

## Distance deterrence, trade barriers and accessibility. An analysis of market potential in the European Union

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The interest in disentangling the role of borders in international trade is growing even within virtually borderless areas like the European Union. While there are a variety of research studies measuring how borders affect trade, there is little insight into the impact of borders on the potential accessibility to markets. The aim of this paper is twofold. First we provide a coherent calibration of the impedance parameters affecting trade (border effect based on best official data available and with a sound estimation of distance and the distance decay parameter with the use of network-based measurements). The second objective is to ascertain to what extent the market potential of different countries is hampered by the border effect. The analysis reveals that calibrating distance decay and considering border effects provides more realistic results. These results evidence that peripheral areas are more sensitive to the estimation of the distance decay parameter, whilst the main metropolitan regions are less affected by both distance decay and border effects. Finally, we present the decomposed market potential in a spillover-like matrix showing those countries that have a diversified set of contributors to their market potential and those where the number of contributors is limited.

*Keywords:* accessibility, border effect, European Union, market potential, spatial spillovers.

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### 1. Introduction

Accessibility is regarded as a key aspect of regional economic development. Regions and countries with better access to the locations of input materials and markets tend to be more productive, more competitive and hence more successful than more remote and isolated areas (Linneker, 1997). Equitable accessibility to markets is considered a crucial factor for the success of the social and economic integration of the European Union and to achieve harmonious economic development. The European Spatial Development Perspective considers that having good accessibility improves not only the competitive position of European regions but also the competitiveness of Europe as a whole (European Commission, 1999). Not surprisingly, accessibility within the European Union has been a popular research topic for many years (some reviews can be found in Bruinsma and Rietveld, 1998; Wegener et al., 2000; Wegener, 2001;

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Spiekermann and Neubauer, 2002). The European Observation Network, Territorial Development and Cohesion (ESPON) has shown great interest in analysing accessibility within the European Union in order to support policy makers engaged with regional competitiveness and territorial cohesion in their considerations in the policy process (ESPON, 2005, 2011, 2007).

Improved infrastructures entail a reduction in transport costs and an increase in accessibility, which can raise regional competitiveness and produce economies of specialisation and scale (Forslund and Johnson, 1995). Consequently, accessibility indicators have been used as a planning tool to measure the potential economic impacts of the construction of new infrastructures (see, for example, López, et al., 2008 or Stepniak and Rosik, 2013). Due to the network effect (Lair et al., 2003), the impact of improving one or several links may affect distant regions, or even regions located in different countries, thus generating what is known as the spillover effect (Pereira and Roca-Sagalés, 2003; López et al., 2009; Gutiérrez, 2010; Condeço-Melhorado et al., 2014). In reality, these impacts are mitigated by the presence of international borders, which lack of consideration may lead to an overestimation of the impact of a new infrastructure at the international level (Gutiérrez et al. 2011).

Several studies confirm that borders still matter within the European Union acting as trade barriers. It has been verified that averaged over all EU countries, intranational trade is about ten times as high as international trade with an EU partner country of similar size and distance other things being equal (Nitsch, 2000). Although it is true that trade tends to decrease progressively with distance (distance decay), accessibility studies should also consider that borders still are barriers that represent abrupt changes in international trade flows. Therefore, in addition to the spatial impedance (distance, travel time or generalized transport costs for accessing markets), political, cultural or linguistic barriers between countries should also be included in accessibility models. However, most studies at the European level ignore the role of borders and other trade barriers when measuring the accessibility of regions and countries, thus leading to unrealistic results. An exception is the paper of Head and Mayer (2004), who calculate market potential with trade barriers in the European Union. Still, they do not analyze their results but simply use them as an input to study the location of Japanese investment. Gutierrez et al. (2011) use the market potential indicator to estimate the spatial spillovers produced by a new motorway in Eastern Europe using a border effect value calibrated in a previous paper. Finally, Salas-Olmedo et al. (in press) focus more on investigating the effect of different distance metrics in the estimation of the border effect than on including its results in accessibility models. In sum, there are very few papers in the accessibility literature that consider trade barriers and they are not properly focused on analyzing their effects on accessibility.

The main aim of this paper is to develop a methodology for including the effect of trade barriers in the calculation of the market potential. This methodology allows reaching more realistic results when measuring accessibility patterns in an international framework and when estimating the accessibility impacts of international projects. We integrate two previously independent lines of research: on the one hand, the role of international borders and other barriers on trade, and on the other hand the calculation of accessibility to markets. For this, we introduce the border effect in the analysis of the market potential within the European Union (EU) after calibrating distance decay, border effect and other trade barriers, such as adjacency, language and currency. This is done with the use of gravity equations. In a second step, both the distance decay and the trade barrier parameters that are found to be statistically significant are introduced in subsequent market potential specifications in order to study the impact of these parameters on accessibility calculations at different spatial scales (national and regional). In addition, the market potential composition of each country is analyzed, identifying its self-potential and the market potential received from each of the other countries.

The paper is organized as follows: Following this introduction, the next section contains an overview of how previous literature tackled the estimation of the market potential and the border effect. Section 3 shows the methods and data used for estimating market potential and trade

barriers in the European Union. Section 4 contains the results of our research and Section 5 presents the final remarks of the paper.

## 2. Market potential and border effects

### 2.1 Accessibility, market potential and spatial spillovers

There has been a growing interest in measuring and studying accessibility since the seminal works of Harris (1954) and Hansen (1959) defining accessibility as the "potential of opportunities for interaction". The vast number of accessibility indicators reflects the intense research activity in the field as well as the broad implications of accessibility for the economy, society and the environment. Bruinsma and Rietveld (1998) provide an in-depth revision of accessibility indicators in the European framework whilst Geurs and van Wee (2004) establish a typology of accessibility indicators according to the components that they analyze.

From the economic perspective, there was an early interest in studying the accessibility of countries and regions to markets within the European Union. Clark et al. (1969) raised awareness to the different impact of border removal on the accessibility of industry to markets in peripheral and central areas, and in recent decades a number of studies have investigated accessibility disparities within the European Union, for example, Keeble et al. (1988), Lutter et al. (1992), Gutiérrez and Urbano (1996), Bruinsma and Rietveld (1998), Spiekermann and Neubauer (2002). In addition, ESPON has been publishing accessibility reports in recent years, concluding that accessibility seen from a European level might not reflect the same patterns as accessibility observed from a national or regional perspective. Moreover, accessibility is recognised today as an important factor in the development of territories, regions and cities.

Most European accessibility studies (see, for example, Spence and Linneker 1994; Geertman and Ritsema 1995; Bruinsma and Rietveld 1998; Gutiérrez, 2001; Lopez, 2005; Yoshida and Deichmann, 2009) use the market potential indicator (Harris, 1954). The underlying assumption in the use of this indicator is that regions with better access to markets have a higher probability of being economically successful (Wegener and Böckmann, 1998). According to this model, the level of opportunities between places of origin  $i$  and destination  $j$  is positively related to the mass of destination  $j$  and inversely proportional to the distance or travel time between the two places. Different distance decay functions can be used for modelling market potential. The exponential function has been widely used in interaction models and when measuring potential accessibility at the regional level (ESPON, 2007, 2011). However, Fotheringham and O'Kelly (1989) point out that the exponential model is scale dependent, which challenges the comparison between accessibility studies from different data sources. In the case of long distances, the potential function is considered to be more appropriate since the tail is longer than the exponential function. Reggiani et al. (2011) and Östh et al. (2013) concluded that from the spatial econometrics and the network analysis viewpoint the potential function provides a better fit to interaction models, with and without restrictions, and to mobility patterns. Considering the European-wide geographic scale and coverage of this research, this study uses the negative potential function. Its classical mathematical expression is as follows:

$$P_i = \sum \frac{m_j}{t_{ij}^a} \quad (1)$$

Where  $P_i$  is the market (economic) potential of node  $i$ ,  $m_j$  is the mass of the destination  $j$ ,  $t_{ij}$  is the distance (in our case, travel time) by the shortest path in the network between origin  $i$  and destination  $j$ , and  $a$  is a parameter that reflects the effect of the distance. The mass of the destination represents the number of interaction opportunities, so it can be modelled with different variables. When estimating accessibility to markets, as is the case with this study, an economic measure such as GDP is more suitable than the demographic measures used by others (ESPON, 2007; O'Kelly and Horner, 2003).

The  $a$  parameter is critical in market potential analyses. Although distance has always a negative effect on spatial interactions, this effect may be greater or lesser, and this variability can be represented on the model by the distance exponent (Haynes and Fotheringham, 1984). High values of this exponent imply strong resistance to movement between one place and another, with more relations produced over short distances. Conversely, low values mean lower distance deterrence and, as a result, although relations over short distances continue to be the most important, those that are established over long distances are gaining significance. While some European accessibility studies choose the value 1 (Keeble et al., 1988; Bruinsma and Rietveld, 1998; Holl, 2007, 2011; Lopez, 2005; Tagai et al., 2008), access to origin-destination matrices is growing and there are a number of accessibility papers that calibrate the distance decay parameter using gravity models (see, for example, Reggiani and Bucci, 2008; Reggiani et al., 2011; Condeço-Melhorado et al., 2013) in order to obtain more realistic results. However, international flows are also affected by borders, since both goods trade and passenger trips experience a sharp fall at international borders (McCallum, 1995). Previous studies (see next subsection) indicate that borders still affect the flow of goods between European countries. Yet, most accessibility studies ignore the influence of borders on accessibility to markets in an international framework.

## 2.2 Barriers to trade

The study of the home bias, i.e. the excessive proportion of domestic versus international trade due to the effect of borders, was pioneered by McCallum (1995), who studied the trade patterns between the US and Canada. McCallum (1995) applied a global gravity model (formula 2) in which exports from a region to any other were a function of the mass at origin and at destination, and the distance between them. In order to account for the home bias, he introduced a dummy variable whose antilogarithm expresses the number of times that a region trades more with another region in the same country than with a region at the same distance located in another country, other things being equal:

$$\ln X_{ij} = \beta_0 + \beta_1 \text{home} + \beta_2 \ln Y_i + \beta_3 \ln Y_j + \beta_4 \ln D_{ij} + \varepsilon_{ij} \quad (2)$$

where trade between country  $i$  and country  $j$  ( $X_{ij}$ ) is a function of the production of the country of origin, expressed in GDP ( $Y_i$ ), the attractiveness of the destination country, expressed in GDP too ( $Y_j$ ), the distance between both countries ( $D_{ij}$ ), a dummy variable to account for foreign trade (*home*, equal to one when country of origin and destination are the same and zero otherwise), and an error term  $\varepsilon_{ij}$ .

McCallum's results were criticized for the extremely high home bias value obtained (he estimated an the overall effect of borders in 22 times between the US-Canadian border). Yet, his gravity model is the base of extensive literature on the issue. Research on European countries evidences a wide range of values. For example, Wei (1996), Nitsch (2000), Head and Mayer (2000) or Chen (2004) found border effect values ranging between 6 and 20. Results seem to be very sensitive to the set of countries introduced in the model as well as to the sector analysed.

In addition, there is a growing interest in understanding the influence of distance measurements on the estimation of the border effect. In a first stage, the main contributions relate to the sensitivity of the gravity model to different estimations of intra-national and international distances still operating with extremely simplified measurements like Euclidean or great circle distances (Head and Mayer, 2002; Clark and van Wincoop, 2001; Nitsch, 2000; Wei, 1996; Chen, 2004). Later, some authors made use of alternative distance measurements, like Road Atlas (Wolf, 1997, 2000) or reported distances in transport surveys (Hillberry and Hummels 2003). Whilst transport surveys rarely cover international frameworks, nowadays, there is growing access to seamless road and ferry networks across Europe, which allows for more accurate calculations of shortest distance and travel time routes. Salas-Olmedo et al. (in press) replicated Chen's work with an updated dataset using four different distance measurements (Euclidean distance, network distance, travel time, and generalized transport costs), and concluded that simpler distance measures underestimate the border effect.

McCallum's seminal model has been modified with additional variables indented to capture other barriers to trade that are independent from the border effect. In European studies, most authors were interested in controlling for adjacency, common language and remoteness (Wei, 1996; Nitsch, 2000; Head and Mayer, 2002). Adjacency (i.e. sharing a common border) and common language are straight-forward indicators and are easily computable as dummy variables. On the contrary, remoteness (i.e. distance to all bilateral partners) is not exempt of critics due its weak theoretical foundation (Anderson and van Wincoop 2001). Not surprisingly, the latter is often not considered at all (Head and Mayer, 2000; Clark and van Wincoop 2001; Chen, 2004; Gil-Pareja et al. 2005).

### 3. Methodology and data

#### 3.1 Source of data and travel time calculation

A full origin-destination matrix with bilateral trade between pairs of countries as well as internal (i.e. domestic) trade is required in order to obtain the dependent variable of the gravity model (formula 2). Traditionally, data of international trade has been extracted from origin-destination trade matrices available in Eurostat's Comext database, the UN trade database or the OECD. The main drawback of these databases is the lack of information on domestic trade (i.e. the diagonal of the matrix), which in turn needs to be estimated. This estimation is typically made by subtracting the sum of all exports from the national production (Wei 1996, Nitsch 2000, Head, Mayer 2000, Chen 2004). Because the data on exports and the value of the national production comes from different data sources, the result of this operation sometimes results in unreliable figures. In addition, it definitively stresses the Rotterdam effect<sup>4</sup>. This means that the diagonal of the matrix is particularly inaccurate for countries whose exports include a large proportion of imported products (as opposed to those countries exporting mainly national production).

The fact that these origin-destination matrices are used precisely to calibrate the home bias (or the border effect, note the difference is in the perspective) makes it essential to obtain accurate values of domestic trade. In this research we use the World Input/Output Database (Timmer et al., 2012) in order to overcome the above-mentioned difficulties to estimate domestic trade. In addition to the traditional national input/output tables, the WIOD comprises an international input/output table detailing flows of different commodities to intermediate sectors and final demand consumers. Unlike previous studies, we have been able to obtain a fully complete and consistent matrix of internal and bilateral trade between countries, thus removing the inaccuracies of estimated domestic trade values. In particular, a country-level origin-destination matrix of the value in Euros of agricultural, mining and manufactured goods in 2011 for the EU-27 was built from this database. While this dataset has been used in some studies related to international trade (Foster-McGregor et al., 2013), to the best of our knowledge our research pioneers the calibration of the effects of borders on international trade with the use of input/output tables, thus overcoming the main drawback of the estimations in previous studies.

The GDP of the country of origin ( $Y_i$ ) and of the destination country ( $Y_j$ ) were taken from EUROSTAT, referring to the year 2011. Special care should be taken when computing origin-destination distances since the border effect is sensitive to both the metric and the procedure for the calculation of intra-national and international distances. Regarding the former, in this study we decided to use travel times because, showing similar results to generalized transport costs (Salas-Olmedo et al., in press), they are easier to compute. This makes the results easier to compare with previous or future research. Travel time was computed for year 2012 based on the Database of European roads 1957-2012 (Stelder, 2013), and common speeds for each road type according with general truck allowances. Similarly to Chen (2004, p. 117), we applied a common

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<sup>4</sup> European Commission (2006) recognizes that Eurostat figures are affected by the so-called Rotterdam effect. For further explanations on its origin and consequences see also ONS (2009).

methodology to compute intra-national and international distances in a homogeneous way based on an aggregation of distances between regions. First, the internal distance of NUTs3 regions in kilometres was computed as in formula (3):

$$D_{ii} = \frac{1}{2} \sqrt{\frac{S_i}{\pi}} \quad (3)$$

where  $D_{ii}$  is the internal distance (in km) of region  $i$ , and  $S_i$  is its surface (in square kilometres).

Since some NUTs3 are urban in nature and others are rural, a congestion effect should be considered within zones. Therefore, the internal speed of each NUTs3 region was estimated according to its population density (as a proxy of congestion). The region with the lowest population density was assigned a speed of 80 km per hour whereas the region with the highest value was assigned a speed of 20 km per hour (Gutiérrez et al., 2011). Finally, the internal travel time within each zone was calculated using the estimated internal distances and speeds. Then, region-to-region travel time (at the NUTs3 level) was computed using a commercial GIS (ArcGIS 10.1) that includes specific network simulation routines for the calculation of minimum paths through the network.

Finally, formulas 4 and 5 was used to calculate the travel time between the exporter country  $i$  and the importer country  $j$  as the average of the travel time between all NUTs3 regions in the country of origin  $i$  and all NUTs3 regions in the destination country weighted by the population size at origin  $i$  and destination  $j$ :

$$T_{ij} = \frac{\sum(T_{mimj} \times S_{m_i} \times S_{m_j})}{\sum(S_{m_i} \times S_{m_j})} \quad (4)$$

$$S_m = \left( \frac{Pop_m}{Pop} \right) \quad (5)$$

where  $T_{ij}$  is the travel time between county  $i$  and country  $j$ ,  $T_{mimj}$  is the travel time between region  $m$  in country  $i$  and region  $m$  in country  $j$ ,  $Pop_m$  is the population of region  $m$  and  $Pop$  is the total population. The weighting factor used was population instead of GDP since EUROSTAT does not provide GDP data for all current NUTS 3 regions.

This methodology has the advantage of providing a homogeneous metric for internal and international distances. However, it is not suitable for very small countries which have only one or two NUT 3 regions. For this reason, and in order to keep a homogeneous distance measurement, Cyprus, Malta and Luxembourg were removed from the analysis.

### 3.2 Methodology

According to its classical formulation, the market potential of each country is positively related to the mass of the destination and inversely proportional to the distance between the two countries. Results from research reported in previous sections evidenced that market potential is also affected by European borders as an element of friction, thus reducing trade. In addition, countries trade less with non-adjacent countries than with adjacent ones, other things being equal. Our contribution in this regard consists in introducing these variables in the traditional market potential specification as additional elements in order to express market potential in a more realistic way. The calibration of the distance decay, border effect and non-adjacency coefficients was made through the gravity model (formula 6):

$$\ln X_{ij} = \beta_0 + \beta_1 \ln Y_i + \beta_2 \ln Y_j + \beta_3 \ln D_{ij} + \beta_4 \text{border} + \beta_5 \text{nonadjacency} + \varepsilon_{ij} \quad (6)$$

where  $\beta_4$  is the coefficient of the border variable,  $\beta_5$  is the coefficient of the non-adjacency variable,  $\beta_3$  is the distance decay parameter, and the other terms are already known (see formula 2). The antilog of  $\beta_4$  indicates the number of times that a country trades less with another country than within its own boundaries, thus it can be interpreted as a reduction factor of the GDP at destination for international relations. Similarly, the antilog of  $\beta_5$  expresses the number of times

that a country trades less with non-adjacent countries than with adjacent ones. Formula 7 shows the specification of the market potential indicator introducing the effect of borders and non-adjacency in international relationships.

$$P_i = \sum \frac{Y_j / (e^{\beta_4} \cdot e^{\beta_5})}{t_{ij}^{\beta_3}} \quad (7)$$

where  $P_i$  is the market potential of country or region  $i$ ,  $Y_j$  is the GDP of destination country or region  $j$ ,  $t$  is the travel time between  $i$  and  $j$ ,  $\beta_3$  is the distance decay parameter,  $\beta_4$  is the coefficient of the border variable, and  $\beta_5$  is the coefficient of the non-adjacency variable. This function indicates that opportunities for interaction decrease with distance in a discontinuous way (due to the border and non-adjacency effects) and not according to a continuous function as the classical specification of the market potential model suggests (Figure 1).

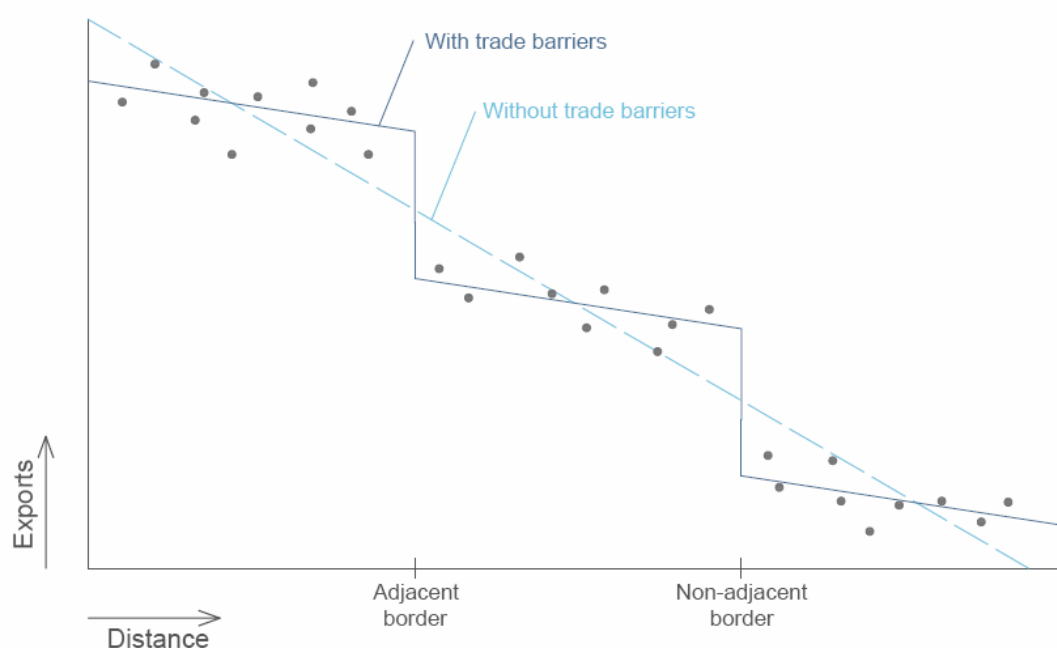


Figure 1. Adjusting distance and exports with and without trade barriers (others things being equal)

Previous studies focussed on the estimation of the border effect from the home bias viewpoint, i.e., they were interested in knowing how much a region trades more within its country than with foreign regions. In contrast, our interest here is to ascertain the border effect, i.e., to what extent trade between foreign areas decreases due to the existence of an international border between them, other things being equal. For this reason, our dummy variable *border* was built the opposite way, i.e. using a value of 1 when the destination country is different from the country of origin, and 0 otherwise. Similarly, our dummy variable non-adjacency is 0 when two countries share a border and 1 otherwise.

We built some additional dummy variables in order to test the role of language and currency as barriers to trade. The variable reflecting the existence of a currency barrier is 0 for countries in the Eurozone and 1 otherwise. In the case of language, we built two dummy variables in order to capture two levels of language difference based on the official languages of the European Union, as stipulated in the latest amendment of *Regulation No 1 determining the languages to be used by the European Economic Community of 1958*. The first variable (language strict) accounts for 0 when two countries share a language that is official in all their territory and 1 otherwise. Then, we

constructed a second variable (language lax) in which for each pair of countries, we recorded 0 when a language is official in at least one region of each country, and 1 otherwise. These variables can be included in equations 6 and 7 analogously to the border effect and non-adjacency variables.

The market potential values obtained are presented at the country level and at the regional level in order to explain how results are affected by the calibrated coefficients of distance and trade barriers. In addition, a full market potential breakdown is performed considering each of the countries involved. This decomposition is presented in the form of a spatial spillover matrix (Gutiérrez et al., 2010, p. 141)), showing the amount of potential a country receives from each of the other countries. Finally, we calculated the coefficient of variation of each column of the spillover matrix, thus showing the degree of concentration of the spillovers received by each country, and the correlation coefficient between the matrices of market potential and exports to check the degree of similarity between both matrices.

## 4. Results

### 4.1 Analysing and calibrating distance deterrence and barriers to trade

Bivariate correlations among the selected variables were calculated in order to explore the influence of every single candidate predictor on trade and the potential existence of multicollinearity issues. The dependent variable, i.e. the exports from country  $i$  to country  $j$ , correlates with the expected signs with all candidate predictors: positively with GDP both at origin and at destination and negatively with distance and trade barriers. The first column in Table 1 evidences that, as expected, distance (travel time in minutes) between origin and destination, the GDP of the origin/destination country and the dummy *border* are largely correlated with exports. Examining the full matrix reveals that mass at origin and destination show low correlation coefficients with most of the other candidate independent variables. All the correlations between the candidate predictors are below the danger level of 0.7 (Clark, Hosking 1986), except for the relationship between the two language variables, but these are not intended to be in the model at the same time.

**Table 1. Pearson's correlation matrix between variables**

|                       | Exp. <sub>ij</sub> | GDP <sub>i</sub> | GDP <sub>j</sub> | D <sub>ij</sub> | Border | Non-A.  | L.B. (s) | L. B.(l) | Curr.B. |
|-----------------------|--------------------|------------------|------------------|-----------------|--------|---------|----------|----------|---------|
| Exports <sub>ij</sub> | 1                  |                  |                  |                 |        |         |          |          |         |
| GDP <sub>i</sub>      | 0.564**            | 1                |                  |                 |        |         |          |          |         |
| GDP <sub>j</sub>      | 0.511**            | 0.000            | 1                |                 |        |         |          |          |         |
| D <sub>ij</sub>       | -0.546**           | 0.002            | 0.002            | 1               |        |         |          |          |         |
| Border                | -0.395**           | 0.000            | 0.000            | 0.542**         | 1      |         |          |          |         |
| Non-Adjacency         | -0.308**           | -0.064           | -0.064           | 0.444**         | -0.072 | 1       |          |          |         |
| Lang. barrier (s)     | -0.203**           | -0.071           | -0.071           | 0.269**         | -0.037 | 0.453** | 1        |          |         |
| Lang. barrier (l)     | -0.260**           | -0.106*          | -0.106*          | 0.315**         | -0.052 | 0.626** | 0.717**  | 1        |         |
| Currency barrier      | -0.149**           | -0.150**         | -0.150**         | 0.054           | 0.107* | 0.058   | 0.082    | 0.100*   | 1       |

\*\* Significant at the 0.01 level (bilateral).

\* Significant at the 0.05 level (bilateral).

Source: authors' calculations from WIOD, EUROSTAT, Database of European roads 1957-2012 and GISCO.

These candidate predictors were subsequently integrated in McCallum's original model as in formula 2. Then, each independent variable that is significant remains in subsequent models until all significant variables are inside. For comparative purposes the gravity model without considering the border effect has also been adjusted (Model 0). Table 2 the shows results of



Ordinary Least Squares (OLS) models (i.e. all flows between the 24 countries are considered). All models show high  $R^2$  values and a high overall significance (F-test). All tolerance values are below 2.2, thus multi-collinearity is not an issue. In models 0, I and model II all independent variables are significant at the 0.05 level and have the expected signs. In contrast, not sharing a common language (models III and IV) is not significant, and not sharing a common currency (i.e. the Euro) (model V) is not highly significant and surprisingly has the opposite sign to the one expected. Therefore, and considering the  $R^2$ , F and AICc values, model II was selected as the best gravity model. In fact this model has the same predictors as those included in models of previous work on border effects (e.g., Chen, 2004). The values obtained for the distance-decay parameter (1.676) and for the border and non-adjacency effects (6.931 and 1.575, i.e. the antilog of -1.936 and -0.454, respectively) are consistent with results obtained in previous research. A look at the models evidences that the introduction of additional trade barriers as dummies leads to a reduction in the value of the distance decay parameter and to an increase in the border effect value. Comparing model 0 (the commonly used, without considering trade barriers) and model II (considering both border and non-adjacency effects) shows that the first not only get a worse fit in terms of adjusted  $R^2$  and AICc, but also (and more important) leads to a large inflation of the distance-decay parameter (Table 2 and Figure 1).

**Table 2. Comparison of gravity models (OLS)**

| Variables          | Model 0 |       |       | Model I |       |       | Model II |       |        | Model III |       |       | Model IV |       |       | Model V |       |       |       |
|--------------------|---------|-------|-------|---------|-------|-------|----------|-------|--------|-----------|-------|-------|----------|-------|-------|---------|-------|-------|-------|
|                    | $\beta$ | Sig   | VIF   | $\beta$ | Sig   | VIF   | $\beta$  | Sig   | VIF    | $\beta$   | Sig   | VIF   | $\beta$  | Sig   | VIF   | B       | Sig   | VIF   |       |
| Intercept          | -11.709 | 0.000 |       | -12.080 | 0.000 |       | -12.103  | 0.000 |        | -12.080   | 0.000 |       | -12.095  | 0.000 |       | -12.993 | 0.000 |       |       |
| GDP <sub>i</sub>   | 0.931   | 0.000 | 1.000 | 0.930   | 0.000 | 1.000 | 0.924    | 0.000 | 1.007  | 0.925     | 0.000 | 1.009 | 0.927    | 0.000 | 1.015 | 0.938   | 0.000 | 1.029 |       |
| GDP <sub>j</sub>   | 0.844   | 0.000 | 1.000 | 0.844   | 0.000 | 1.000 | 0.837    | 0.000 | 1.007  | 0.838     | 0.000 | 1.009 | 0.841    | 0.000 | 1.015 | 0.851   | 0.000 | 1.029 |       |
| D <sub>ij</sub>    | -2.127  | 0.000 | 1.000 | -1.836  | 0.000 | 1.417 | -1.676   | 0.000 | 2.135  | -1.684    | 0.000 | 2.167 | -1.688   | 0.000 | 2.151 | -1.663  | 0.000 | 2.138 |       |
| No Home            |         |       |       | -1.623  | 0.000 | 1.417 | -1.936   | 0.000 | 1.718  | -1.922    | 0.000 | 1.730 | -1.914   | 0.000 | 1.725 | -2.035  | 0.000 | 1.740 |       |
| No Adjacency       |         |       |       |         |       |       | -0.454   | 0.000 | 1.527  | -0.490    | 0.000 | 1.703 | -0.583   | 0.089 | 2.072 | -0.488  | 0.000 | 1.533 |       |
| No Lang. Str       |         |       |       |         |       |       |          |       | -0.173 | 0.402     | 1.282 |       |          |       |       |         |       |       |       |
| No Lang. Lax       |         |       |       |         |       |       |          |       |        |           |       |       | -0.297   | 0.089 | 1.681 |         |       |       |       |
| No Currency        |         |       |       |         |       |       |          |       |        |           |       |       |          |       |       |         | 0.293 | 0.000 | 1.064 |
| Exp No Home        |         |       |       | 5.069   |       |       | 6.931    |       |        | 6.831     |       |       | 6.831    |       |       | 7.654   |       |       |       |
| Exp No Adj         |         |       |       |         |       |       | 1.575    |       |        | 1.632     |       |       | 1.632    |       |       | 1.628   |       |       |       |
| R <sup>2</sup>     | 0.880   |       |       | 0.894   |       |       | 0.896    |       |        | 0.896     |       |       | 0.896    |       |       | 0.899   |       |       |       |
| Adj R <sup>2</sup> | 0.880   |       |       | 0.893   |       |       | 0.895    |       |        | 0.895     |       |       | 0.895    |       |       | 0.898   |       |       |       |
| F-Stat             | 1400    | 0.000 |       | 1199    | 0.000 |       | 982      | 0.000 |        | 818       | 0.000 |       | 822      | 0.000 |       | 847     | 0.000 |       |       |
| AICc               | 1405    |       |       | 1339    |       |       | 1328     |       |        | 1327      |       |       | 1327     |       |       | 1312    |       |       |       |

Source: authors' calculations from WIOD, EUROSTAT, Database of European roads 1957-2012 and GISCO.

#### 4.2 The role of international borders in market potential

Table 3 shows the effect of introducing the different parameters of model II on market potential (formula 7) taking the non-calibrated market potential (i.e. distance decay = 1) as a starting point. The influence of these three parameters in market potential values is very high and decreasing (see average figures at the bottom of the table). More interestingly, the introduction of the different parameters enhances the disparities between countries (coefficient of variation, CV). The calibrated distance decay parameter has a major impact on market potential values, evidencing a reduction of over 97 per cent in all cases. This reduction is even greater in relative terms across the peripheral countries of the EU. The impact of the border effect is more unevenly distributed across the EU. The border effect has a greater impact on the market potential of the Baltic and

Eastern countries, whereas countries with large internal markets, like the UK and Germany, and to a lesser extent Belgium, Netherlands, Italy, France and Spain, show a lesser reduction in their market potential after considering the border effect. Introducing non-adjacency in market potential calculations evidences the reproduction of the previous pattern of changes. As expected, the countries with the largest market potential are those with the strongest economies (Germany, UK, and France) and/or a very high GDP density (Belgium and Netherlands). On the opposite side, Baltic and South-Eastern countries have reduced potential access to markets.

**Table 3. Market potential values: effects of the introduction of the different parameters of model II (results per country)**

| Country       | Non calibrated market potential | Calibrated market potential (Model II) |                                      |                                      | Differences (in %)                                |                           |                        |
|---------------|---------------------------------|--|--------------------------------------|--------------------------------------|---|---------------------------|------------------------|
|               | Distance decay = 1              | Introducing calibrated distance decay  | Introducing calibrated border effect | Introducing calibrated non-adjacency | Loss due to introducing calibrated distance decay | Loss due to border effect | Loss due non-adjacency |
| Austria       | 21202846479                     | 324876054                              | 100959483                            | 95500217                             | -98.468   | -68.924                   | -5.407                 |
| Belgium       | 35553701619                     | 935328483                              | 410422035                            | 400036185                            | -97.369   | -56.120                   | -2.531                 |
| Bulgaria      | 10758880593                     | 99169850                               | 19612571                             | 15297548                             | -99.078   | -80.223                   | -22.001                |
| Czech R.      | 21317266603                     | 329116663                              | 82387306                             | 75745418                             | -98.456   | -74.967                   | -8.062                 |
| Germany       | 27091491071                     | 478959340                              | 272455649                            | 267231084                            | -98.232   | -43.115                   | -1.918                 |
| Denmark       | 19944142764                     | 311720016                              | 109904979                            | 102024370                            | -98.437   | -64.742                   | -7.170                 |
| Estonia       | 14358219566                     | 177025026                              | 31892935                             | 23093610                             | -98.767   | -81.984                   | -27.590                |
| Spain         | 16674181510                     | 210886059                              | 85742403                             | 80529603                             | -98.735   | -59.342                   | -6.080                 |
| Finland       | 12812650994                     | 141736789                              | 38057456                             | 32673505                             | -98.894   | -73.149                   | -14.147                |
| France        | 23013281942                     | 345718460                              | 152366530                            | 147290364                            | -98.498   | -55.928                   | -3.332                 |
| Great Britain | 26204670426                     | 497856908                              | 286024968                            | 273548725                            | -98.100   | -42.549                   | -4.362                 |
| Greece        | 13304170822                     | 148042483                              | 43792330                             | 37430861                             | -98.887   | -70.419                   | -14.526                |
| Hungary       | 16617389009                     | 216216259                              | 52579430                             | 44315772                             | -98.699   | -75.682                   | -15.717                |
| Ireland       | 19009652327                     | 294939471                              | 85022859                             | 78177214                             | -98.448   | -71.173                   | -8.052                 |
| Italy         | 19498273067                     | 274584913                              | 136199841                            | 130140911                            | -98.592   | -50.398                   | -4.449                 |
| Lithuania     | 15330146857                     | 186160274                              | 35164416                             | 26778323                             | -98.786   | -81.111                   | -23.848                |
| Latvia        | 13889261321                     | 159780778                              | 29472949                             | 21743577                             | -98.850   | -81.554                   | -26.225                |
| Netherlands   | 35195911017                     | 905487933                              | 436721127                            | 422419195                            | -97.427   | -51.770                   | -3.275                 |
| Poland        | 16976715542                     | 217978924                              | 62383258                             | 56718055                             | -98.716   | -71.381                   | -9.081                 |
| Portugal      | 12719495380                     | 149786338                              | 53032893                             | 48828121                             | -98.822   | -64.594                   | -7.929                 |
| Romania       | 11132307980                     | 104617681                              | 25125903                             | 20482718                             | -99.060   | -75.983                   | -18.480                |
| Sweden        | 14683099596                     | 173958711                              | 49686730                             | 42527697                             | -98.815   | -71.438                   | -14.408                |
| Slovenia      | 19504282525                     | 283533201                              | 62494801                             | 53917863                             | -98.546   | -77.959                   | -13.724                |
| Slovakia      | 17334534205                     | 232284656                              | 48748644                             | 40796486                             | -98.660   | -79.013                   | -16.313                |
| Average       | 18921940551                     | 299990220                              | 112927146                            | 105718643                            | -98.56  | -67.65                    | -11.61                 |
| STD           | 6516001692                      | 212640347                              | 115521136                            | 113973467                            | 0.42  | 11.87                     | 7.62                   |
| CV            | 34.4                            | 71                                     | 102                                  | 108                                  | -0.4  | -17.5                     | -65.6                  |

Source: authors' calculations from WIOD, EUROSTAT, Database of European roads 1957-2012 and GISCO.

These market potential losses are closely linked to self-potential values. Countries with less self-potential (see Table 4) experience a greater loss of their total potential due to their greater dependency on international relationships. This is the case with small countries in terms of population and GDP located in Central and Eastern Europe. In contrast, a smaller loss of market potential is evidenced in countries with larger self-potential values. There is a progressive increase in self-potential in relative terms after introducing the selected impedance factors, which leads to more realistic results (Table 4). There is evidence that using a distance decay equal to 1, as it has commonly been used in some previous studies, implies an overestimation of the role of long-distance relationships. In contrast, calibrating the distance decay allows that trade flows fall sharply with distance. Consequently, trade over short distances (most of them being intra-national relationships) are more relevant than what estimations based on distance decay of value

**Table 4. Self-potential values: effects of the introduction of the different parameters of model II (results per country)**

| Country       | Non calibrated market potential | Calibrated market potential (Model II) |                                      |                                      | Differences (in %)         |                           |                           |
|---------------|---------------------------------|--|--------------------------------------|--------------------------------------|----------------------------|---------------------------|---------------------------|
|               | Distance decay = 1              | Introducing calibrated distance decay  | Introducing calibrated border effect | Introducing calibrated non-adjacency | Gain due to Distance Decay | Gain due to border effect | Gain due to non-adjacency |
| Austria       | 9.1                             | 19.5                                   | 62.6                                 | 66.2                                 | 114.7                      | 221.8                     | 5.7                       |
| Belgium       | 15.5                            | 34.4                                   | 78.4                                 | 80.5                                 | 121.5                      | 127.9                     | 2.6                       |
| Bulgaria      | 2.0                             | 6.3                                    | 31.6                                 | 40.5                                 | 219.8                      | 405.6                     | 28.2                      |
| Czech R.      | 5.3                             | 12.4                                   | 49.5                                 | 53.8                                 | 132.5                      | 299.5                     | 8.8                       |
| Germany       | 37.5                            | 49.6                                   | 87.2                                 | 88.9                                 | 32.5                       | 75.8                      | 2.0                       |
| Denmark       | 9.8                             | 24.3                                   | 69.0                                 | 74.4                                 | 147.4                      | 183.6                     | 7.7                       |
| Estonia       | 1.2                             | 4.2                                    | 23.3                                 | 32.1                                 | 264.5                      | 455.1                     | 38.1                      |
| Spain         | 19.4                            | 30.7                                   | 75.4                                 | 80.3                                 | 58.4                       | 146.0                     | 6.5                       |
| Finland       | 6.4                             | 14.5                                   | 54.1                                 | 63.0                                 | 127.7                      | 272.4                     | 16.5                      |
| France        | 26.3                            | 34.6                                   | 78.6                                 | 81.3                                 | 31.6                       | 126.9                     | 3.4                       |
| Great Britain | 34.2                            | 50.3                                   | 87.5                                 | 91.5                                 | 47.2                       | 74.1                      | 4.6                       |
| Greece        | 7.4                             | 17.7                                   | 59.9                                 | 70.0                                 | 139.7                      | 238.1                     | 17.0                      |
| Hungary       | 4.3                             | 11.6                                   | 47.5                                 | 56.4                                 | 171.7                      | 311.2                     | 18.6                      |
| Ireland       | 6.8                             | 16.8                                   | 58.4                                 | 63.5                                 | 145.9                      | 246.9                     | 8.8                       |
| Italy         | 27.3                            | 41.1                                   | 82.9                                 | 86.7                                 | 50.8                       | 101.6                     | 4.7                       |
| Lithuania     | 1.6                             | 5.2                                    | 27.6                                 | 36.2                                 | 217.6                      | 429.4                     | 31.3                      |
| Latvia        | 1.3                             | 4.7                                    | 25.5                                 | 34.5                                 | 258.9                      | 442.1                     | 35.5                      |
| Netherlands   | 20.3                            | 39.5                                   | 81.9                                 | 84.7                                 | 94.4                       | 107.3                     | 3.4                       |
| Poland        | 8.8                             | 16.6                                   | 57.9                                 | 63.7                                 | 87.5                       | 249.4                     | 10.0                      |
| Portugal      | 8.7                             | 24.5                                   | 69.2                                 | 75.2                                 | 181.1                      | 182.4                     | 8.6                       |
| Romania       | 4.5                             | 11.2                                   | 46.7                                 | 57.2                                 | 147.2                      | 316.4                     | 22.7                      |
| Sweden        | 9.1                             | 16.5                                   | 57.8                                 | 67.6                                 | 82.4                       | 250.1                     | 16.8                      |
| Slovenia      | 2.4                             | 8.9                                    | 40.4                                 | 46.8                                 | 266.4                      | 353.7                     | 15.9                      |
| Slovakia      | 2.9                             | 7.7                                    | 36.5                                 | 43.6                                 | 166.1                      | 376.5                     | 19.5                      |
| Average       | 11.3                            | 20.9                                   | 57.9                                 | 64.1                                 | 137.8                      | 249.7                     | 14.0                      |
| STD           | 10.4                            | 13.9                                   | 19.7                                 | 17.8                                 | 69.9                       | 116.9                     | 10.5                      |
| CV            | 91.8                            | 66.2                                   | 34.0                                 | 27.7                                 | 50.7                       | 46.8                      | 74.7                      |

Source: authors' calculation from WIOD, EUROSTAT, Database of European roads 1957-2012 and GISCO.

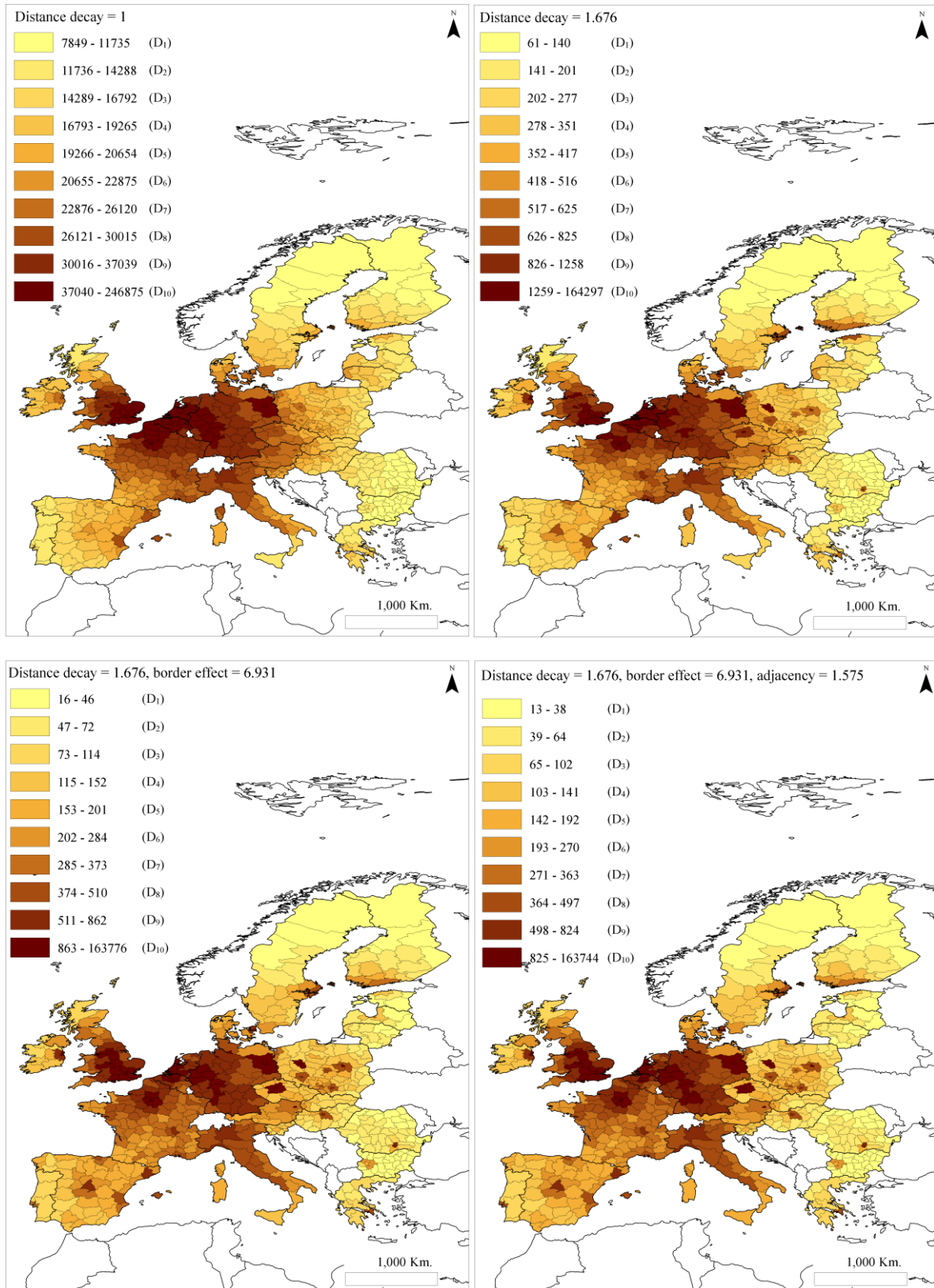
1 reveal. In addition to the fall as a function of distance, potential opportunities fall sharply with the presence of international borders. Therefore, introducing the calibrated border effect in market potential estimations produces a notable decrease in the weight of international relationships, which in turn increases the relative weight of self-potential. The same applies when controlling for non-adjacency. On the other side, the introduction of distance and trade parameters leads to a continuous fall in the variation coefficient values, revealing a reduction in self-potential disparities between countries.

When introducing the different calibrated parameters in the market potential model at the regional level, we face the Modifiable Areal Unit Problem (MAUP) (Kendall, 1939; Griffith, 1992; Bivand, 1998). The MAUP is basically divided in two parts: a) scale dependency (e.g. results at the national level are not equal to the overall results at the regional level), b) the number and layout of internal divisions (zones should be equivalent in form and size). The first part of the problem is not possible to be solved in this research, since there are not reliable trade matrices among EU regions. Regarding the second part, from the different alternatives suggested in ESPON (2006, p.184), we chose the use of a combination of NUTS 2 and NUTS 3 regions<sup>5</sup>. In particular, we updated the NUTS 2/3 level that were used in the EU-LUPA (ESPO, 2012) project with the new NUTS 2010 version. The results we have obtained at the regional level should be interpreted with caution, since the MAUP has been only mitigated. It can be seen, for example, that the small size of some urban regions located in Eastern Europe highlights their accessibility values, yet some general trends can be clearly identified. The maps of market potential at NUTS 2/3 level (Figure 2) evidence a typical concentric spatial pattern at the European level with the area within the Pentagon showing larger values and the peripheral regions obtaining lower values of market potential in the simplest model (distance decay =1). Calibrating the distance decay allows a better differentiation between the market potential of large urban areas and the market potential of less urbanized regions. Considering the effect of borders and non-adjacency between countries reveals the particular disadvantages of some border, peripheral and sparsely populated regions.

Changes produced by the introduction of the different parameters can be seen in Figure 3, which shows differences in percentage between each subsequent model. Obviously, the greatest loss in market potential is due to the calibration of the distance decay parameter, since it is an exponent to the origin-destination distance. This loss is greater for the peripheral regions (more distant from the main markets), and lower, although always very large, for the main urban regions (because of their high self-potential values). Changes produced by border and non-adjacency effects are particularly intense in less populated regions surrounding the German border, with the German regions and the main urban regions being the least affected by the introduction of these two parameters.

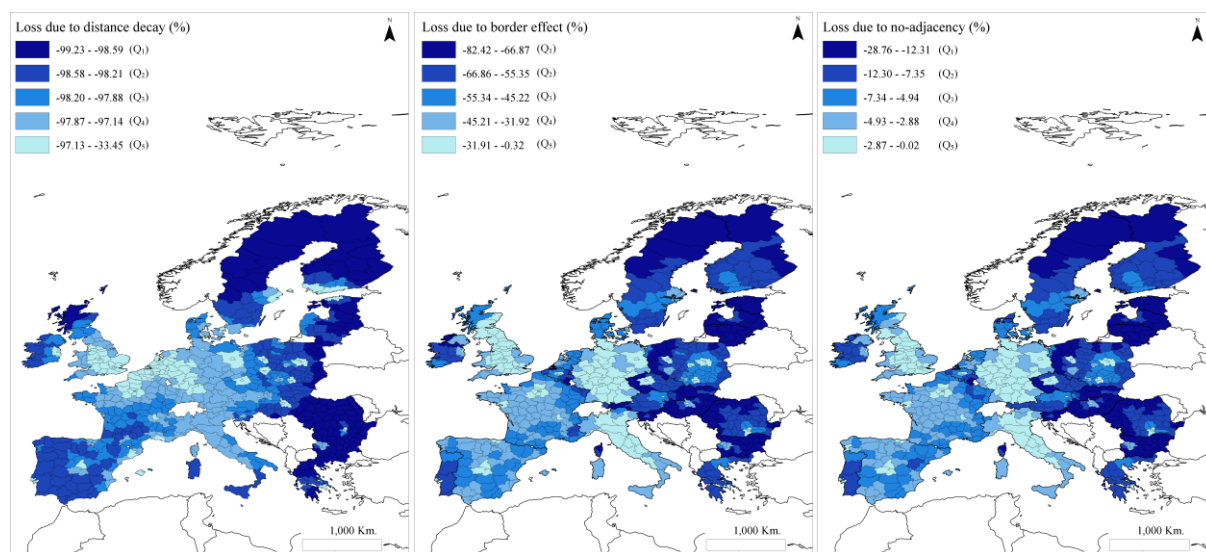
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<sup>5</sup> One of these solutions proposed by ESPON is using a grid of 80 x 80 km<sup>2</sup>. This size was chosen as "probably the best possible compromise between conservation of spatial differences and elimination of biases introduced by the conversion from territorial units to grid cells" (ESPO, 2006, p. 184). While this grid could be computed from the existing 1 km<sup>2</sup> grid with GDP and population data, it is complicated to obtain data at this scale for the target years (i.e. most recent road database and international bilateral trade matrix). Interestingly, the above-mentioned ESPON report indicates that the 80x80km<sup>2</sup> grid is "relatively similar to the distribution obtained with a mixture of NUTS2 & NUTS3 units or to the smoothed map with a gaussian neighbourhood span 50 km". We understand that either the 80x80 km<sup>2</sup> grid or the NUTS 2/3 combination are suitable options to minimise the MAUP at the European scale. From these options, we choose the combination of NUTS2 & NUTS3 units because is the easiest to compute and replicate with current available datasets. In addition, given the focus of the research on the border effect the real limits of international boundaries need to be respected. Finally, we consider that results for regions are politically more relevant than at the grid level.



Source: authors' calculations from WIOD, EUROSTAT, Database of European roads 1957-2012 and GISCO.

Figure 2. Market potential values according to different formulations: results per NUTS 2/3 level (in millions of market potential units)



Source: authors' calculations from EUROSTAT, Database of European roads 1957-2012 and GISCO.

Figure 3. Difference in market potential results after introducing subsequent control variables, as a percentage

#### 4.3 Market potential composition: analysing spillover effects

The market potential of each country depends on its internal (self-potential) and international relationships. Tables 5 and 6 present the contribution of each country to the market potential of the others in absolute and relative terms respectively. They may be interpreted as spatial spillover matrices (see Subsection 3.2), thus revealing to what extent each country benefits from the potential opportunities offered by another in terms of market potential. The main diagonal of the matrix shows the self-potential of each country. Each row indicates the amount of market potential that each country provides to the rest of countries, and each column shows the potential that each country receives from the rest of countries. The matrix is highly asymmetric; for example, Germany receives 1.51 million potential units from Austria, whilst Austria only receives 13.13 million from Germany. This reflects the different size of each market. The market potential composition of each country can be identified by following its column. Therefore, for example, the countries that most contribute to the market potential of France are Germany (5.97%), UK (3.10%), Italy (2.95%), Spain (2.14%) Belgium (1.63%), and The Netherlands (1.29%). As a big market, the self-potential value of France is very high (81.31%). As expected, Germany is the country that provides most potential to most of the other countries, due to its high GDP and its central location. However, this is not true in the case of Portugal and Ireland, for example, which are more linked to Spain and the UK, respectively, than to Germany due to their peripheral location and the existence of intermediate opportunities (Spain and the UK, respectively).

The coefficient of variation of each column (excluding the values of the main diagonal) measures the degree of concentration of the potential received from other countries (Table 7). High values indicate that market potential is very dependent on one or a few countries. This is the case of Ireland (highly dependent on the UK) and the Netherlands, Denmark and Czech Republic (closely linked to Germany in terms of market potential). Other countries at a greater distance from large markets show low coefficient of variation values and therefore much less polarized profiles, such as Austria, Bulgaria, Romania, Hungary and the Baltic states.

**Table 5. Spillover matrix: contribution of each country to each other's market potential (in millions of market potential units)**

|       | AT   | BE    | BG   | CZ   | DE    | DK    | EE   | ES   | FI   | FR    | GB    | GR   | HU   | IE   | IT    | LT   | LV   | NL    | PL    | PT    | RO    | SE    | SI    | SK    | Total   |
|-------|------|-------|------|------|-------|-------|------|------|------|-------|-------|------|------|------|-------|------|------|-------|-------|-------|-------|-------|-------|-------|---------|
| AT    | 63.2 | 0.5   | 0.3  | 3.8  | 1.5   | 0.4   | 0.3  | 0.3  | 0.2  | 0.4   | 0.3   | 0.3  | 2.8  | 0.2  | 1.0   | 0.3  | 0.3  | 0.5   | 0.74  | 0.16  | 0.42  | 0.29  | 4.98  | 2.99  | 86.32   |
| BE    | 0.6  | 321.9 | 0.2  | 0.7  | 3.2   | 0.8   | 0.4  | 0.4  | 0.3  | 2.4   | 2.4   | 0.2  | 0.4  | 1.0  | 0.5   | 0.5  | 0.4  | 15.1  | 0.47  | 0.23  | 0.19  | 0.41  | 0.50  | 0.41  | 353.38  |
| BG    | 0.0  | 0.0   | 6.2  | 0.0  | 0.0   | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.1  | 0.1  | 0.0  | 0.0   | 0.0  | 0.0  | 0.03  | 0.02  | 0.24  | 0.02  | 0.05  | 0.05  | 0.05  | 7.14    |
| CZ    | 2.0  | 0.3   | 0.1  | 40.8 | 1.0   | 0.3   | 0.2  | 0.1  | 0.2  | 0.2   | 0.2   | 0.1  | 0.7  | 0.1  | 0.2   | 0.3  | 0.2  | 0.3   | 1.16  | 0.07  | 0.19  | 0.22  | 0.61  | 1.83  | 51.36   |
| DE    | 13.1 | 22.6  | 1.6  | 16.1 | 237.6 | 12.4  | 3.5  | 2.3  | 2.8  | 8.8   | 5.9   | 1.8  | 4.3  | 3.4  | 3.9   | 4.4  | 3.5  | 24.8  | 8.88  | 1.40  | 1.87  | 3.90  | 5.61  | 5.11  | 399.59  |
| DK    | 0.3  | 0.5   | 0.1  | 0.5  | 1.1   | 75.9  | 0.8  | 0.1  | 0.6  | 0.2   | 0.3   | 0.1  | 0.3  | 0.2  | 0.2   | 1.2  | 0.8  | 0.7   | 0.74  | 0.08  | 0.14  | 1.19  | 0.24  | 0.33  | 86.75   |
| EE    | 0.0  | 0.0   | 0.0  | 0.0  | 0.0   | 0.1   | 7.4  | 0.0  | 0.1  | 0.0   | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.1  | 0.3  | 0.0   | 0.04  | 0.00  | 0.01  | 0.11  | 0.01  | 0.02  | 8.35    |
| ES    | 0.9  | 1.1   | 0.6  | 0.7  | 0.9   | 0.5   | 0.4  | 64.6 | 0.3  | 3.2   | 0.9   | 1.0  | 0.7  | 0.6  | 1.9   | 0.4  | 0.4  | 1.0   | 0.49  | 4.79  | 0.54  | 0.39  | 1.10  | 0.64  | 88.20   |
| FI    | 0.1  | 0.2   | 0.1  | 0.2  | 0.2   | 0.5   | 1.7  | 0.1  | 20.6 | 0.1   | 0.1   | 0.1  | 0.1  | 0.1  | 0.1   | 0.6  | 0.9  | 0.2   | 0.33  | 0.05  | 0.09  | 1.34  | 0.12  | 0.18  | 27.90   |
| FR    | 2.7  | 13.0  | 1.0  | 2.4  | 6.7   | 2.0   | 1.2  | 6.0  | 1.1  | 119.8 | 5.2   | 1.7  | 1.7  | 2.9  | 5.5   | 1.4  | 1.2  | 6.3   | 1.57  | 1.97  | 1.01  | 1.31  | 2.49  | 1.70  | 191.89  |
| GB    | 1.7  | 11.5  | 0.6  | 1.9  | 4.0   | 2.4   | 1.3  | 1.5  | 1.1  | 4.6   | 250.3 | 0.8  | 1.2  | 16.6 | 1.4   | 1.5  | 1.3  | 12.1  | 1.55  | 0.94  | 0.69  | 1.44  | 1.44  | 1.31  | 323.39  |
| GR    | 0.2  | 0.1   | 0.8  | 0.2  | 0.1   | 0.1   | 0.1  | 0.2  | 0.1  | 0.2   | 0.1   | 26.2 | 0.3  | 0.1  | 0.5   | 0.1  | 0.1  | 0.1   | 0.14  | 0.13  | 0.27  | 0.08  | 0.33  | 0.22  | 30.70   |
| HU    | 0.9  | 0.1   | 0.2  | 0.4  | 0.2   | 0.1   | 0.1  | 0.1  | 0.1  | 0.1   | 0.1   | 0.1  | 25.0 | 0.0  | 0.2   | 0.1  | 0.1  | 0.1   | 0.26  | 0.04  | 0.44  | 0.09  | 0.92  | 1.74  | 31.43   |
| IE    | 0.1  | 0.4   | 0.0  | 0.1  | 0.2   | 0.1   | 0.1  | 0.1  | 0.1  | 0.2   | 1.5   | 0.1  | 0.1  | 49.6 | 0.1   | 0.1  | 0.1  | 0.4   | 0.10  | 0.07  | 0.05  | 0.10  | 0.10  | 0.09  | 54.09   |
| IT    | 5.5  | 2.0   | 1.6  | 2.2  | 2.4   | 1.1   | 0.8  | 2.9  | 0.7  | 4.3   | 1.3   | 3.5  | 2.6  | 0.9  | 112.9 | 0.9  | 0.8  | 1.7   | 1.33  | 1.48  | 1.43  | 0.84  | 7.87  | 2.10  | 163.17  |
| LT    | 0.0  | 0.0   | 0.0  | 0.1  | 0.1   | 0.2   | 0.2  | 0.0  | 0.1  | 0.0   | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 9.7  | 0.5  | 0.0   | 0.18  | 0.01  | 0.02  | 0.12  | 0.03  | 0.05  | 11.40   |
| LV    | 0.0  | 0.0   | 0.0  | 0.0  | 0.0   | 0.1   | 0.4  | 0.0  | 0.1  | 0.0   | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.3  | 7.5  | 0.0   | 0.05  | 0.01  | 0.01  | 0.09  | 0.01  | 0.02  | 8.74    |
| NL    | 1.0  | 24.4  | 0.3  | 1.2  | 5.7   | 1.6   | 0.7  | 0.6  | 0.6  | 1.9   | 4.1   | 0.3  | 0.6  | 1.6  | 0.7   | 0.9  | 0.7  | 357.7 | 0.87  | 0.33  | 0.31  | 0.79  | 0.77  | 0.69  | 408.26  |
| PL    | 0.9  | 0.5   | 0.3  | 2.8  | 1.3   | 1.1   | 0.9  | 0.2  | 0.7  | 0.3   | 0.3   | 0.2  | 1.0  | 0.2  | 0.3   | 2.1  | 0.9  | 0.5   | 36.15 | 0.12  | 0.39  | 0.86  | 0.64  | 2.60  | 55.27   |
| PT    | 0.1  | 0.1   | 0.1  | 0.1  | 0.1   | 0.1   | 0.0  | 0.8  | 0.0  | 0.2   | 0.1   | 0.1  | 0.1  | 0.1  | 0.2   | 0.0  | 0.0  | 0.1   | 0.06  | 36.72 | 0.06  | 0.05  | 0.11  | 0.07  | 39.29   |
| RO    | 0.2  | 0.1   | 0.8  | 0.2  | 0.1   | 0.1   | 0.1  | 0.1  | 0.1  | 0.1   | 0.1   | 0.2  | 0.6  | 0.0  | 0.1   | 0.1  | 0.1  | 0.1   | 0.14  | 0.05  | 11.72 | 0.07  | 0.19  | 0.27  | 15.27   |
| SE    | 0.4  | 0.4   | 0.2  | 0.6  | 0.6   | 1.9   | 2.6  | 0.1  | 2.7  | 0.3   | 0.3   | 0.1  | 0.3  | 0.2  | 0.2   | 1.5  | 1.7  | 0.5   | 0.89  | 0.10  | 0.20  | 28.73 | 0.28  | 0.43  | 45.30   |
| SI    | 0.6  | 0.0   | 0.1  | 0.1  | 0.1   | 0.0   | 0.0  | 0.0  | 0.0  | 0.0   | 0.0   | 0.1  | 0.3  | 0.0  | 0.2   | 0.0  | 0.0  | 0.0   | 0.06  | 0.02  | 0.05  | 0.03  | 25.23 | 0.15  | 27.36   |
| SK    | 0.7  | 0.1   | 0.1  | 0.8  | 0.1   | 0.1   | 0.1  | 0.0  | 0.1  | 0.1   | 0.1   | 0.1  | 1.2  | 0.0  | 0.1   | 0.1  | 0.1  | 0.1   | 0.48  | 0.03  | 0.14  | 0.08  | 0.29  | 17.80 | 22.70   |
| Total | 95.5 | 400.0 | 15.3 | 75.7 | 267.2 | 102.0 | 23.1 | 80.5 | 32.7 | 147.3 | 273.5 | 37.4 | 44.3 | 78.2 | 130.1 | 26.8 | 21.7 | 422.4 | 56.72 | 48.83 | 20.48 | 42.53 | 53.92 | 40.80 | 2537.25 |

Note: Values below 50,000 Euros are shown as 0.0. but are considered in the total.

Source: authors' calculations from WIOD, EUROSTAT, Database of European roads 1957-2012 and GISCO.

**Table 6. Spillover matrix: contribution of each country to each other's market potential (as a percentage)**

|       | AT    | BE    | BG    | CZ    | DE    | DK    | EE    | ES    | FI    | FR    | GB    | GR    | HU    | IE    | IT    | LT    | LV    | NL    | PL    | PT    | RO    | SE    | SI    | SK    |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| AT    | 66.18 | 0.13  | 2.20  | 4.96  | 0.56  | 0.41  | 1.20  | 0.32  | 0.72  | 0.27  | 0.11  | 0.93  | 6.35  | 0.26  | 0.80  | 1.27  | 1.28  | 0.12  | 1.31  | 0.33  | 2.04  | 0.69  | 9.23  | 7.33  |
| BE    | 0.67  | 80.47 | 1.09  | 0.90  | 1.20  | 0.77  | 1.59  | 0.49  | 0.95  | 1.63  | 0.88  | 0.62  | 0.83  | 1.23  | 0.36  | 1.68  | 1.70  | 3.56  | 0.83  | 0.47  | 0.94  | 0.97  | 0.92  | 1.00  |
| BG    | 0.05  | 0.00  | 40.52 | 0.05  | 0.01  | 0.02  | 0.07  | 0.03  | 0.04  | 0.01  | 0.00  | 0.39  | 0.16  | 0.01  | 0.03  | 0.07  | 0.07  | 0.00  | 0.05  | 0.03  | 1.15  | 0.04  | 0.10  | 0.13  |
| CZ    | 2.04  | 0.07  | 0.98  | 53.85 | 0.36  | 0.33  | 0.91  | 0.13  | 0.53  | 0.12  | 0.06  | 0.36  | 1.59  | 0.15  | 0.16  | 1.02  | 0.98  | 0.07  | 2.05  | 0.14  | 0.95  | 0.52  | 1.14  | 4.49  |
| DE    | 13.75 | 5.66  | 10.29 | 21.19 | 88.93 | 12.19 | 14.96 | 2.83  | 8.69  | 5.97  | 2.16  | 4.85  | 9.67  | 4.36  | 2.98  | 16.52 | 16.03 | 5.87  | 15.66 | 2.88  | 9.14  | 9.18  | 10.40 | 12.53 |
| DK    | 0.35  | 0.13  | 0.72  | 0.70  | 0.43  | 74.37 | 3.53  | 0.15  | 1.79  | 0.17  | 0.12  | 0.28  | 0.58  | 0.27  | 0.13  | 4.56  | 3.65  | 0.16  | 1.30  | 0.17  | 0.66  | 2.80  | 0.44  | 0.82  |
| EE    | 0.02  | 0.00  | 0.04  | 0.03  | 0.01  | 0.05  | 32.14 | 0.01  | 0.45  | 0.01  | 0.00  | 0.02  | 0.03  | 0.01  | 0.01  | 0.31  | 1.32  | 0.00  | 0.07  | 0.01  | 0.04  | 0.26  | 0.02  | 0.04  |
| ES    | 0.96  | 0.28  | 4.08  | 0.91  | 0.34  | 0.52  | 1.59  | 80.27 | 1.03  | 2.14  | 0.32  | 2.80  | 1.60  | 0.81  | 1.50  | 1.53  | 1.70  | 0.23  | 0.86  | 9.81  | 2.65  | 0.92  | 2.05  | 1.56  |
| FI    | 0.16  | 0.04  | 0.46  | 0.28  | 0.08  | 0.45  | 7.40  | 0.08  | 62.98 | 0.07  | 0.04  | 0.17  | 0.32  | 0.12  | 0.06  | 2.05  | 4.02  | 0.04  | 0.58  | 0.09  | 0.42  | 3.14  | 0.22  | 0.44  |
| FR    | 2.80  | 3.25  | 6.83  | 3.12  | 2.52  | 2.00  | 5.23  | 7.49  | 3.26  | 81.31 | 1.89  | 4.46  | 3.79  | 3.75  | 4.23  | 5.24  | 5.59  | 1.50  | 2.76  | 4.03  | 4.95  | 3.09  | 4.62  | 4.16  |
| GB    | 1.83  | 2.88  | 4.00  | 2.54  | 1.50  | 2.36  | 5.66  | 1.82  | 3.47  | 3.10  | 91.50 | 2.21  | 2.64  | 21.28 | 1.11  | 5.79  | 6.05  | 2.86  | 2.74  | 1.93  | 3.35  | 3.38  | 2.66  | 3.20  |
| GR    | 0.25  | 0.03  | 5.13  | 0.24  | 0.05  | 0.09  | 0.33  | 0.26  | 0.21  | 0.12  | 0.04  | 70.04 | 0.67  | 0.10  | 0.35  | 0.33  | 0.36  | 0.03  | 0.24  | 0.26  | 1.31  | 0.18  | 0.61  | 0.55  |
| HU    | 0.97  | 0.02  | 1.17  | 0.59  | 0.06  | 0.10  | 0.37  | 0.08  | 0.23  | 0.06  | 0.02  | 0.38  | 56.39 | 0.06  | 0.12  | 0.42  | 0.41  | 0.02  | 0.46  | 0.09  | 2.16  | 0.20  | 1.70  | 4.25  |
| IE    | 0.12  | 0.11  | 0.30  | 0.16  | 0.08  | 0.14  | 0.38  | 0.12  | 0.24  | 0.16  | 0.56  | 0.16  | 0.18  | 63.48 | 0.07  | 0.38  | 0.41  | 0.10  | 0.18  | 0.14  | 0.25  | 0.23  | 0.18  | 0.22  |
| IT    | 5.75  | 0.50  | 10.73 | 2.86  | 0.88  | 1.11  | 3.42  | 3.66  | 2.16  | 2.95  | 0.47  | 9.27  | 5.76  | 1.20  | 86.73 | 3.39  | 3.65  | 0.41  | 2.34  | 3.03  | 6.97  | 1.97  | 14.60 | 5.14  |
| LT    | 0.04  | 0.01  | 0.10  | 0.07  | 0.02  | 0.15  | 0.68  | 0.02  | 0.28  | 0.01  | 0.01  | 0.04  | 0.08  | 0.02  | 0.01  | 36.24 | 2.31  | 0.01  | 0.32  | 0.02  | 0.09  | 0.29  | 0.05  | 0.12  |
| LV    | 0.02  | 0.01  | 0.06  | 0.04  | 0.01  | 0.07  | 1.55  | 0.01  | 0.29  | 0.01  | 0.01  | 0.02  | 0.04  | 0.01  | 0.01  | 1.23  | 34.50 | 0.01  | 0.09  | 0.01  | 0.05  | 0.20  | 0.03  | 0.06  |
| NL    | 1.05  | 6.10  | 1.75  | 1.55  | 2.13  | 1.61  | 3.02  | 0.69  | 1.78  | 1.29  | 1.50  | 0.91  | 1.35  | 2.05  | 0.50  | 3.27  | 3.23  | 84.67 | 1.54  | 0.69  | 1.52  | 1.86  | 1.43  | 1.70  |
| PL    | 0.96  | 0.12  | 1.87  | 3.67  | 0.47  | 1.12  | 3.70  | 0.22  | 1.99  | 0.20  | 0.12  | 0.65  | 2.23  | 0.30  | 0.24  | 8.03  | 4.10  | 0.13  | 63.73 | 0.25  | 1.92  | 2.01  | 1.19  | 6.37  |
| PT    | 0.10  | 0.03  | 0.45  | 0.10  | 0.03  | 0.06  | 0.19  | 0.97  | 0.13  | 0.11  | 0.03  | 0.28  | 0.17  | 0.09  | 0.12  | 0.18  | 0.20  | 0.02  | 0.10  | 75.20 | 0.30  | 0.11  | 0.20  | 0.17  |
| RO    | 0.19  | 0.02  | 5.26  | 0.22  | 0.04  | 0.07  | 0.29  | 0.08  | 0.18  | 0.05  | 0.02  | 0.45  | 1.33  | 0.05  | 0.09  | 0.31  | 0.32  | 0.02  | 0.25  | 0.10  | 57.23 | 0.16  | 0.35  | 0.66  |
| SE    | 0.39  | 0.11  | 1.04  | 0.73  | 0.22  | 1.87  | 11.33 | 0.18  | 8.35  | 0.17  | 0.11  | 0.38  | 0.76  | 0.29  | 0.16  | 5.66  | 7.64  | 0.12  | 1.57  | 0.21  | 0.96  | 67.56 | 0.53  | 1.07  |
| SI    | 0.63  | 0.01  | 0.33  | 0.19  | 0.03  | 0.04  | 0.11  | 0.05  | 0.07  | 0.03  | 0.01  | 0.15  | 0.76  | 0.03  | 0.14  | 0.12  | 0.12  | 0.01  | 0.11  | 0.05  | 0.25  | 0.06  | 46.79 | 0.37  |
| SK    | 0.72  | 0.02  | 0.61  | 1.07  | 0.05  | 0.09  | 0.34  | 0.05  | 0.20  | 0.04  | 0.02  | 0.20  | 2.73  | 0.05  | 0.07  | 0.39  | 0.37  | 0.02  | 0.85  | 0.06  | 0.69  | 0.18  | 0.54  | 43.64 |
| Total | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   |

Source: authors' calculations from WIOD, EUROSTAT, Database of European roads 1957-2012 and GISCO.



In Table 5 it is evident that, excluding the main diagonal values, the row sum is equal to the market potential provided by each country to the rest of the countries, and the column sum is equal to the market potential received by each country from the rest of the countries. Table 8 compares both sums for each country. It can be seen, for example, that Germany and other big markets, such as France, the UK or Italy, provide more potential to other countries than they receive from them. For other countries the picture is just the opposite (more potential received than provided). This is particularly the case of small countries, such as the Baltic countries, Bulgaria and Slovenia, whose market potential composition depends largely on the contribution of other countries.

The spillover matrix of the market potential in relative terms (Table 6) was checked against the matrix of real proportional trade flows between countries in the EU (Table 10). The same operation was repeated for different market potential specifications. Table 11 evidences that, as expected, controlling for distance decay, border effect and non-adjacency increases the correlation coefficient between market potential and trade, leading to more realistic market potential estimations than assuming a distance decay value of 1 or calibrating distance decay without considering trade barriers.

**Table 7. Coefficient of variation of the market potential received by each country**

| Country       | Coefficient of variation |
|---------------|--------------------------|
| Austria       | 90.8                     |
| Belgium       | 208.3                    |
| Bulgaria      | 119.0                    |
| Czech R       | 214.4                    |
| Germany       | 144.0                    |
| Denmark       | 221.0                    |
| Estonia       | 127.2                    |
| Spain         | 197.3                    |
| Finland       | 145.7                    |
| France        | 177.6                    |
| Great Britain | 167.3                    |
| Greece        | 165.2                    |
| Hungary       | 125.2                    |
| Ireland       | 274.2                    |
| Italy         | 176.9                    |
| Lithuania     | 132.7                    |
| Latvia        | 123.1                    |
| Netherlands   | 216.1                    |
| Poland        | 198.0                    |
| Portugal      | 201.0                    |
| Romania       | 121.3                    |
| Sweden        | 141.4                    |
| Slovenia      | 162.7                    |
| Slovakia      | 124.7                    |

Source: authors' calculations from WIOD, EUROSTAT, Database of European roads 1957-2012 and GISCO.

**Table 8. Market potential provided to/received from other European countries (in millions of market potential units)**

| Country       | Provided to other countries | Received from other countries | Difference received - provided | Ratio received / provided |
|---------------|-----------------------------|-------------------------------|--------------------------------|---------------------------|
| Austria       | 23                          | 32                            | 9                              | 1.4                       |
| Belgium       | 31                          | 78                            | 47                             | 2.5                       |
| Bulgaria      | 1                           | 9                             | 8                              | 9.6                       |
| Czech R       | 11                          | 35                            | 24                             | 3.3                       |
| Germany       | 162                         | 30                            | -132                           | 0.2                       |
| Denmark       | 11                          | 26                            | 15                             | 2.4                       |
| Estonia       | 1                           | 16                            | 15                             | 16.9                      |
| Spain         | 24                          | 16                            | -8                             | 0.7                       |
| Finland       | 7                           | 12                            | 5                              | 1.7                       |
| France        | 72                          | 28                            | -45                            | 0.4                       |
| Great Britain | 73                          | 23                            | -50                            | 0.3                       |
| Greece        | 4                           | 11                            | 7                              | 2.5                       |
| Hungary       | 6                           | 19                            | 13                             | 3.0                       |
| Ireland       | 4                           | 29                            | 24                             | 6.4                       |
| Italy         | 50                          | 17                            | -33                            | 0.3                       |
| Lithuania     | 2                           | 17                            | 15                             | 10.1                      |
| Latvia        | 1                           | 14                            | 13                             | 11.5                      |
| Netherlands   | 51                          | 65                            | 14                             | 1.3                       |
| Poland        | 19                          | 21                            | 1                              | 1.1                       |
| Portugal      | 3                           | 12                            | 10                             | 4.7                       |
| Romania       | 4                           | 9                             | 5                              | 2.5                       |
| Sweden        | 17                          | 14                            | -3                             | 0.8                       |
| Slovenia      | 2                           | 29                            | 27                             | 13.5                      |
| Slovakia      | 5                           | 23                            | 18                             | 4.7                       |

Source: authors' calculations from WIOD, EUROSTAT, Database of European roads 1957-2012 and GISCO.

**Table 9. Real trade flow matrix (in millions of Euros)**

|       | AT     | BE     | BG    | CZ     | DE      | DK    | EE   | ES     | FI     | FR     | GB     | GR    | HU    | IE    | IT     | LT    | L<br>V | NL     | PL     | PT    | RO     | SE     | SI    | SK    | Total   |
|-------|--------|--------|-------|--------|---------|-------|------|--------|--------|--------|--------|-------|-------|-------|--------|-------|--------|--------|--------|-------|--------|--------|-------|-------|---------|
| AT    | 74537  | 1207   | 644   | 3563   | 35065   | 493   | 51   | 2023   | 472    | 4514   | 3267   | 486   | 4100  | 179   | 7978   | 90    | 73     | 1167   | 2560   | 259   | 1696   | 1192   | 1226  | 931   | 14777   |
| BE    | 1692   | 47608  | 320   | 1635   | 37010   | 1868  | 92   | 5790   | 1471   | 29533  | 17886  | 1591  | 1180  | 957   | 11586  | 238   | 135    | 22595  | 2889   | 1054  | 815    | 3942   | 220   | 339   | 192447  |
| BG    | 212    | 475    | 20941 | 127    | 1323    | 51    | 2    | 316    | 21     | 521    | 184    | 761   | 102   | 7     | 1258   | 13    | 12     | 80     | 233    | 47    | 957    | 38     | 70    | 33    | 27783   |
| CZ    | 5770   | 1719   | 356   | 69559  | 32820   | 622   | 63   | 2297   | 545    | 5780   | 4898   | 289   | 2186  | 220   | 4165   | 161   | 81     | 1948   | 5047   | 291   | 990    | 1308   | 383   | 4652  | 146149  |
| DE    | 48995  | 29898  | 2477  | 26796  | 831117  | 13147 | 615  | 31823  | 8176   | 93549  | 59817  | 6154  | 16551 | 3826  | 61920  | 1342  | 820    | 39639  | 34008  | 6342  | 7484   | 21443  | 2796  | 7233  | 1355967 |
| DK    | 465    | 699    | 86    | 664    | 10795   | 34368 | 87   | 1756   | 1662   | 2783   | 7725   | 485   | 281   | 475   | 1993   | 256   | 170    | 1609   | 1985   | 247   | 334    | 9224   | 50    | 184   | 78382   |
| EE    | 23     | 65     | 4     | 39     | 383     | 140   | 3148 | 27     | 1134   | 130    | 112    | 4     | 11    | 5     | 121    | 297   | 391    | 89     | 120    | 3     | 8      | 843    | 4     | 12    | 7112    |
| ES    | 1981   | 6059   | 427   | 1855   | 25117   | 964   | 59   | 367965 | 816    | 35879  | 13066  | 1959  | 791   | 724   | 19537  | 180   | 90     | 5128   | 3051   | 16464 | 1103   | 1802   | 470   | 479   | 505968  |
| FI    | 457    | 1191   | 50    | 327    | 7026    | 1452  | 631  | 1205   | 73240  | 2004   | 2760   | 191   | 251   | 121   | 1309   | 343   | 342    | 2051   | 1383   | 97    | 119    | 5839   | 65    | 94    | 102549  |
| FR    | 3502   | 23679  | 821   | 3506   | 66743   | 2187  | 121  | 29208  | 1734   | 598894 | 27541  | 2712  | 2561  | 1989  | 33018  | 263   | 182    | 11287  | 6551   | 3533  | 2565   | 5934   | 749   | 1502  | 830785  |
| GB    | 1827   | 11180  | 300   | 1877   | 39662   | 5756  | 230  | 12220  | 1803   | 25080  | 306142 | 1553  | 1301  | 14038 | 11417  | 192   | 112    | 20353  | 3879   | 1437  | 1133   | 7122   | 241   | 523   | 469378  |
| GR    | 64     | 110    | 506   | 60     | 937     | 60    | 2    | 319    | 89     | 354    | 320    | 59391 | 37    | 17    | 887    | 5     | 2      | 123    | 235    | 40    | 229    | 59     | 43    | 29    | 63920   |
| HU    | 2976   | 670    | 610   | 2103   | 17590   | 404   | 52   | 1998   | 164    | 3451   | 3710   | 266   | 42318 | 111   | 3233   | 68    | 87     | 854    | 2488   | 226   | 3438   | 847    | 409   | 1573  | 89648   |
| IE    | 376    | 3993   | 45    | 601    | 10205   | 663   | 34   | 2422   | 236    | 5013   | 11591  | 201   | 239   | 46458 | 2123   | 26    | 13     | 1660   | 584    | 348   | 176    | 1392   | 45    | 164   | 88606   |
| IT    | 8357   | 5969   | 1297  | 3993   | 49783   | 2034  | 178  | 21042  | 1419   | 37461  | 16315  | 5121  | 3041  | 721   | 615158 | 440   | 216    | 4629   | 7980   | 2674  | 5057   | 3253   | 2782  | 1446  | 800366  |
| LT    | 50     | 124    | 21    | 75     | 1081    | 244   | 245  | 129    | 182    | 725    | 381    | 14    | 36    | 32    | 218    | 8724  | 899    | 432    | 650    | 25    | 29     | 389    | 5     | 18    | 14728   |
| LV    | 16     | 30     | 7     | 26     | 381     | 122   | 217  | 41     | 169    | 71     | 143    | 5     | 11    | 83    | 53     | 507   | 4638   | 51     | 101    | 1     | 14     | 239    | 2     | 8     | 6934    |
| NL    | 2953   | 39939  | 463   | 2424   | 69216   | 4772  | 153  | 9656   | 3109   | 21626  | 29536  | 2237  | 2225  | 2404  | 19904  | 532   | 243    | 84418  | 4800   | 2056  | 1186   | 5648   | 306   | 502   | 310307  |
| PL    | 2297   | 2171   | 456   | 7143   | 35775   | 2092  | 369  | 3678   | 995    | 8346   | 9140   | 434   | 3335  | 544   | 7969   | 1847  | 631    | 3263   | 159638 | 363   | 1906   | 3549   | 388   | 1763  | 258093  |
| PT    | 322    | 762    | 24    | 241    | 3783    | 130   | 8    | 7210   | 155    | 3761   | 1624   | 107   | 95    | 86    | 1197   | 11    | 7      | 759    | 306    | 56979 | 125    | 310    | 27    | 62    | 78089   |
| RO    | 643    | 272    | 925   | 419    | 4827    | 79    | 8    | 657    | 43     | 1772   | 816    | 298   | 1232  | 31    | 3099   | 11    | 9      | 433    | 659    | 62    | 74516  | 154    | 100   | 224   | 91289   |
| SE    | 1259   | 3951   | 143   | 903    | 14488   | 9006  | 424  | 2635   | 7753   | 6309   | 8220   | 413   | 791   | 418   | 3594   | 498   | 235    | 4176   | 2886   | 494   | 224    | 109266 | 108   | 232   | 178427  |
| SI    | 834    | 93     | 133   | 357    | 3698    | 143   | 14   | 197    | 47     | 1150   | 314    | 94    | 548   | 10    | 1632   | 20    | 19     | 133    | 410    | 26    | 263    | 126    | 7806  | 156   | 18223   |
| SK    | 2317   | 338    | 209   | 4342   | 8339    | 203   | 12   | 1380   | 100    | 2366   | 1364   | 134   | 2435  | 36    | 2189   | 66    | 49     | 408    | 2327   | 80    | 572    | 870    | 180   | 1974  | 50063   |
| Total | 161928 | 182201 | 31266 | 132632 | 1307166 | 80999 | 6816 | 505994 | 105534 | 891074 | 526872 | 84900 | 85654 | 73491 | 815559 | 16129 | 9455   | 207286 | 244770 | 93146 | 104937 | 184790 | 18476 | 41908 | 5912984 |

Source: WIOD.

**Table 10. Real trade flow matrix (as a percentage)**

|       | AT    | BE    | BG    | CZ    | DE    | DK    | EE    | ES    | FI    | FR    | GB    | GR    | HU    | IE    | IT    | LT    | LV    | NL    | PL    | PT    | RO    | SE    | SI    | SK    |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| AT    | 50.44 | 0.88  | 0.76  | 3.95  | 3.61  | 0.59  | 0.32  | 0.39  | 0.45  | 0.42  | 0.39  | 0.10  | 3.32  | 0.42  | 1.04  | 0.34  | 0.23  | 0.95  | 0.89  | 0.41  | 0.70  | 0.71  | 4.58  | 4.63  |
| BE    | 0.82  | 24.74 | 1.71  | 1.18  | 2.20  | 0.89  | 0.91  | 1.20  | 1.16  | 2.85  | 2.38  | 0.17  | 0.75  | 4.51  | 0.75  | 0.84  | 0.43  | 12.87 | 0.84  | 0.98  | 0.30  | 2.21  | 0.51  | 0.68  |
| BG    | 0.44  | 0.17  | 75.38 | 0.24  | 0.18  | 0.11  | 0.06  | 0.08  | 0.05  | 0.10  | 0.06  | 0.79  | 0.68  | 0.05  | 0.16  | 0.15  | 0.11  | 0.15  | 0.18  | 0.03  | 1.01  | 0.08  | 0.73  | 0.42  |
| CZ    | 2.41  | 0.85  | 0.46  | 47.59 | 1.98  | 0.85  | 0.55  | 0.37  | 0.32  | 0.42  | 0.40  | 0.09  | 2.35  | 0.68  | 0.50  | 0.51  | 0.38  | 0.78  | 2.77  | 0.31  | 0.46  | 0.51  | 1.96  | 8.67  |
| DE    | 23.73 | 19.23 | 4.76  | 22.46 | 61.29 | 13.77 | 5.39  | 4.96  | 6.85  | 8.03  | 8.45  | 1.47  | 19.62 | 11.52 | 6.22  | 7.34  | 5.49  | 22.31 | 13.86 | 4.84  | 5.29  | 8.12  | 20.29 | 16.66 |
| DK    | 0.33  | 0.97  | 0.19  | 0.43  | 0.97  | 43.85 | 1.96  | 0.19  | 1.42  | 0.26  | 1.23  | 0.09  | 0.45  | 0.75  | 0.25  | 1.66  | 1.76  | 1.54  | 0.81  | 0.17  | 0.09  | 5.05  | 0.79  | 0.40  |
| EE    | 0.03  | 0.05  | 0.01  | 0.04  | 0.05  | 0.11  | 44.27 | 0.01  | 0.62  | 0.01  | 0.05  | 0.00  | 0.06  | 0.04  | 0.02  | 1.66  | 3.13  | 0.05  | 0.14  | 0.01  | 0.01  | 0.24  | 0.08  | 0.02  |
| ES    | 1.37  | 3.01  | 1.14  | 1.57  | 2.35  | 2.24  | 0.38  | 72.72 | 1.18  | 3.52  | 2.60  | 0.50  | 2.23  | 2.73  | 2.63  | 0.87  | 0.59  | 3.11  | 1.43  | 9.23  | 0.72  | 1.48  | 1.08  | 2.76  |
| FI    | 0.32  | 0.76  | 0.07  | 0.37  | 0.60  | 2.12  | 15.95 | 0.16  | 71.42 | 0.21  | 0.38  | 0.14  | 0.18  | 0.27  | 0.18  | 1.23  | 2.43  | 1.00  | 0.39  | 0.20  | 0.05  | 4.35  | 0.26  | 0.20  |
| FR    | 3.05  | 15.35 | 1.88  | 3.95  | 6.90  | 3.55  | 1.83  | 7.09  | 1.95  | 72.09 | 5.34  | 0.55  | 3.85  | 5.66  | 4.68  | 4.92  | 1.02  | 6.97  | 3.23  | 4.82  | 1.94  | 3.54  | 6.31  | 4.73  |
| GB    | 2.21  | 9.29  | 0.66  | 3.35  | 4.41  | 9.86  | 1.57  | 2.58  | 2.69  | 3.32  | 65.22 | 0.50  | 4.14  | 13.08 | 2.04  | 2.59  | 2.06  | 9.52  | 3.54  | 2.08  | 0.89  | 4.61  | 1.72  | 2.72  |
| GR    | 0.33  | 0.83  | 2.74  | 0.20  | 0.45  | 0.62  | 0.05  | 0.39  | 0.19  | 0.33  | 0.33  | 92.91 | 0.30  | 0.23  | 0.64  | 0.10  | 0.07  | 0.72  | 0.17  | 0.14  | 0.33  | 0.23  | 0.52  | 0.27  |
| HU    | 2.77  | 0.61  | 0.37  | 1.50  | 1.22  | 0.36  | 0.15  | 0.16  | 0.25  | 0.31  | 0.28  | 0.06  | 47.20 | 0.27  | 0.38  | 0.24  | 0.15  | 0.72  | 1.29  | 0.12  | 1.35  | 0.44  | 3.01  | 4.86  |
| IE    | 0.12  | 0.50  | 0.02  | 0.15  | 0.28  | 0.61  | 0.06  | 0.14  | 0.12  | 0.24  | 2.99  | 0.03  | 0.12  | 52.43 | 0.09  | 0.22  | 1.20  | 0.77  | 0.21  | 0.11  | 0.03  | 0.23  | 0.05  | 0.07  |
| IT    | 5.40  | 6.02  | 4.53  | 2.85  | 4.57  | 2.54  | 1.71  | 3.86  | 1.28  | 3.97  | 2.43  | 1.39  | 3.61  | 2.40  | 76.86 | 1.48  | 0.77  | 6.41  | 3.09  | 1.53  | 3.39  | 2.01  | 8.96  | 4.37  |
| LT    | 0.06  | 0.12  | 0.05  | 0.11  | 0.10  | 0.33  | 4.18  | 0.04  | 0.33  | 0.03  | 0.04  | 0.01  | 0.08  | 0.03  | 0.05  | 59.24 | 7.31  | 0.17  | 0.72  | 0.01  | 0.01  | 0.28  | 0.11  | 0.13  |
| LV    | 0.05  | 0.07  | 0.04  | 0.06  | 0.06  | 0.22  | 5.50  | 0.02  | 0.33  | 0.02  | 0.02  | 0.00  | 0.10  | 0.01  | 0.03  | 6.10  | 66.88 | 0.08  | 0.24  | 0.01  | 0.01  | 0.13  | 0.11  | 0.10  |
| NL    | 0.79  | 11.74 | 0.29  | 1.33  | 2.92  | 2.05  | 1.25  | 1.01  | 2.00  | 1.36  | 4.34  | 0.19  | 0.95  | 1.87  | 0.58  | 2.94  | 0.73  | 27.20 | 1.26  | 0.97  | 0.47  | 2.34  | 0.73  | 0.82  |
| PL    | 1.73  | 1.50  | 0.84  | 3.45  | 2.51  | 2.53  | 1.69  | 0.60  | 1.35  | 0.79  | 0.83  | 0.37  | 2.77  | 0.66  | 1.00  | 4.41  | 1.46  | 1.55  | 61.85 | 0.39  | 0.72  | 1.62  | 2.25  | 4.65  |
| PT    | 0.18  | 0.55  | 0.17  | 0.20  | 0.47  | 0.31  | 0.04  | 3.25  | 0.09  | 0.43  | 0.31  | 0.06  | 0.25  | 0.39  | 0.33  | 0.17  | 0.02  | 0.66  | 0.14  | 72.97 | 0.07  | 0.28  | 0.14  | 0.16  |
| RO    | 1.15  | 0.42  | 3.44  | 0.68  | 0.55  | 0.43  | 0.11  | 0.22  | 0.12  | 0.31  | 0.24  | 0.36  | 3.84  | 0.20  | 0.63  | 0.20  | 0.20  | 0.38  | 0.74  | 0.16  | 81.63 | 0.13  | 1.44  | 1.14  |
| SE    | 0.81  | 2.05  | 0.14  | 0.89  | 1.58  | 11.77 | 11.85 | 0.36  | 5.69  | 0.71  | 1.52  | 0.09  | 0.95  | 1.57  | 0.41  | 2.64  | 3.45  | 1.82  | 1.38  | 0.40  | 0.17  | 61.24 | 0.69  | 1.74  |
| SI    | 0.83  | 0.11  | 0.25  | 0.26  | 0.21  | 0.06  | 0.05  | 0.09  | 0.06  | 0.09  | 0.05  | 0.07  | 0.46  | 0.05  | 0.35  | 0.03  | 0.02  | 0.10  | 0.15  | 0.03  | 0.11  | 0.06  | 42.84 | 0.36  |
| SK    | 0.63  | 0.18  | 0.12  | 3.18  | 0.53  | 0.23  | 0.17  | 0.09  | 0.09  | 0.18  | 0.11  | 0.05  | 1.75  | 0.18  | 0.18  | 0.12  | 0.12  | 0.16  | 0.68  | 0.08  | 0.25  | 0.13  | 0.86  | 39.45 |
| Total | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   | 100   |

Source: WIOD.

**Table 11. Correlation coefficients between the actual international trade matrix and market potential matrices**

| Market potential specification                                     | Pearson's correlation coefficient | Sig.  |
|--|-----------------------------------|-------|
| Non-calibrated market potential: Distance decay = 1                | 0.416                             | 0.042 |
| Model 0: Calibrating distance decay without trade barriers = 2.127 | 0.741                             | 0.000 |
| Model II: Calibrating distance decay and trade barriers:           | 0.620                             | 0.001 |
| Introducing calibrated distance decay = 1.676                      |                                   |       |
| Introducing calibrated border effect = 6.931                       | 0.892                             | 0.000 |
| Introducing calibrated non-adjacency = 1.575                       | 0.915                             | 0.000 |

## 5. Final remarks

This research attempts to integrate two scientific traditions that have evolved separately: market potential and border effect. Market potential studies assume that trade decreases progressively with distance (the distance decay parameter). However research on the border effect shows that borders cause trade to fall abruptly, particularly between non-adjacent countries. This means that only calibrating the distance decay parameter without considering trade barriers leads to a misspecification of the potential market model due to an overestimation of the distance decay, and thus ignoring the actual behaviour of goods at borders. In this paper different impedance parameters (distance decay and trade barriers) were calibrated using a gravity equation and were then introduced into the market potential model, leading to a discontinuous function instead to a continuous one.

It has been shown that the assumption of the value 1 for the distance decay parameter (common in market potential studies in the European Union using a negative potential function) distorts accessibility values, thereby overestimating relationships over long distances. Instead, introducing the calibrated impedance parameters (distance decay and trade barriers) in the market potential model leads to more realistic results, dramatically increasing self-potential values and spatial disparities in market potential distribution. The effect of the calibrated distance decay parameter is more intense in peripheral regions, while the densest ones (main urban regions) tend to experience lower losses. Border and non-adjacency effects especially affect sparsely populated border regions, which are highly dependent on the market potential received from other countries.

The market potential decomposed matrix (equivalent to a spillover matrix) allows the market potential that a country receives from others to be identified. This value depends on a set of factors, such as GDP and geographical location. Logically, a small country located near a big market tends to receive a high potential value from this big market. Results show that countries with higher GDP values exhibit higher self-potential values and are less dependent on the market potential that they receive from others. Meanwhile, the matrix shows the degree of concentration of the potential that a country receives from other countries, thus evidencing the degree of dependency from the largest contributors. This is significant from the point of view of the vulnerability of a country's exports. Finally, the high correlation coefficient between the actual exports matrix and the market potential composition evidences the realism of the market potential specification proposed and the spillovers matrix presented.

It has been demonstrated that potential market studies in an international framework should take into account not only the distance deterrence, but also the effect of trade barriers. Introducing calibrated distance decay and trade barriers in the market potential model leads to a better modelling of economic flows. The consideration of these impedance parameters enables longitudinal studies to be produced in order to evaluate not only the impact of transport policies

(e.g. the extension of trans-European networks) but also to assess the effect of the progressively diminishing role of borders on market potential. This is a subject for further research.

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