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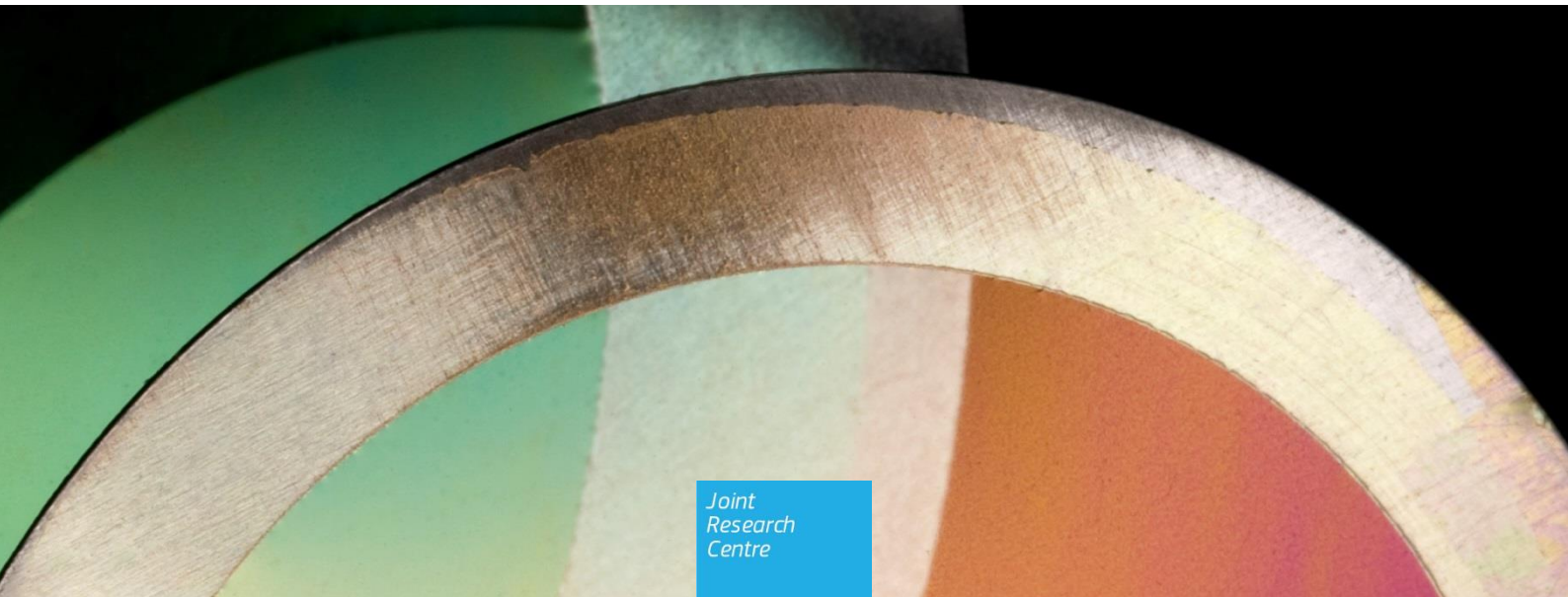

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Abstract

Transport costs are a crucial element of any spatial economic model. Surprisingly, good transport cost estimates at a detailed spatial level for the EU are not readily available. In this paper we address this issue by estimating a novel dataset of road freight transport costs for goods for the EU regions at the NUTS 2 level. In the spirit of the generalized transport cost (GTC) concept, we calculate the composite cost related to distance and time for the optimal route of a representative truck. We consider routes between large random samples of centroids drawn from a 1kmx1km population density grid. These transport costs are averaged to obtain an origin-destination cost matrix (in euros) at the region-pair level. The sampling approach also allows calculating the average transport cost within the regions. We separately report the corresponding iceberg transport costs for each pair of European regions, since this is the form of input required by many economic models. We also consider the effect of changes in the components of the GTC in order to evaluate transport policies. We set up a transport policy tool to assess the impact of road-transport infrastructure investment in a region by considering upgrading roads to highways. We apply this tool to study transport infrastructure investment through the European Cohesion Policy program 2014-2020.

Estimating road transport costs between EU regions

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1 Introduction

Transport costs are a crucial element of any spatial economic model. They directly affect trade flows, which are the main transmission channel for spillover effects between regions. The assumptions on transport costs therefore directly affect the results of any model analysis. Unfortunately, good transport cost estimates at the regional level for the European Union (EU) are not readily available. Moreover, many economic models require appropriately transforming the transport costs into the restrictive `iceberg' form where transport costs are expressed as an ad-valorem tariff.

In this paper we address these issues by estimating a unique and comprehensive dataset of freight transport costs for the EU regions at the NUTS 2 level. Specifically, we focus on transport costs by road as this transport mode represents 76.4% of total freight transport in the EU in comparison to less than 25% of freight transport carried out by other inland transport modes, that is railway and inland waterways (Eurostat, 2016).

Following the existing literature (Combes and Lafourcade, 2005; Zofío et al., 2014) on the estimation of generalized transport costs (GTC), we estimate transport costs as the average cost of road freight transport between pairs of centroids within the regions.[1] These centroids are taken from a 1kmx1km population grid, which allows us to sample hundreds of centroids for each European region based on the spatial population distribution. Thanks to considering a large number of centroids in each region, 1) we account for the spatial distribution of economic activity within each region, and 2) we can calculate precise transport costs within and between every region.[2] Specifically, we calculate a composite cost over each road segment which allows us to calculate the optimal route between two centroids. This optimal route is defined as the minimum cost entailed by a representative 40t Heavy Duty Vehicle (HDV).

Thanks to the use of a geographical information system (PostGIS), an open source database for digitalized road networks, OpenStreetMap (OSM), and a number of additional datasets, we build a database with more than 4 millions road-segments (arcs) containing highways, primary and secondary roads (including bridges and tunnels), and ferries in Europe, with a total length of over 1.500.000 km. We also obtain from OSM additional information on the characteristics of the roads such as the presence of traffic lights and roundabouts, the curvature, and the surface material. We then associate these arcs with a series of attributes related to the costs of the transport activity. Among these costs, we consider those related to the distance and the time dimensions of any single route. More concretely, for the distance-related costs, we combine the length of the arc with information on fuel prices and fuel consumption, tolls, taxes, and maintenance costs. For the time-related costs we focus on the travel time over the arc (influenced by the maximum speed, the length, and road characteristics), the salaries in the transport

[1] The regions considered are the EU NUTS 2 level regions (excluding the French overseas regions). The analysis includes two regions for Croatia.

[2] The computational burden of considering many centroid pairs is considerable. Instead, we consider on average 60 centroids for each of the 267 regions, and repeat the analysis 10 times to further increase precision and obtain bootstrap estimates of the remaining sampling error. Thus, our analysis requires computing over 1.000.000.000 optimal routes between centroid pairs.

sector, maximum national speeds, and European transport regulations on resting times. Additionally, actual geography is controlled for by the use of the European Digital Elevation Model, modifying the fuel consumption, the speed, and the travel times according to the gradients of each road-segment. After building the road-network, we calculate the minimum-cost route among the set of all possible itineraries between any pair of centroids using the Dijkstra (1959) algorithm. The averages of the costs associated with these optimal routes over all centroid-combinations within a region-pair are portrayed in a baseline origin-destination cost matrix expressed in euros.

This baseline cost matrix can be incorporated in spatial economic models in the form of `iceberg' transport cost. We also provide estimates of these iceberg transport costs by resorting to a novel database on interregional trade flows for the EU regions in 2013 (Thissen et al., 2019). This new iceberg-type transport cost matrix allows us to appropriately implement and include transport cost shocks and road-transport infrastructure investments into a spatial CGE models for Europe such as the RHOMOLO CGE model (Lecca et al., 2018).

Due to the setup with detailed components within the GTC, we can assess the effect of changes in its attributes, modifying our baseline origin-destination matrix. As a result, we obtain a new counterfactual transport-cost matrix that can be used to evaluate transport policies. We perform a series of policy experiments by modifying the attributes of the GTC as showcases of our methodology.

Because of considering distance and time dimensions in the GTC, we are able to disentangle core-periphery structures of the EU regions due to transport costs. That is, the centrality of the regions within the road network is the main driver of the distance-related costs, being smaller for geographically central regions, whereas the salaries in the transport sector directly affect the time-related costs of the GTC, being lower in regions with low wages in the transport sector and vice versa.

In a further step, we create a transport policy tool to assess the impact of road-transport infrastructure investment in a region, whereby the investment is considered to upgrade roads to highways. The roads to be upgraded are selected according to where the direct economic benefits in terms of saved expenses on transport would be the largest relative to the amount of resources that are invested and taking into consideration the cost of building highways in each EU country. Among the road attributes, we modify those related to the maximum speed, and the ones related to penalties for curvature, slope, traffic lights and surface. After selecting and modifying all the upgraded roads, we re-calculate the set of cheapest routes between regions to get new transport cost matrices which can be compared to the baseline case. We take the European Cohesion Policy program 2014-2020 as a case study. We show that Eastern European countries are the ones clearly experiencing the biggest reductions in transport cost, although there exist some positive spillover effects on central EU regions.

The remainder of the paper is structured as follows. Section 2 presents the methodology for the GTC, the transport policy tool, and the iceberg-type transport costs. Section 3 describes the data. Section 4 portraits the results by way of descriptive analysis. Section 5 presents the transport policy simulations. Section 6 concludes.

2 Methodology

2.1 Generalized transport costs

Several attempts have been made to estimate transport costs going beyond the traditional physical distance and travel time proxies.[3] Recent studies estimated economic transports costs depending on distance and time accessibility variables according to the so-called GTC concept proposed by Nichols (1975). For example, Combes and Lafourcade (2005) accurately estimate transport costs for the French employment areas over the period 1978-1998. Hanssen et al. (2012) consider intermodal transport solutions when estimating the GTC in transporting fresh fish between Norway and Continental Europe. Zofío et al. (2014) resort to index numbers to disentangle the effect of economic and infrastructure determinants on the reduction of generalized transport costs for the case of Spain in the years 1980-2007. At the European level, transport network models such as Transtools[4] cover passenger and freight transport databases to assess the impact in transport costs due to changes in the transport infrastructure network by considering different transport modes (air, water, rail, and road).

We contribute to this literature by building a database with estimates of the GTC between all the possible pairs of the 268 EU regions. In comparison with previous work, 1) we base our analysis on trips between a very large number of centroids in each NUTS-2 region, which allows calculating not only between- but also within-region transport costs while taking into account the often very unequal spatial distribution of the population within regions; 2) we make use of the digitalised network from the open source database OSM which contains an up-to-date network for roads and ferries reflecting the actual state of the European roads; and 3) we greatly simplify the analysis and the computational counterparts by focussing on a single mode of transport.

We start from Zofío et al. (2014) and estimate the bilateral GTC between any two pair of locations ij within the EU. The GTC_{ij} is defined as the cheapest itinerary I_{ij} in the portfolio of possible trips between two locations. An itinerary is divided into segments of roads *a* (arcs), which possess several characteristics affecting the cost of traversing them. We associate all costs required to go through the arcs considering the distance in km (d_a) and travel time in minutes (t_a) counterparts. Thus, we define the GTC as:

$$GTC_{ij} = \min_{I_{ij} \in \boldsymbol{I}_{ij}} \left(DistC_{ij} + TimeC_{ij} \right) + Tax_i + Vignettes_{ij}, \quad (1)$$

where $DistC_{ij}$ stands for distance related costs and $TimeC_{ij}$ stands for time-related costs. The former is defined as follows:

$$DistC_{ij} = \sum_{a \in I_{ij}} \left(\sum_k e_{ak}^d \right) d_a = \sum_{a \in I_{ij}} (fuel_a + toll_a)\, d_a + (tireCS + maintCS)(fuel_a\, d_a), \quad (2)$$

where e_a^d (in EUR per km) entails fuel costs ($fuel_a$), which is computed as the fuel price (in EUR per litre) multiplied by the fuel consumption in litres per kilometre of the representative truck. The fuel cost per km over an arc differs across EU Member States (MS) because of differences in fuel prices. The fuel consumption will be affected by road properties such as the slope; toll costs ($toll_a$) are also MS-specific because of differences

[3] Teixeira (2006) computes a transport costs matrix using a digital road network that allows him to calculate the lowest cost (the fastest and shortest) itineraries between Portuguese districts to assess the dispersion/agglomeration of industries as a result of changing transport costs. Martínez-Zarzoso and Nowak-Lehmann (2007) analyse the determinants of maritime transport and road transport costs resorting to alternative factors affecting them such as unit values, services structures and services qualities, but also transport conditions. They apply their analysis to the Spanish exports to Poland and Turkey to study the impact of transport costs in trade flows. Finally, Jacobs-Crisioni et al. (2016) calculate a set of travel-time accessibility measures to model population changes at a very fine spatial level due to varying transport costs in the cases of Poland, Germany, Austria and Czech Republic.

[4] See http://energy.jrc.ec.europa.eu/transtools/

in nation-wide tolling (either through vignettes, or a country-wide electronic toll) or also per road-segment (for countries that have tolling on a limited set of road segments). Costs related to maintenance and tires represent a relatively small share of the total transport costs.[5] Time-related costs are defined as follows:

$$TimeC_{ij} = \sum_{a \in I_{ij}} (\sum_k e_{ak}^t) t_a = \sum_{a \in I_{ij}} (1 + amortFinCS + insCS + indCS)\,(t_a lab_{ij}), \qquad (3)$$

where the main component is the labour cost of the driver ($t_a lab_{ij}$). The hourly wage cost lab_{ij} from Eurostat is multiplied by the time (in hours) it takes to cross the arc. The hourly wage cost is calculated starting from the annual wage cost (including employer social contributions, benefits, allowances etc.) and assuming 90 hours can be driven in 2 weeks of time, in line with regulation regarding resting times ((EC) no. 561/2006). We assume two weeks of rest per year in addition to these compulsory resting times, for a total of 2250 hours driven per year. By dividing the annual wage cost by this estimate of hours driven per year, we get an estimate of the wage cost per hour driven, including all resting times. The remaining costs related to amortization and financing costs ($amortFinCS$) of the vehicle, insurance ($insCS$) and indirect costs ($indCS$) are assumed to be proportional to labour costs, with the relative cost shares matching those in Zofío et al. (2014).[6]

Taxes (Tax_i) are added to the distance and time costs components to compute the generalized transport costs. We assume that taxes are given and affect all the roads departing from any origin in a single country so they are not taken into account when computing the optimal route between a pair of cities. The same hold for the cost of vignettes: we assume this cost is fixed between any pair of origin and destination. We calculate it as the sum of the cost of a yearly vignette, divided by an estimate of the number of trips that can be made within one year, adding up this cost for all vignette-countries that a pre-calculated optimal route takes the truck through.

2.2 From inter-centroid GTC's to inter and intra region GTC's

The GTC as described in section 2.1 is calculated at the level of pairs of centroids. Economic models mostly operate at some higher level of aggregation (regional, national). Thus, we define and calculate the GTC between two regions *o* and *d* as the arithmetic average of the GTC between the *m* centroids belonging to region *o* indexed by $x = 1, \dots, m$, and the n centroids belonging to the region *d* indexed by $y = 1, \dots, n$. The final inter-regional GTC equals:

$$GTC_{od} = \frac{1}{mn} \sum_{x=1}^{m} \sum_{y=1}^{n} GTC_{xy}^{*} \qquad (4)$$

This simple arithmetic average will give an average GTC that is representative for a random draw of a pair of centroids drawn from the population distribution. However, as emphasised Head and Mayer (2002), given that trade is more likely to occur between centroids that are at shorter distances, the average GTC between two regions that is relevant when modelling international trade rather is the harmonic average, which gives more weight to centroids at shorter distances.

[5] Zofío et al. (2014) find that cost shares of tires and maintenance costs are 4.92% and 4.24% of the total, respectively, whereas fuel consumption costs accounts for 29.04% of the total transport cost. We assume that tire and maintenance costs for all trips are related to fuel costs in the same proportion. Thus, we assume that for every euro spent on fuel during a trip, *tireCS*=4.92/29.04=0.17 additional euros are spent on tires and *maintCS*=4.24/29.04=0.146 euros are spent on maintenance costs.

[6] Our hourly wage data includes allowances. Zofío et al., (2014) consider accommodation together with allowances. We assume that accommodation costs are relatively small for the case of internal Spanish transport costs considered by Zofío et al. and ignore them. We then compare costs shares of capital expenditures (amortisation and financing), insurance costs and indirect costs relative to the sum of wages and allowances, so *amortFinCS*=13.16/32.96=0.4, *insCS*=5.24/32.96=0.16, and *indCS* = 8.31/32.96 = 0.25.

$$GTC_{od}^{h} = \left(\frac{1}{mn}\sum_{x=1}^{m}\sum_{y=1}^{n} GTC_{xy}^{*\,-1}\right)^{-1} \quad (5)$$

We report harmonic averages alongside the arithmetic averages in the datasets accompanying this paper.[7]

2.3 The iceberg trade cost matrix

The GTC as calculated above is easy to interpret and it is standard in the transport literature. Many economic models, however, consider a specific transformation of transport costs which is known as the "iceberg" representation. The name stems from the fact that it represents the transport costs as a "wasteful ad valorem tax", that is the transport costs are assumed to be proportional to the value of the good, and the receipts of the tax are lost for society. This would be equivalent to assuming one has to ship some extra proportion of the good which disappears or "melts" during transport.

Real transport costs obviously are not proportional to the value of the good being transported, but will rather depend on the weight, volume, or special measures such as cooling which must be taken during transport. Assuming transport costs to be proportional to the value has clear advantages for the algebra involved in typical economic models,[8] but is otherwise clearly a crude approximation. Given that many economic models use this representation, we also calculate the iceberg transport cost equivalent of the transport cost for every pair of regions, separately per sector, as follows:

$$\tau_{ij} = \frac{F_{ij}\left(\frac{1}{L}\right)GTC_{ij}}{V_{ij}} \quad (6)$$

Where F_{ij} is the flow of goods between region i and j; GTC_{ij} is the weighted GTC between both regions; and L is the EU-wide average loading of trucks.[9] The numerator expresses the total transport cost of the observed trade flow between both regions, multiplying the trade flow (manufacturing and agricultural goods) in tonnes by the number of trucks required to ship one ton and by the cost of the trip for one truck. Expressing the total transport cost relative to the value of the trade flow gives the trade costs expressed in *ad valorem* terms (Hummels, 1999), which is the form required in many economic models.

3 Data

To compute the GTC matrix and the iceberg cost matrix we rely on an open-source road network database and complementary databases on costs at the regional level as explained in the following sub-sections.

3.1 Open Street Map

The road network over which transport costs are calculated is a subset of the publicly available OSM data. We extract over 4.000.000 road segments of motorways, trunk roads, primary and secondary roads, and ferry lines from the original data. The total length of the network adds up to over 1.569.000 km. An image of this network is given in Figure A.1 in appendix A. The covered area includes the EU countries under consideration, with the addition of some selected areas through which an optimal route may lead such as Norway, Switzerland, and Western Turkey. We add four "virtual" ferry routes to the network, connecting the islands of Madeira and the Azores Islands to

[7] These are available from the authors on request.
[8] See Hummels (1999), and Hillberry and Hummels (2013) for a deeper discussion.
[9] According to the European Road Freight Transport database (Eurostat 2016) the average load of a truck in the EU is 13.6 tonnes per truck.

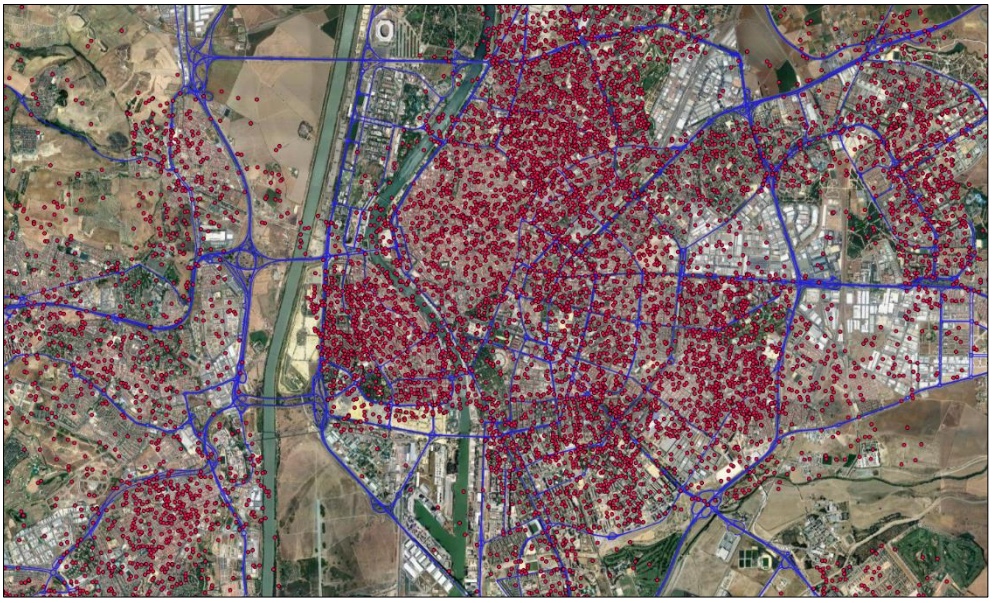
Lisbon, connecting the Island of Rhodes to the mainland, and one over the English Channel to mimic the Channel Tunnel. All ferry lines have an assumed speed of 20 km/h, and average fuel price for the EU at different distance-thresholds set to reflect ticket prices as reported in Martino and Brambilla (2016), as explained below.

The size of the road network and the large number of routes to be calculated implies that special care needs to be used to use a suitable and scalable method. We opted to use the freeware *osm2po tool*[10] to convert the OSM data into a *PostgreSQL* database residing on a dedicated server with 40 cores and 240GB of RAM. This database was accessed using the software *R* to start 40 parallel queries, each of them calculating a many-to-many routing problem corresponding to an adequately sized portion of the origin-destination matrix of centroids. The optimal routes themselves are calculated using the Dijkstra algorithm from the *pgRouting* project.

3.2 Centroids

The centroids which are used to calculate driving time and transport costs originate from a population density grid at a one square kilometer resolution, which was obtained from the European Environmental Agency. Every square kilometer from the original raster is populated with a randomly placed centroid for every 100 individuals estimated to inhabit that area. Figure 1 below shows the centroids (the red dots) for the city of Seville, superimposed on an aerial image from Google Earth, and the OSM road network used in the analysis (in blue). The picture shows that the centroids are a quite good approximation of the population density at a fine level of spatial disaggregation: there are lots of dots in the historic centre (located within the curve of the old course of the Guadalquivir river), but population density is higher in the newer (and cheaper) residential areas to the north-east.

Figure 1. The population grid for the urban area of Seville



Source: Own elaboration using Google Maps, OSM, and the European Environmental Agency population grid.

The full set of centroids generated from the population grid represents the location of population quite precisely, even in excess of what is needed for our analysis. We therefore do not consider all these centroids in the calculations, but rather take random samples, with larger samples for region pairs at shorter distances. Table 1 shows the sample sizes of centroids (dots) for each distance-threshold.

[10] See http://osm2po.de/

Table 1. Centroid sample size used to calculate distances between regions

Distance (d)	Number of centroids between	Formula (area in km^2)	Average number of centroids
0 (intra-region)	250 and 120	min(250,max(area/100*3,120))	229
0 km <= d < 160 km	160 and 100	min(160,max(area/100*2,100))	148
160 km <= d < 320 km	120 and 80	min(120,max(area/100*1.5,80))	113
320 km <= d < 520 km	90 and 60	min(90,max(area/100*1.2,60))	85
520 km <= d < 870 km	60 and 40	min(60,max(area/100*1.1,40))	58
870 km <= d < 1,350 km	50 and 30	min(50,max(area/100,30))	48
1,350 km <= d	30 and 20	min(30,max(area/200,20))	28

Source: Own elaboration.

For intraregional distances, we include a large number of centroids because the NUTS 2 regions are quite unequal in terms of area, but also with respect to the internal distribution of economic activity within them. The distribution of economic activity is very uneven, for example in coastal regions. Since most trade typically occurs within the region and over relatively short distances between regions, using many centroids for short distances will improve the representativeness of the calculated trade costs especially for those pairs of origin and destinations where most trade is happening.

Figure 2 below shows a random sample of 160 centroids (green) which have been selected for the estimation of the transport costs of the Spanish region of Andalusia to some neighbouring regions, superimposed with a night-time satellite images from NASA's Earth Observatory. The sample size of dots appears sufficiently large within the region to capture the geographical dispersion of economic activity and population revealed by the satellite image.[11]

Figure 2. A sample of 160 centroids obtained for the Spanish region of Andalusia

Source: Own elaboration based on NASA Earth Observatory data and the European Environmental Agency population grid.

[11] A bootstrapping analysis using 10 samples with an average of 60 centroids (around 127.000.000 routes per sample) revealed the sampling error for calculated transport costs between regions for a sample to be over 5% for less than 0.12% of the region-pairs (82 out of 71825 routes). The largest standard error of 7.5% was found for the internal transport costs for the Danish capital region Hovedstaden (DK01). Averaging the estimated transport costs over these 10 runs, however, allows reducing the standard error according to $\sigma_{ij}/\sqrt{10}$ where σ_{ij} is the original sampling error. Our reported results average over 10 simulations, reducing the standard error for 99% of the estimates below 1% (and a much smaller standard error for the majority of them). All estimated individual sampling standard errors are below 2.5%.

A population grid may underestimate the spatial concentration of the origin and destination of freight flows, which may be dominated by a limited number of transport hubs, industrial areas and sea-ports. The implicit assumption that freight flows are widely spread in space which follows from sampling many points from a population grid is a possible reason why we find relatively small effects of transport infrastructure investment on the average trade costs between regions in section 5.

3.3 Data sources for the GTC

The GTC is composed by distance and time costs as per equation (1). To calculate each component we assume all trips are made by a representative EURO VI truck (HDV) consuming a constant rate of 34.5 L/100km (Dünnebeil *et al*., 2015).

3.3.1 Distance-related costs

The base fuel cost depends on fuel prices per member state (MS)[12] and a constant rate of fuel consumption. The fuel consumption is assumed to change with the slope of the road, which we derive from the European digital elevation model for Europe developed by the European Environment Agency.[13] More concretely, an increase in the slope of a road segment in absolute value of 1% increases fuel consumption by 5.5%, which corresponds to the value of 11% found by Chen et al. (2017), adjusted for the fact that a positive slope will be present only for either the trip or the return trip. This implies a fuel consumption penalty of over 10% for about 15% of the roads with slopes in excess of 2%, and a penalty of over 44% for about 1% of the road segments which have a slope higher than 8%.

Tolls are proportional to the distance travelled on toll roads. Van Essen et al. (2012) provide detailed data for 2012 on the average toll-cost (in euros per km) for EU countries based on road distance-related charges. Table 4 in Annex A reports the countries and the tolls considered for the GTC.

For the tire ($tire$) and maintenance costs ($mant$) per km, we assume these costs to be constant between all arcs in all MS. Specifically, they are set as to correspond to a joint cost share of 9%, as found for Spain by Zofío et al. (2014).[14]

3.3.2 Time-related costs

The base travel time over an arc is calculated using the length of the arc and the maximum allowed speed over the arc. This maximum speed is the value which is provided for the segment in the OSM database. In case no value is provided in OSM, we take the legal maximum speed for HDV in each MS and road type according to DG MOVE.[15] Nevertheless, further assumptions were taken to better reflect the real world properties of the roads. These are the following:

- The maximum speed on all primary roads was limited to the value from OSM or 70 km/h, whichever was smaller. Likewise, the maximum speed on secondary roads was set to 60 km/h.
- The presence of a traffic light adds 30 seconds to the travel time to cross the arc.
- Curvature: the tortuosity of an arc is calculated as the ratio of the great circle distance between source and endpoint and the effective length of the road segment. We reduce the maximum speed by 2/3 for cases where the tortuosity of

[12] Fuel prices for each country are taken from "Europe's Energy Portal" (https://energy.eu/).
[13] We use the raster map at a resolution of 1cmx1cm, which are interpolated values from the original 25mx25m data. Available at: https://www.eea.europa.eu.
[14] Previous studies (Combes and Lafourcade, 2005; Zofío et al., 2014) find tire and maintenance costs to represent a combined share in total cost of about 10% or less.
[15] Legal speed limits for HDV are taken from DG MOVE (European Commission). Available at: http://ec.europa.eu/transport/road_safety/going_abroad

the road exceeds 1.5, resulting in a speed of about 25 km/h on those segments on a primary road.
- We divide the speed by 7 on surfaces like sand, cobblestone, etc. to give a typical speed of 10 km/h for a primary road with this surface type.
- Roundabouts: we divide the maximum speed by 7 on roundabouts and highway ramps, to give a typical speed of 10 km/h on a on a roundabout on primary road.

All these changes affect the travel times which, jointly with salaries, are the main determinants of the time costs. In our dataset, salaries include the definition of wages and direct remuneration for the transport sector according to the European Labour Cost Survey (2012) from Eurostat. Available information is at the NUTS 1 level for some countries, while for most countries there are no regional data. We impute the same salary for all the NUTS 2 regions contained within each NUTS 1 region with this information, whereas in countries with no salaries at the regional level we use the corresponding one at the national level for the transport sector.

Salaries are on an annual basis, so in order to compute a salary per minute to get a measure equivalent in units with the travel time, we use the average hours worked per week in each of the 28 EU MS published by Eurostat. Finally, we rely on European Commission regulation ((EC) no. 561/2006) for resting times as an extra cost for travel times. This regulation states that the driver must rest 45 min after 4 h driving and 11 h after 9 h. In our case, resting times are considered as paid hours with the same salary per hour as before, so we add resting times to the time economic cost as an additive salary for those trips accomplishing the 2006 EC regulation.

3.3.3 Taxes and ferries costs of the GTC

Ownership taxes of HDV are paid yearly independently on the trade route the truck is performing. However, it is reasonable to assume that the truck owner will transfer the tax incidence to the client of the transport services – the firm shipping the goods. Ownership taxes come from Van Essen, et al. (2012) and reported in Table 5 in Annex A. Given the time needed to go from each origin to each destination, we compute the number of trips that a truck can perform between each two regions within a year by dividing the working hours in a year, including resting times, over the time needed to travel the transport route via the cheapest route. Then, the ownership tax added to the GTC of each trade link is calculated as the yearly ownership tax divided by the number of trips that the truck can perform in a year.

Ferries are considered equivalent to a regular road route, with no gradients and penalties. We follow Martino and Brambilla (2016) for the average price (cost) of a ferry-ticket charged to passengers in the EU.[16] This price varies according to three distance thresholds: short (less than 100 km), medium (100-300 km) and large (more than 300 km). We add this cost of the ferry ticket per km as the fuel cost for ferries, depending on the length (in km) of the ferry line. Table 6 in Annex A presents the different tickets (in €/km) imputed for each ferry-arc.

3.3.4 Data sources for the iceberg trade costs

The iceberg trade cost matrix relies on trade flows among the EU regions. We resort to Thissen et al. (2019) to get trade flows in monetary units and quantities (tonnes). These authors estimate the inter-regional trade flows at NUTS 2 level for the EU using a set of regionalized "Supply and Use" tables and probability matrices "*derived from freight transport data, airline data and business travel data, taking into account transhipments locations (hub) and without pre-imposing any geographical structure on the data*". They

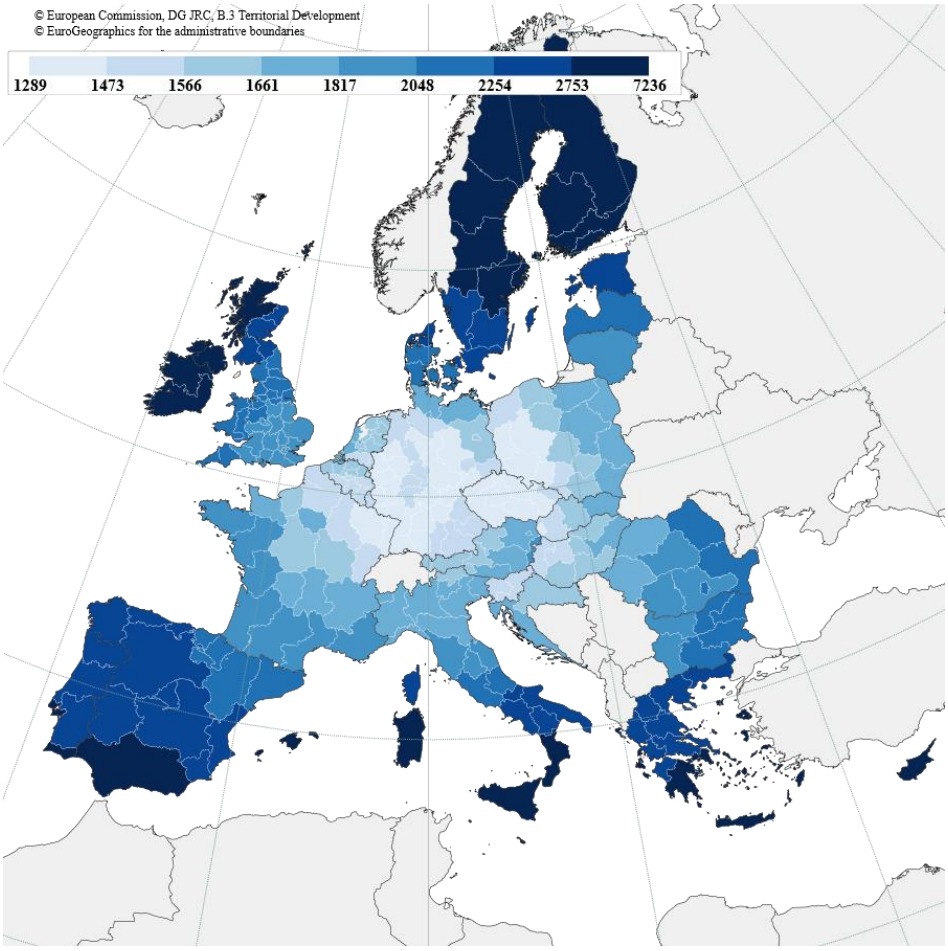
[16] This price concerns a trip with four persons and a car. The non-representative sample used by Martino and Brambilla (2016) contains 50 observations. However, the values found by Martino and Brambilla closely match the values which we found for ferry prices charged to a HDV.

provide data for different sectors entailing goods and services in 2013. Given our GTC approach based on transport costs by trucks, we take flow data in euros and tons for manufacturing goods, agricultural and forestry products, and raw materials and energy sources such as mining, quarrying, electricity and gas.[17]

4. Descriptive analysis of the GTC

The full table with the estimated GTC between all pairs of 268 regions.[18] This section portraits a descriptive analysis of these estimates. Figure 3 plots the simple average GTC across all destinies for each region *i,* an inverse accessibility measure for each region. As shown, geographically central regions have the lowest transport costs due to their location within the road network, whereas far distant regions suffer from higher transport costs.

Figure 3. Average GTC for each NUTS 2 region



Source: Own elaboration.

As described in section 2.1, the GTC is composed of many cost elements. As Table 2 portraits, fuel and time costs are the most predominant components, both representing around 60% of the total transport cost. Time costs are mainly driven by salaries and, to a lesser extent, by resting times. Distance costs in turn are determined by fuel prices and fuel consumption. Ownership taxes represent a negligible share of costs, whereas the

[17] See Thissen et al. (2019) for a deeper understanding of the methodology behind the trade flows database.
[18] The GTC origin-destination matrix is available from the authors on request.

rest of the other costs (maintenance, accommodation, insurances, financing and amortization costs, plus indirect costs) stand for the remaining 40% of the costs.

Table 2. EU average GTC cost components

Component	Percentage
Driver wage costs	42.1%
Fuel costs	21.1%
Ownership Taxes	0.6%
Vignettes and Tolls	5.9%
Other (time)	17.1%
Other (distance)	13.3%

Source: Own elaboration.

As can be observed in Table 3, the GTC has on average a value of 2,039€. The internal GTC presents values of 2.42€ (for the city-region of Melilla measuring just 12km²) up to 759€ (for the Greek Southern Aegean region where the population is spread over 50 islands). The external GTC possesses more variability and highest average values.

Table 3. EU GTC descriptive statistics

GTC	Observations	Mean	Std. Dev.	Min	Max
Total	71,824	2,039.0	1,269.10	2.42	10,329.30
Internal	268	101.3	78.00	2.42	758.73
External	71,556	2,046.3	1,265.89	43.80	10,329.30

Source: Own elaboration.

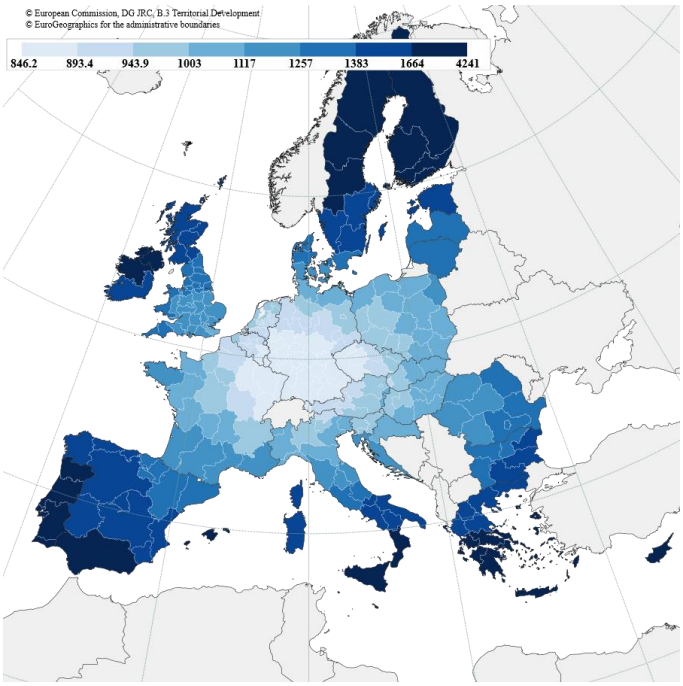
Distance and time costs are not only the most important components of the GTC, they also show remarkable heterogeneity among regions. To reflect these regional differences, Figure 4 separates out the (simple) average distance (a) and time (b) related costs of each region. Distance costs are mainly driven by fuel consumption and fuel prices, so regions that require shorter distances when travelling to other regions reduce significantly their fuel consumption. That is why we see a core-periphery structure in Figure 4a.

Salaries in the transport sector are the leading determinant of the time-related costs in Figure 4b. Regions with lower salaries present lower GTC, while the opposite holds for regions with high salaries. Far-distant regions require more time and resting times to perform shipments by truck, forcing them to suffer higher GTCs even though salaries are lower in these peripheral regions. This seems to be the cases of Greek, Portuguese, Spanish, and southern Italian regions. Moreover, central regions in the road network also benefit from low GTCs even in the eventual case of having high salaries in the transport costs due to the lower required travel times. Western and central regions in Germany are examples of this.

In summary, the GTC patterns reflect sources of comparative advantages across regions caused either by their geographical location within the road network or by the time-related costs. A core-periphery structure within the EU market emerges as a result of regional differences in travel time and geographical distances.

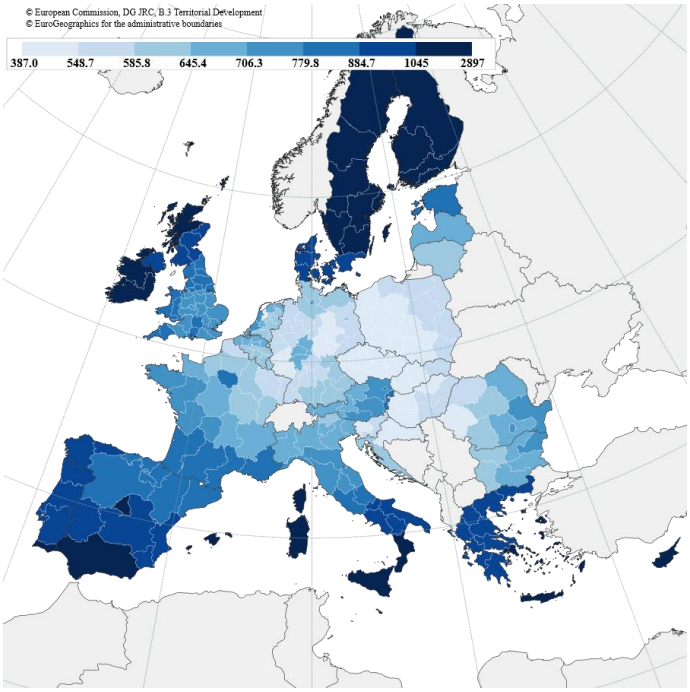
Figure 4. Distance and time related costs of GTC for each NUTS 2 region

a) Distance-related costs



Source: Own elaboration.

b) Time-related costs

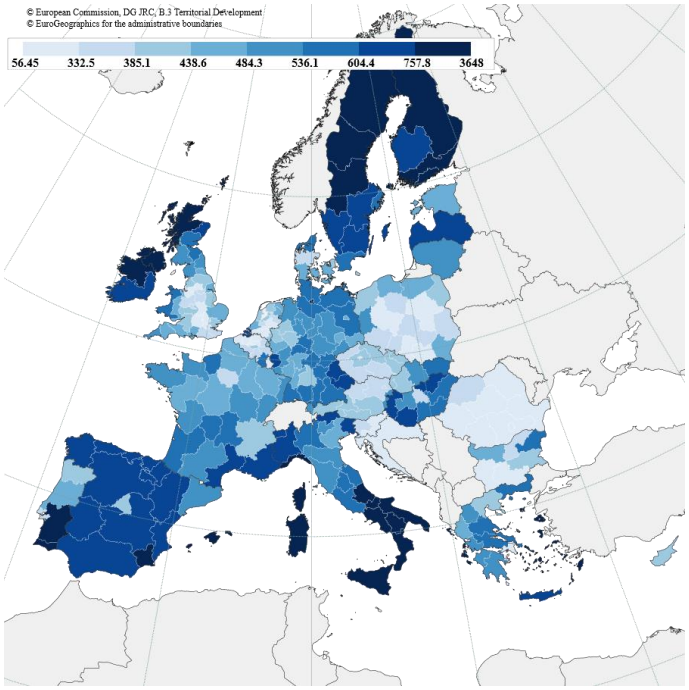


Source: Own elaboration.

Alternatively, we consider the average GTC of each region i weighing by the bilateral trade flows between each pair ij using trade data from Thissen et al. (2019). This weighted GTC more accurately reflects the average transport costs of a region in relation to its trade partners. That is, the weighted version of the GTC captures both the trade and transport costs links among regions. When graphically illustrating the effect of policies on transport costs in a map, we will consider changes in this weighted version of

the GTC as the most appropriate single index number summarising how the policy is affecting individual regions. Figure 5 plots this weighted indicator. As shown, once trade flows are included, truly integrated regions, as those in the core of Europe (regions in Belgium, the Netherlands, or even the UK) are characterised by low transport costs. Most of the Eastern European regions still benefit from low transport costs thanks to their low time costs (salaries), although regions in Hungary do not present the same geographical advantages as in Figure 3. Indeed the geographical pattern of trade will affect the average trade costs: the fact that Greek regions now show a low average GTC reflects the fact that the majority of their trade is over short distances, whereas far-located regions highly dependent on long-distant trade still suffer from high transport costs. On the contrary, the relatively high weighted average GTC German or Hungarian regions may be due to trading over larger distances, or larger ratio of external relative to internal trade flows.

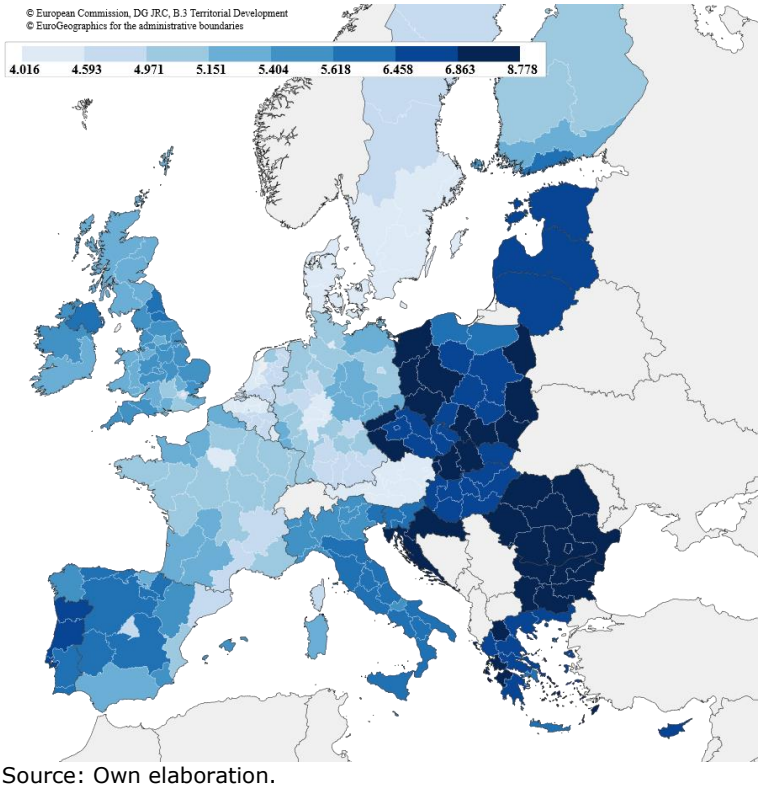
Figure 5. Average GTC weighted by trade flows for each NUTS 2 region



Source: Own elaboration.

Up to now we focused on the spatial structure of the baseline GTC estimates. However, an interesting application lies in the feasibility to perform policy experiments. By modifying the components of the GTC, we can get an alternative transport cost matrix for the EU regions. We compare this new counterfactual matrix with the baseline matrix to get a new one with the (bilateral) changes in transport costs. As an example, in Figure 6 we plot the percentage change in the weighted GTC after a 20% increase in fuel prices for all the regions. The darker regions are more affected by the increase in fuel prices as fuel represents a relatively large share of their costs. These are regions where wages (and therefore the share of labour costs) are lower, as well as their endowment of infrastructure (see for instance the Eastern European regions), leading consequently to higher fuel consumption.

Figure 6. Change in the weighted GTC due to a 20% increase in fuel prices



Source: Own elaboration.

5. Policy simulations: Transport infrastructure investment

In order to estimate the effect of transport infrastructure investment on transport costs, we identify those roads that would create the largest net economic benefit when being upgraded to a highway. For the cost of upgrading, we take the estimated cost of building a km of highways in the EU from the European Court of Auditors (2013). We adjusted this construction cost per country by applying the Eurostat price level index for civil engineering construction projects. In Annex A, Tables 7 and 8 respectively show the baseline cost for building highways and the adjustments per country. This cost is further adjusted depending on several road properties: we increase the cost by 10% for every 1% increase in the slope of the road; by 30% for every 1000 inhabitants in a 1 km radius around the road; by 70% if the road is a bridge or tunnel.

We identify roads for upgrading by comparing the economic cost of upgrading to the economic benefit. To calculate the benefit, we look for network segments which are the most important bottlenecks for traffic. This is done by ranking the primary and secondary roads in each region according to the estimated traffic (in number of trucks) over them, per lane.[19] The traffic between two centroids i and j belonging to regions o and d respectively, is assumed to depend on the flow F of goods in tonnes between the regions o and d; the estimated number of trucks required to perform the transport of 1 tonne of goods, L; the great-circle distance *dist* between the centroids i and j; and finally, the population share of both the centroid of origin and destination in the respective regional populations. More specifically, we assume that the number of trucks travelling between centroids i and j equals the following:

[19] This approach obviously does not mean to suggest that the improved roads are always a choice policy makes will or should make, and oftentimes it is not realistic to assume that a specific road segment would be improved. Nevertheless, we believe the approach can provide an estimate of how the transport costs would change in case of real world, fully planned road infrastructure projects.

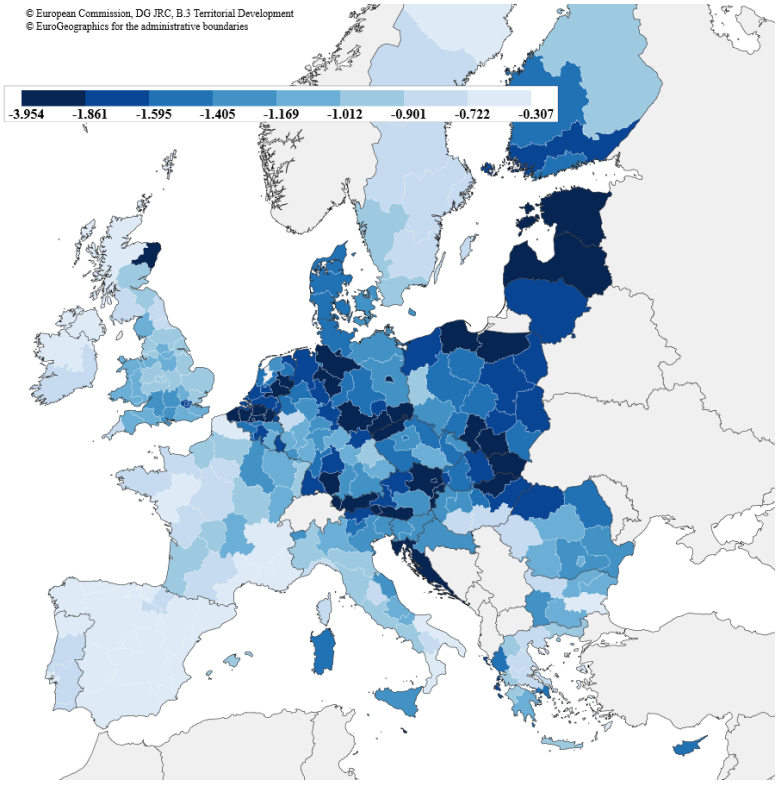
$$T_{ij} = \frac{(F_{od}+F_{do})}{2} L \frac{1}{dist_{ij}} \quad (7)$$

The effect of transport infrastructure investment will depend on the number of centroids, that is, when using more centroids, traffic will be spread over more roads, and improvements in a road segment will affect a proportionally smaller share of transport. However, given that (especially in cities) centroids may be sampled at arbitrarily close distances, these would be assigned overly large shares of the trade flows. We therefore impose a minimum distance of 15km.

Primary and secondary roads then are ranked according to the difference between the aggregate generalised transport cost, calculated by multiplying the GTC of the arc by the number of trucks travelling over them, compared to the aggregate cost assuming the arc is upgraded. We then progress by changing the characteristics of the primary and secondary roads earmarked for upgrading to match those of a motorway: removing any speed or distance penalty due to the presence of traffic lights, roundabouts, surface material, curvature or slope, and increasing the effective speed to 90 km/h. The road segments are changed sequentially starting from the arc with the largest estimated net economic gain from upgrading, up to the point where a segment improvement can no longer be financed for more than 50% (this ensures that on average all the investment money is spent, although individual regions will have some small amount of over- or underspending). We exclude toll costs from being affected by policies, as it is unclear whether or how constructing a highway would change toll costs on a given route.

Figure 7 below shows the change in transport costs when all the EU regions receive the same amount of investment (€500 million). Centrally-located regions benefit the most as a result of the spillover effects among regions. That is, although all the EU regions experience a reduction in transport costs, those that are located in the core of the road network enjoy the highest benefits in terms of spillover from neighbouring regions (Condeço-Melhorado et al., 2011). An important determinant of the observed change in transport cost is the size of the region: we observe larger effects in the smaller regions in, Belgium, the Netherlands, and Germany compared to the larger regions in Spain and France.

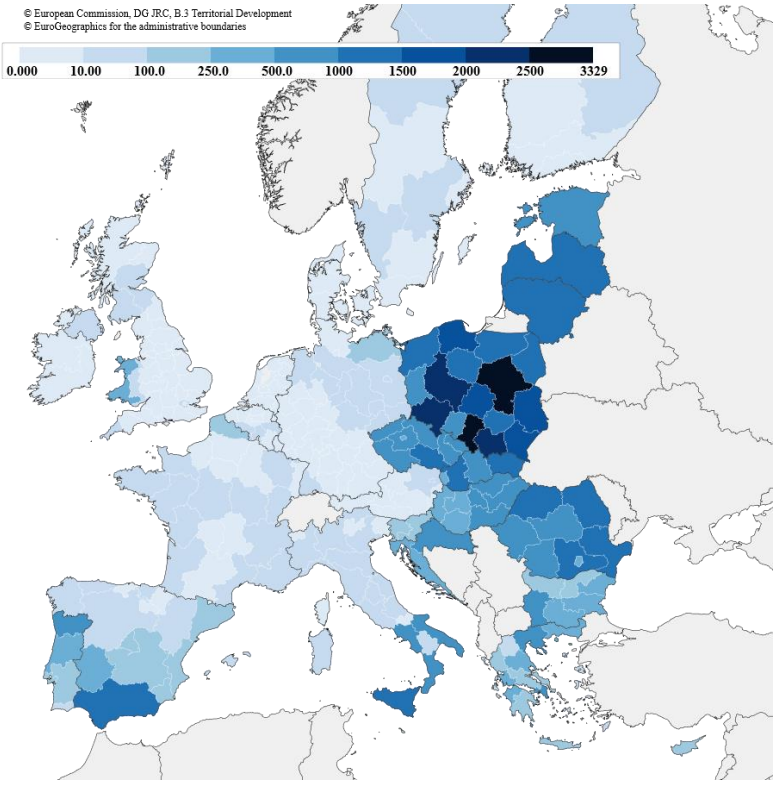
Figure 7. Change in weighted GTC as a result of investing 500M€ in each NUTS 2 region



Source: Own elaboration.

Next, we turn to the EU's 2014-2020 Cohesion Policy programme. Figure 8 shows the total amounts invested per region, adding up investments in all types of transport infrastructure and considering expenditure over the entire programming period. The programme clearly targets regions in Poland, Romania, Slovakia, and the Baltic countries. There are smaller investments in Southern Italy and Spain.

Figure 8. Transport Infrastructure investment in the Cohesion Programme 2014-2020 (Millions of €)



Source: Own elaboration.

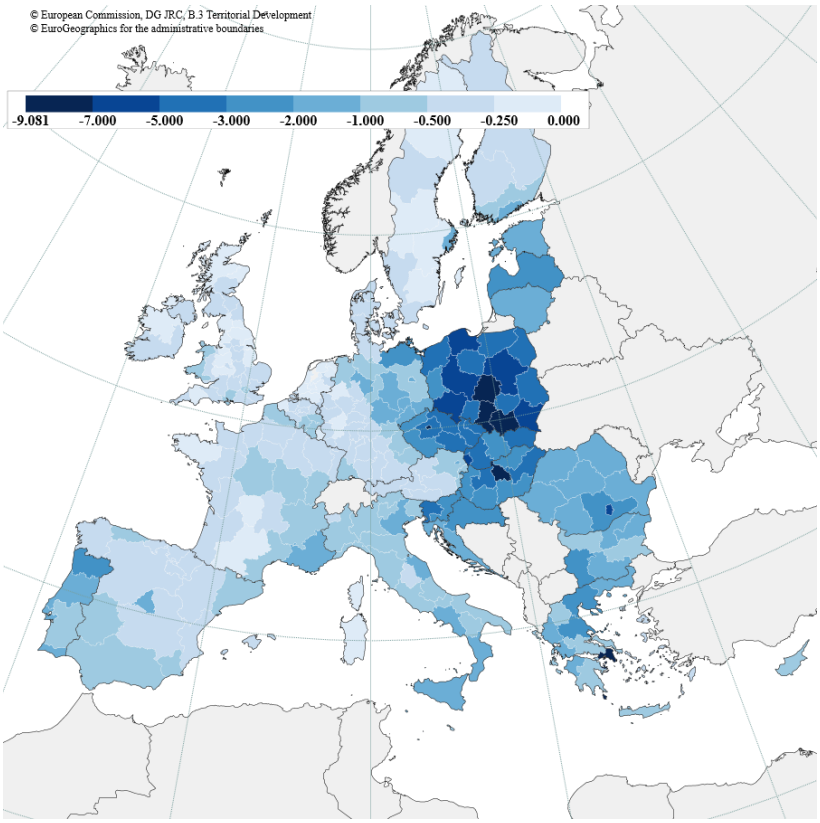
Figure 9 portraits the simulated change in transport costs due to the transport infrastructure investment. Given that the EU Cohesion Policy is a targeted policy for less endowed regions, Eastern European regions are, overall, the ones with the highest reduction in transport costs. However, there are significant spillovers to non-targetted regions, such as some Eastern and Central German and Northern Italian regions. There is much less impact on some targeted regions in the south of Spain.

We then separately consider changes in transport costs within the region (Panel b) and between regions (Panel c). As for the former, the regions with a less developed road network like in Eastern Europe show the largest reduction in internal transport costs.

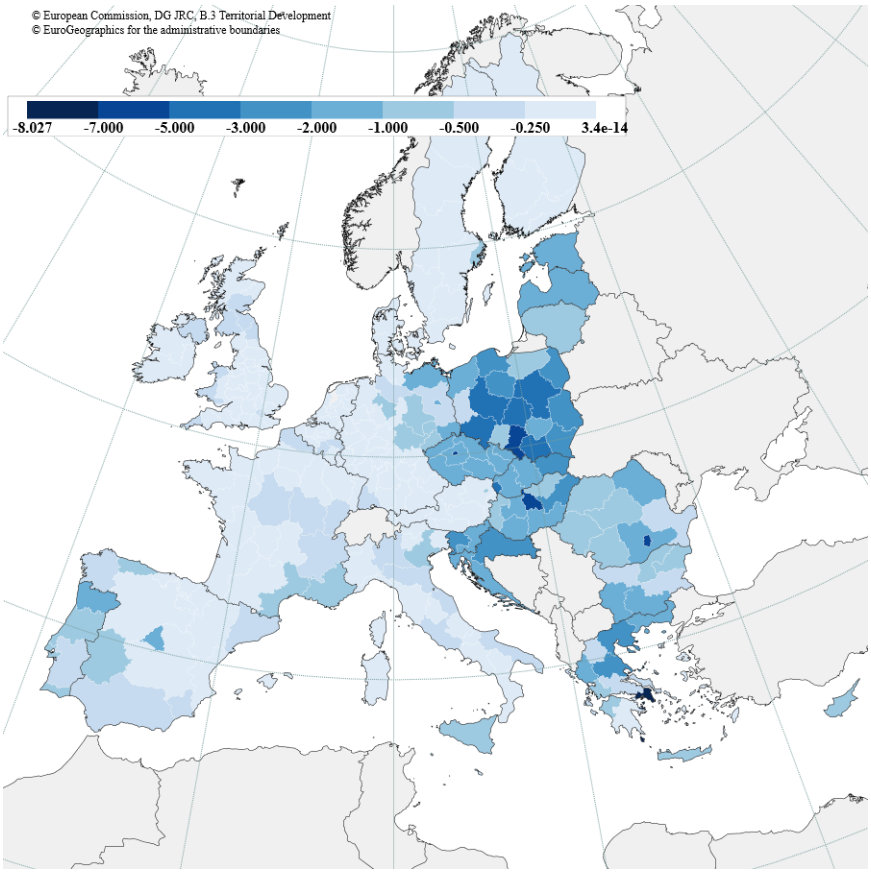
Complementary to this, transport costs between regions (Panel c) follow the same pattern as the overall transport costs. This panel shows some clear evidence of spillover effects in Eastern Germany and Northern Italy, which benefit from a reduction in their external transport cost even without receiving many funds directly. Understandably because of its location, also Southern Finland emerges as a region which benefits significantly from the large investments in road infrastructure in the Baltic countries and Central and Eastern Europe.

Figure 9. Change in the GTC due to the Cohesion Policy investment

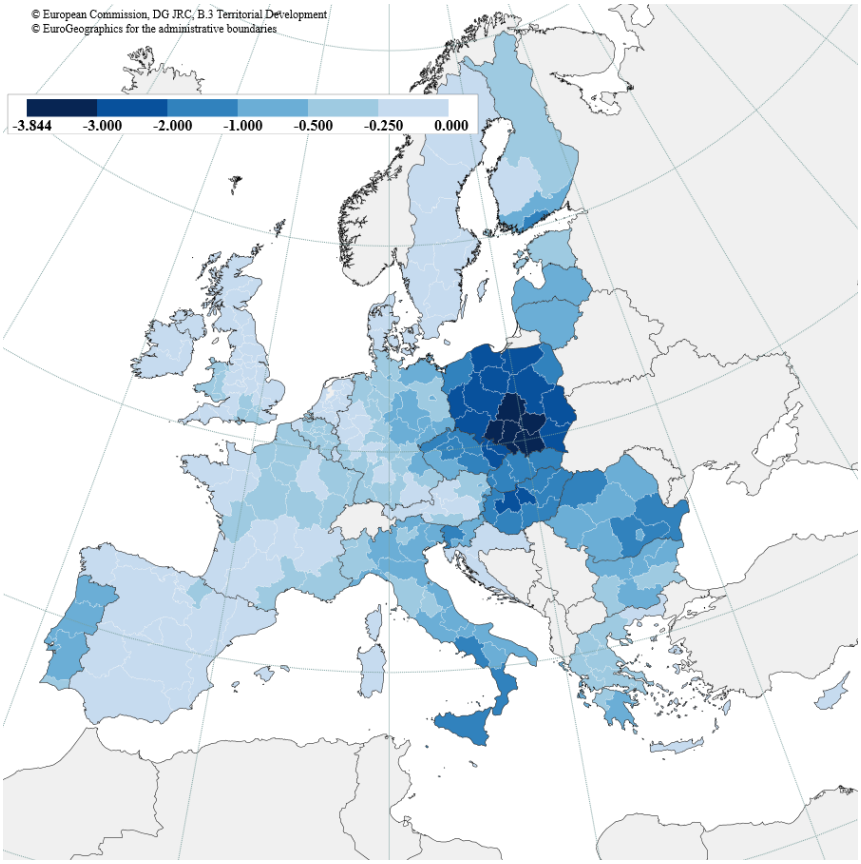
a) Percentage change in the weighted GTC



b) Percentage change in the internal GTC



c) Percentage change in the external weighted GTC



Source: Own elaboration.

6. Conclusion

Transport costs are not usually well captured in spatial economic models. In an attempt to overcome this limitation, we create a unique dataset of interregional transport costs for the EU regions (NUTS 2) by taking use of the open digitalised road network OSM. Combining this database with other information allows us to calculate the optimal route of transport by truck and calculate the associated average transport cost between regions. A first contribution of our paper is to provide a comprehensive set of transport cost estimates between EU regions at the NUTS2 level, along with a set of underlying variable such as driving times and distances.

The results indicate that transport costs follow a core-periphery structure within the EU, where geographically central regions benefit from shorter trips and reduced fuel consumption, and more peripheral regions tend to benefit from lower salaries within the transport sector.

Moreover, the method allows performing transport policy analysis. We provide an example in this paper by studying the effects of a generalised increase in fuel prices. We describe a tool for policy analysis on transport infrastructure investment. We apply it to estimate the impact of the EU's 2014-2020 Cohesion Policy programme, showing that Eastern European regions are the regions benefitting the most from road infrastructure investments, with positive spillover effects across the whole EU, but especially to neighbouring regions.

In future research, we aim to expand the definition of transport costs considered to include also costs related to loading/unloading or warehousing, and to consider other modes such as rail or inland waterways. Clearly, including more costs would reduce the

estimated impact of any infrastructure investment on such a wider definition of trade and transport costs. This would be especially the case for transport costs internal to the region or neighbouring regions, where these additional costs may be expected to represent a larger share of the total trade and transport cost. Other aspects of the analysis that can be improved are the use information on land-use to better estimate the origin and destination of the freight flows, which are now assumed to be distributed according to the population grid; and to use more information on the specifics of goods and sectors such as loading factors or volume/weight ratio's.

7. References

Chen, Y., Zhu, L., Gonder, J., Young, S., and Walkowicz, K. (2017). Data-driven fuel consumption estimation: A multivariate adaptive regression spline approach. *Transportation Research Part C: Emerging Technologies* 83, 134-145.

Combes, P.P. and Lafourcade, M. (2005). Transport Costs: Measures, Determinants, and Regional Policy Implications for France. *Journal of Economic Geography* 5 (3), 319–49.

Condeço-Melhorado, A., Martín, J. C., and Gutiérrez, J. (2011). Regional spillovers of transport infrastructure investment: A territorial cohesion analysis. *EJTIR* 4(11), 389-404.

Dijkstra, E.W. (1959). A note on two problems in connexion with graphs. *Numerische Mathematik 1*(1), 269-271.

Dünnebeil, F., Reinhard, C., Lambrecht, U., Kies, A., Hausberger, S., and Rexeis, M. (2015). Future measures for fuel savings and GHG emission reduction of heavy-duty vehicles. *Federal Environment Agency*, Germany, TEXTE 32/2015.

European Court of Auditors (2013). Are EU cohesion policy funds well spent on roads?. *European Court of Auditors*, Special Report No. 5, Luxembourg, ISBN 978-92-9241-270-8.

Eurostat (2016). Road Freight Transport Methodology. *Eurostat*, Luxembourg, ISBN 978-92-79-60068-5.

Head, K., and Mayer, T. (2009) Illusory border effects: distance mismeasurement inflates estimates of home bias in trade. In: *The Gravity Model in International Trade: Advances and Applications*. Editors: Bergeijk and Brakman.

Hillberry, R. and Hummels, D. (2013). Trade elasticity parameters for a computable general equilibrium model. Handbook of computable general equilibrium modelling, Elsevier, Vol. 1, 1213-1269.

Hummels, D. (1999). Toward a geography of trade costs. GTAP Working Paper No. 17.

Jacobs-Crisioni, C., Silva, F.B., Lavalle, C., Baranzelli, C., Barbosa, A., and Castillo, C.P. (2016). Accessibility and territorial cohesion in a case of transport infrastructure improvements with changing population distributions. *European Transport Research Review* 8(1), 9.

Lecca, P., Barbero, J., Christensen, M., Conte, A., Di Comite, F., Diaz-Lanchas, J., Diukanova, O., Mandras, G., Persyn, D., and Sakkas, S. (2018). RHOMOLO V3: A Spatial Modelling Framework. EUR 29229 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-85886-4.

Martino, A. and Brambilla, M. (2016). Research for TRAN Committee-The EU Maritime Transport System: Focus on Ferries, *European Parliament*, Committee on Transport and Tourism, Brussels.

Martinez-Zarzoso, I. and Nowak-Lehmann, F.D. (2007). Is distance a good proxy for transport costs? The case of competing transport modes. *The Journal of International Trade & Economic Development* 16(3), 411-434.

Teixeira, A. C. (2006). Transport policies in light of the new economic geography: The Portuguese experience. *Regional Science and Urban Economics* 36(4), 450-466.

Thissen, M., Husby, T. Ivanova, O., and Mandras, G. (2019). European NUTS 2 regions: construction of interregional trade-linked Supply and Use tables with consistent transport flows. JRC Working Papers on Territorial Modelling and Analysis No. 01/2019, European Commission, Seville, 2019, JRC115439.

Van Essen, H., Nelissen, D., Smit, M., Van Grinsven, A., Aarnink, S., Breemersch, T., Martino, A., Rosa, C., Parolin, R., and Harmsen, J. (2012). An inventory of measures for internalising external costs in transport. European Commission, Directorate-General for Mobility and Transport, Brussels, DM 28 – 0/110.

Zofío, J. L., Condeço-Melhorado, A. M., Maroto-Sánchez, A., and Gutiérrez, J. (2014). Generalized transport costs and index numbers: A geographical analysis of economic and infrastructure fundamentals. *Transportation Research Part A: Policy and Practice* 67, 141-157.

Annex A: Data description and further figures

A.1 The Road Network

The subset of the OSM road network used in the analysis contains motorways, trunk roads, primary roads, secondary roads and ferry lines, for a total length of about 1.500.000 km over a surface area of about 5.730.000 km², giving an average road density of 0.26 km/km².

Figure 10. Road and ferries networks (2017)

Source: OSM.

A.2 Tolls

Table 4. Tolls considered in each country for Heavy Duty Vehicles (2018)

Country	Cost per km (EUR)	Toll applied on	Yearly vignette (EUR)	Source
Austria	0.419	Highway and Schnellbahn		asfinag.at go-maut.at
Belgium	0.142	All highways and selected national roads		viapass.be
Bulgaria			1066	web.bgtoll.bg
Croatia	0.18	All highways		Sample route on hac.hr (Zagreg-Dubrovnik)
Czech Republic	0.18	OSM toll tag		mytocz.eu
Denmark			1250 EUR	Eurovignettes.eu
Estonia			1100	Teetasu.ee
France	0.24	all highways		Sample routes on autoroutes.fr (Marseille-Paris and Aix-en-Provence to Lyon)
Germany	0.198	All highways and primary		Toll-collect.de

		roads		
Greece	0.197	All highways		Sample route on diodia.com.gr (Athens-Patras)
Hungary	0.32 highway 0.2 primary	OSM toll tag		hu-go.hu
Latvia			711	Lvvignette.eu
Lithuania			753	Keliumokestis.lt
Luxembourg			1250	Eurovignettes.eu
Ireland	0.063	All highways		Sample route on www.tii.ie (Galway-Dublin)
Italy	0.18	All highways		Sample route on autostrade.it (Milan-Bari)
Netherlands			1250	Eurovignettes.eu
Poland	0.27	All highways		Viatoll.pl
Portugal	0.18	All highways		Sample route on estradas.pt (Porto-Lisbon)
Romania			1210	Roviniete.ro
Slovakia	0.19 highway 0.16 primary	All highway and primary roads		Emyto.sk
Slovenia	0.38	All highways		dars.si
Spain	0.286	OSM tag		Van Essen et al. (2012)
Sweden			1250	Eurovignettes.eu
United Kingdom			740	Multiservicetolls.com
Norway	0.068	All highways		Sample route on fjellinjen.no (Fredrikstad – Kristiansand)
Switzerland	0.81	All highways		Ezv.admin.ch

A.3 Taxes

Table 5. Ownership Taxes by country (EU, 2012)

Country	Tax (in euros)
Belgium	517€
Bulgaria	1833.63€
Czech Republic	1772.63€
Denmark	517.85€
Germany	556€
Estonia	515.2€
Ireland	3160€
Greece	1320€
Spain	392.74€
France	516€
Croatia	N/A (set at 0)
Italy	549.92€
Cyprus	521€
Latvia	507.61€
Lithuania	654.54€
Luxembourg	520€
Hungary	1503.57€

Malta	515€
Netherlands	876€
Austria	912€
Poland	801.32€
Portugal	713€
Romania	510.92€
Slovenia	2347.25€
Slovakia	1033.74€
Finland	1460€
Sweden	3675.54€
United Kingdom	1570.5€

Source: Van Essen et al. (2012).

A.4 Ferry ticket prices

Table 6. Ferry ticket prices per kilometre (EU, 2015)

Range	Distance (in km)	Average price (€/km)
Short	Less than 100	2.74
Medium	100-300	1.73
Long	More than 300	1.06

Source: Martino and Brambilla (2016).

A.5 Infrastructure costs

Table 7. Average cost per kilometre of different type of roads (EU, 2013)

Type of road	Average cost (€/km)
Highway	10,941,402
Primary Roads	6,225,187
Secondary Roads	4,159,281

Source: Eurpean Court of Auditors (2013).

Table 8. Civil engineering works price level index (2016, EU27=100)

Country	2016
Belgium	103.4
Bulgaria	67.4
Czech Republic	82.4
Denmark	139.0
Germany	130.3
Estonia	88.3
Ireland	92.9
Greece	73.1
Spain	77.0
France	134.3
Croatia	66.9
Italy	82.6
Cyprus	83.6
Latvia	71.8
Lithuania	84.8
Luxembourg	119.8

Hungary	65.4
Malta	105.2
Netherlands	108.3
Austria	112.6
Poland	87.3
Portugal	57.9
Romania	52.6
Slovenia	89.0
Slovakia	79.0
Finland	157.2
Sweden	146.7
United Kingdom	115.2

Source: Eurostat.

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