Schneider and Cyrille Schwellnus for helpful comments. We also thank Celia Rutkoski for excellent editorial assistance.

2. This means that trade within a country will be two to ten times higher than with other countries of similar size and distance; see e.g. Helliwell (1996; 1997; 2002); Wei (1996); Hillberry (2002); Evans (2001; 2003); Wolf (2000); Helliwell and Verdier (2001); Nitsch (2000); Head and Mayer (2000); Anderson and van Wincoop (2003); de Serres *et al.*, 2001; Chen (2004).

Systematic differences in road distances relative to the great circle distance between domestic and international road shipments could contribute to explain the large border effects reported in the literature. If connections between cities located in the same country are shorter and/or permit higher speeds than cross-border connections, then great circle distance measures overestimate internal relative to external transport costs. Differences in the quality of road transport links domestically and internationally may be due to several factors. They may, for example, stem from geography, as national borders often overlap with natural barriers, e.g. in terms of mountain ranges, forests and rivers. In addition, international road connections may have been shaped by the need for border checks, lowering both the number of border crossings and their capacity.[3] Finally, lower-quality international links may stem from deliberate policies, generating lower investment in international than national road links.[4]

Recent studies have emphasised the importance of time for total transport costs. At a general level, lengthy shipping times translate into higher costs because of the need for larger inventories, higher depreciation and changing market conditions (Deardorff, 2001). Time-related trade costs may thus explain part of the border effect. Everything else equal, road cross-border shipments are characterised by lower speed, because for instance crossing national borders lengthens travel time, so that countries will trade less internationally and more domestically.

Recent empirical evidence confirms the importance of time-related costs for international trade. Close to the spirit of this paper, Combes and Lafourcade (2005) analyse domestic road transport shipments in France. They decompose total road transport costs into distance- and time-related components and show that time-related trade costs dominate. They account for around 63% of total road transport costs (in 1998) and for slightly less than half of the 38% decline in total road transport costs from 1978 to 1998. Evans and Harrigan (2005) show that products for which delivery time is important will be imported from locations close to final demand. Djankov, Freund and Pham (2010) find that countries with long customs delays experience lower trade volumes, with the largest impact on the most time-sensitive products. Comparing air and sea shipping, Hummels and Shaur (2012) find that customers are willing to pay a substantial premium to shorten delivery time. Their estimates suggest that a day in transit is worth between 0.6 and 2% of the value of the good.

This study is also pertinent to the strand of research examining the trade effect of transport infrastructure. Bougheas *et al.* (1999) show theoretically and empirically how transport infrastructure impinges positively on the volume of trade by lowering trade costs. However, their empirical results are based on the overall length of the national motorway network and therefore do not distinguish between domestic and international road connectivity. Limao and Venables (2001) found that infrastructure is an important determinant of total transport costs, accounting for up to 60% of them. They use an index that does not allow them to decompose the relative contribution of the different kinds of infrastructure (e.g. roads, railways, telecommunications).

We extracted road distances and travel times for bilateral links between 220 continental European cities. As described in Section 2, we use city-pair road distances and travel time to compute population-weighted within (i.e. internal) and between (i.e. external) countries road and "travel-time" distance. In a second step we estimate gravity equations of bilateral trade flows at the industry level using these novel distance measures. We focus on continental Europe for several reasons. First, road freight is the dominant mode of transport within the EU, accounting for around 75% of total freight traffic, pointing to the

3. Border checks were suppressed in the Schengen area since 1999. However, as road networks change only slowly they may still reflect the erstwhile need for them.

4. International coordination for building and managing infrastructure projects is notoriously difficult.

importance of road transport costs in the European transport sector. Second, we want to focus on road-only links, avoiding connections that partly rely on sea transport. This restriction relates both to our need to measure road distance correctly, but also due to the fact that we analyse travel time effects too. Third, the lack of compulsory border checks within large parts of Europe removes a possible source of (unobservable) travel time variation.

The descriptive statistics shown in Section 3 for the 48 180 city pairs indicate that great circle distances systematically overestimate the internal-to-external road distance ratio. For the same great circle distance, the road between two cities located in the same country is around 10% shorter than that between cities in different countries. Thus, everything else equal, road networks provide shorter and therefore cheaper connections within countries than between them. Furthermore, travel time (speed) is shorter (higher) for national than international connections. Overall, this evidence indicates that great circle distance overestimates national trade costs relative to international ones, potentially overstating border effects.

The gravity equation estimates reported in Section 4 indeed show that the use of road distances reduces the border effect by around 15%, with some variation across countries and industries. The largest border effect is estimated for countries with longer international road connections in comparison with national ones, and for industries whose products are less easily transportable by road. The inclusion of travel time reduces the border effect by an additional 10%, underlining the importance of time-related trade costs. From a policy perspective these findings suggest that enhancing international road connectivity – rather than simply increasing the length of national road networks – will lead to greater market integration.

Methodology and data

Road distances and travel times were extracted from the Bing Maps Route Service for 22 continental European countries (Table A1 lists the countries). This online service estimates the route (and distance) between any two addresses or coordinates that minimises travel time.[5] The predominance of travel time in terms of transport costs implies that a time minimizing route is likely to provide a good proxy for the cost minimizing route. The data were extracted during October 2012. Cities' coordinates were taken from the World Gazetteer website along with cities' population, which are used as weights.[6] Our set of cities includes the ten most populous cities in each country. We dropped cities on islands, however, to avoid links combining road and sea transport and replaced them with the next mainland city in terms of population. This affects one or two cities in Greece, Italy, Portugal and Spain.[7]

The road distance between any two countries (i.e. external distance) is computed as in Head and Mayer (2002; 2010) and Chen (2004), but unlike them we use road rather than great circle distance:

$$D_{od} = \sum_{i \in o} \sum_{j \in d} D_{ij} \frac{P_i}{P_o} \frac{P_j}{P_d} \quad (1)$$

5. Note that estimated travel times and distances do not include potential effects from congestion.

6. Coordinates in World Gazetter refers to "city centre", which most often is defined as the city's administrative centre like the mayor's office.

7. For Denmark, two of the ten cities are located on the island Sjaelland. While bridge-connections to continental Europe exist, these are typically less cost and time efficient than ferry connections which are the route recommended by Bing Maps. As distance and time on ferry (and delays related to loading and unloading ferries) are not accounted for in our data, international travel times and distances may be slightly underestimated for Denmark.

where i and j index the cities in the origin (o) and destination (d) countries respectively. Internal distances are computed analogously with $o = d$. Table A2 reports the internal and external road distances and travel time for the set of countries in our data set. Travel times within and between countries were computed analogously to road distances and are reported in Table A3.

We use these distance measures to estimate the border effect employing a standard gravity equation. The popularity of the gravity model in international trade can be ascribed to its generality as it is robust to different theoretical specifications (e.g. Anderson and van Wincoop, 2003; Anderson 2010). Using industry level data for a set of continental European countries, we estimate the canonical gravity model:

$$\ln X_{ods} = \alpha + \beta_1 home + \beta_2 \ln Y_{os} + \beta_2 \ln Y_d + \beta_3 \ln Dist_{od} + \gamma C_{od} + \varepsilon_{ods} \quad (2)$$

where X is the value (expressed in common currency) of exports of sector s from the origin (o) to the destination (d) country, Y_{os} is the total production of sector s in the origin country and Y_d is the GDP of the importing country; C_{od} is a vector of bilateral characteristics affecting trade costs, which include a common language and an adjacency dummy (the latter is one if the origin and destination countries are contiguous); ε_{ods} is a classical error term.

The border effect is captured by the coefficient of the dummy variable *home*, which is one when $o = d$.[8] In this case, the dependent variable measures domestic trade (X_{oos}). As in previous studies, domestic trade is computed as sector s' total output minus its total exports to the world. This approach to estimate the border effect using national rather than sub-national (e.g. regional) trade data was proposed by Wei (1996) and subsequently applied, *inter alia*, by Evans (2001), Nitsch (2000), Head and Mayer (2000) and Chen (2004). A positive and significant β_1 shows the extent of excess within-country trade in comparison with what is predicted by standard explanatory variables, such as distance and economic importance. As we are estimating a logarithmic equation, the effects of international borders trade can be recovered taking exp[β_1], where e.g. exp[β_1] = 2 would mean that domestic trade is twice as large as cross-border trade, everything else constant. In a similar manner, the adjacency dummy captures the difference in trade with an adjacent country and a non-adjacent country.

The industry level production data (ISIC Rev. 3) come from the OECD STAN data base, and refer to the year 2007. This data was merged with bilateral trade data at the same industry level from the OECD. The set of countries analysed covers the subset of continental Europe for which trade and production data is available.[9]

Internal and external distance

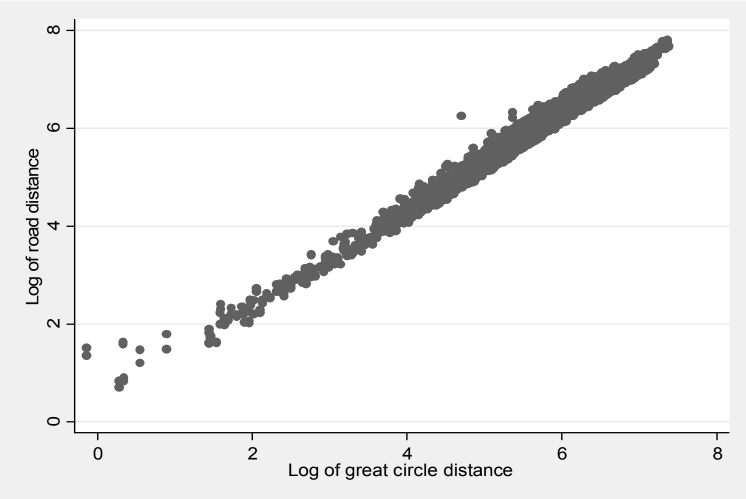
Figure 1 shows the road and great circle distance (in logarithm) for all 48 810 city pairs in our dataset. On average road distance exceeds the great circle distance by around 29%.[10] The mean hides considerable variation across city pairs, however. For the bottom 5% of city pairs, road routes are less than 14% longer than great circle distance whereas for the top 5% they are more than 51% longer.

8. The common language and adjacency dummies are also set to one when $o = d$ since we assume that languages are shared within countries and countries are assumed to be adjacent to themselves. Setting these dummies to zero when $o = d$ could inflate the border effect as the home dummy would then also capture language and adjacency effects on trade. Wei (1996) and Wolf (2000) adopt the same specification used in this paper whereas Head and Mayer (2002, 2010) and Chen (2004) set these dummies to zero when $o = d$.

9. The countries listed in Table A1 and not included in the gravity equation estimation are Bulgaria, Lithuania, Latvia, Portugal, and Romania.

10. This percentage is computed as the log difference between road and great circle distance.

Figure 1. Intercity road and great circle distance in continental Europe



The use of great circle distances as a proxy for transport costs in equation (1) might result in inflated border effects if great circle distances systematically overestimate the internal-to-external distance ratio. To investigate this issue, we regress city-pair road distance (in log) on the great circle distance (in log) and a within-country dummy, which is one if the two cities are located in the same country.

The specification shown in column one of Table 1 suggests that, for the same great circle distance, within-country intercity road links are more than 6% shorter than links between cities in different countries. Column 2 adds the population of departure and arrival cities, as larger cities are likely to have better and more direct road links. The coefficients for cities' size are negative and significant as expected, and the within-country dummy coefficient remains virtually unchanged. The specification in column three controls for country-level unobservable effects – such as remoteness and topography – by means of origin and destination dummies. In this specification, the difference in road distance between cities located in the same countries and those in different ones rises to around 10%, while the impact of city size roughly doubles.

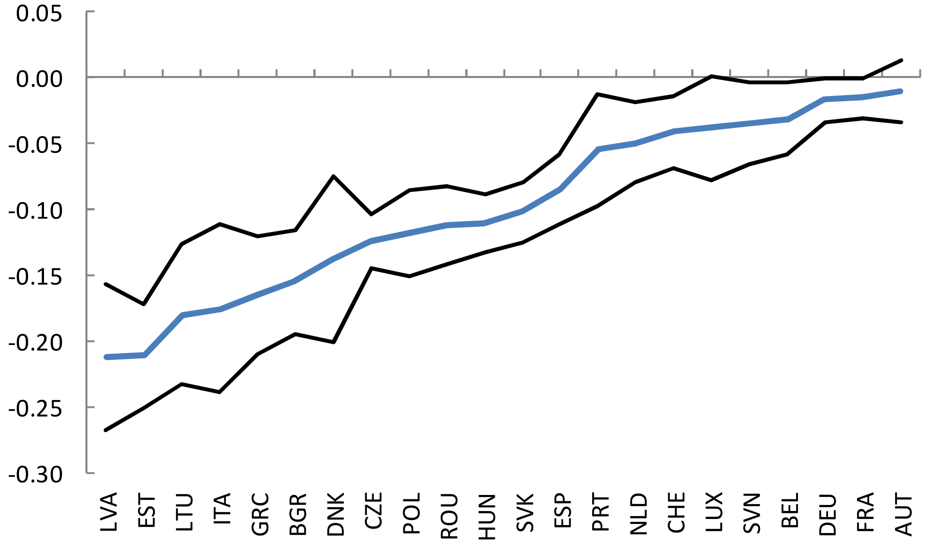
Table 1. Difference between road and great circle distance within and between countries

	(1)	(2)	(3)
Within country dummy	-0.066**	-0.065**	-0.097**
	[-4.656]	[-4.533]	[-6.197]
Log of great circle distance	0.974**	0.975**	0.959**
	[238.611]	[238.397]	[189.614]
Log of population of departure city		-0.004*	-0.008**
		[-2.275]	[-10.052]
Log of population of arrival city		-0.003*	-0.007**
		[-2.090]	[-10.157]
Constant	0.459**	0.539**	0.670**
	[0.029]	[0.040]	[0.035]
R-squared	0.99	0.99	0.99
N	48180	48180	48180
Origin and destination country fixed effects	No	No	Yes

Note: The dependent variable is the log of road distance between two cities; robust clustered standard errors by origin-destination country pairs in brackets; ** denotes significant at 1% level, * at 5%.

Figure 2 shows country-specific estimates of the within-country dummy. These are estimated by interacting origin country dummies with the within-country dummy, using the specification with origin and destination country fixed effects (Column 3). National road connections are more than 15% shorter than those spanning different countries for the Baltic States, Italy, Greece and Bulgaria but less than 5% shorter for Germany, France and Austria. For Austria the within-country effect is not significant at 5% level.

Figure 2. Country-specific road-distance difference between national and international trips



Note: This figure shows country-specific estimates of the within country dummy using the specification in column three of Table 1; the black lines show robust clustered 95% confidence interval.

Table 2 reports results on speed differences between national and international road trips obtained regressing travel time on road distance and city populations. The results show that travel time (speed) is around 5% shorter (faster) for national than international trips, *ceteris paribus*. This speed effect likely reflects higher quality domestic roads, which allow higher travel speeds (see Braconier and Pisu, 2013 for a discussion). For instance, national shipments might take place on motorways for comparatively longer stretches than international ones, as roads that cross borders are less likely to be motorways. Our estimate of the travel time difference is also likely to understate the true difference as we rely on theoretical travel time, which does not account for potential time losses due to delays at national borders.

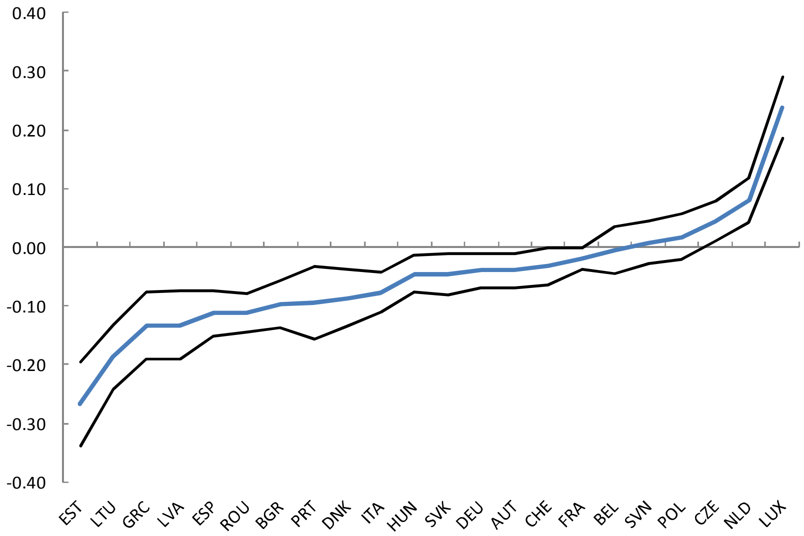
Table 2. Regression of travel time on road distance

	(1)
Within country dummy	-0.049*
	[0.020]
Log of road distance	0.886**
	[0.006]
Log of population of departure city	-0.001
	[0.001]
Log of population of arrival city	-0.001
	[0.001]
Constant	4.210**
	[0.044]
R-squared	0.99
Number of observations	48180
Origin and destination country fixed effects	Yes

Note: The dependent variable is the log of travel time; robust clustered standard errors by origin-destination country pairs in brackets; ** denotes significant at 1% level, * at 5%.

Figure 3 shows country-specific estimates of speed differences between domestic and international road trips. Speed differences are even more heterogeneous across countries than road-link lengths. For Luxemburg and the Netherlands – and to a lesser extent for the Czech Republic – they are even estimated to be positive and statistically significant, suggesting that the average speed is lower for national than international trips.

Figure 3. Country-specific estimates of the speed difference between national and international trips



Note: This figure shows country specific estimates and the 95% confidence interval of the speed difference between national and international road connections; they are obtained using the specification in Table 2 and interacting the within-country dummy with origin country dummies.

Overall, the total travel time difference between international and national trips – controlling for great circle distance and city population – is therefore attributable to two factors: the longer *road* distance that international trips involve – due the "degree of straightness" of the road network – and the lower speed. The descriptive evidence presented above indicates that both straightness and speed might be relevant for explaining the cost differential between domestic and international trade.

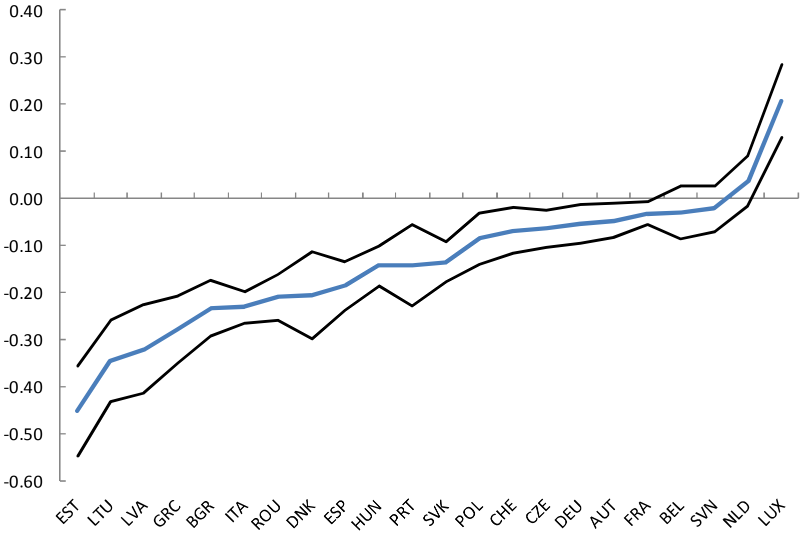
Table 3 presents estimates of the total travel time difference due to these two factors by regressing travel times on the great circle rather than the road distance. The coefficient estimate of the within country dummy suggests that road trips within national borders take about 14% less time than those crossing them. This value is similar to the sum of the within country dummies shown in Table 1 (column three) and Table 2, which capture the two effects separately. The country specific estimates of the difference in total travel times between national and international trips are shown Figure 4. On average, travel time differences are larger than those in Figures 2 and 3 – as they account for both factors mentioned above – and are highly correlated with them.

Table 3. Regression of travel time on great circle distance

	(1)
Within country dummy	-0.136**
	[0.029]
Log of great circle distance	0.850**
	[0.009]
Log of population of departure city	-0.007**
	[0.001]
Log of population of arrival city	-0.007**
	[0.001]
Constant	4.805**
	[0.059]
R-squared	0.98
Number of observations	48180
Origin and destination country fixed effects	Yes

Note: The dependent variable is the log of travel time; robust clustered standard errors by origin-destination country pairs in brackets; ** denotes significant at 1% level, * at 5%.

Figure 4. Country-specific estimates of the total travel time difference between national and international trips



Note: This figure shows country specific estimates and the 95% confidence interval of the total travel time difference between national and international road connections; they are obtained using the specification in Table 3 and interacting the within-country dummy with origin country dummies.

Estimates of the border effects on trade

The gravity equation (2) was estimated using alternatively the great circle or road distance measures.[11] Results are presented in Table 4, where columns one and two report the estimates from specifications including industry dummies only. In both specifications, the point estimate of the border effect points to domestic trade being around 5.5 times [=exp(1.7)] higher than international trade, *ceteris paribus*. The

11. The border effects were estimated for the 17 countries – out of the total 22 used in the previous section - for which trade and production data are available. Bulgaria, Latvia, Lithuania, Portugal and Romania are excluded.

elasticity of industrial production in the origin country and GDP of the destination country are not far from unity, as expected. The adjacency dummy is positive and significant whereas common language is not significant.

Relative prices of goods in the origin and destination countries are other important determinants of international trade, in addition to income and trade costs. These prices are unobserved and they are likely to bias estimates as they depend on trade barriers (Anderson and Wincoop, 2003). To control for these prices, we adopted the methodology proposed by Feenstra (2002) and included origin and destination dummies interacted with industry fixed effects.[12]

Table 4. Estimation of the average effect: Basic specification

	(1)	(2)	(3)	(4)
Home	1.712**	1.702**	1.460**	1.316**
	[0.21]	[0.21]	[0.25]	[0.25]
Log Y_{os}	0.898**	0.895**		
	[0.02]	[0.02]		
Log Y_{d}	0.894**	0.890**		
	[0.03]	[0.03]		
Log of great circle distance	-1.320**		-1.497**	
	[0.10]		[0.11]	
Log of road distance		-1.349**		-1.571**
		[0.10]		[0.11]
Adjacency	0.604**	0.591**	0.336**	0.295**
	[0.13]	[0.13]	[0.11]	[0.11]
Common language	-0.121	-0.172	0.115	0.126
	[0.15]	[0.15]	[0.13]	[0.13]
Observations	5374	5374	5374	5374
R2	0.78	0.78	0.76	0.76
Fixed effect	Industry	Industry	Origin-Industry; Destination-Industry	Origin-Industry; Destination-Industry

Note: Robust clustered standard errors in brackets; ** denotes statistical significance at 1%; * at 5%.

After correcting for the bias due to price differences, the border effect estimate obtained using road distance is around 10% smaller than the one estimated with great circle distance (column three and four). As pointed out above, border effect estimates using great circle distance are biased upwards as it tends to overestimate countries' internal-to-external distance ratio. Using road distance yields a lower border effect estimate, which is, however, still sizeable – domestic trade being around 3.7 times (=exp[1.316]) larger than trade across borders. The adjacency effect also drops by about 30%, as this effect stems, at least partly, from mis-measured distances, as underlined by Head and Mayer (2002; 2010).

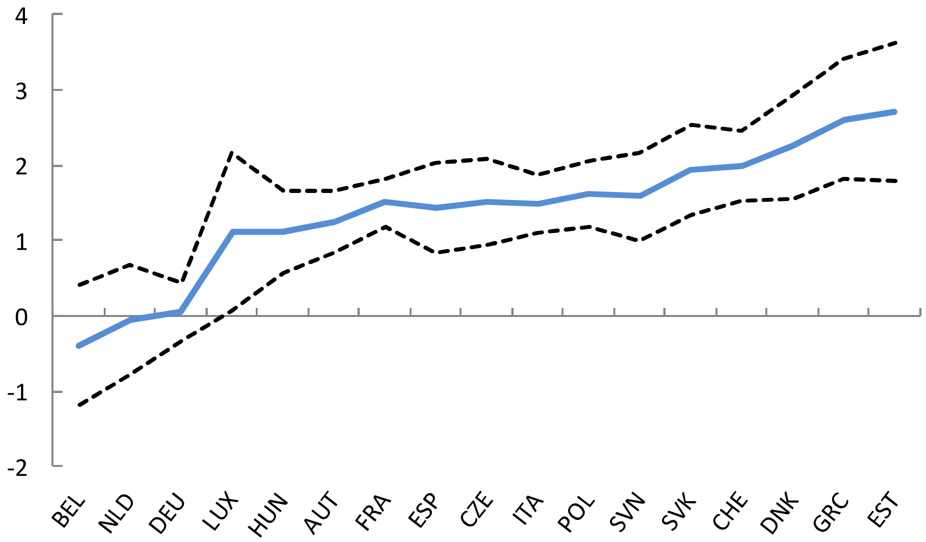
Chen (2004) reported heterogeneous border effects for a set of continental European countries. She found that technical barriers to trade and product-specific information costs are the main determinants of cross-country differences. The different degree of national and international connectivity provided by road networks could also contribute to explain unequal border effects across countries. We investigate this issue by estimating country-specific border effects using the specifications in the last two columns of Table 4.

12. The inclusion of these dummies prevents the estimation of the coefficient of industrial production and GDP.

Figure 5 depicts country-specific border effects estimated with road distance.[13] The largest border effects are estimated for Estonia and Greece, where domestic trade is more than 13 times higher than what standard gravity equation variables predict. The border effect is lowest (and not significant) for the Netherlands, Belgium and Germany. Smaller countries seem to exhibit larger border effects, although Luxemburg is a notable exception. This is consistent with Anderson and van Wincoop (2003) who argue that small countries should have a larger border effect than large ones, as a small drop in international trade will lead to a comparatively larger domestic-trade increase in the former than in the latter.

The country-specific estimates also provide supportive evidence that estimates based on the great circle distance produce biased estimates of the border effect. Figure 6 shows that the bias of the country-specific estimates of the border effect is bigger the longer international road links are compared with national ones, given the same great circle distance. The difference between the length of national and international road links is measured by the within-country coefficients of the road-length regressions (shown in Figure 2). The correlation coefficient with the bias in the border effect is -0.40. Denmark is the only country whose border effect estimated using great circle distance is lower than that using road distance. This can be explained by Denmark's geography as this is the only country in our sample in which maritime transport plays an important role because of its numerous and relatively populous islands. Thus, for Denmark road distance is likely a less good proxy for the actual costs of national and international transport.

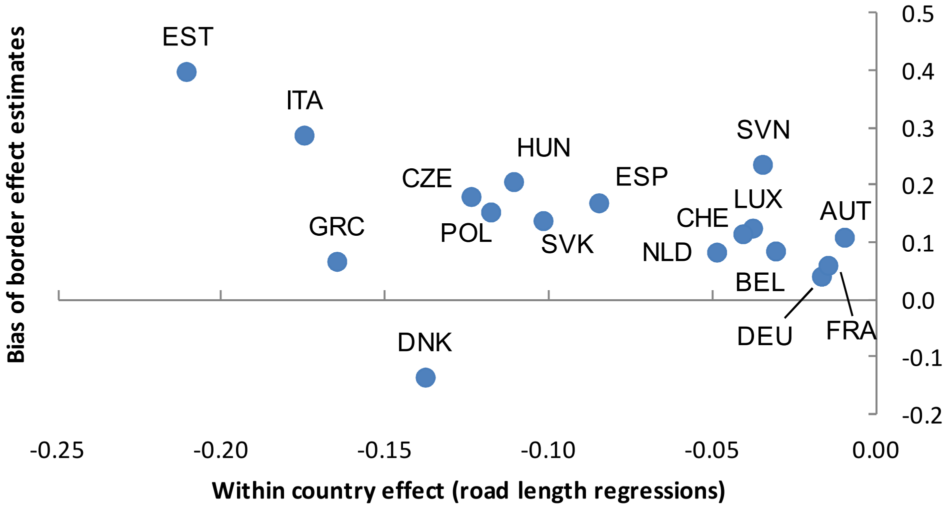
Figure 5. Country specific border effects



Note: This figure shows the point estimates and 95% confidence intervals of country-specific border effects using road distance. The specification in column four of Table 4 was used. The 95% confidence intervals were computed using robust clustered standard errors.

13. The coefficient estimates of the other variables included in the regression, i.e. distance, adjacency and common language, are similar to those shown in column four of Table 2; the differences are less than 5%.

Figure 6. Bias of the border effect using great circle distance and within – versus between-country road length difference



Note: This figure shows the relationship between the bias of the country-specific border effect using great circle distance (y axis) and the country specific within-country dummy (x axis) shown in Figure 2. The bias of country-specific border effects is computed as the difference between the estimates obtained using great circle distance and those using road distance. Both sets of estimates are based on the specification of the gravity equation that include industry fixed effects interacted with origin and destination dummies. Some of the countries shown in Figure 2 are missing as they were not used in the gravity equation estimation because of unavailable trade data.

Although estimations using the road distance lower the country-specific border effects, the relative size of country-specific border effects remain stable. Road-based distance estimates of the border effect are on average 14% smaller than those based on great circle distance but the rank correlation coefficient between the two sets of estimates is 0.98. Similarly, Chen (2004) found that different distance metrics affect the magnitude of the country-specific border effects but not the ranking of countries. This underlines that the border effect is also driven by factors unrelated to road distance.

Further evidence on the importance of road connectivity for the border effect can be seen from industry-specific estimates. Table 5 reports the estimated border effect separately for each industry. The gravity equation has been re-estimated by interacting the home dummy with industry dummies. We also interacted all the other explanatory variables with industry dummies since theory suggests that forcing all industries to have the same distance coefficient will bias the border effect.[14]

14. The elasticity of trade with respect to any trade barrier – for instance, distance – is given by the elasticity of substitution between foreign and domestic products and the elasticity of trade costs with respect to distance. There is evidence that these two elasticities are different across industries. Broda and Weinstein, (2004) and Imbs and Méjean (2009) show that the elasticity of substitution between domestic and foreign varieties is heterogeneous across product categories and industries whereas the elasticity of trade costs with respect to distance depends on their transportability or value-to-weight ratio. Therefore, for industries with a high elasticity of trade costs relative to distance, the border effect will be biased upward if all industries are forced to have the same distance coefficient as the home dummy will capture some of the distance-related trade costs.

The results in Table 5 show that, when significant, the estimated border effect using the great circle distance is always larger than the one estimated using road distance. The only exception is for electricity, gas, steam and hot water supply, for which the border effect is virtually the same when using either of the two distance metrics. This is probably due to the limited transportability of gas - and the non-transportability of the other components - by road. The difference between the two sets of border effect estimates should indeed be less pronounced for those industries whose products cannot be easily transported by road, as their transport costs are only weakly related to the length and quality of road links. That the border effect is unchanged only for electricity and gas is evidence that the lower border effects of the other industries obtained when road distance is used is genuinely related to the different degree of connectivity road networks provide within and between countries.

To further explore how road transportability affects the border effect we computed a transportability index using the Community Flow Survey for the US. This survey records the average length of shipments by a variety of transport modes for different NAICS industries. We considered shipments by trucks only. We matched these industries with the ISIC two-digit industries used in this study and computed a transportability index, as in Head and Mayer (2002; 2010). The index is computed dividing the length of road-shipments of each industry by the average of all shipments (Table A4 in the Appendix).[15] Thus, the lower the index, the less easily goods can be transported by road. From Table A4, it is possible to see that the industries with the lowest road transportability index are, unsurprisingly, mining and quarrying, and electricity, gas, steam and hot water supply. For these industries, road shipments' length is only 25% of the overall average. The industry whose goods are most easily transported by road is radio, television and communication equipment, with shipments about 60% longer than the average.

15. Although the average distance of road shipments for a particular good may not be the same in the US and continental Europe, its transportability relative to other goods – captured the transportability index – is likely to be similar. To match NAICS with ISIC industries we used the correspondence table provided by the United States Census Bureau. The correspondence between the two classifications is not always one to one. Often more than one NAICS industry corresponds to an ISIC industry. In these instances, we took the mean or alternatively the median of the average miles per shipment of the different NAICS industries corresponding to a given ISIC industry. Taking the median or the average makes little difference. The two measures are highly correlated (0.98) and produce similar regression results.

Table 5. Industry specific estimates

	Home		Distance		Adjacency		Common language	
	Great circle distance	Road distance	Great circle distance	Road distance	Great circle distance	Road distance	Great circle distance	Road distance
Mining and quarrying	0.971	0.801	-2.580**	-2.645**	1.064**	1.030**	0.228	0.245
	[0.71]	[0.74]	[0.33]	[0.35]	[0.38]	[0.39]	[0.42]	[0.42]
Food products, beverages and tobacco	0.822	0.621	-1.752**	-1.863**	0.549**	0.482*	0.591*	0.602*
	[0.52]	[0.53]	[0.21]	[0.22]	[0.20]	[0.20]	[0.29]	[0.29]
Textiles, textile products, leather and footwear	0.307	0.114	-1.467**	-1.569**	0.294	0.232	-0.296	-0.286
	[0.65]	[0.66]	[0.19]	[0.20]	[0.19]	[0.19]	[0.23]	[0.23]
Wood and products wood and cork, except furniture; articles straw and plaiting materials	1.430**	1.340**	-1.382**	-1.417**	0.845**	0.832**	0.422+	0.435+
	[0.38]	[0.38]	[0.20]	[0.20]	[0.18]	[0.19]	[0.22]	[0.22]
Pulp, paper, paper products, printing and publishing	1.807**	1.639**	-1.355**	-1.455**	0.353*	0.292+	0.376+	0.380+
	[0.36]	[0.37]	[0.18]	[0.19]	[0.17]	[0.18]	[0.20]	[0.20]
Coke, refined petroleum products and nuclear fuel	0.006	-0.231	-3.263**	-3.399**	0.964*	0.899*	-0.578	-0.543
	[0.83]	[0.84]	[0.46]	[0.49]	[0.40]	[0.41]	[0.49]	[0.49]
Chemicals and chemical products	0.172	0.056	-1.025**	-1.082**	0.351*	0.319+	0.345*	0.352*
	[0.45]	[0.44]	[0.18]	[0.19]	[0.17]	[0.17]	[0.18]	[0.17]
Rubber and plastics products	1.470**	1.366**	-1.010**	-1.064**	0.402+	0.371+	0.048	0.055
	[0.33]	[0.34]	[0.28]	[0.31]	[0.21]	[0.22]	[0.21]	[0.21]
Other non metallic products	1.670**	1.507**	-1.615**	-1.701**	0.371+	0.321	0.324	0.336
	[0.43]	[0.44]	[0.21]	[0.23]	[0.21]	[0.22]	[0.28]	[0.28]
Basic metals	0.097	-0.086	-1.747**	-1.844**	0.176	0.121	0.344+	0.358+
	[0.34]	[0.36]	[0.19]	[0.20]	[0.16]	[0.16]	[0.20]	[0.20]
Fabricated metal products, except machinery and equipment	2.167**	2.020**	-1.398**	-1.477**	0.13	0.085	0.169	0.177
	[0.32]	[0.33]	[0.17]	[0.18]	[0.16]	[0.17]	[0.17]	[0.17]
Machinery and equipment n.e.c.	1.229**	1.163**	-0.942**	-0.980**	0.176	0.158	-0.016	-0.005
	[0.25]	[0.25]	[0.15]	[0.16]	[0.13]	[0.13]	[0.12]	[0.12]
Office, accounting and computing machinery	0.373	0.271	-1.035**	-1.052**	0.603**	0.600**	-0.099	-0.083
	[0.55]	[0.56]	[0.22]	[0.24]	[0.22]	[0.23]	[0.27]	[0.27]
Electrical machinery and apparatus n.e.c.	1.079**	0.926*	-1.310**	-1.412**	-0.16	-0.22	0.293	0.297
	[0.35]	[0.37]	[0.19]	[0.21]	[0.19]	[0.20]	[0.20]	[0.20]
Radio, television and communication equipment and apparatus	1.620**	1.533*	-0.876**	-0.914**	0.096	0.076	0.237	0.244
	[0.60]	[0.60]	[0.19]	[0.21]	[0.19]	[0.20]	[0.24]	[0.24]
Medical, precision and optical instruments, watches and clocks	1.296**	1.138*	-1.307**	-1.383**	-0.063	-0.109	0.115	0.122
	[0.44]	[0.45]	[0.20]	[0.21]	[0.18]	[0.19]	[0.20]	[0.20]
Motor vehicles, trailers and semi-trailers	0.871**	0.804*	-0.889**	-0.896**	0.312+	0.314+	-0.072	-0.058
	[0.33]	[0.34]	[0.18]	[0.19]	[0.17]	[0.17]	[0.19]	[0.19]
Other transport equipment	1.208*	1.016+	-1.779**	-1.897**	0.3	0.229	-0.39	-0.379
	[0.52]	[0.53]	[0.25]	[0.27]	[0.26]	[0.27]	[0.29]	[0.29]
Manufacturing n.e.c. and recycling	0.963*	0.807*	-1.426**	-1.513**	0.133	0.081	0.534*	0.543*
	[0.37]	[0.38]	[0.18]	[0.18]	[0.18]	[0.18]	[0.21]	[0.21]
Electricity, gas, steam and hot water supply	4.014**	4.020**	-0.746	-0.737	1.900**	1.916**	1.979**	1.966**
	[0.81]	[0.85]	[0.56]	[0.60]	[0.58]	[0.57]	[0.55]	[0.55]

Note: Industry specific estimates of the explanatory variables are obtained interacting them with industry dummies. Regressions also include origin and destination fixed effects interacted with industry dummies; robust clustered standard errors in brackets; ** denotes statistical significance at 1%; * at 5%.

Table 6 shows gravity equation estimates obtained when interacting the log of the transportability index with the home dummy. The interaction term is negative and significant, indicating that the border effect is larger for industries characterized by less easily transportable products. According to these estimates the border effect for electricity and gas is around 4. This is remarkably close to the point estimate shown in Table 5. This shows that domestic trade of electricity and gas products is more than 50 times larger than trade with other countries of similar economic size and proximity. Overall, the correlation between the border effect shown in Table 5 and those that can be computed from Table 6, using the value of the transportability index for each industry, is 0.34. The confidence interval around point estimates and industry-specific characteristics not captured by the transportability variable - but captured by the industry dummies in Table 5 - might explain this modest correlation coefficient.

Table 6. Border effect and transportability index

Home	1.032**
	[0.24]
Home * Transportability	-2.295**
	[0.18]
Log of road distance	-1.534**
	[0.11]
Adjacency	0.342**
	[0.11]
Common language	0.144
	[0.12]
Observations	5374
R-squared	0.594
Fixed effect	Origin-Industry Destination-Industry

Note: The model includes a set of origin-industry and destination-industry fixed effects; transportability refers to the log of the transportability index; robust clustered standard errors in brackets; ** denotes statistical significance at 1%; * at 5%

We now turn to trade costs due to travel time. We computed within- and between-country distances based on travel time analogously to the road distance metrics. The road and travel-time measures are highly correlated, which prevents us from indentifying their separate effects. Table 7 shows results for the two specifications. The first one uses travel time instead of road distance (column one) while the other uses the first principal component of travel time and road distance to capture the joint impact of the two types of costs (column two).[16]

Overall, the results support the hypothesis that time-related costs matter. The point estimate of the border effect using the first principal component of time and road distance (column two) is about 10% lower than the one estimated using road distance only. Thus, accounting for time- and road-distance-related trade costs lowers the border effect estimates by around 25%, compared with traditional estimates based of great circle distance only. Using travel time reduces the border effect even further (column one) as these estimates capture the effects due to road distance and speed differences between national and international road trips. Still, the border effect does not disappear, with domestic trade being more than three times as large as cross-border trade.

16. The first principal component explains more than 95% of the variance.

Table 7. Border effects and time-related costs

	(1)	(2)
Home	1.124**	1.207**
	[0.26]	[0.26]
Log of travel time	-1.769**	
	[0.12]	
Log of principal component		-1.683**
		[0.12]
Adjacency	0.262*	0.265*
	[0.11]	[0.11]
Common language	0.187	0.153
	[0.13]	[0.13]
Observations	5374	5374
R-squared	0.76	0.76
Fixed effect	Origin-Industry Destination-Industry	Origin-Industry Destination-Industry

Note: The principal component captures the common variation in travel time and road distance; the model includes a set of origin-industry and destination-industry fixed effects; robust clustered standard errors in brackets; ** denotes statistical significance at 1%; * at 5%

The estimates presented thus far can be used to provide back-of-the-envelope calculations of the likely impact of improved international road links on international trade. For the 17-country sample used in the gravity equations above, national road links are on average around 8.6% shorter than international links – given the same great circle distance and city populations – while the corresponding difference in total travel times is 10.5%.[17] Based on the estimate of the road distance elasticity of -1.57 (column four of Table 4), a reduction of the road-to-great-circle-distance ratio of international links to the same level as that of national links could spur international trade by almost 14% ($\approx -8.6\% * [-1.57]$). The same calculation for total travel time savings – which captures both road-distance and speed differences – and based on the travel time elasticity of -1.77 (first column of Table 7) indicates that international trade within Europe could increase almost 19% ($\approx -10.5\% * [-1.769]$) if international roads were as straight and speeds were as high as on comparable national links.

These figures suggest that improving international road networks could significantly enhance European market integration. However, these gains may difficult to achieve, as it is probably unrealistic to expect international road links to provide the same degree of connectivity as national roads. International links are more exposed to geographical barriers (like mountain ranges and rivers) that are difficult and expensive to overcome. On the other hand, it is likely that factors that are amenable to improved policy settings (better cross-country planning or more motorways crossing national borders for instance) could generate more modest and realistic improvements in international road links that would have non-negligible trade effects.

The impact of improved international road links is likely to differ substantially across industries. Lower international transport costs are likely to affect industries with high – but not prohibitive – transport costs more than industries facing low transport costs (i.e. characterised by high road transportability). For industries with prohibitive road transport costs (as electricity, gas, steam and hot water supply), marginal

17 . The averages 8.6% and 10.5% are computed using the within-country dummy estimates shown in Figure 2 and 4, respectively, considering only the set of countries used in the gravity equation. This excludes Bulgaria, Latvia, Lithuania, Portugal and Romania from the list in Table A1.

changes in those costs may not have any impact. Electricity, gas, steam and hot water supply is indeed the industry with the lowest (in absolute value) - and not significant - road distance elasticity (Table 5). Based on the industry-specific estimates of the elasticity of road distance shown in Table 5, trade across countries could increase by between 8% ($\approx -8.6\% * [-0.914]$) – for machinery and equipment n.e.c and motor vehicles – and 30% ($\approx -8.6\% * [-3.4]$) - for coke, refined petroleum products and nuclear fuel (Table 8).[18]

Table 8. Industry-specific impacts of improved international road connections on international trade

Mining and quarrying	22.8
Food products, beverages and tobacco	16.1
Textiles, textile products, leather and footwear	13.5
Wood and wood products and cork, except furniture; articles straw and plaiting materials	12.2
Pulp, paper, paper products, printing and publishing	12.5
Coke, refined petroleum products and nuclear fuel	29.3
Chemicals and chemical products	9.3
Rubber and plastics products	9.2
Other non metallic products	14.7
Basic metals	15.9
Fabricated metal products, except machinery and equipment	12.7
Machinery and equipment n.e.c.	8.4
Office, accounting and computing machinery	9.1
Electrical machinery and apparatus n.e.c.	12.2
Radio, television and communication equipment and apparatus	7.9
Medical, precision and optical instruments, watches and clocks	11.9
Motor vehicles, trailers and semi-trailers	7.7
Other transport equipment	16.3
Manufacturing n.e.c. and recycling	13.0
Electricity, gas, steam and hot water supply	6.4
Average	*13.1*

Note: Figures show the percentage increase in international trade for different industries associated with a reduction in the road-to-great-circle-distance ratio of international links to the same level as that of national links and are based on the industry specific road distance elasticities in Table 5.

Countries suffering from particularly bad international road connections could benefit more from raising the connectivity of international to that of national links. Table 9 shows the potential trade increases for the 17 countries used in the gravity equation associated with making international links as straight as national ones. These estimates are obtained using a common distance elasticity of -1.51 and multiplying it by the country-specific potential improvements in international road links shown in Figure 2.[19] The largest increment in international trade is found for Estonia, Greece and Italy (above 25%) – as these countries suffer from especially poor international road connections as compared to national ones. It is lowest in Austria, France and Germany (below 3%). It is worth noting that both the industry-level and the country-

18. It is worth noting that the mean of these industry-specific effects is 13%, which is close to the 14% increase in international trade at the national level resulting from bringing the road-to-great-circle-distance ratio of international links to the same level as national ones.

19. -1.51 is the road distance elasticity obtained in the specification estimating country-specific border effects (Figure 5). This is similar to the elasticity Table 4 column four, reporting a common border effect estimate to all countries.

level calculations reported above do not include the extra trade gains that increasing the travel speed of international trips to the same level of national ones could engender. In this respect the results provide a lower bound of potential trade increases.

Table 9. Country-specific impacts of improved international road connections on international trade

Austria	1.5
Belgium	4.7
Switzerland	6.2
Czech Republic	18.8
Germany	2.6
Denmark	20.9
Spain	12.9
Estonia	32.0
France	2.3
Greece	25.0
Hungary	16.8
Italy	26.5
Luxemburg	5.8
Netherlands	7.4
Poland	17.9
Slovakia	15.5
Slovenia	5.3
Average	*13.1*

Note: Figures show the percentage increase in international trade associated with a reduction in the road-to-great-circle-distance ratio of international links to the same level as that of national links and are based on a common road distance elasticity of -1.5.

Conclusions

This paper investigated the impact of road connectivity on cross-country trade flows in continental Europe. It provides new evidence on the border effect by focusing on actual internal and cross-country road distances rather than the great circle distance that has been widely used in previous studies. The paper also takes into account time-related trade costs by considering road travel time in addition to road distance.

The analysis shows that the large border effects reported in the literature are partly due to the overestimation of internal trade costs by the great circle distance as compared with external ones. City-pair road distance regressions indicate that road links within countries are about 10% shorter than those crossing national borders. Also, travel speeds are roughly 5% higher for domestic links. Overall, this suggests that internal shipping costs due to both road distance and travel time are lower than what can be inferred from great circle distance.

Gravity equation estimates indicate that replacing the great circle distance measure with road distance reduces the border effect by around 15% on average. The inclusion of travel time reduces the border effect by an additional 10%, underlining the importance of time-related trade costs. Back-of-the-envelope calculations based on gravity equation estimates indicate that reducing the length of international road links to levels comparable to those of national links – given the same great circle distance – could boost international trade among continental European countries by around 14%, thus enhancing market integration significantly. Equalizing the travel speed of international and national trips would take the increase in international trade to 19%. These effects would vary substantially across industries and countries, with the largest increases in international trade taking place for industries with high road transport costs and countries suffering from particularly bad international road links.

From a policy perspective these findings suggest that – despite decades of economic integration, harmonisation and removal of intra-European trade barriers – cross-border road links within continental Europe are still of lower quality than those within European countries. This has a sizeable impact on cross-country trade and hampers market integration. A stronger focus on cross-national road infrastructure links therefore seems warranted. Several caveats apply, however. First, the coincidence of national borders and geographic obstacles – in terms of rivers and mountains, for instance – may render international links inherently more costly to build than domestic ones. Compensating fully for such disadvantages with more infrastructure investment may not always be efficient. Second, the results presented in this study only indicate that *relative* spending on cross-country links in relation to national links should be stepped up, and do not provide evidence on whether investment is too low or too high. Finally, implementation and coordination issues and persistent optimism-bias in cost-benefit analyses (Flyvbjerg, 2009; Short and Kopp, 2005) call for careful evaluation of cross-European road projects.

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APPENDIX

Table A1. Continental European countries considered

Austria	Hungary
Belgium	Italy
Bulgaria	Lithuania
Switzerland	Luxembourg
Czech Republic	Latvia
Germany	Netherlands
Denmark	Poland
Spain	Portugal
Estonia	Romania
France	Slovak Republic
Greece	Slovenia

Table A2. Road distance within and between countries (km)

Origin	Destination																				
	AUT	BEL	BGR	CHE	CZE	DEU	DNK	ESP	EST	FRA	GRC	HUN	ITA	LTU	LUX	LVA	NLD	POL	PRT	ROU	SVK	SVN
AUT	161.88	1066.06	1223.93	760.84	350.61	759.47	1204.93	2205.89	1760.89	1251.33	1644.30	388.59	957.04	1250.96	884.43	1480.23	1093.29	748.89	2740.25	1105.60	361.77	339.18
BEL	1066.33	60.87	2254.53	659.59	991.54	556.69	914.59	1616.15	2102.06	660.90	2662.01	1402.53	1274.43	1700.56	231.82	1804.14	188.85	1202.42	1979.24	2130.55	1337.47	1200.74
BGR	1228.82	2254.52	218.68	1860.94	1438.30	1895.31	2312.07	3063.30	2535.62	2284.16	837.14	931.45	1620.93	2045.80	2050.14	2267.15	2277.40	1640.57	3673.44	446.62	1142.52	1106.34
CHE	761.95	659.90	1861.33	143.58	864.51	724.85	1246.92	1478.72	2268.20	627.10	2244.73	1121.55	676.03	1866.69	439.52	1970.27	825.76	1329.01	1999.27	1836.69	1099.95	783.28
CZE	354.01	989.71	1439.66	861.53	162.70	599.40	934.50	2274.21	1644.91	1275.88	1923.99	568.17	1186.37	1140.99	828.25	1320.64	961.28	571.11	2754.61	1295.07	407.68	645.81
DEU	764.64	556.50	1894.36	721.97	601.85	380.25	635.79	2013.91	1698.91	1026.61	2311.61	1041.18	1232.47	1297.40	524.07	1400.99	509.50	789.86	2453.82	1770.00	915.97	949.47
DNK	1214.01	913.16	2309.64	1240.44	937.72	635.21	150.94	2475.37	1381.48	1483.54	2735.98	1433.30	1768.79	1347.15	952.71	1388.41	792.58	958.37	2891.45	2155.80	1238.82	1450.93
ESP	2204.09	1615.27	3058.14	1477.65	2273.43	2015.89	2484.11	420.67	3629.64	1152.80	3418.97	2459.88	1708.99	3228.14	1584.11	3331.72	1780.47	2701.16	795.89	3069.79	2533.00	1995.67
EST	1771.57	2109.40	2558.43	2274.65	1636.39	1706.05	1387.38	3634.66	115.59	2625.77	3227.36	1875.95	2691.85	595.28	2121.68	358.89	2016.70	1149.32	4069.96	2164.16	1595.14	2058.91
FRA	1252.42	657.52	2283.77	642.89	1276.04	1026.07	1489.05	1153.89	2615.35	485.38	2667.97	1563.24	1044.95	2213.85	604.38	2317.43	819.34	1688.03	1605.36	2237.41	1561.23	1210.97
GRC	1639.74	2657.45	837.19	2238.31	1920.60	2304.07	2726.25	3416.94	3229.32	2662.51	214.11	1444.65	1564.98	2729.75	2453.06	2942.29	2680.97	2206.87	4027.08	1172.94	1653.96	1570.87
HUN	389.47	1404.07	927.42	1122.02	565.36	1039.24	1428.93	2465.00	1854.54	1565.48	1444.62	127.62	1171.98	1356.76	1234.93	1534.77	1425.41	795.47	3071.29	786.21	273.15	477.77
ITA	958.10	1271.89	1620.46	676.02	1185.28	1232.20	1769.24	1711.78	2684.19	1045.91	1580.36	1170.28	390.09	2173.87	1050.84	2368.38	1435.45	1636.53	2321.92	1744.90	1250.38	707.04
LTU	1257.73	1703.53	2048.54	1868.79	1135.87	1300.19	1364.67	3228.80	596.13	2219.90	2766.54	1355.83	2177.41	139.29	1715.82	273.42	1610.84	638.55	3664.10	1619.43	1097.48	1548.18
LUX	884.55	228.61	2050.21	436.00	828.74	524.44	955.75	1586.41	2117.03	606.40	2457.69	1233.10	1050.48	1715.53	16.07	1819.11	376.75	1188.27	2031.19	1958.79	1182.19	975.71
LVA	1486.24	1810.28	2262.79	1975.54	1272.44	1406.93	1427.85	3335.54	359.43	2326.65	2971.22	1538.43	2374.80	272.61	1822.56	107.97	1717.58	819.38	3770.84	1845.44	1279.16	1728.62
NLD	1094.27	190.13	2277.38	822.01	965.90	509.92	793.74	1782.02	2009.08	822.37	2685.93	1424.39	1435.79	1607.57	378.06	1711.15	82.83	1117.77	2143.79	2151.70	1323.99	1234.31
POL	755.63	1202.88	1639.69	1328.94	562.26	789.55	958.84	2700.71	1140.59	1691.15	2200.67	774.74	1638.32	642.23	1186.62	817.90	1116.15	293.01	3147.18	1364.04	590.55	1006.55
PRT	2741.67	1979.27	3670.61	2000.63	2754.15	2453.37	2892.17	795.17	4061.41	1605.83	4031.45	3068.54	2321.46	3659.90	2026.64	3763.48	2143.19	3145.36	151.11	3682.27	3072.37	2608.14
ROU	1105.69	2130.91	447.94	1836.56	1291.70	1767.18	2150.65	3075.06	2120.87	2239.07	1173.59	785.80	1746.64	1620.73	1959.41	1807.84	2151.64	1367.08	3685.20	260.80	964.78	1152.70
SVK	362.40	1337.39	1142.24	1099.80	407.95	913.24	1236.84	2535.86	1584.89	1562.62	1655.57	274.85	1251.73	1090.98	1183.25	1280.74	1312.50	589.96	3072.97	967.00	189.24	569.59
SVN	338.46	1198.46	1106.26	782.67	615.95	947.58	1448.97	2002.26	2041.71	1211.72	1570.95	477.89	710.11	1537.15	974.83	1730.25	1232.18	1003.24	2612.40	1152.91	567.84	73.87

Source: Bing Maps Route Service and authors' calculations.

Table A3. Road travel time within and between countries (hh:mm)

Origin	Destination																					
	AUT	BEL	BGR	CHE	CZE	DEU	DNK	ESP	EST	FRA	GRC	HUN	ITA	LTU	LUX	LVA	NLD	POL	PRT	ROU	SVK	SVN
AUT	1:36	9:11	12:46	7:2	3:49	6:50	11:43	19:49	21:11	11:13	16:16	3:51	8:46	14:10	7:44	16:45	9:26	7:25	24:54	13:32	3:39	3:17
BEL	9:8	0:42	21:6	6:29	8:29	4:51	8:22	14:48	23:10	6:8	24:37	12:12	12:6	16:42	2:16	18:52	1:57	10:10	18:8	22:5	11:51	10:17
BGR	12:41	21:12	2:55	18:14	16:0	18:24	23:10	28:51	31:39	21:51	10:29	11:15	17:34	25:2	19:44	27:52	21:25	19:15	34:18	6:27	13:33	12:24
CHE	7:4	6:28	18:14	1:28	7:34	6:15	11:4	13:19	24:35	6:5	21:48	10:22	6:31	18:7	4:31	20:17	7:14	11:15	18:18	19:31	10:10	7:21
CZE	3:49	8:30	16:3	7:35	1:49	5:21	9:18	20:11	20:25	11:19	21:55	5:51	10:51	13:20	7:12	15:58	8:16	6:13	24:49	15:47	4:45	6:50
DEU	6:50	4:50	18:30	6:14	5:23	3:17	6:18	17:59	19:56	9:7	22:0	9:30	10:56	13:28	4:48	15:38	4:29	6:54	22:4	19:17	8:38	8:11
DNK	11:46	8:21	23:25	11:4	9:23	6:17	1:28	22:25	20:53	13:26	26:55	14:5	16:10	16:17	8:51	18:17	7:25	9:39	26:9	23:58	12:44	13:23
ESP	19:50	14:48	28:49	13:19	20:10	18:1	22:27	3:55	36:48	10:38	32:23	22:21	15:33	30:20	14:28	32:30	16:24	23:33	7:22	30:29	22:55	18:1
EST	21:10	22:58	31:40	24:26	20:21	19:45	20:51	36:37	1:40	27:35	39:45	23:19	28:18	7:53	23:20	5:12	22:21	15:22	40:41	27:48	20:49	24:52
FRA	11:15	6:8	21:50	6:4	11:19	9:9	13:27	10:37	27:46	4:31	25:23	14:9	9:48	21:18	5:42	23:28	7:37	14:33	14:40	23:13	14:12	10:57
GRC	16:8	24:39	10:28	21:44	21:50	21:51	26:36	32:21	39:42	25:19	2:31	17:10	19:14	32:14	23:11	35:15	24:52	25:23	37:48	15:22	19:28	18:9
HUN	3:50	12:18	11:15	10:21	5:47	9:27	13:56	22:21	23:17	14:9	17:12	1:28	10:55	15:49	10:53	18:50	12:30	9:5	27:47	10:52	3:19	5:2
ITA	8:44	12:5	17:31	6:31	10:49	10:56	16:9	15:32	28:28	9:49	19:10	10:53	3:43	21:52	10:7	24:8	12:49	14:47	20:59	19:1	11:35	6:33
LTU	14:12	16:40	25:5	18:8	13:21	13:26	16:13	30:19	7:54	21:16	32:20	15:54	21:55	1:40	17:2	3:42	16:2	8:25	34:22	21:52	13:25	17:28
LUX	7:46	2:16	19:43	4:32	7:15	4:53	8:55	14:26	23:38	5:40	23:14	10:54	10:7	17:10	0:17	19:20	3:36	10:22	18:36	20:46	10:37	8:45
LVA	16:44	18:43	27:52	20:10	15:55	15:29	18:5	32:21	5:12	23:19	35:19	18:53	24:1	3:41	19:5	1:39	18:5	10:59	36:25	24:30	16:23	20:26
NLD	9:21	1:57	21:18	7:13	8:19	4:29	7:24	16:22	22:31	7:37	24:49	12:23	12:50	16:3	3:36	18:12	0:59	9:35	19:42	22:16	11:49	10:29
POL	7:28	10:8	19:19	11:14	6:15	6:51	9:34	23:32	15:27	14:31	25:30	9:10	14:50	8:25	10:14	11:2	9:32	3:25	27:44	17:36	6:52	10:45
PRT	24:57	18:8	34:17	18:20	24:46	22:6	26:12	7:24	40:54	14:41	37:50	27:48	21:1	34:26	18:38	36:36	19:42	27:47	1:29	35:57	28:2	23:29
ROU	13:28	22:8	6:26	19:29	15:44	19:12	23:46	30:29	27:47	23:11	15:19	10:53	19:2	21:53	20:43	24:32	22:20	17:35	35:56	3:47	12:57	13:48
SVK	3:38	11:56	13:34	10:8	4:44	8:34	12:35	22:54	20:51	14:11	19:30	3:20	11:37	13:23	10:36	16:24	11:50	6:50	28:1	12:58	2:20	5:59
SVN	3:16	10:20	12:26	7:20	6:48	8:13	13:23	18:2	24:52	10:57	18:13	5:2	6:36	17:24	8:44	20:25	10:35	10:41	23:29	13:52	5:58	0:53

Source: Bing Maps Route Service and authors' calculations.

Table A4. Transportability index

Industry (ISIC Rev 3)	Index
Mining and quarrying	0.24
Food products, beverages and tobacco	0.56
Textiles, textile products, leather and footwear	1.23
Wood and products wood and cork, except furniture; articles straw and plaiting materials	0.81
Pulp, paper, paper products, printing and publishing	1.01
Coke, refined petroleum products and nuclear fuel	0.74
Chemicals and chemical products	1.02
Rubber and plastics products	1.23
Other non metallic products	0.91
Basic metals	0.82
Fabricated metal products, except machinery and equipment	0.98
Machinery and equipment n.e.c.	1.22
Office, accounting and computing machinery	1.34
Electrical machinery and apparatus n.e.c.	1.26
Radio, television and communication equipment and apparatus	1.61
Medical, precision and optical instruments, watches and clocks	1.35
Motor vehicles, trailers and semi	1.12
Other transport equipment	1.19
Manufacturing n.e.c. and recycling	1.08
Electricity, gas, steam and hot water supply	0.27

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