Border effects in Europe

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Abstract
This paper exploits a novel database on interregional trade between European NUTS 2 regions to estimate 380 bilateral border effects between 20 European countries from a gravity model that is fully consistent with the general equilibrium of a New Economic Geography (NEG) model. It finds that border effects are still substantial in Europe, in spite of the Single Market, but differ starkly across country pairs. Some borders do not seem to matter at all or do even facilitate trade while other borders impede trade heavily. The border effects are also not symmetric. Exports from western to eastern Europe, for example, seem to face heavy impediments while those in the opposite direction do not.

JEL classification: C54, F14, F15, R12

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1. Introduction

The European Union has devoted much effort to fostering institutional and economic integration among its member states by reducing the impediments to trade, migration and investment across countries during the past decades. Milestones of these efforts are the Single Market program of the late 1980s and early 1990s, which aimed at removing the institutional barriers to trade and factor migration, and the establishment of a common currency in the late 1990s. In spite of these integration efforts, the border impediments to trade among European countries are arguably still fairly high. Domestic trade within the individual countries is still much higher than trade across countries (Head and Mayer 2000, Nitsch 2000, Cheptea, 2013). There should thus be ample room for policies that push integration even further.

The present paper documents the first step of an analysis that identifies those policies that may further reduce trade impediments in Europe and evaluates the consequences of these policies for trade flows and economic geography in Europe. It quantifies the extent of the border impediments to trade between European countries from a new economic geography (NEG) model of interregional trade using a new database on trade between 250 NUTS 2 regions from 20 European countries compiled by the Netherlands Environmental Assessment Agency (Thissen et al. 2013a, 2013b). Subsequent steps will then identify the determinants of these border impediments, identify policies that manipulate these determinants to reduce the border impediments, and run counterfactual simulations of the fitted NEG model to assess the consequences of these policies for the regional distribution of employment and wages in Europe.

In contrast to most of the earlier studies for border impediments, we estimate the border effects from a gravity model that is rooted rigorously in economic theory. Deriving gravity equations from trade theory has been state of the art since Anderson and van Wincoop (2003). But we go one step further. We not just derive the gravity equation from a single equilibrium condition of the trade model, the trade equation. We make sure that our estimation results are consistent with the fully parameterized general equilibrium of the underlying trade model, i.e., solve all equilibrium conditions simultaneously. Following Behrens et al. (forthcoming), we do this by pursuing an iterative estimation and simulation procedure. We iteratively estimate trade costs (including the border impediments) from a constrained gravity model for observed trade flows and (simulated) equilibrium employment and wages in all regions, and then update the equilibrium values of employment and wages in all regions for observed trade flows and the estimated trade costs by simulation. This iterative estimation-simulation procedure has several advantages. First, it avoids estimation problems from endogeneity of the multilateral resistance terms. Rather than burying the multilateral resistance terms in origin and destination country dummies, which may cause endogeneity problems, we simulate them from the theoretical model such that they are consistent with the observed trade flows and trade costs. And second, the estimated model gives the perfect baseline for counterfactual simulations of trade policies. Like the simulated counterfactuals, the baseline will be perfectly consistent with the general equilibrium of the underlying theoretical model. We will show that the simulated equilibrium distributions of employment and wages fit the actual distributions fairly well. We use as our theoretical foundation the multi-region version of the NEG model by Helpman (1998) developed in Hanson (2005), which has been the workhorse model for empirical analyses of agglomeration and trade in regional economics for decades. In contrast to models of international trade, this NEG model will allow us assess the effects of trade liberalization on the distribution of economic activity both between and within countries. Even if a country as a whole will gain from trade liberalization, worries about adverse effects of trade policies on single regions within this country may raise serious opposition against this liberalization.

We use interregional rather than international trade data to estimate trade costs and border impediments. Even though this data may be less precise than international trade data because it is based on estimates,[1] we still expect it to yield more precise estimates for the distance-related transport costs. Rather than from a single trade flow between origin and destination country, we identify the distance-related trade cost parameter from the trade flows between all pairs of regions in the two countries.[2] Even more importantly, we are able to estimate separate border effects for each pair of countries and direction of trade rather a single average border effect for all countries. Each bilateral border effect is identified from all the bilateral trade flows between the regions in the respective countries. In addition to this, we identify a domestic border effect for each country from the bilateral trade flows between the regions in this country. Relating these two pieces of information to each other, we will assess by how much international trade barriers impede trade across countries relative to trade across regions within these countries.

Our main results are that border effects do, on the one hand, still matter in Europe in spite of the Single Market but that they differ, on the other hand, widely not only across country pairs and the direction of trade. These results do not only qualify the results of earlier studies that assume the magnitudes of border effects to be the same across country pairs and directions of trade. Our estimates also offer ample scope for a thorough analysis of the economic and political determinants of the border effects.

The plan of this paper is straightforward. Section 2 sketches the theoretical model, Section 3 explains the empirical methodology and the data. Section 4 presents the results and assesses their robustness, and section 5 concludes.

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[1] It is important to note that the interregional trade data we use is consistent with international trade data but were not estimated from any trade model or gravity-like approach. Our estimation will thus not just recover the model used to estimate this data.

[2] Head and Mayer (2009) show that border effects may be significantly overstated when distances are mismeasured.

2. Theory

We derive our gravity equation, and simulate the associated multilateral resistance terms, from the Helpman-Hanson model (Helpman 1998, Hanson 2005). In this model, the distribution of economic activity across regions results from the interplay of microeconomically well-founded forces that jointly give rise to agglomeration economies and diseconomies: Increasing returns to scale at the firm-level, monopolistic competition, consumers' love of variety, and transport costs. On top of these forces, an immobile local good in fixed supply, housing, constitutes an additional agglomeration diseconomy. Since the Helpman-Hanson model has been the workhorse for empirical tests of NEG models for more than a decade, we will just summarize its equilibrium conditions for the sake of brevity.[3] The general equilibrium of this model for R regions $r = 1, \dots, R$ is the solution to the $2R$ equations (1)–(3), which jointly determine and nominal wages, $w_1, \dots, w_R$, and employment, $\mathrm{L}_1, \dots, \mathrm{L}_\mathrm{R}$, in all regions:

$$\mathrm{w_r} = \frac{1}{\mathrm{L_r}} \sum_{\mathrm{s}=1}^{\mathrm{R}} \mathrm{X_{rs}}, \qquad r = 1, \dots, R, \tag{1}$$

$$\frac{\mathrm{w_r}}{\mathrm{G_r^{\mu} P_r^{1-\mu}}} = \frac{\mathrm{w_k}}{\mathrm{G_k^{\mu} P_k^{1-\mu}}} \qquad \forall\, \mathrm{r} \neq \mathrm{k}, \tag{2}$$

$$\sum_{r} \mathrm{L_r} = \mathrm{L}. \tag{3}$$

In these equations,

$$\mathrm{X_{rs}} = \frac{\mu}{\mathrm{F}\sigma} \left(\frac{\sigma \mathrm{c}}{\sigma - 1}\right)^{1-\sigma} \mathrm{L_r w_r^{1-\sigma} G_s^{\sigma-1} Y_s T_{rs}^{1-\sigma}}, \qquad \mathrm{r, s} = 1, \dots, \mathrm{R}, \tag{4}$$

$$\mathrm{G_r} = \frac{\sigma \mathrm{c}}{\sigma - 1} (\mathrm{F}\sigma)^{\frac{1}{\sigma-1}} \left[\sum_{\mathrm{s}=1}^{\mathrm{R}} \mathrm{T_{sr}^{1-\sigma}\, w_s^{1-\sigma} L_s}\right]^{\frac{1}{1-\sigma}}, \qquad r = 1, \dots, R, \tag{5}$$

$$\mathrm{P_r} = (1 - \mu) \frac{\mathrm{Y_r}}{\mathrm{H_r}}, \qquad r = 1, \dots, R, \tag{6}$$

$$\mathrm{Y_r} = \frac{1}{\mu} \mathrm{w_r\, L_r}, \qquad r = 1, \dots, R. \tag{7}$$

[3] The reader interested in the detailed setup of the model is referred to Helpman (1998), Hanson (2005) or Mion (2004). The various NEG textbooks, including Fujita et al. (1999) and Brakman et al. (2009), offer good introductions into the basic core-periphery model (Krugman 1991), from which the Helpman model differs only insofar as it replaces the immobile agricultural sector by immobile housing. This difference affects only equilibrium conditions (6) and (7) below.

Notation:

X_{rs}	Total sales from region r to region s,
T_{rs}	(Iceberg) transport costs between regions r and s,
Y_r	Total income in region r,
G_r	Consumer price index (CPI) in region r,
P_r	Price of the immobile consumption good housing in region r,
H_r	Fixed housing supply in region r,
L	Total employment in all regions;
σ	Elasticity of substitution between any two varieties of the traded good ($\sigma > 1$),
μ	Income share spend by households on the traded good,
F	Fixed production costs (in terms of labor) for the traded good,
c	Marginal production costs for the traded good,

Equation (1) is our version of the wage equation. The wage equation originally relates the wage rate in each region to this region's real market potential.[4] In our version, the real market potential is expressed in terms of total sales per worker because we use the observed trade data to simulate the equilibrium regional employment and wages, which determine the multilateral resistance terms in the gravity model. Equation (2) is the no migration condition, which requests that real wages are equal across all regions in equilibrium, or, equivalently, are the same as those in an (arbitrarily chosen) reference region k. The real wage discounts the nominal wage by the weighted average of the local prices of the traded good (G; see equation 5) and the local housing price (P; see equation 6). In contrast to trade models, workers are mobile across regions in NEG models. We assume that they are freely mobile even across national borders.[5] This implies that we assume real wages to equalize all over Europe. Equation (3) is the labor market clearing condition.

Equation (4) is the trade equation, from which we derive our gravity equation. Similar to many trade models (e.g., Anderson and van Wincoop, 2003, equation 13, Head and Mayer 2014, Table 3.1), the value of trade between any two regions depends on bilateral (iceberg) transport costs, T_{rs} ($T_{rs} \geq 1$) and the economic characteristics of the trading regions. For the sake of simplicity, we will label these characteristics outward multilateral resistance, $\Pi_r = [w_r \sigma c/(\sigma - 1)]^{1-\sigma} L_r / F\sigma$, where $[w_r \sigma c/(\sigma - 1)]^{1-\sigma}$ is the mill price of varieties in region r and $L_r / F\sigma$ the number of varieties produced in r, and inward multilateral resistance, $\Omega_s = \mu G_s^{\sigma-1} Y_s$, where G_s and Y_s are the local CPI and income.[6]

Equation (5) determines the CPIs (G_r) and equation (6) the housing prices (P_r) in all regions. Since housing is in fixed supply, housing prices will be higher in cities. Finally, equation (7)

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[4] See Hanson (2005, equation 7) or Fujita et al. (1999, equation 4.27). The wage equation given in Hanson or Fujita et al., $w_r = A[\Sigma_s T_{rs}^{1-\sigma} G_s^{\sigma-1} Y_s]^{1/\sigma}$can easily be derived by substituting the trade equation (4) into our wage equation (1). The constant tem A=$[(\sigma - 1)/(\sigma c)][(\mu c)/(F(\sigma - 1))]^{1/\sigma}$.

[5] While immobility of workers across national borders could be introduced fairly straightforwardly, it would not affect our results decisively.

[6] In the literature, the term 'multilateral resistance' usually refers only to the price variables. We include the size variables for expositional simplicity.

defines regional income as the sum of income from labor and housing. For the sake of simplicity, we follow Redding and Sturm (2008) in assuming that the housing rents are distributed uniformly among the households in the region of origin of the rents.[7]

3. Empirical methodology and data

3.1. Methodology

This section explains the method of our estimation, which iteratively combines a gravity regression with a simulation of regional employment and wages from the Helpman-Hanson model.

To fit the whole multiregional Helpman-Hanson model, represented by its equilibrium conditions outlined in Section 2, to the data, we pursue an iterative two-stage estimation strategy similar to that used by Behrens et al. (forthcoming). Assuming the economy under study to be in (long-run) equilibrium, we iteratively

– estimate the bilateral trade costs, T_{rs}, from the trade equation (3) for observed trade flows and given employment and wages in all regions in the first stage, and
– simulate the equilibrium employment and wages in all regions for observed trade flows and the estimated trade costs from the system of equations (1) and (2) in the second stage.

This procedure iteratively updates the multilateral resistance terms in the gravity regression by the simulation results and the bilateral trade costs in the simulation by the regression results until the estimated and simulated values stabilize. In this way, we ultimately identify the trade costs and associated vectors of regional employment and wages that solve all equilibrium conditions simultaneously for given observed trade flows.[8]

For the gravity regression in the first stage of this estimation, we use data on the values of bilateral trade in goods and services among 250 NUTS2 regions from 20 European countries in the early 2000s (average of 2000 – 2002) provided by Netherlands Environmental Assessment Agency. The data will be described in more detail in the next subsection. We concentrate the multilateral resistance terms in equation (3) for the origin and the destination of the bilateral trade flows on the right-hand side, which gives

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[7] Helpman (1998) and Hanson (2005) assume, by contrast, that the rents are distributed uniformly among all households in the economy, which implies that there is redistribution of rental income from urban to rural areas. This does, however, not affect our empirical results notably.

[8] An alternative approach, which may be preferable when interregional trade data is not available, would be estimating the trade costs from the wage equation of the Helpman model. This approach is, however, complicated by the fact that the wage equation cannot as easily be (log-) linearized as the trade equation. While Hanson (2005) estimates the wage equation directly by non-linear two-stage least squares, Mion (2004), Huber et al. (2011) and Bode and Mutl (2010) linearize the wage equation by first-order Taylor approximation. The linearization may come along with significant approximation errors whose effects on the estimated parameters are largely unknown.

$$\frac{X_{rs}}{\frac{\mu}{F\sigma}\left(\frac{\sigma c}{\sigma-1}\right)^{1-\sigma} L_r w_r^{1-\sigma} G_s^{\sigma-1} Y_s} = \frac{X_{rs}}{\Pi_r \Omega_s} = T_{rs}^{1-\sigma}, \tag{8}$$

$r, s = 1, \ldots, R, r \neq s$. We quantify the bilateral sales, X_{rs}, by observed data and the multilateral resistance terms, Π_r and Ω_s, by their simulated equilibrium values implied by the Helpman-Hanson model.[9] We additionally assume all parameters of the model except those of the trade costs (σ, μ, F, c) to be known ex ante.[10] The detailed specification of the trade costs, which account for transport costs and border impediments, will be discussed later.

Concentrating all the endogenous variables of the Helpman-Hanson model on the right-hand side of (8) relieves us of endogeneity problems that plague structural estimations of NEG models like Hanson (2005) or Redding and Venables (2004) seriously. Employment and wages in the origin or destination are most likely not independent of the trade intensities. Even replacing the economic characteristics of the regions of origin and destination by exporter and importer dummies will not solve this endogeneity problem, if the underlying theoretical model is true. The concentration of the endogenous variables on the right-hand side comes at a cost, however. We can estimate only a single parameter, the trade costs, directly from (8) while we have to take all other parameters, most notably the substitution elasticity, σ, as given.

We assume that the trade costs between any regions r and s, T_{rs} in equation (8), consist of a distance-related and two fixed cost components, domestic and international border impediments. The distance-related costs are the iceberg transport costs, which we model as the usual power function, D_{rs}^{τ}. D_{rs} denotes the geographical distance (in kilometers) and τ is the transport cost parameter to be estimated.

The domestic border impediments capture the costs of exporting to other regions within the same country. Several studies[11] report significant domestic border effects that impede trade across regional borders, such as those between US states or even ZIP code areas. Local sales may be higher than domestic sales across larger distances because production of some goods, like specific household and business services, requires suppliers and customers to be in the same place at the same time.[12] Assuming all goods to be tradable at uniform trade cost, the Helpman-Hanson model may not fully account for these non-traded goods. Local sales may also be higher because suppliers and customers cluster in the same region to reduce

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[9] In the first iteration, we use the observed values of regional wages and employment as start values.

[10] We choose $\sigma = 9$, $\mu = 0.715$, $F = 1$ and $c = 1$ in our baseline specification. We check the robustness of our results to the value for σ in Section 4.2. The value of the income share spend on traded goods, $\mu = 0.715$, is derived from from the 2000 Harmonized Index of Consumer Prices (HICP) by the European Commission. We actually determine the expenditure shares for items typically considered local goods, $1 - \mu = 0.2848$. Table A1 in the Appendix lists the goods we consider local as well as their expenditure shares.

[11] See Nitsch (2000), Wolf (2000), Hillberry and Hummels (2008) or Coughlin and Novy (2013), among others.

[12] Examples of these services are hairdressing, cleaning, maintenance or health care. Unfortunately, we cannot exclude sales of these services from our data.

information and search costs (Coughlin and Novy 2013). While NEG focuses prominently at explaining the clustering of suppliers and customers by forward-backward linkages that result from the interplay of trade costs and economies of scale, it does not account for more complex or subtle agglomeration economies. We account for domestic border impediments a dummy variable for each country that is one for the trade flows between all regions within this country.

International border effects are well documented in the literature.[13] For European countries, significant border effect have been reported by Nitsch (2000), Head and Mayer (2000), Chen (2004), Helble (2007) and Cheptea (2013). While these studies estimate only a single, aggregate border effect for all trade flows across countries, we estimate separate border effects for each pair of countries and direction of trade flows. We thus allow the fixed costs of, say, French exports to Germany to differ from those of French exports to Hungary. And we also allow them to differ from those in the opposite directions, i.e., from Germany or Hungary to France. With $N = 20$ European countries in our sample, we thus assume T_{rs} to comprise $N(N-1) = 380$ different international border effects.

Compared to the previous literature, which estimates only aggregate domestic and international border effects, our approach has an advantage and a disadvantage. The advantage is that we avoid the border effects to be biased by aggregation across the bilateral trade flows. We will show below that the border effects do, in fact, differ notably across country pairs. These differences will also be helpful in determining the causes of border effects in the future. The disadvantage is that we can control only for exporter but not for importer region fixed effects. The exporter region fixed effects are identified from the local, intraregional sales. Most studies control for both exporter and importer fixed effects because they need to account for the unobservable multilateral resistance terms. We do not need them for this purpose because we quantify the multilateral resistance terms explicitly by equilibrium values simulated from the Helpman-Hanson model. However, there may still be unobserved heterogeneity among exporting or importing regions that result from sources outside the Helpman-Hanson model. The heterogeneity among the exporters will be captured by the exporter region fixed effects while that among the importers will be captured by the bilateral border effects dummies or the error term.

Formally, we denote the border dummy for exports from region r in country i to region s in country j as B_{ij}, $i, j = 1, \ldots, N$, defined as $\mathrm{B}_{ij} := I[r \in C_i, s \in C_j, r \neq s,]$. I is a (0,1) indicator function. For any pair of regions r and s, $r \neq s$, B_{ij} is an international border dummy, if $C_i \neq C_j$, i.e., region s is from a different country as region r, or an interregional border dummy, if $C_i = C_j$, i.e., both are from the same country. The associated parameters, denoted

[13] See McCallum (1995), Anderson and van Wincoop (2003), or most recently, Coughlin and Novy (2013), among many others. While earlier studies estimated border effects from an ad hoc, theoryless gravity equation, more recent studies follow Anderson and van Wincoop (2003) in deriving the gravity models they estimate from a model of international trade.

by φ_{ij}, measure to what extent interregional exports from country i to country j are subject to higher trade impediments than local sales within the region of origin.

In summary, the trade costs on the right-hand side of (8) take the form

$$T_{rs} = e^{\tau D_{rs} + \varphi_{ij} \mathrm{B}_{ij}}, \qquad r \in C_i, s \in C_j, r \neq s; \tag{9}$$

and $T_{rr} = 0$. Log-linearizing equation (8) with trade costs from (9), and adding exporter region fixed effects, α_r, as well as an error term, u_{rs}, which accounts for trade shocks and errors in the estimation of the interregional trade flows, we obtain the gravity model to be estimated as

$$ln\left(\frac{X_{rs}}{\Pi_r^* \Omega_s^*}\right) = \tau(1-\sigma)D_{rs} + \varphi_{ij}(1-\sigma)B_{ij} + \alpha_r + u_{rs}, \tag{10}$$

$r, s = 1, \ldots, R$, $r \in C_i, s \in C_j$, where Π_r^* and Ω_s^* are equilibrium values of the two multilateral resistance terms simulated from the Helpman-Hanson model. $\exp(\varphi_{ij}(1-\sigma))$ is the factor by which the respective border effect reduces sales across the respective regional borders $(i = j)$ or the respective international border $(i \neq j)$ relative to the sales within the region of origin ($\exp(\alpha_r)$).

While we will report the estimates for the border effects φ_{ij} in the results section, we will draw inferences only from the ratio of international to domestic border effects, $\exp((\varphi_{ii} - \varphi_{ij})(1-\sigma))$, which is the factor by which an international border effect reduces foreign exports relative to domestic interregional exports, ceteris paribus. The reason for this is that our estimates of the exporter region fixed effects, α_r, may not be reliable because they are identified from data on sales within the regions (X_{rr}), which are estimated from an NEG-flavored model. The φ_{ij} may thus not be invariant to the way interregional trade data were estimated.

Assuming the trade shocks and estimation errors to be random across region pairs, we estimate (10) by OLS. Since the overwhelming majority of the export values is positive, there is no need for using regression methods that account for the lower bound of the dependent variable. We use the results of the estimation of (10) to determine the bilateral transport costs that go into the simulation as

$$\hat{T}_{rs} = exp\left[\hat{\tau}(1-\sigma)D_{rs} + \hat{\varphi}_{ij}(1-\sigma)B_{ij}\right], \qquad r, s = 1, \ldots, R \tag{11}$$

To ensure that the gravity model we estimate actually represents equilibrium, we measure the characteristics of the regions of origin and destination by values simulated from the Helpman-Hanson model. We could, of course, simply calculate $\Pi_r \Omega_s$ in (10) from observed regional employment and wages, assuming that these values do, like the bilateral exports, represent equilibrium values. However, this would most likely violate equilibrium condition (1), which holds that factor costs equal total sales in each and every region. Our estimates of the trade costs would consequently not be consistent with equilibrium of the Helpman-Hanson model.[14]

We simulate the (long-run) equilibrium values of employment and wages in all regions in the second stage for

- observed bilateral trade flows, X_{rs}, including the local sales in each region;
- trade costs estimated from the gravity model, $\hat{T}_{rs}$ (see equation 11);
- observed quantities of housing supply, H_r; and
- predetermined parameters $\sigma = 9$, $\mu = 0.715$, $F = 1$ and $c = 1$, whose values are the same as those that enter the gravity regression.

In contrast to most of the earlier structural estimations of NEG models, we take the local sales into account when determining regional wage rates. In most earlier studies, including Hanson (2005) and Redding and Venables (2004), local sales are assumed to be zero in order to mitigate endogeneity problems. This is even though these sales account for a significant fraction of total sales[15] and should therefore have a strong impact on local wages, according to NEG models.

The setup of the simulation, which is iterative in itself, follows Brakman et al. (2009, pp. 121–123) who suggest determining the long-run equilibrium by a sequence of short-run equilibria. We iteratively update the vector of regional wages for given employment, and the vector of regional employment for given wages until convergence.[16]

Convergence of the iterative estimation-simulation procedure requires that neither the estimated trade costs nor the simulated values of regional employment and wages change across subsequent iterations. As convergence criteria, we request that none of the 620 estimated parameters changes by more than $1E-10$ in absolute terms from one iteration to another, i.e., $max\left(abs\left(d\tau(\iota)\right), abs\left(d\varphi_{ij}(\iota)\right)\right) < 1E-10,\ i,j = 1,\ldots,N$, and that none of the regional employment or nominal wage values changes by more than $1E-5$ in absolute terms, , i.e., $max_r\left(abs\left(dL_r(\iota)\right), abs\left(dw_r(\iota)\right)\right) < 1E-5$.[17]

[14] The trade costs as well as the simulated values of regional employment and wages do indeed change notably in the course of the iterations.

[15] In our dataset, the share of local in total sales is 77% on average across the 250 regions (Std dev.: 10%), ranging from 28% to 89%.

[16] To update the employment vector, we use the ad-hoc migration function suggested by Fujita et al. (1999, p. 62), which mimics regional migration in response to real wage differences. The higher a region's real wage rate relative to the (employment-weighted) EU average, the more workers move to this region. For simplicity, we do not impose any restrictions on the mobility of workers across countries. We assume convergence of the simulation if real wages are the same in all regions. Formally, we request $max_r\left(abs\left(d\omega_r(\iota)\right)\right) < 1E-10$, where $d\omega_r(\iota)$ is the change of the real wage rate in region r (see equation 2) between iterations $\iota-1$ and ι.

[17] In addition to these convergence criteria, we abort the procedure if more than five regions run out of employment in the course of the iterations. While equilibria where a significant number of regions has zero employment are clearly within the scope of the Helpman model, we do not consider these equilibria relevant

3.2. Data

The trade data, available from the Netherlands Environmental Assessment Agency, cover the values of bilateral trade in goods and services among 256 NUTS2 regions from 20 European countries on average over three years, 2000 – 2002. The averaging is meant to reduce the effects of annual outliers. While the trade data is available for a longer time period, which would allow us estimating equation (10) for a panel, we are restricted by the fact that data on regional housing is available only from centennial censuses in 2001 and 2011. Since the European economy was in a severe crisis in 2011, which may bias our results, we focus this analysis on the early 2000s only.

The regional trade data are estimated by essentially breaking down international trade flows and national Supply and Use Tables to the level of regions. See Thissen et al. (2013a, 2013b) for a detailed description of the data and estimation procedure. The list of regions in our dataset is given in Table A2 in the Appendix. Importantly, the estimation of the interregional and international trade data does not rely on the gravity approach and does not impose any geographical structure on the trade data (Thissen et al. 2013a). Our gravity regression does consequently not just recover the geographical patterns from which the trade data were constructed.

However, Thissen et al. estimate the share of products produced and used within the same region separately for each region and industry from an NEG-flavored two-region model (see Thissen et al. 2013a, Section 2.2.3). This raises concerns that the trade data we seek to explain by an NEG model is constructed from just this NEG model. Our estimation results may consequently just "recover" the parameter values used to construct the data, and the model fit statistics will be biased upward. These statistics include not only the R^2 of the gravity regression but also the correlations between the vectors of estimated (equilibrium) and observed employment quantities and wages.

In fact, the way how Thissen et al. estimate the share of products produced and used locally corrupts the information in the data on how intensively the regions in our sample engage in interregional or international trade. It does, however, not affect the regional distributions of the regions' exports. Thissen et al. estimate the share of local sales separately for each region from a two-region model (where the second region is the aggregate of all other regions). The data contamination is therefore separable across regions and will be captured by the exporter fixed effects in our regression. Nonetheless, these exporter fixed effects constitute the reference for the domestic and international border effects in our model. Recall that the parameters φ_{ij} in equation (10) measure how much the regional or national borders impede trade relative to local trade within the same region. To eliminate this reference, and with it all the information from the NEG model used to construct the data, we will draw inferences only

for our purpose of fitting the Helpman (1998) model to European regions.

from the ratio of the estimated international and the domestic border effects. That is, we will use our estimation results to determine how much the national border between two countries impedes trade relative to domestic interregional trade within the exporting country. We will nonetheless report the estimates for the parameters φ_{ij} for the sake of completeness in the results section. To escape identification problems for parameters for countries that comprise only one NUTS2 region, we merge the three Baltic countries, Estonia, Latvia and Lithuania, to a single country, Baltic (BA), and assume the state of Luxembourg to be a NUTS 2 region within Belgium.

Our dataset thus comprises N=250*250= 62,500 observations of intra- or interregional trade flows among European regions on average across the years 2000 – 2002.

The data on regional employment and wages (GDP per worker), which serve as start values in the iterative estimation and as a reference for the simulated equilibrium values of employment and wages, are from Eurostat. They are also averaged over the years 2000 – 2002. Missing values for some German and Italian regions are approximated by corresponding data published by the national statistical offices.

Housing supply, H_r, which enters the simulations as an exogenous variable, is measured by numbers of dwellings in 2001, available from the 2001 census on dwellings by type of building and NUTS 3 regions by Eurostat (cens_01rdbuild). Data for Belgium, Germany and Sweden, which are not available from this census, are taken from the national statistical offices. For Belgium, where regional dwelling stocks are not available from the national or the regional statistical offices, we estimate the regional dwelling stocks from population data, assuming a uniform 407 dwellings per 1,000 inhabitants in all regions (see Dol and Haffner (2010, p. 62, Table 3.3). Geographic distances between regions are calculated as great circle distances from coordinates provided by Eurostat (shapefile NUTS_2010_03M_SH).

4. Results

4.1. Trade costs and border effects in Europe

Table 1 summarizes the results of our iterative estimation and simulation of the gravity equation from the Helpman-Hanson model for 62,500 bilateral trade flows across 250 European regions from 20 countries in the early 2000s. These estimates represent the general equilibrium of the Helpman-Hanson model. According to the R^2 of 0.812, the gravity model fits the observed trade flows net of the simulated income and multilateral resistance terms reasonably well. And according to the correlation coefficients depicted at the bottom of the table, the simulated equilibrium regional wages and employment are reasonably close to observed wages (r = 0.816) and employment (r = 0.932). This suggests that our simplifying assumption of workers being freely mobile across countries does not affect the results too much.

The transport cost parameter, τ, is estimated to be 0.087 (distance decay: $\hat{\tau}(1-\sigma) =- 0.69$), which is somewhat lower but not too far away from distance decay values of slightly below one estimated elsewhere. The parameters of the 20 domestic border dummies (φ_{ii}) are jointly highly significant (F = 51.9). Their mean across all countries is 0.107, which implies that, ceteris paribus and on average across all countries, trade intensity drops by the factor of 2.3 (≈ exp(0.107*(9-1))) at NUTS 2 boundaries. This estimate is slightly below the estimates reported by earlier studies.[18] The estimates of the 380 bilateral international border effects are also jointly highly significant (F = 431.2). Most of the bilateral parameters are also individually significant. Their mean across all country pairs is 0.417, which implies that, ceteris paribus and on average across Europe, trade intensity across national borders is 28 (≈ exp[0.417*(9-1)]) times lower than that within NUTS 2 regions.

The ratio of these two estimates, $\exp\left[\left(\varphi_{ii}-\varphi_{ij}\right)(1-\sigma)\right]$, is our main indicator of the bilateral border effects. It is the factor by which international border effects reduce foreign exports relative to domestic interregional exports, all else being equal. Calculated from the averages of the bilateral and domestic border effects reported in Table 1, this factor is 12 (= exp[(0.107–0.417)*8]). This value is fairly close to the factor of 11 reported by Nitsch (2000) for the EU but higher than the factor of three reported by Head and Mayer (2009). Coughlin and Novy (2013) also report lower factors of three to four for exports from the US. The average of the 380 individual bilateral border effects, $\sum_{i,j}\exp\left[\left(\varphi_{ii}-\varphi_{ij}\right)(1-\sigma)\right]$, is 203, by contrast, which suggests that these averages hide considerable variation and skewness of the bilateral border effects across the country pairs.

Table 1 about here.

Table 2 reports the estimated factors by which international trade is reduced relative to domestic interregional trade for all the 380 country pairs in our sample in matrix form. The rows of the table refer to the exporting, the columns to the importing country. All point estimates are significant at the 5% level except those for Irish exports (in italics), which are not significant at the 10% level. The table reveals a number of interesting patterns.

Table 2 about here.

First, the estimated bilateral border effects vary enormously across country pairs. They range from a low of about 0.026 (BA → BE), which implies that exports exceed domestic

[18] For example, Wolf (2000) and Hillberry and Hummels (2008) find that trade intensity drops by the factor of three at the borders of US states or of five-digit ZIP code regions, respectively, while Coughlin and Novy (2013) find a factor of seven for US state borders. Chen (2004) finds a significant domestic trade coefficient for EU, at industry-level, of almost four times, but it decreases to 1.17 when a different measure for distance is introduced instead of the conventional one.

interregional trade by the factor of 40 (ceteris paribus), to a high of almost 4,000 (EL $\rightarrow$ BA), which implies that foreign exports fall short of domestic interregional trade by the factor of 4,000. This suggests that earlier studies that estimate a single aggregate border effect for several countries may not be too informative. Their estimates can be expected to be rather sensitive to the choice of the countries in their samples. The fact that the estimated border effects vary strongly across destination countries (columns in Table 2) for most of the exporting countries suggests that even studies that estimate a single aggregate border effect for each exporting country (e.g., Coughlin and Novy 2013) will not be able to capture the heterogeneity of the bilateral border effects across destination countries. Second, a considerable number of the estimated border effects are below one. The border effects for German exports, for example, are below one for as many as 10 of the 19 European trade partners, suggesting that exports to these countries are subject to lower impediments that domestic trade across German NUTS 2 regions. These estimates tend to corroborate Coughlin and Novy (2013) who find that the impediments for domestic trade across US states are larger than the (average) impediments for US exports to foreign countries. Nonetheless, most of our point estimates are above one, suggesting that Coughlin and Novy's results for the US cannot be considered representative for Europe. Higher domestic than foreign border effects are an exception rather than the rule in Europe. Third, exports by the five eastern European countries in our sample toward western Europe faced fairly low trade barriers. The barriers for exports from the Baltic countries, the Czech Republic, Hungary and Poland to Germany are even estimated to be lower than those for interregional trade within these countries, as the estimated border effects of below one indicate. This result corroborates Cheptea (2013) who also finds larger domestic than international border effects in CEE countries. This may have to do with the strong reorientation of the Eastern European countries towards western markets after the fall of the Iron Curtain. It may also indicate that the obstacles to trade within the eastern European countries are still fairly high. Third, compared to the particularly low barriers faced by eastern European exports, the estimated barriers faced by exports from western to eastern European countries are frequently much higher, as the columns for the eastern European countries in Table 2 indicate. Fourth, even though there are notable differences between western European countries, the variation of the border effects across country pairs can obviously not be explained by characteristics of the exporting or the importing country alone. Exporter and importer characteristics play a role, of course. For example, most of the estimated border effects for German exports are lower than those for Austrian, Belgian, Danish or French exports. Likewise, exports to countries like Belgium, Germany, Ireland or Sweden are lower than those to Austria, Denmark or France. However, a simple regression of the estimated bilateral border effects on full sets of exporter and importer country dummies explains less than 50% of the total variation of the border effects across the country pairs. This suggests that there is ample scope for a future thorough analysis to identify the determinants of the bilateral border effects in Europe, which may lay the foundation for identifying national or EU-wide policies toward reducing border impediments where they are still high.

4.2. Robustness

This section investigates to what extent the border effects estimates reporter in the previous subsection are affected by characteristics of the importing countries, which are not controlled for in the gravity regression, and by our choice of the predetermined value of the substitution elasticity.

To identify bilateral border effects for each pair of countries, we have to omit importer country (or region) fixed effects in our baseline model. This is not a problem from a theoretical point of view. Importer fixed effects mainly serve the purpose of capturing the importer multilateral resistance term, Ω_s, in standard gravity regressions. We determine resistance term from the theoretical model for each importing region. However, the importer fixed effects may also account for specificities of the importing country the theoretical model does not account for. These specificities will be captured by the border dummies in our model. To assess the extent to which the bilateral border dummies capture specificities of the importing countries, we regress the bilateral border effects reported in Table 2 on a set of importer country dummies. The R^2 of this regression is 0.33, which indicates that our estimated border effects carry some information on the characteristics of the importing countries but are not dominated by these characteristics. We also note that the correlation between the bilateral border effects and the residuals of the auxiliary regression is fairly high ($r = 0.82$).

The substitution elasticity, σ, which governs how easily consumers can substitute imported for domestic goods in the theoretical model and also determines the mark-up over variable costs charged by the firms, is not be identified in our empirical model. We set it to $\sigma = 9$. Alternative choices may, of course, change the estimation results. We test the robustness of our results to the choice of σ by estimating equation (10) for two alternative values of σ, 6 and 12. Table 3 reports the results. For comparison, the middle column reports the results of our baseline model where $\sigma = 9$ (see Table 1). The table shows that the point estimates for the transport costs, the domestic and the international border effects as well as for the exporter region fixed effects are fairly sensitive to the choice of σ. The transport costs parameter and the averages of the 20 domestic and 380 international border effects decrease while the average of the 250 exporter region fixed effects increases (in absolute terms) with increasing σ. In spite of these differences, our parameters of main interest, the factors by which the international border effects reduce foreign trade relative to domestic interregional trade (see Table 2), do not differ notably. The factors implied by the two alternative models are highly correlated with those implied by the baseline model, as the correlation coefficients of 0.957

and 0.973 in the last row of Table 3 show. The R^2s and the correlations between observed and equilibrium values of wages and employment are also very similar.

Table 3 about here.

5. Conclusions

This paper corroborates the results of earlier studies that show that border effects still impede trade across national borders significantly even within the single European market. It also qualifies these results, however, by showing that their assumption of a uniform border effect across exporting and importing countries is inappropriate. Using a novel dataset on trade between 250 NUTS 2 regions from 20 European countries compiled by the Netherlands Environmental Assessment Agency, we show that the border effects differ widely across country pairs. These differences are not just due to some characteristics of the respective importing or exporting country. They are truly bilateral. We also show that the border effects are not symmetric for country pairs. Exports from eastern European countries to western Europe, for example, frequently face much lower trade impediments than exports in the opposite direction.

In contrast to earlier studies, the paper does not just estimate a gravity equation derived from the trade equation of some model of international trade. It rather fits the general equilibrium of a trade model to the data by employing an iterative procedure that involves repeated estimation of a constrained gravity equation and simulation of equilibrium values of the multilateral resistance terms. This procedure relieves the estimation of the gravity equation from endogeneity problems and minimizes the wedge between theory and data. Especially the small wedge between theory and data will be very helpful when it comes to simulations of economic consequences of trade liberalization from the theoretical model.

This paper constitutes only the first stage of a broader research project. The project aims at identifying policies that may further reduce trade impediments in Europe and evaluating the consequences of these policies for trade flows and economic geography in Europe. The next stage will be explaining the bilateral border effects estimated in this paper econometrically by the similarities and differences between the respective exporting and importing countries. The final stage will then identify promising policies at the EU or the national level that may, through the determinants of the border effects, contribute to reducing the border effects in Europe. It will also evaluate the consequences of these policies for trade flows and economic geography in Europe by simulating counterfactual equilibria of the theoretical model.

Appendix

Tables A1 and A2 here.

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Table 1: Results of iterative Helpman-Hanson gravity model estimation: Summary

	Parameter	Std.dev.
Gravity regression		
Iceberg transp. costs (τ)	0.087	0.00
20 domestic border effects (φ_{ii})	0.107	0.171
F test of joint significance [p-value]	51.9	[0.00]
380 international border effects ($\varphi_{ij}, i \neq j$)	0.417	0.30
F test of joint significance [p-value]	431.2	[0.00]
250 Exporter region fixed effects (α_r)	–28.953	1.12
R^2	0.812	
Number of observations	62,500	
Simulation		
Number of regions	250	
Correlation observed-equilibrium wages	0.816	
Correlation observed -equilibrium employment	0.932	
Number of iterations	109	

Notes: Iterative estimation of trade costs by OLS (for given simulated equilibrium multilateral resistance terms) and simulation of multilateral resistance terms (for given trade costs) from the Helpman-Hanson model (equations 1–3) for 250 European NUTS2 regions from 20 countries in the early 2000s (average 2000–2002), assuming $\sigma = 9$, $\mu = 0.715$, $F = 1$ and $c = 1$. The rows for the domestic and international border effects as well as the exporter fixed effects report the means and standard deviations of the 20, resp. 380 or 250 estimated parameters. “Correlation observed-equilibrium wages” (“employment”): Pearson correlation coefficients.

Table 2: Results of iterative Helpman-Hanson gravity model estimation: Estimated international relative to domestic interregional border effects

Exporter (i)	Importer (j)																			
	AT	BA	BE	CZ	DE	DK	EL	ES	FI	FR	HU	IE	IT	NL	NO	PL	PT	SE	SK	UK
AT		2616	3.4	74.1	2.1	124.7	22.2	38.7	45.0	27.3	45.8	7.9	20.2	14.7	58.5	551.5	16.8	15.8	66.8	18.2
BA	0.2		0.0	0.4	0.0	0.0	0.8	0.3	0.1	0.2	1.1	0.1	0.2	0.1	0.1	2.1	0.5	0.0	1.6	0.2
BE	19.1	2795		330.3	8.1	28.1	32.3	37.5	30.4	14.0	327.7	2.3	27.4	10.2	34.2	1338	16.6	8.5	375.6	26.4
CZ	1.4	310.2	0.8		0.5	20.1	4.3	5.3	6.7	3.9	13.2	1.8	4.9	3.9	5.8	41.3	7.7	1.8	1.6	3.6
DE	0.3	68.7	0.1	2.0		2.0	0.8	0.9	1.0	1.0	2.1	0.1	1.2	0.5	0.8	10.1	0.5	0.4	3.2	0.8
DK	46.8	138.5	1.6	319.6	4.6		7.7	22.7	10.7	14.1	382.6	3.5	26.4	9.8	2.1	278.0	8.8	1.0	322.7	9.3
EL	29.9	3934	1.6	170.5	3.2	42.7		13.2	25.7	6.6	518.0	8.5	7.6	3.0	9.3	1657	20.0	5.9	342.7	7.1
ES	8.3	1545	1.0	73.4	1.6	21.9	10.6		9.0	3.1	61.7	1.4	5.1	3.6	10.1	411.4	3.4	2.7	143.4	3.8
FI	16.5	614.8	2.0	167.4	4.7	5.5	27.7	20.4		18.1	218.9	2.9	31.6	6.5	3.9	1197	13.6	1.4	229.9	10.6
FR	7.5	1122	0.6	66.2	1.8	23.8	10.5	3.9	8.8		51.9	1.2	4.4	4.0	2.8	221.0	2.5	2.4	75.7	4.2
HU	0.8	836.5	0.6	9.4	0.5	11.7	10.8	5.9	11.0	3.2		1.1	3.2	2.2	16.3	87.8	7.9	1.8	28.2	3.0
IE	*133.4*	*8808*	*13.2*	*1043*	*24.5*	*77.1*	*236.5*	*265.9*	*345.4*	*80.5*	*2007*		*112.2*	*43.5*	*73.3*	*5162*	*102.1*	*45.3*	*2802*	*12.5*
IT	3.3	1172	0.6	52.8	1.4	19.8	4.1	3.8	8.7	2.4	35.0	0.8		2.7	7.1	177.6	4.5	2.5	31.4	3.0
NL	11.5	528.8	0.7	77.7	2.0	22.4	8.5	10.5	6.8	9.8	56.6	1.3	16.5		3.8	187.7	4.0	2.0	79.9	4.9
NO	83.4	1458	50.2	1124	28.9	12.0	51.8	69.1	28.8	53.9	1672	17.6	87.7	30.0		1455	26.2	2.6	1176.3	24.4
PL	0.4	74.1	0.1	1.3	0.1	0.7	1.3	0.8	1.8	0.4	4.1	0.2	0.5	0.3	0.5		1.1	0.2	4.2	0.5
PT	32.2	7138	4.0	310.2	4.3	230.7	50.5	6.5	249.6	11.1	773.4	19.3	17.9	11.9	5.4	1954		11.7	2328	16.5
SE	43.8	885.7	5.8	407.1	10.5	9.1	51.6	43.7	14.1	36.1	493.4	5.9	65.0	16.4	3.1	950.7	18.6		687.4	16.3
SK	2.4	1555	2.5	2.6	1.4	37.8	34.6	14.8	62.8	10.0	46.3	12.0	11.2	9.9	45.5	194.6	24.8	7.4		15.1
UK	3.3	382.2	0.7	32.4	1.5	4.2	3.7	3.2	3.6	2.9	39.7	0.5	3.4	2.0	1.0	169.1	2.6	1.0	93.2	

Notes: Detailed results of the estimation reported in Table 1. The value of each cell is calculated as $\exp\left[\left(\hat{\varphi}_{ii}-\hat{\varphi}_{ij}\right)(1-\sigma)\right]$ where $\hat{\varphi}_{ij}$ denotes the estimated international border effect for exports from country i to j, $\hat{\varphi}_{ii}$ the estimated domestic border effect for exports from and to regions in country i, and $\sigma = 9$ the predetermined substitution elasticity. A value of 19.1, for example, means that the international border effect reduces foreign exports relative to domestic interregional exports by the factor of 19.1. Values below one mean that the domestic border effect is estimated to exceed the international border effect. All estimates except those in Italics (exports from Ireland) are significant at the 5% level. BA: Baltic states (Estonia, Latvia, Lithuania). BE: Belgium including Luxembourg.

Table 3: Robustness: Alternative predetermined values of the substitution elasticity

	σ = 6		σ = 9 (baseline)		σ = 12	
	Para-meter	Std. dev.	Para-meter	Std. dev.	Para-meter	Std. dev.
Gravity regression						
Iceberg transp. costs (τ)	0.117	0.00	0.087	0.00	0.072	0.00
20 domestic border effects (φ_{ii})	0.284	0.27	0.107	0.17	0.032	0.12
F test (p-value)	83.0	[0.00]	51.9	[0.00]	27.8	[0.00]
380 internat. border effects (φ_{ij})	0.816	0.40	0.417	0.30	0.244	0.25
F test (p-value)	371.2	[0.00]	431.2	[0.00]	426.6	[0.00]
250 exporter region FE	–20.80	0.88	–28.95	1.12	–36.61	1.40
R^2	0.805		0.812		0.797	
# observations	62,500		62,500		62,500	
Simulation						
# regions	250		250		250	
Correlation wages	0.779		0.816		0.815	
Correlation employment	0.942		0.932		0.927	
# iterations	147		109		85	
Correlation w/baseline $\exp[(\hat{\varphi}_{ii} - \hat{\varphi}_{ij})(1-\sigma)]$	0.957		1.000		0.973	

Notes: Iterative estimation of trade costs by OLS (for given simulated equilibrium multilateral resistance terms) and simulation of multilateral resistance terms (for given trade costs) from the Helpman-Hanson model (equations 1–3) for 250 European NUTS2 regions from 20 countries in the early 2000s (average 2000–2002), assuming $\mu = 0.715$, $F = 1$ and $c = 1$. The rows for the domestic and international border effects as well as the exporter fixed effects report the means and standard deviations of the 20, resp. 380 or 250 estimated parameters. "Correlation wages" ("employment"): Pearson correlation coefficients between observed and simulated (equilibrium) values of wages (employment). "Correlation w/baseline $\exp[(\hat{\varphi}_{ii} - \hat{\varphi}_{ij})(1-\sigma)]$": Correlation (Pearson correlation coefficients) of implied ratios of international to domestic border effects between baseline model (see Table 2) and alternative model.

Table A1: EEAICP 2000 items assumed to be not traded

Code	Item	Weight (%)
03.1.4.	Cleaning, repair and hire of clothing	0.18
04.1	Actual rentals for housing.	6.18
04.3.2	Services for the maintenance and repair of the dwelling	0.95
04.4.	Water supply, miscellaneous services relating to the dwelling	2.36
04.5.1.	Electricity	2.17
04.5.5.	Heat energy	0.46
05.3.3.	Repair of household appliances	0.11
05.6.2.	Domestic services and household services	0.75
06.2.	Out-patient services	1.48
09.4	Recreational and cultural services	2.74
10.	Education	0.97
11.1	Catering services. (Restaurants, cafés etc, Canteens)	7.75
12.1.1	Hairdressing salons and personal grooming establishments	1.11
12.3.	Personal effects n.e.c.	1.03
12.5.2.	Insurance connected with the dwelling	0.24
Sum		28.48

Source: European Commission (2001), Annex II.

Table A2: European NUTS 2 regions

Nuts	Name	Nuts	Name	Nuts	Name
AT11	Burgenland (AT)	DEF0	Schleswig-Holstein	HU32	Eszak-Alfold
AT12	Niederosterreich	DEG0	Thuringen	HU33	Del-Alfold
AT13	Wien	DK01	Hovedstaden	IE01	Border, Midland and Western
AT21	Karnten	DK02	Sjaelland	IE02	Southern and Eastern
AT22	Steiermark	DK03	Vest for Storebælt	ITC1	Piemonte
AT31	Oberosterreich	EL11	Anatoliki Makedonia, Thraki	ITC2	Valle d Aosta/Vallee d Aoste
AT32	Salzburg	EL12	Kentriki Makedonia	ITC3	Liguria
AT33	Tirol	EL13	Dytiki Makedonia	ITC4	Lombardia
AT34	Vorarlberg	EL14	Thessalia	ITF1	Abruzzo
[BA10]	Eesti (EE00)	EL21	Ipeiros	ITF2	Molise
[BA20]	Lietuva (LT00)	EL22	Ionia Nisia	ITF3	Campania
[BA30]	Latvija (LV00)	EL23	Dytiki Ellada	ITF4	Puglia
BE10	Bruxelles-Capitale	EL24	Sterea Ellada	ITF5	Basilicata
BE21	Prov. Antwerpen	EL25	Peloponnisos	ITF6	Calabria
BE22	Prov. Limburg (BE)	EL30	Attiki	ITG1	Sicilia
BE23	Prov. Oost-Vlaanderen	EL41	Voreio Aigaio	ITG2	Sardegna
BE24	Prov. Vlaams-Brabant	EL42	Notio Aigaio	ITH1	Bolzano/Bozen
BE25	Prov. West-Vlaanderen	EL43	Kriti	ITH2	Trento
BE31	Prov. Brabant Wallon	ES11	Galicia	ITH3	Veneto
BE32	Prov. Hainaut	ES12	Principado de Asturias	ITH4	Friuli-Venezia Giulia
BE33	Prov. Liege	ES13	Cantabria	ITH5	Emilia-Romagna
BE34	Prov. Luxembourg (BE)	ES21	Pais Vasco	ITI1	Toscana
BE35	Prov. Namur	ES22	Comunidad Foral de Navarra	ITI2	Umbria
[BE99]	Luxembourg (LU00)	ES23	La Rioja	ITI3	Marche
CZ01	Praha	ES24	Aragon	ITI4	Lazio
CZ02	Stredni Cechy	ES30	Comunidad de Madrid	NL11	Groningen
CZ03	Jihozapad	ES41	Castilla y Leon	NL12	Friesland (NL)
CZ04	Severozapad	ES42	Castilla-La Mancha	NL13	Drenthe
CZ05	Severovychod	ES43	Extremadura	NL21	Overijssel
CZ06	Jihovychod	ES51	Cataluna	NL22	Gelderland
CZ07	Stredni Morava	ES52	Comunidad Valenciana	NL23	Flevoland
CZ08	Moravskoslezsko	ES53	Illes Balears	NL31	Utrecht
DE11	Stuttgart	ES61	Andalucia	NL32	Noord-Holland
DE12	Karlsruhe	ES62	Region de Murcia	NL33	Zuid-Holland
DE13	Freiburg	ES63	Ceuta	NL34	Zeeland
DE14	Tubingen	ES64	Melilla	NL41	Noord-Brabant
DE21	Oberbayern	ES70	Canarias	NL42	Limburg (NL)
DE22	Niederbayern	FI18	Etelä-Suomi	NO01	Oslo og Akershus
DE23	Oberpfalz	FI19	Lansi-Suomi	NO02	Hedmark og Oppland
DE24	Oberfranken	FI1D	Pohjois- ja Ita-Suomi	NO03	Sor-Ostlandet
DE25	Mittelfranken	FI20	Aland	NO04	Agder og Rogaland
DE26	Unterfranken	FR10	Ile de France	NO05	Vestlandet
DE27	Schwaben	FR21	Champagne-Ardenne	NO06	Trondelag
DE30	Berlin	FR22	Picardie	NO07	Nord-Norge
DE40	Brandenburg	FR23	Haute-Normandie	PL11	Lodzkie
DE50	Bremen	FR24	Centre	PL12	Mazowieckie
DE60	Hamburg	FR25	Basse-Normandie	PL21	Malopolskie
DE71	Darmstadt	FR26	Bourgogne	PL22	Slaskie
DE72	Giessen	FR30	Nord - Pas-de-Calais	PL31	Lubelskie
DE73	Kassel	FR41	Lorraine	PL32	Podkarpackie
DE80	Mecklenburg-Vorpommern	FR42	Alsace	PL33	Swietokrzyskie
DE91	Braunschweig	FR43	Franche-Comte	PL34	Podlaskie
DE92	Hannover	FR51	Pays de la Loire	PL41	Wielkopolskie
DE93	Luneburg	FR52	Bretagne	PL42	Zachodniopomorskie
DE94	Weser-Ems	FR53	Poitou-Charentes	PL43	Lubuskie
DEA1	Dusseldorf	FR61	Aquitaine	PL51	Dolnoslaskie
DEA2	Koln	FR62	Midi-Pyrenees	PL52	Opolskie
DEA3	Munster	FR63	Limousin	PL61	Kujawsko-Pomorskie
DEA4	Detmold	FR71	Rhone-Alpes	PL62	Warminsko-Mazurskie
DEA5	Arnsberg	FR72	Auvergne	PL63	Pomorskie
DEB1	Koblenz	FR81	Languedoc-Roussillon	PT11	Norte
DEB2	Trier	FR82	Provence-Alpes-Cote d Azur	PT15	Algarve
DEB3	Rheinhessen-Pfalz	FR83	Corse	PT16	Centro (PT)
DEC0	Saarland	HU10	Kozep-Magyarorszag	PT17	Lisboa
DED2	Dresden	HU21	Kozep-Dunantul	PT18	Alentejo
DED4	Chemnitz	HU22	Nyugat-Dunantul	SE11	Stockholm
DED5	Leipzig	HU23	Del-Dunantul	SE12	Ostra Mellansverige
DEE0	Sachsen-Anhalt	HU31	Eszak-Magyarorszag	SE21	Smaland med oarna

to be continued …

Table A2 (continued)

Nuts	Name	Nuts	Name	Nuts	Name
SE22	Sydsverige	UKD7	Merseyside	UKI2	Outer London
SE23	Vastsverige	UKE1	East Yorkshire and Northern Lincolnshire	UKJ1	Berkshire, Buckinghamshire and Oxfordshire
SE31	Norra Mellansverige	UKE2	North Yorkshire	UKJ2	Surrey, East and West Sussex
SE32	Mellersta Norrland	UKE3	South Yorkshire	UKJ3	Hampshire and Isle of Wight
SE33	Ovre Norrland	UKE4	West Yorkshire	UKJ4	Kent
SK01	Bratislavsky kraj	UKF1	Derbyshire, Nottinghamshire	UKK1	Gloucestershire, Wiltshire and Bristol/Bath area
SK02	Zapadne Slovensko	UKF2	Leicestershire, Rutland and Northamptonshire	UKK2	Dorset and Somerset
SK03	Stredne Slovensko	UKF3	Lincolnshire	UKK3	Cornwall and Isles of Scilly
SK04	Vychodne Slovensko	UKG1	Herefordshire, Worcestershire and Warwickshire	UKK4	Devon
UKC1	Tees Valley and Durham	UKG2	Shropshire and Staffordshire	UKL1	West Wales and The Valleys
UKC2	Northumberland, Tyne, Wear	UKG3	West Midlands	UKL2	East Wales
UKD1	Cumbria	UKH1	East Anglia	UKM2	Eastern Scotland
UKD3	Greater Manchester	UKH2	Bedfordshire and Hertfordshire	UKM3	South Western Scotland
UKD4	Lancashire	UKH3	Essex	UKM5	North Eastern Scotland
UKD6	Cheshire	UKI1	Inner London	UKM6	Highlands and Islands
				UKN0	Northern Ireland

Note: NUTS codes in squared brackets were invented to merge Luxembourg to Belgium and the three Baltic states to a single country, “Baltic” (BA).

Source: Thissen et al. (2013b, Table 3).