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Borders and interregional trade integration between Spain and the European Union: Theoretical foundations and empirical analysis in the context of the gravity model and the New Economic Geography

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Te la dedico a ti, aunque ya no estés conmigo,
Os la dedico a vosotros, que habéis estado siempre,
Y a ellos, que seguro pronto llegarán.

Agradecimientos y reconocimientos

"Muchos años después, frente al pelotón de fusilamiento, el coronel Aureliano Buendía había de recordar aquella tarde remota en que su padre lo llevó a conocer el hielo".

Cien años de soledad
Gabriel García Márquez

Y es que, de forma magistral y sin quererlo, Gabriel García Márquez con el arranque de este libro, resume lo que es para mí el largo proceso de elaboración de la tesis, desde su comienzo más ingenuo, hasta su final más drástico. ¿Acaso no están ahora claros algunos de los agentes que dan inicio y fin a esta inverosímil historia? Con ello, debo empezar con la figura del padre, que muestra a su hijo un mundo nuevo y deslumbrante, como reflejan los destellos del hielo con la luz del sol. Gracias Carlos Llano Verduras y Jose Luis Zofío Prieto, por ser ese padre que me deslumbró con los reflejos del hielo.

Pero antes de llegar al día del fusilamiento, que para tranquilizar al que aún no ha leído la novela (acaba con final feliz), son cientos los personajes que interviene en esta historia, y hacen de ella un relato irrepetible.

Todo empezó mucho antes de mi llegada a la Universidad Autónoma de Madrid, por eso **quiero, y creo que debo,** agradecer y reconocer la labor que han tenido todos mis profesores, empezando desde el colegio (Colegio público Seneca), pasando por el instituto (Instituto público Lluís Braille), y terminando en la universidad en la que me licencie (Universidad Rey Juan Carlos).

No obstante, entre los pasillos laberínticos de la Universidad Autónoma de Madrid, se podría decir que es donde realmente arranco este proyecto. Mi primera parada fue en el **Instituto de Predicción Económica Lawrence R.** Klein. Gracias equipo/familia CEPREDE por acogerme como a uno más. Son muchas las personas que he conocido allí, y hoy me gustaría recordar algunas de ellas. Empezando por los compañeros de despacho, y aunque de forma más breve, han intervenido en esta etapa, hoy quiero recordar a: Martin, un venezolano con historias increíbles de su país; Antonia, la búlgara más toledana que he conocido nunca; Álvaro, un piloto que buscando su camino en la vida aterrizó a repostar por aquí; y sobretodo Juan, un rojiblanco empedernido con el que he compartido debates más o menos profundos. En segundo lugar, quiero recordar a esas personas que han tenido una vinculación más permanente con el proyecto, como son: la profesora Milagros, los profesores Julián y Juan Jose, Mar, Carmen, Jose, Jose Ros, Jose Antonio, Guillermo y Almudena, y por supuesto, Antonio Pulido, culpable de todo. Gracias a todos, porque habéis hecho que en la UAM me sienta como en casa. También quiero recordar a los socios de las distintas comunidades autónomas del proyecto C-intereg, en los que he encontrado la complicidad de un amigo. Gracias a las juntas semestrales de CEPREDE, he podido pasar buenos momentos con ellos. Gracias: Mª Concepción Ciruelos (Conchi), Carlos Casado, David Armengol, Prudencia Serrano, Moisés Fernández, Xabier Pascual, Vicent Ahuir, Maripaz Rojo…

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Esta parte del texto estará escrita en ingles, dado que la mayor parte de los actores que intervienen no hablan español.

- **Kiel (Germany) August-September, 2009**. This was my first research stay abroad; I spent two months at the Kiel Institute for the World Economy, under the supervision of Professor Dr. Eckhardt Bode. I really appreciate his hospitality and patience with my really first steps as a researcher. Thank you for your generosity. I will never forget the coffee-breaks and talks with you and the rest of your colleagues at your office. I would like also to remember other people who were an important support there: Micaela Kulesz, Mathias Weitzel, Wan-Hsin Liu and Christiane Krieger-Boden. Gracias/danke/谢谢.
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Y como desenlace de este apartado de agradecimientos y reconocimientos, debo agradecer a mi familia su apoyo y su guía. A mis padres, que a su manera, han velado por mí, alegrándose con mis triunfos y sufriendo con mis caídas. A mis abuelos, especialmente a mi abuelo Antonio (mi primer educador). A mis suegros, por su ánimo y generosidad. **A mi hermano**, que pese a ser siete años menor que yo, ha sido fuente de inspiración y admiración, y que ha constituido un elemento fundamental en mi visión del mundo.

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"The extension and use of railroads, steamships, telegraphs, break down nationalities and bring peoples geographically remote into close connection commercially and politically. They make the world one, and capital, like water, tends to a common level."

David Livingstone, reflecting on his experiences in Africa in the 1850s

Hace mucho, mucho tiempo…

El intercambio de bienes y servicios entre países era una tarea ardua y no exenta de peligros y contrariedades. Aduanas, aranceles, sabotajes, contrabando… eran sólo algunos de los obstáculos a los que el comerciante se tenía que enfrentar. Los ciudadanos de cada país apenas podían elegir entre un número limitado de productos locales, y el acceso a la variedad de los productos extranjeros era un lujo al alcance de unos poco…

Once upon a time…

The international trade of goods and services was a real challenge, an activity full of obstacles. Customs, tariffs, smuggling…, were just some of the impediments that traders had to face. Citizens of the different countries hardly could choose among a restricted array of varieties from their own country, while the access to the foreign products was a privileged available to very few…

No somos pocos los que soñamos con que en un futuro no muy lejano…

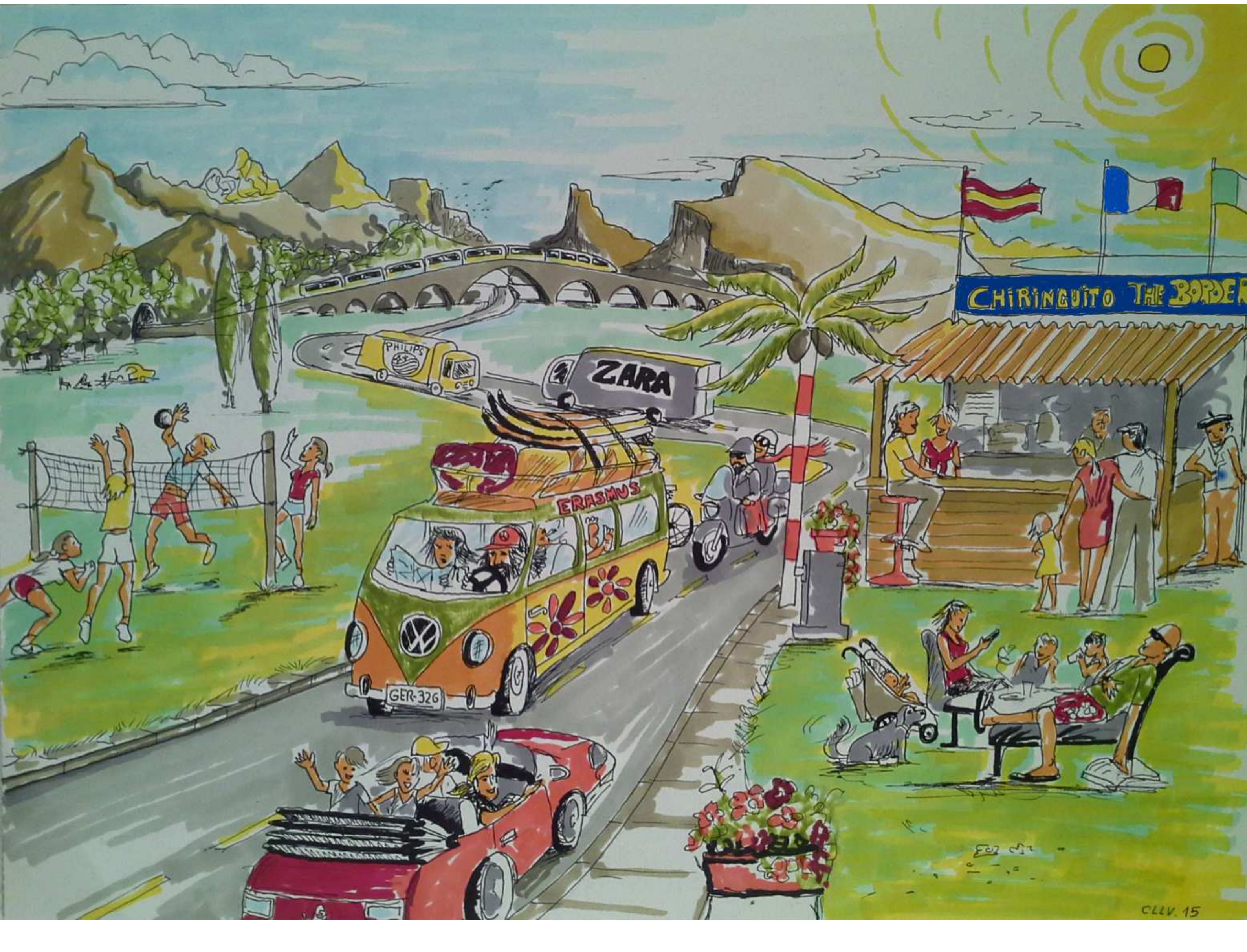
No sólo los bienes y servicios cruzarán libremente las fronteras nacionales como actualmente cruzan las regionales, sino también las personas, sus ideas y sus proyectos de inversión.

… pero incluso cuando todo eso ocurra…, muy posiblemente, seguiremos manteniendo el amor y predilección por lo propio, lo nuestro, lo más ligado a nuestra tierra y a la gente que nos rodea y con la que se desarrolla las vivencias más íntimas y cotidianas.

Many people dream with a future where….

Not just the goods and services but also citizens, their ideas and investment projects can freely cross political frontiers between countries in the same natural way than they do between regions inside countries,

… but even when that happen…, probably, we will still love more what is ours, and what is more deeply connected with our intimate and daily live



Resumen

La motivación de esta Tesis Doctoral surge del deseo de dar respuesta a dos preguntas que creemos de gran interés dadas sus implicaciones en términos de política económica: i) queremos cuantificar hasta qué punto las fronteras políticas siguen suponiendo un obstáculo significativo en las relaciones comerciales, y cuál ha sido el efecto de la crisis económica actual sobre ellas; ii) queremos saber si la apertura comercial de un país, en combinación con la configuración de la red de transporte de los países implicados, puede provocar que éste se enfrente a la disyuntiva entre la integración regional interna o la integración regional con las regiones extranjeras, lo que podría generar asimetrías en la distribución de la actividad económica del país.

En relación a la primera pregunta relativa a la cuantificación del efecto frontera, ponemos la atención en las fronteras administrativas que existen dentro de un país (entre sus regiones) y entre un país y sus socios internacionales (entre las regiones de los distintos países). A través de la estimación del efecto de las fronteras internas de un país (efecto frontera interno) obtenemos una primera aproximación de lo que varios autores (Hillbery and Hummels, 2008; Garmendia et al. 2012) han denominado el efecto "home-bias" (sesgo hacia los productos intra-regionales), donde la mayor intensidad de comercio dentro de las regiones (unidades intra-nacionales que forman los países) sólo se podría explicar a través de preferencias de los consumidores hacia los bienes locales, dado que no deberíamos esperar restricciones al comercio dentro de los países. Sin embargo, es difícil describir la presencia de barreras externas al comercio incluso entre regiones que pertenecen al mismo país, tales como las barreras a la información, o diferencias culturales, históricas, etc. [1] Adicionalmente, con la estimación del efecto de las fronteras con el exterior (efecto frontera exterior) medimos el grado de integración de una economía con sus socios internaciones, lo que es de especial interés cuando los socios pertenecen a un mismo sistema aduanero donde no existen a priori fronteras arancelarias.

Para poder responder a esta primera cuestión, se ha realizado un trabajo empírico que se fundamenta dentro de la literatura del efecto frontera, y que utiliza como principal metodología la estimación econométrica de diferentes especificaciones de la ecuación gravitatoria. Para ello que se han utilizando tanto datos de sección cruzada como de panel. Este análisis empírico toma como referencia el caso de la economía española y sus relaciones con la Unión Europea. En concreto, se han considerado las relaciones comerciales que se dan entre las comunidades autónomas dentro del territorio nacional y entre cada una de ellas con las regiones (Nuts 2, siguiendo la clasificación

[1] En España, por ejemplo, se da un intenso debate alrededor de las posibles restricciones al libre movimiento de bienes y servicios, fruto de decisiones tomadas a nivel regional (Nuts II), asunto que ha sido tratado incluso por la OCDE y otras organizaciones, y que ha sido el objeto de la reciente ley estatal de 2012; "Ley de Unidad de Mercado".

de Eurostat) de los 7 países europeos con los que España mantiene mayor intensidad de comercio. El periodo temporal disponible abarca desde 2004 al 2011, lo que nos ha permitido observar el efecto de la crisis en dichas relaciones comerciales.

En cuanto a la segunda pregunta a la que se enfrenta este trabajo de Tesis Doctoral, ésta tiene por objeto proporcionar un marco teórico diseñado para evaluar el efecto que tiene el proceso de apertura comercial sobre la redistribución de la actividad económica del país.

A la hora de abordar esta cuestión, se ha desarrollado un modelo teórico que combina la literatura de la Nueva Teoría del Comercio (NTT, según sus siglas en inglés) y la Nueva Economía Geográfica (NEG). Con este modelo teórico se pretende simular la respuesta de los agentes ante la apertura comercial a la hora de elegir su localización dentro del país. Para ello se tiene en cuenta: los efectos de la red interna, antes de la apertura comercial; los efectos de la nueva red, tras la apertura comercial; y los efectos de considerar dos sectores (uno móvil y otro fijo) que producen bienes diferenciados, y que a su vez, en ambos casos asumen costes de transporte en sus envíos.

<u>Estructura simplificada de la tesis: Los capítulos y su conexión</u>

La Tesis Doctoral que aquí se presenta está estructurada en cuatro grandes secciones: "Section I": Introducción, contextualiza la importancia del efecto frontera en un mundo cada vez más global, haciendo a su vez un breve repaso de las teorías que están detrás del comercio internacional, y poniendo en detalle el desarrollo teórico de la ecuación de gravedad formulada por Anderson and van Wincoop (2003). La segunda sección, "Section II", está destinada a la cuantificación del efecto frontera para el caso español. Esta sección está formada por tres capítulos, cada uno de los cuales se corresponde con tres artículos desarrollados de forma independiente pero interconectada, cuyo principal objetivo es encontrar la especificación de la ecuación de gravedad más idónea para estimar de forma eficiente e insesgada los efectos frontera para el caso español. La tercera sección, "Section III", cuenta con un único capítulo: "Trade Openness, Transport Networks and the Spatial Location of Economic Activity", y trata de dar respuesta a la segunda de las dos cuestiones planteadas en la Tesis; es decir, modeliza de forma teórica el efecto de la apertura comercial en la distribución de la actividad económica dentro de un país. Finalmente en la sección IV, pasamos a resumir los principales resultados obtenidos, subrayando los que consideramos factores clave para la elaboración de políticas económicas. Por último, repasamos las líneas de investigación que pasarán a formar parte de la futura agenda de trabajo, fruto de esta Tesis Doctoral.

Short summary

The motivation of this Doctoral Thesis emerges from the desire to answer two questions that we think are of great interest given its implications for economic policy making: i) to quantify to what extent political boundaries still constitute a significant obstacle to trade of goods, analyzing the impact of the current crisis on them and its spatial disaggregation; and ii) to know how trade openness of a country, together with the trading network configuration of the countries involved, can generate a trade-off between the internal and the external regional integration of a country, which may lead to asymmetries in the distribution of its economic activity.

Regarding the first question related to the quantification of the border effect, we focus on administrative boundaries that exist within a country (between its regions) and between countries (among regions of different countries). By means of the estimation of the border effect within a country (internal border effect) we get a first insight of what some authors have called the "home bias" effect (Hillbery and Hummels, 2008; Garmendia et al. 2012), where the higher intensity of trade within regions (sub-national political units that conform countries) is only explained by the preferences of consumers towards local goods. In so far as, inside of a country, one should not expect any type of tariff or non-tariff trade barriers but simple transportation costs, and the only factor that could explain the higher intensity of intra-regional trade versus inter-regional trade comes for the preferences of individuals. However it is not difficult to describe the presence of external barriers to trade even between regions within countries, such as information barriers, cultural and historical differences, etc[2]. In addition, through the estimation of the border effect between countries (external border effect) we obtain a measure of their level of integration, which is especially interesting when the countries involved belong to the same customs (and reciprocal) tariff system, where a priori there may be no tariff barriers.

To address the first question, we have developed an empirical study grounded on the border effect literature, where the methodological approach relies on the econometric estimation of various specifications of the gravity equation, using both cross-sectional and panel data. This empirical analysis takes as reference the Spanish economy and its relations with the European Union (EU, hereafter). More precisely, it considers the trade flows among the Spanish regions (Nuts 2, following Eurostat classification) and between them and those of the 7 main European

[2] In Spain, for example, there is an intense debate around the potential restrictions to the free movement of goods and services derived from specific decisions taken at the regional level (Nuts II), something that has even been commented by the OCDE and other national and international organizations, and has been object of a recent state law issued in 2012 on "The Unity of the Internal Market" (Ley de Unidad de Mercado).

trade partners of Spain. The time period available covers from 2004 to 2011, so that we can observe the effect of the crisis in the intensity of trade.

As previously mentioned, the other question is related to the effect of trade openness in the internal economic landscape of a country. More specifically we want to model the impact of the trade liberalization process on the economic distribution within the countries involved, given the characteristics of the transport network configuration that connects each of the regions with the foreign market.

When addressing this issue, we have developed a theoretical model that combines the literature of the New Trade Theory (NET) and New Economic Geography (NEG). With this theoretical model we have simulated the response of firms in their location decisions when the economy faces a trade liberalization process. To do this we have taken into account: i) the effects of the internal transport network of the country of interest, before trade openness takes place; ii) the effects of the new trading network, after liberalization; and iii) the effects of considering two sectors (one mobile and one fixed) that produce differentiated goods, and which in turn, both bear transport costs in their shipments.

Main structure of this Doctoral Thesis: chapters and their connection

The Doctoral Thesis is structured in four main sections: Section I: Introduction, contextualizes the importance of the border effect in an increasingly global world, making a brief review of the international trade theories, and developing in detail the theoretical foundation of the gravity equation performed by Anderson and van Wincoop (2003). The second section, Section II, aims to quantify the border effect for the Spanish case. This section is composed by three chapters, where each of them corresponds to different works developed independently, but ultimately interconnected, and whose main goal is to get the most appropriate specification of the gravity equation for estimating the border effects in the Spanish case. The third section, Section III, corresponding to a single chapter: 'Trade Openness, Transport Networks and the Spatial Location of Economic Activity', attempts to answer the second of the two main questions of this Doctoral Thesis; i.e. the theoretical modelling of the effect of trade liberalization in the distribution of economic activity within a country. Finally in section IV, we summarize the main results and highlights the main contributions of the present research, emphasizing what we believe are keys factors for policy making. Lastly, we list the lines of research that will take part of the future agenda, which emerged along the writing of this Doctoral Thesis.

Detailed description of each chapter

Chapter 1: Introduction

Throughout the introductory chapter we make a review of the central concepts and theories that provide the basis for the following sections. The first part of the introduction presents a summary with the main tendencies of international trade, jointly with the persistence of some obstacles that constitute the so-called border effects. Then, we briefly review the main trade theories in international trade, specially the New Trade Theory (NTT) and New Economic Geography (NEG), and revisit some stylized facts in the study of the border effects. Given the importance of the gravity equation to get an efficient and unbiased estimate of the border effects, we briefly review the evolution of this equation and develop in detail the approach described by Anderson and van Wincoop (2003).

Chapter 2: Toward a region-to-region international trade dataset for the Spanish case

One of the limitations that most authors have faced when they have tackled the task of estimating the effect of political boundaries is the lack of data, particularly at sub-national level. The European case is not an exception; to date, there is no data on region-to-region trade flows between different countries within the EU. Due to this limitation, several important questions regarding the dynamics of EU integration remain unsolved.

This chapter describes the methodology developed to produce data on region-to-region trade flows for the Spanish case, considering three possible destinations: intra-regional trade flows, inter-regional trade flows within the country and inter-regional international trade flows. Then, based on the new dataset, a number of analyses are conducted with the aim of testing the robustness of the data taking as benchmark other official statistics on region-to-country level. Finally, we conduct an exploratory analysis, with the purpose of analyzing the spatial patterns of the Spanish international trade, with the region-to-region specific breakdown.

Regarding the methodology used in the estimation of this database it should be stressed that it lies on the combination of actual data on trade and transport flows. Therefore we do not use any econometric model to obtain the data, what could affect the final results of the estimates.

The results of comparing our database of international trade with the official information (AEAT) show a high correlation between the flows. Having said that, the dataset used in the following chapter for the estimation of the border effect will be re-scaled, so the new dataset exactly matches the official trade data at the region-to-country level.

Chapter 3: Thin and thick borders in the EU Single Market: how deep internal integration is within countries, and how shallow between them

This chapter has a threefold goal. Firstly, it attempts to test results based on our database by replicating previous specifications such as McCallum's (1995) and Anderson and van Wincoop's (2003), which consider information on province-to-state data (Canadian provinces versus U.S. states), and following exiting work for the Spanish case, we replicate the specification of Gil et al. (2005). Secondly, it also aims to estimate border effects within the country and with outside (foreign) regions. Here we estimate these two types of borders separately. By doing so, we gain in terms of comparability with others works, which do not estimate simultaneously these border effects. In this part of the chapter, we have added two more detailed analyses, one studying the effect of the crisis on the magnitude of the border effects, and the other shedding light in the spatial dimension of the external border effect (by origin region and destination country, and by destination region and country). Finally, this chapter introduces a modest extrapolation exercise, that computes 'trade potential' levels that would be expected in a fully integrated Europe, and estimate how long would take each Spanish exporting region to achieve these hypothetical 'trade potential' magnitudes. To this regard, two alternative scenarios are considered: one using the growth rates of Spanish exports before the crisis (2001-2008) and other considering more recent trade growths (2011-2013).

The backbone of our estimations is the gravity equation defined by Anderson and van Wincoop (2003) and Feenstra (2002, 2004). From an econometric perspective, we follow Santos Silva and Tenreyro (2006) and use the Poisson Pseudo Maximum Likelihood (PPML) estimator as our dataset considers zero trade flows. As regards to the treatment of distance, we use the traditional logarithmic transformation of this variable and, following Hillberry and Hummels (2008), Llano-Verduras et al. (2011) and Garmendia et al. (2012), we also introduce its quadratic specification.

According to the results obtained when replicating the reference specifications, the signs and values of the coefficients align with the expectations. By revising McCallum's (1995) specification we estimate an external border effect of 24 (vs. McCallum's 22 for Canada-US). So that, on average, each Spanish region trades around 24 times more with another domestic region than with a third region in other European country. Similarly, when considering multilateral resistance terms (Anderson and van Wincoop, 2003 and Feenstra, 2002, 2004), we observe a significant decrease in the external border effect (to a factor of 14). In relation to Gil et al. (2005) specification, we find an external border effect of 13, while these authors obtained a somewhat higher external border effect (around 20).

Regarding the second set of results for the whole period (2004-2011), that includes zero values and uses data on region-to-region level, the external border effect is 8. Llano-Verduras et al. (2011) obtained a lower border effect (3.3) for region-to-country data, and slightly larger (4.9) for the case of province-to-country breakdown. In the estimates of the internal border effect, we found a great variability depending on whether the distance was included into the model under its log-transformation (where the internal border effect is not significant) or its quadratic form (where this border effect reaches a significant factor of 5).

Regarding the evolution of the external border effect before and during the current crisis, it is remarkable its increment during the years before the biggest adjustments (2007-2008), time in which the country was more focused on its internal demand. In 2009, domestic consumption fell deeply, what resulted in the reduction of the external border effect. More recently (2010-2011), we obtain again a slightly increase on the external border effect estimate, which coincides with a shy recover of intra-national trade and the focus of Spanish exporters on new (non-European) markets, less affected by the crisis.

The border effect by destination country and/or destination region show striking results, by which Spanish regions appear to be more integrated with the set of countries and/or regions located in the so-called 'Blue Banana'. Instead, despite the proximity and the relatively high intensity of trade with French regions, actual trade flows are lower than those estimated by the model.

Finally, from our extrapolation exercise to measure the number of years required by each Spanish region to achieve the same level of integration with European regions that exists between Spanish regions, we observe a large variability in the results. According to the pre-crisis growth rates (2001-2008), the range of years needed for each region is between 30 years for Galicia and 425 years for Asturias. Alternatively, if we consider the recent evolution of regional exports (2010-2013), the range is even higher, from 31 years in Castilla-La Mancha to 1.337 years in Aragon. These results concur with what would be expected, since the main European partners of Spain are deeply affected by the current crisis, what limits their domestic demand.

Chapter 4: The Border Effect and the Non-linear Relationship between Trade and Distance

Here, we estimate the two kind levels of border effects, internal and external, simultaneously. However, the main goal of this chapter is to study the non-linear effect of transport costs (proxied by distance) on trade. We follow those authors who have attempted to address this issue (Hillberry and Hummels, 2008; Llano-Verduras et al., 2011 and Garmendia et al., 2012; Henderson and Millimet, 2008). Particularly, Henderson and Millimet (2008) are concerned about the consequences of this non-linearity on the estimation of the border effects; therefore they go one step further by adding more flexible (non-parametric) methods, and concluding that more research is needed in this area. This chapter contributes to shed light on this issue, testing alternative ways to deal with this non-linearity.

Specifically, we have divided overall distance into various segments (or legs) under three different criteria, all of them completely exogenous to trade. By doing this, we attempt to identify different slopes for the trade-distance relationship. As robust-check, we incorporate two more alternative regressions: first, we include piecewise (or spline) regressions, and secondly, semi-parametric regressions, where the nonparametric part corresponds to the variable of distance. Additionally, we have employed Hausman and Taylor (1981) procedure to handle the likely existence of any kind of (right-side) endogeneity problem.

For these estimates we have used data for the period 2004-2008, to avoid the effect of the crisis. The results show that the treatment of distance matters, especially along the first kilometers (short shipments). According to the estimated coefficients for the different segments of distance, these follow the expected pattern: all negative, but decreasing with distance. The results of the spline procedure and semi-parametric regression (data-driven procedures) for the border effects' coefficients do not turn out to be very different from those obtained by dividing the distance following the first criterion. In conclusion, the effect of national borders is estimated by a factor of 4, while the international boundary effect is also around 4.

With regard the evaluation of endogeneity issue, the result for the Hausman test confirms the need to instrument the product of the GDPs. Once we tackle the endogeneity problem, border effect estimates remain close to previous results; in the case of internal borders, this reaches a factor between 2 and 3, and the external, around 5.

Chapter 5: Trade Openness, Transport Networks and the Spatial Location of Economic Activity

This chapter analyzes to what extent the effect of trade openness of a country, together with its initial network configuration as well as the new (and extended) network resulting from progressive trade liberalization, determine the relocation of economic activity across its regions. Paradoxically, the empirical evidence remarks that trade openness may promote a more equal distribution of economic activity between trading countries (convergence across countries), but at the same time establish the emergence of large inequalities within countries (i.e., divergence across regions within countries). In this regard, along with the importance of promoting a single free market, the European Commission is concerned about these possible negative implications in terms of regional inequalities, more frequent in the peripheral countries.

The methodology presented in this chapter is based on a NEG/NTT model with two economic sectors, where both sectors incur transport costs. Following Fujita, Krugman and Venables (1999, chapter 7), our model adds a certain degree of differentiation also for the commodities produced by the immobile sector, which provides a more realistic scenario. In this setting, we study two opposite internal topologies: the triangle topology or homogeneous space, where all domestic regions are identically distributed with respect to each other (i.e., space is neutral); and the star topology or heterogeneous space, where one of the domestic regions enjoys a privileged location in the trade network. Keeping in mind the Spanish case, but with the highest degree of simplicity in the model, we consider a network that describes the centralized position of Madrid in the domestic networks (e.g., a shipment from Barcelona to Andalusia, passing through Madrid), against the location of Cataluña and País Vasco, better positioned for international trade with the European core.

Regarding the results, in both cases (triangle or star topologies), trade liberalization tends to favor border regions. However, this result is less evident when the core region in the star topology is the region that initially agglomerates the production. In fact, the hub status of the inner region can be re-forced with the trade openness. In short, given the parameters chosen, the final configuration will depend on both the network and the initial distribution of the economic activity.

Chapter 6: Final remarks, policy implications and future research agenda

In this last chapter, which belongs to section 4, we summarize the main results and contributions of this Doctoral Thesis, which can be classified as follows: i) the compilation of a new dataset for estimating region-to-region trade flows; ii) the presentation of new estimates for the internal and the external border effects, departing from the initial setting proposed by McCallum (1995), using for the first time European region region-to-region flows; iii) methodologically, testing a broad range of alternative treatments for the non-linear relationship between trade and distance; and iv) developing a new theoretical model for the case of a core-periphery structure, that studies the effects of the opening process to international trade ion the location of economic activity. Once we have reviewed the more remarkable results we dare to suggest relevant policy implications. To conclude this last section we review all the analyses that have been addressed in this Doctoral Thesis, and that will take part of a future research agenda.

TABLE OF CONTENTS

List of Tables

List of Figures

List of Abbreviation

CES	Constant Elasticity of Substitution
c.i.f	Cost, insurance, freight
EU	European Union
EMU	European Monetary Union
FDI	Foreign Direct Investment
f.o.b	Free on board
FTA	Free Trade Agreement
GAT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
NAFTA	North American Free Trade Agreement
OECD	Organization for Economic Co-operation and Development
ROW	Rest of the World
ROS	Rest of Spain
UNCTAD	United Nations Conference on Trade and Development
US	United States
WTO	World Trade Organization

SECTION I: INTRODUCTION

1 Introduction: International Trade, Border Effect and Gravity Equation

1.1 Growing International Trade

"Whatever the reasons may be and whatever the future may hold, the fact that even the relatively innocuous Canada-U.S. border continues to have a decisive effect on continental trade patterns suggests that national borders in general continue to matter".

McCallum (1995)

International trade and regional inequalities have been two phenomena that have undergone a quick expansion since the mid-70s. In particular, international trade has shown a strong development as consequence of the recent globalization process and the fragmentation of the global value chain; facts that have taken place in a context of notable progresses in transport facilities and in the information technologies. These factors have favoured, to a large extent, the relationships between countries, what in data has resulted in a growing intensity of international trade since 2002. Between 2003 and 2008 world international trade reached its highest and more stable growth rates, which correspond to an annual average rate of around 16%. The arrival of the current crisis has brought strong fluctuations in the intensity of international trading transactions. However, recent data (2010-2013) seems to suggest the return towards the pre-crisis rates. The three main economies that contribute most to international exports are the European Union (EU27) with a 16%, which is one of the largest integrated markets; China with a 13.8% and United States (US) which accounting for 11.2%, in 2010. A similar picture emerges from the import side.

In terms of GDP, the international exports of the world and its division into three groups (developing, transaction and developed economies), has grown much faster than the GDP, especially for those countries that belong to the group of developing countries (24% in 1980 to a 33% in 2012), and more recently, for those countries that are classified as transaction economies (6% in 1980 to a 30% in 2012).

There are evidences that the recent growth of international trade is creating a self-reinforcing effect in the international exchanges by generating relevant improvements in trade infrastructures and in the institutions of the countries involved. Hochman et al. (2013) find how trade leads to improve infrastructures, especially in countries with firms with high productivity or low fixed costs, whereby domestic firms can better compete internationally. Other important figures are the Free Trade Agreement (FTA), which can emerge as consequence of proliferative international interchanges, and the current World Trade Organization (WTO), which followed the initial General Agreement on Tariffs and Trade (GATT), both set up to promote trade world. As a point of reference, around 300 economic integration agreements have been notified to the GATT/WTO since 1947, being almost half of them in the last 20 years. Subramanian and Wei (2007) find that WTO membership has an important positive effect in trade, resulting in a 120% of additional world trade. They use information for the period 1950-2000 and estimate a gravity equation whose results point out that international trade between two WTO members is around 57% more intense, while international trade between two FTA is around 80%. Kucharčuková et al. (2012), who also employed a rich augmented gravity model, taking into account the effect of multiples factors related to policy, geographical, and institutional indicators, over a sample that covers 82% of total worldwide trade flows during 1997-2004, find that trade between two WTO members is around 50% higher than trade between non-members, anything else equal. In the same paper, these authors also quantified that joint membership in a FTA boosts bilateral trade around 120%. At this point, it is relevant to highlight that the fast growth of international trade has generated some concerns among various policy makers, who are particularly worried about the likely rise of regional inequalities from a hasty trade openness, especially for those lagged regions which neither enjoy a good access to trading hubs (e.g., ports, airports, railroad and road infrastructure), nor to the major markets.

However, still nowadays in a context much more globalized where one could believe that the initial obstacles to trade have been overcome, due to the reduction of the traditional transport costs and in information costs; significant barriers persist hampering the commercial integration between countries. Empirically, many authors have found important differences between the intensity of intra-national and international trade, even among countries that belong to the same FTA, once controlled by distance, the size of partners and other factors. Of course, this fact is even more emphasized when it is compared to the inter-national transaction between countries that do not belong to the same WTO geographical area; as it is the case of South America, Africa, the Middle East and the Commonwealth of Independent States, whereas the trade between the countries belonging to the common area has increased, the trade toward external countries remains small. The range of barriers that can be hindering international transactions is still broad. Starting from the most evident tariff-barriers, and passing to more subtle obstacles, like differences in technical standards or excessive administrative burdens what result in harmful delays for perishable goods.

Turning to the EU data, the weight of the extra-European trade (exports+imports) over the total trade between the European partners only represented around 51% until 2007. With the recent crisis this has increased to a 75% in 2011, before falling back to 62% in 2013. The recent tendency seems to respond to the strong depression of the internal European demand, which has prompted European producers to look for new markets less affected by the crisis, like Asian, American and African markets. In this regard, it is worth reviewing all the efforts done by European bodies, in particular by the European Commission, to foster the internal integration. After the initial steps toward the European economic integration, once World War II (WWII) was ended, such as the European Coal and Steel Community agreement in 1951 (see **Table 1.1** for a list), the more relevant developments toward trade unification started with the elimination of the tariffs barriers in 1968. Since then, for the EU's bodies one of their main concerns has been regional inequalities[3]. However, the persistence of some subtle impediments (non-tariff barriers) coming from differences in national regulations, which hamper free trade between countries, pushed to UE's authorities to look for the identification and elimination of these artificial barriers. With the aim of getting a much more integrated area, the European Commission addressed this issue in the White Paper of 1985[4], which identified the main barriers and proposed many ways to prevent them. A year later, in 1986, the Single Market Act emerged, in the same year that Spain became member of the EU. The goal of this program was to eliminate those non-tariff barriers by the end of 1992. For the European Commission, regions (sub-national units of countries) are the reference units, not countries; this gives an idea of one of the main worries of its officials.

[3] Regional inequalities are basically understood in terms of disparities in income levels, unemployment rates and standards of livings. The Structural Funds are just an example of the regional support provided by European authorities.

[4]Completing the Internal Market, COM (1985) 310 final, 14 June 1985. It is one of the White Papers from the Commission to the European Council.

Table 1.1. Timeline of European Union Integration Process

1951	ECSC	European Coal and Steel Community Members: Belgium, France, West Germany, Italy, Luxembourg and the Netherlands
1955	EEC Euratom	European Atomic Energy Community European Atomic Energy Community First steps toward establishing the common market, customs union and free movement of capital and labor.
1958		Creation of a Free Trade Area
1962		The EEC adopts regulations to provide a common market in agriculture, as well as to provide financial regulation and rules to govern competition
1965	EC	European Communities. It combines ECSC, EEC and Euratom
1968		The custom union
1972		The EC launches its first attempt to harmonize exchange rates.
1973		New members: Denmark, Ireland and the United Kingdom
1977		Custom duties are abolished between the nine members
1979	EMS	European Monetary System Through the Exchange Rate Mechanism (ERM) the members (except to UK) coordinate a central exchange rate. This constitutes the basis for the Euro.
1981		New member: Greece
1986		New members: Portugal and Spain
1987	SEA	Single European Act It is meant to reinforce the progress toward the common market. 1992 is the deadline to get the single market (freedom of goods, services, people and capital)
1992	EU	European Union
1993		The Single Market
1994		EMI: European Monetary Institute It is established to guarantee the coordination of the monetary policies of national central banks and to promote the creation of the European Central Bank.
1995		New members: Finland, Austria and Sweden
1998	ECB	European Central Bank
1999	EMU	Economic and Monetary Union The Single Currency Members involved: 11 out of 15; Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain.
2002		12 EU states introduce the Euro coins and notes as legal tender.
2004		New members: Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland and Slovenia.
2007		New members: Bulgaria and Romanian
2013		New members: Croatia

According to the findings of some papers (Rodriguez-Pose and Gill, 2006; Melchior, 2008b, among others), although the divergence or convergence process is country specific, in general the EU integration trends have shown a convergence process among the countries, but a divergence process within countries, where a core-periphery pattern around the *Blue Banana* is latent. Brülhart (2011) pointed out in his paper that the biggest worries of trade liberalization are "that trade liberalization increases within-country spatial inequalities, and that it favours regions with better access to international trade routes".

Undoubtedly, the interest of studying the EU integration process comes from the fact that it has meant a stretched and significant experience of trade integration. This thesis, on the one hand, empirically studies in a comprehensive way the integration process of Spain in the EU; a country whose integration was a year before the implementation of the Single European Act (SEA), that brought a progressive liberalisation in many of its activities (from tariff and non-tariff barriers) with the rest of EU's members, and a country that was also one of the main beneficiaries of the cohesion funds before the integration of the CEEs countries. On the other hand, this thesis presents a theoretical model to evaluate the effect of trade liberalization on the internal regional distribution of economic activity within a country given its transport infrastructure network configuration. In this exercise, the network configuration chosen is inspired in the centrality configuration of Spain.

The remaining of the chapter is as follows: in section (1.2), we briefly describe the main milestones in explaining international trade relations, through the review of trade theories from the oldest to the newest approaches. Section (1.3) discusses a series of stylized facts related to the uneven distribution of trade, more concentrated between domestic boundaries than through international ones (regions, countries, etc.), in the context of difference geographical or commercial areas (Europe, North America, OECD, etc.). Section (1.4) describes the origin and evolution of the commonly used gravity equation, which has served as an appropriate framework to control for the traditional elements that drive trade relations, and quantify the level of integration between various scales of political units (countries, regions, etc.). We pay special attention to Anderson and van Wincoop's (2003) micro-foundation approach of the gravity equation.

1.2 Brief general overview of the trade theories

Since the 18th century, when the industrial revolution started with its production in large scale and subject to increasing returns, and the mercantilist theories were overcome, many economists have attempted to explain the existence of international trade and its implications in the involved economies. In short, two have been the main mechanisms considered as drivers of international trade: On one side, the differences among countries (basically, in terms of technologies or factor endowments), which predict the benefits coming from the specialization in the production and export of those products where a country has an relative advantage, and the import of the goods where the country is less efficient. Therefore, international trade emerges as way to ripe the gains from specialization according to natural endowments of the countries involved, which seems more efficient than an autarky situation where the own country has to supply the whole array of the products required for a domestic economy. On the other side, a more recent driver of international trade is based on the similarities among countries. In fact, we can see that most of the trade is between countries that are very similar in terms of endowments or technologies. From the demand side, the love for variety (in products), and from the supply side, the production of differentiated products under economies of scale at firm level, foster international exchanges between very similar countries (i.e., intra-industry trade). In other words, whereas the Classical Trade Theory focused on natural advantages, called '*first nature'* in the literature (Cronon, 1991), which are related with natural endowments of a country, such as climate features, raw materials and natural means of transportation, and that generate inter-industry trade, the New Trade Theory (NTT) and the New Economic Geography (NEG) initially explain second nature advantages resulting from economic forces, by doing away with first nature advantages. This is achieved by considering fully symmetric countries or regions in terms of size, preferences and technology, and without considering an explicit spatial topology (i.e., models are presented for two countries in an abstract and dimensionless space). Both types of models allow the study of '*second nature inequalities'*, which are the results of human actions; sometimes improving '*first nature'* advantages if the model explicitly considers the multi-country and/or multi-region case with a spatial topology, and that are more related with intra-industry trade, which is the trade of products belonging to the same class or sector of products (e.g., chemicals, motor vehicles,…).

The evolution of trade patterns in the growing international trade has triggered the emergence of subsequent branches of theories, trying to explain the predominant realities of each period. This does not mean that the most recent theories substitute the formers; instead the old theories serve as complement to the new ones in some aspects. As previously stated, one can distinguish two groups among theories explaining the existence of international trade: Classical Trade Theories and the Modern Trade Theories. Although, both branches play a role in explaining international trade, here we are just going to focus in the Modern Trade Theories, since currently they contribute to explain the biggest percentage of international transactions.[5]

1.2.1 Modern Trade Theories

Until the late 70's and early 80's international trade theory was dominated by the so-called Classic Trade Theories, which argue the prevalence of two-way trade for different industries based on the comparative advantages that arise from differences across countries (differences in technology for Ricardo (1817), and in factor endowments according to Hecksher-Ohlin, (HO), hereafter). Both models were considered as paradigm and enjoyed the greatest popularity. The HO model was the most prevalent by the end of this period, since it represented an improvement over the Ricardian model by being able to explain why relative costs could differ across countries and by introducing a more complex model: 2 countries, 2 products and 2 factors of production. Developed between 1919 and 1924, HO's model states that a country will specialize in the production and export of that good that requires an intensive use of the relative abundant factor (labor or capital) in the economy. However, the empirical studies seemed not be able to validate these theories, since the domestic and international reality had changed. At this point, several authors (Grubel and Lloyd, 1971, Balassa, 1966) started to introduce new elements in the contemporaneous framework, closer to the actual reality, such as economies of scale in production, product differentiation and imperfect competition.

So far the classical models assumed that the comparative differences were the drivers of trade between countries, being higher the intensity among countries the greater were their differences. Thus, these theories were valid to explain the inter-industry trade, i.e., exports and imports of different sectors between countries. However, the empirical evidences in that time started to show the predominance of intra-industry trade (Grubel and Lloyd, 1971); i.e., exports and imports in the same sector between countries. The new patterns of trade showed a relevant growth of trade between countries with similar preferences, technologies, factor endowments and competitive advantages. This made that a relevant part of the international trade could not be explained by the classical trade theories.

In this background, the modern trade theories are based on the empirical evidence, and try to identify the main drivers of the intra-industry trade among very similar countries. The New Trade Theory (NET) and the New Economic Geography (NEG) build their fundaments on a framework of imperfect competition –monopolistic competition- where producers are able to supply

[5] Note that here we just make a brief review of the literature, taking special attention on those works that can have a connection with the next chapters of this thesis. In the same way, we understand that the models quoted here have already been described by the own authors. Additionally, there are useful papers that make a deeply review in the literature (Fujita and Thisse, 1996; Neary, 2001).

differentiated products, thereby consumers enjoy of a greater diversity, since the love variety; and firms produce under economies of scale, what makes profitable the production in large scale. Additionally, the modern trade theory takes into account the tariff and non-tariff barriers, whose abolition can be a key element for the international pattern of specialization of production.

- **The New Trade Theory**

The first bases of this new literature rely on the seminal paper by Dixit and Stiglitz (1977), which provides a tractable formalization of the Chamberlinian monopolistic competition model (1950) where, on the demand side, firms face symmetric CES preferences, while on the production side, firms enjoy increasing returns to scale technologies, this latter issue is modeled by a production function with set-up costs and constant marginal costs. Due to the fixed set-up costs that firms bear, they need to sell large amounts of production to ensure that they recoup them, what can be easier when they offer differentiated and diverse products.

The seminal paper by Dixit-Stiglitz (1977) has generated a thriving research in the field. Adopting the Dixit-Stiglitz model, Krugman (1979) developed a monopolistic competition model for an open economy. This model has the virtue of combining the main elements of the Dixit-Stiglitz's work with the reinforcing effects of the foreign market. Therefore, for one side, the model embeds the symmetric production function of firms based on increasing returns to scale into an international open context, where firms can serve bigger markets, allowing them to produce in a more efficient scale. On the other side, since consumers like variety, they could enjoy a greater array of goods coming from foreign markets. Moreover, due to the increase of competitors, consumers also benefit from lower prices.

In a subsequent paper, Krugman (1980) introduces in a multi-country model the effect of transport costs. The inclusion of this friction to trade, until certain level, brings the result that production tends to concentrate close to the consumers to avoid transport costs and be more competitive. At the same time, consumers want to locate closely to the variety, what allows them to enjoy lower prices, and then, higher real wages. Being therefore in the crowded markets where the production activity agglomerates. In that way, in a context of increasing returns to scale, large markets turn to be net exporter locations (the so-called home-market effect).

The final combination of these works (Dixit-Stiglizt, 1977, Krugman, 1979, 1980 and 1981) is known as the Dixit-Stiglizt-Krugman model, representing a relevant breakthrough in explaining the international trade between very similar countries by incorporating elements more according to the contemporary reality: economies of scale, imperfect competition, transport costs, love for variety modeled by CES preferences, and reflecting Lindner's (1961) assumption whereby similar countries have similar preferences, and the effect of the actual location of the economic activity. It must be noticed that the assumption of economies of scale supposes the subsequent reduction of the unitary production costs with the expansion of the market. For the consumer, a rise in welfare occurs as consequence on the increasing number of varieties. Therefore, by exploiting the economies of scale, trade between industrialized countries or developed countries, i.e., with very similar demands, can be explained.

- **New Economic Geography Theory**

The New Economic Geography theory tries to explain the uneven distribution of economic activities across space within a country (cities, regions, etc.), taking into account variables such as the accessibility of the locations and the transport costs. The first NEG models are similar to classic and new trade theories, where two of the first contributions are by Myrdal (1957), with the concept of "circular and cumulative causation theory", which claims that the locations that hold most economic activity are usually the location with higher market potential, and by Hirshman (1958) with the concepts of "forward and backward linkages". New Economic Geography formalizes this cumulative self-reinforcing mechanism, whereby an excessive agglomeration of firms attracts more population, which in turn expands market demand and makes these places more profitable than others, all of this in a context of imperfect competition, increasing returns to scale, trade costs and preference for variety.

In comparison with the New Trade Theory, these models include endogenously the relocation of workers and firms, allowing their migration within regions, what brings a broad range of locational patterns depending on the predominance of agglomeration or dispersion forces. So then, instead of considering a given immobile labor endowment, as under New Trade Theories, the New Economic Geography allows for free labor mobility between the regions of countries, or even across countries. That is, instead of assuming an initial comparative advantage in labor factor, this emerges from the location decision of the economic agents (consumers and firms).

In such a setting, some authors (Fujita, 1988; Krugman, 1991 and Venables, 1996, among others) developed general equilibrium models under monopolistic competition embedding the framework of Dixit and Stiglitz's (1977) model. Probably the most influential model that has generated a vast stream of new breakthroughs is the core-periphery model of Krugman (1991). This introduces a causal cumulative mechanism that shows how regions initially symmetric in their underlying structures can endogenously turn out into rich "core" regions (industrialized) and poor "peripheral" regions (agricultural).

In general, under this kind of models, the long-run equilibrium of the spatial distribution of economic activities (core-periphery pattern versus disperse equilibrium) depends on the centrifugal and centripetal forces considered. Where the centripetal forces refer to the factors that make more attractive the agglomeration of companies and consumers, emerging from the Home Market Effect (economies of scale, transport costs, differentiation of the products), and the centripetal forces refer to the factors that constrain the concentration, such as competition effect, relative higher transport costs, labor costs, land or commuting costs, or the immobile demand of farmers (Henderson, 1974; Krugman and Livas-Elizondo, 1996). Therefore, these models can yield different patterns of location of the population depending on the net effect of the two sets of opposite forces. As relevant forces, often mentioned, that affect the agglomeration process, it must be highlight the forward and backward linkages. Where backward linkages are understood as the interest of companies of settling close to consumers, in order to avoid transport costs and be more competitive by exploiting the large scope of increasing returns in production. The forward linkages (Venables, 1996; Puga, 1999), from the consumers' side, are related to the tendency of inhabitants to locate in places with a better access to commodities, which in turn increases their real wages. At the same time, from the companies' side, they tend to agglomerate to save on transport costs in their intermediate consumptions and to have a large pool of qualified workers.

Regarding the effect of open liberalization or the alleviation of tariff and non-tariff barriers, it is done in a more comprehensive review in the last chapter of this thesis, where we study the effect of openness in the spatial distribution of the economic activity in multi-country multi-regional setting, with two differentiated sectors and explicitly modeling the world trade network.

1.3 Inter-national versus intra-national trade integration: some stylized facts on the border effect literature

It is a reality that economic activity is not evenly distributed across countries or even among the regions within countries. Economic geography seeks to find the explanations that lead to a spatial development of the economies resulting in unequal patterns. And trade theory tries to find what factors affect the national and international trade relation between locations. Under both prisms, the explanation to the first independent economic centers comes from features that are rooted on their own ground; we are mainly referring to the endowments of natural resources, which normally condition the capacity of production, and consequently the extent of export and import flows. Nevertheless, even nowadays where we live in a context more open to the circulation of people, ideas, goods, and less dependent on the initial factor endowments, second nature factors are reinforcing the concentration of economic activities in relatively small areas, being trade not completely free across political barriers, and involving places between countries relatively similar in terms of manufacturing commodities produced and traded.

1.3.1 A review of the stylized facts around the world

The existence of large border effects is one of the main puzzles of international macroeconomics (Obstfeld and Rogoff, 2000). After the striking results found by the seminal paper of McCallum (1995), a broad group of researchers have attempted to quantify and/or resolve the *border puzzle*. McCallum (1995) found that trade between any two Canadian provinces was (on average) 22 times greater than trade between any Canadian province and any U.S. state, once controlled for distance and the sizes of the partners. The surprising of this result comes from the fact that both countries share many cultural and economic similarities, therefore they were supposed to represent the most integrated countries. As said, since then many authors have repeated the exercise with other countries[6] and other spatial units, whether countries, regions, provinces or even zip codes (see **Table 1.2** for a summary). Their findings indicate a tendency for countries to sell and buy products originating from their home country consumers and suppliers. In this section we highlight some of the main results found in the literature of border effect depending on different geographical areas and emphasizing the spatial scale level (countries, regions, provinces, or zip-code) considered in each case.

- **The external border effect between the U.S. and Canada**

After the seminal contribution of McCallum (1995), other authors, such as Helliwell (1996, 1998), Hillberry (1998) and Anderson and Smith (1999), have confirmed the existence of the *external border* effect between Canada and United States, using province-to-state data, and considering just one international border. In his estimate, Hillberry (1998) used data from the commodity transportation survey carried out by the U.S. Transportation Department, finding similar results than McCallum and Helliwell. Then, Helliwell (2001) quantified the *internal* and *external border* of the Canadian provinces with regards to the U.S. states for the period 1991-1996. He found an *external border* effect that suggests that a Canadian province traded about 15 times in 1991 (and 10 times in 1996) more with other domestic subunits than with a state from U.S.

[6] Japan (Okubo, 2004), U.S. (Wolf, 2000; Hillberry, 2002; Hillberry and Hummels, 2003; 2008; Millimet and Osang, 2007), the European Union (Chen, 2004; Nitsch, 2000, 2002; Evans, 2003), Germany (Shultze and Wolf, 2009), Russia (Djankov and Freund, 2000) and Brazil (Daumal and Zignago, 2008), among others.

Table 1.2. Selected Papers on External Border Effect for North America, OCDE, Europe and Spain, Classified by Data Type and Spatial Unit.

Paper	Country	Sectoral analysis	Time period	External border effect
		Region-to-region		
1995. McCallum	Canada-United States	No	1988	22
1996. Helliwell	Canada-United States	No	1988–1990	22
1998. Hillbery	Canada-United States	No	1993	20
2001. Helliwell	Canada-United States	No	1991–1996	15–10
2002. Head & Mayer	United States (Wolf, 1997, 2000)	Yes	1997	11
		Country-to-country		
1996. Wei	OCDE	No	1982–1994	10-2.6
1997. Helliwell	OCDE	No	1996	13
2000. Nitsch$_a$	EU-10	No	1979–1990	7–10
2000. Head & Mayer	EU-9	Yes	1976–1995	30-11
	EU-12	Yes	1993–1995	13
2004. Chen	EU-7	Yes	1996	6
		Region-to-country		
1999. Anderson & Smith	Canada-United States	No		12
2005. Gil et al.	Spain (17 regions), Rest of Spain(*) and OECD-27	No	1995–1998	21
2003. Minondo	Basque Country, Rest of Spain(*), 201 countries	No	1993–1999	20–26
2007. Helble	France, EU-14 Germany, EU-14	No	2002	8 3
2010. Requena &Llano	Spain (17 regions) OECD-28	No Yes	1995 & 2000	13
2010. Ghemawat et al.	Catalonia, Rest of Spain(*), OECD	Yes	1995–2006	55
2011. Llano-Verduras et al.	Spain (17 regions; 50 provinces, OECD)	No	2000 & 2005	40

(*) Rest of Spain considered as a country, with total exports computed from one Spanish region to the rest of Spain (ROS). The purpose of this aggregation is to measure external border effects when region-to-region data is not available.

Some years later, the literature of border effect and gravity equation was revolutionized by Anderson and van Wincoop (2003) and Feenstra (2002, 2004), who digging deeper in the theoretical underpinnings of the gravity equation, showed that the border effect was overestimated when the model specification does not control for the effect that non observable price indices exert on each specific trading partner (multilateral resistance), and when it was just considered the intra-national trade of a relatively small open economy as Canada (in comparison with U.S.). The intuition of the latter fact is simple; even a little increase on the international barrier between Canada and United State implies a large multilateral resistance for the Canadian provinces, due to their dependence on the rest of the world.

- **The external border effect between OECD countries**

Wei (1996) studied the external border effect in the context of the OECD countries for the period 1982-1994, finding that -on average- OECD's countries trade 10 times more with themselves than with other countries. Then, using an "augmented" gravity equation that includes additional variables such as remoteness, common language and common frontier, the border effect dropped to a factor of 2.6. Helliwell (1997) used the same dataset of Wei (1996) for the year 1990. He considered a more complete specification of the border effects and included a more elaborated variable of common language, as well as a different remoteness measure. In his work he found an external border effect roughly 12, what means that their internal trade among OECD countries is 12 times higher than the trade that they have with third countries.

- **The external border effect between European Countries**

In Europe, Nitsch (2000) measured the impact of national borders on the international trade between the EU countries for the period of 1979-1990, finding that on average their intra-national trade was around 10 times larger than their international one. Then he analyzed the evolution of this effect over time, considering two different samples: for the period 1979-1990 (not including Spain and Portugal); and for 1983-1990 (including the two latter countries). His results showed that the border for the first sample dropped gradually from 9 to 7, while for the second reduced from 12 to 11. For his estimation, Nitsch, in contrast to previous authors (Wei, 1996; Wolf, 1997), used alternative measures of the intra national distance, which defined it as the square root of a country's area multiplied by some scaling constant. Similarly, Head and Mayer (2000) focused on the sources of the Non-Tariff Barriers (NTB) to trade in the EU. For the average flows in 1984-86, they found that European purchases tended to be 16 times higher from the domestic country than from other European country. The same effect for the period 1993-95 fell to a ratio of 13. Additionally, Head and Mayer (2002) showed how the estimation of the border effect was affected by the distance measure (mainly in the case of the internal distance). They also found that the border and the adjacency effects in Europe have been reduced over time, but they have not fully disappeared. Chen (2004) focuses in the estimate and explanation of border effects between 7 EU countries using manufacturing industry specific flows for 78 industries for the year 1996. She found that controlling for multilateral resistance, the size of the border effect decreases. She got a border effect that suggests an intra-national trade roughly 6 times larger than the inter-national trade, *ceteris paribus* the rest of variables. Finally, we refer to Helble (2007), who estimated the border effect for France and Germany. In his research he works with an extensive data on trade between each region and 14 EU countries, combining inter-national trade and intra-national transport flows. His results suggest that France trades roughly 8 times more with itself than with any other EU country, and Germany does about 3 times.

- **Previous investigations in the case of Spain**

Regarding the border effect in Spain, Gil et al. (2005) examined the magnitude of the external border effect using bilateral trade flows between each of the 17 Spanish regions (Nuts 2) and 27 OECD countries for the period 1995-1998. Using panel data regressions with random effects, they found that, on average, exports from a Spanish region to the rest of Spain (as a whole) exceed 19 times the inter-national exports, while a factor of 54 was found for imports. All these results were obtained controlling for size, distance, contiguity, being an island or a member of the EU or EFTA.

Afterwards, at least four papers revised the Spanish border effect also using region-to-country trade flows. Requena and Llano (2010) estimated *the internal and external border effect* at the regional level (Nuts 2), using industry specific flows. Their dataset includes intraregional trade flows and interregional trade flows for each of the 17 Spanish regions, and the international trade flows of each of these regions with the OECD (28) countries. The authors found that, on average, the internal border effect reaches a value of 17, indicating that a Spanish region tends to trade 17 times more with itself than with the rest of the country. Their *external border* effect indicated that a Spanish region tends to trade 13 times more with the rest of the country (as a whole) than with any other country in the sample. With a similar dataset, Ghemawat et al. (2010) focused on Cataluña's *external border effect*, comparing the intensity of trade between Cataluña and the rest of Spain, as a whole, with the equivalent trade with other 22 OECD countries. The results suggest a fall of the border effect of Cataluña from 1995 to 2005, passing from a factor of 80 to 29 times.

Instead, when this analysis is repeated just considering the international trade of Cataluña with the adjacent France (exports + imports), the external border effect decrease to 23 in 2005. Llano-Verduras et al. (2011) revised the external border effect in Spain using flow data at two different spatial scales, namely, regions (Nuts 2) and provinces (Nuts 3), finding that the size of the border depends largely on the spatial unit used. One of the limits of this final paper is that although they are able to control for the spatial scale of Spanish units (from Nuts 2 regions to Nuts 3 provinces), the spatial scale of the foreign partner is always a country. Garmendia et al. (2012) re-estimated the internal border effect in Spain using provincial data (Nuts 3) and social and business networks effects.

1.4 Brief history of the gravity equation evolution: from physics to trade

As we have seen in the previous section there are evidences of the existence of the "border effect", which is traditionally measured through the use of the gravity equation. In this part of the document we attempt to describe the two main formulations of the gravity equation often used to quantify the border effect. We start with the simplest version of the gravity equation which is inspired on the physical law of Newton (1687), termed *naïve gravity* equation, then we pass to describe a much more comprehensive gravity equation, which is micro-founded and we refer to it as *special structural gravity* equation (Head and Mayer, 2014). To do this, we go close to the handbook of Head and Mayer (2014) and the papers by Anderson and van Wincoop (2003) and Feenstra (2002), whose theoretical grounded gravity equation represents the main reference for recent empirical exercises, as well as for this Thesis.

The primitive gravity equation is formulated for the first time by Newton in the field of physics. According to this equation the attraction between two bodies is proportional to the product of their mass and inversely proportional to the square of the distance separating them. The reasoning behind this equation is straightforward: the bigger the partners are, the higher the trade expected between them is, what inversely happens with the distance separating them. Nevertheless, since the nineteenth century, it has been long used on a diverse scope of topics within the social sciences.

After being applied to explain migration flows or consumer's shopping behavior, Tinbergen (1962) brings this equation to the field of international trade. Since then, it has been widely used to evaluate the effect of some cultural or political features on international trade, such as tariff and non-tariff barriers, currency unions (Rose 2000; Frankel and Rose 2002), exchange rate variability (Frankel and Wei 1993; Lizardo 2009; Chit et al. 2010), cultural specificities, for example, linguistic identities, ethnic ties, among others, (Felbermayr and Toubal 2010; Tadesse and White 2010) cultural or political border effect. To this respect, in this Thesis we pay special attention on the use of the gravity equation on the estimation of the political barrier, what is commonly known as border effect or home-bias effect, whose estimation is one of the main goals of this Thesis.

In his seminal paper, McCallum (1995) estimated the national border effect for the case of Canada and United State with 1988 data. This research accounts for a high empirical fit, and represents a relevant benchmark for subsequent empirical and theoretical works. In estimating the Canadian border effect, the author applied what is called the *naïve gravity* equation (Head and Mayer, 2014).

Naïve gravity equation:

$$T_{ij} = G\frac{Y_i^{\alpha_1} Y_j^{\alpha_2}}{dist_{ij}^{\alpha_3}} \qquad (1.1)$$

This expression[7] includes the main variables of the Newton's formulation, where T_{ij} stands for the bilateral flow from region *i* to region *j*; *G* is the equivalent of the "gravitational constant" in the physics equation, Y_i and Y_j refer to the export and import capacity of the origin and the destination, respectively, which are normally approximated by their GDP's; and $dist_{ij}$ is a proxy for various factors that can influence trade such as transport costs, communication costs, transaction costs or cultural distance, which is approximated by the distance carried out by trade flows. In the case of $\alpha_1 = \alpha_2 = 1$ and $\alpha_3 = 2$, this expression will correspond to the universal gravitational equation postulated by Newton. By taking natural logarithm, this equation allows for a lineal transformation of the original multiplicative expression, which in turn lets for an interpretation of the coefficients in terms of elasticities.

$$Ln(T_{ij}) = Ln(G) + \alpha_1 Ln(Y_i) + \alpha_2 Ln(Y_j) - \alpha_3 Ln(dist_{ij}) \qquad (1.2)$$

[7] Observe that in order to get a uniformed presentation thoughout the Thesis we do not use exactly the same notation that the referred authors (Dixit-Stiglitz, 1977; Krugman, 1980; McCallum, 1995; Feenstra, 2002-2004; Anderson and van Wincoop, 2003; Combes et al. 2008). Instead we use a notation that is coherent with the empirical analysis of the following chapters.

Contrary to what one could believe, due to its surprising empirical success, this equation was not founded on microeconomic grounds. But its high empirical fit claimed for a theoretical foundation. The following equation (1.3) shows a much more sophisticate specification; this is called the *special structural gravity* equation (Head and Mayer, 2014). This expression has theoretical foundations and includes some terms that are new respect to the original.

Special structural gravity equation:

$$T_{ij} = \frac{Y_i}{\Omega_i} \frac{T_j}{\Phi_j} \phi_{ij} \tag{1.3}$$

where $Y_i = \sum_j T_{ij}$ is the total amount of production sold and $T_j = \sum_i T_{ij}$ is the total value of imports of the location *j*. Normally, in the empirical works both variables are approximate by the GPD of the origin and the destination regions, respectively. The term ϕ_{ij} refers to the accessibility between the markets, which in turn combines the trade costs effect and the elasticity effect. This variable is usually modeled with the distance between partners. The terms Ω_i and Φ_j are the new variables respect to the original gravity equation. These parameters represent the "*multilateral resistant*" terms, which were formulated for the first time by Anderson (1979). This concept puts the bilateral trade between two partners in a much more complex context, where apart from the mutual attraction between two partners, there are additional forces coming from *all* the rest of the agents in the world. The intuition is this: the more resistant is the trade between two partners with respect to the rest of world, the higher would be the amount of their bilateral trade. Anderson and van Wincoop (2003) developed formally the "*multilateral resistant*" terms from their well-grounded gravity equation.

The form of the multilateral resistant terms is as follows

$$\Phi_j = \sum_l \frac{\phi_{lj} Y_l}{\Omega_l} \tag{1.4}$$

and

$$\Omega_i = \sum_l \frac{\phi_{il} T_l}{\Phi_l} \tag{1.5}$$

Special structural gravity is based on two important conditions; one refers to the allocation of expenditure for the importer, and the other refers to the market-clearing condition. The former assumes that if T_j is the total expenditure to allocate, π_{ij} will be the share of the expenditure allocated in region (or country) *i*. This brings us to the following expression:

$$T_{ij} = \pi_{ij} T_j , \tag{1.6}$$

where $\sum_i \pi_{ij} = 1$.

The share of expenditure of *j* allocated on a specific region is not trivial, as it is related to the relative transport costs, and the capability to export of that specific region, what can be expressed as:

$$\pi_{ij} = \frac{S_i \phi_{ij}}{\Phi_j}, \tag{1.7}$$

where $\sum_i \phi_{ij} / \Phi_j = 1$ and

$$\Phi_j = \sum_l S_l \phi_{lj} \tag{1.8}$$

S_i represents "capabilities" of exporter *i* to supply to all destinations. The term ϕ_{ij} / Φ_j represents the relative transport costs between partners *i-j* (ϕ_{ij}), respect to total transport costs that partner *j* faces (Φ_j). Therefore, Φ_j is a measure of the level of competition of that market.

Related to the market-clearing condition, this assumes that the sum of exports from region *i* to all destinations must equal the value Y_i.

$$Y_i = \sum_j T_{ij} = S_i \sum_j \frac{\phi_{ij} T_j}{\Phi_j} \tag{1.9}$$

From this equation one can see that the total production exported depends on the exports of the rest of the regions and the relative transport cost between region *i* and those regions. Isolating the term that measures the capability to export (S_i), we have the next expression:

$$(S_i = Y_i / \Omega_i), \tag{1.10}$$

where

$$\Omega_i = \sum_l \frac{\phi_{il} T_j}{\Phi_l} \tag{1.11}$$

Ω_i represents an average of expenditures of all regions weighted by their relative transport costs (or access) to region *i*. This term is frequently used in economic geography as an index of access or market potential, which can be understood as a measure of the "openness" of a region (Baldwin and Taglioni (2007)).

Then, substituting (1.10) into (1.8) we get

$$\Phi_n = \sum_l \frac{Y_l \phi_{lj}}{\Omega_l} \tag{1.12}$$

If one now substitutes Eq. (1.10) into Eq.(1.7), and again into Eq.(1.6), it results into Eq.(1.3) above:

$$T_{ij} = \frac{Y_i}{\Omega_\mathrm{i}} \frac{T_j}{\Phi_\mathrm{j}} \phi_{ij}$$

1.4.1 Theoretical foundation of the *special structural gravity* equation and the border effect

The gravity model has been commonly used to explain international trade flows and to assess different administrative arrangements. In fact, one of the main concerns of policy makers is the impact of borders on international and national trade. In the *border effect* literature this concept is understood as how much more a region/country trades with itself than with any other region/country, once a set of factors (size of the partners, distance between them, etc.) is controlled for. In the empirical context, the gravity equation has been the main measurement tool of these differences in volume of trade. There is no doubt that the seminar paper by McCallum (1995) inspired many works based on the simplest form of the gravity equation Eq.(1.1) to estimate the border effect in different political areas. Although it performs extremely well empirically, the lack of theoretical foundation represented a relevant backward. In fact, there are two important implications of using in its naïve specification (Anderson and van Wincoop (2003)): (i) estimation results are biased due to the omission of relevant variables; (ii) this approach does not allow for comparative statics exercise, which is generally the main purpose of these studies. Therefore, as Anderson and van Wincoop (2003) pointed out, McCallum's formulation of the gravity equation is not valid to infer the *border effect*. This fact has triggered the proliferation of many studies trying to endow this equation with a micro-theoretical basis. Indeed, the gravity model can be justified by a broad range of trade theories based on factor-endowment assumptions (Deardorff 1998), monopolistic competition (Helpman and Krugman, 1985), home-preferences (Anderson, 1979; Anderson and van Wincoop, 2003), and increasing returns to scale (Helpman and Krugman 1985; Evenett and Keller, 2002).

Anderson (1979) was one of the first researchers who developed a theoretical foundation of the gravity model. The interest of his model is that products are differentiated by their place of origin, also known as Armington assumption. This author (Armington, 1969) differentiates goods not only by the needs they satisfy (e.g. cars, chemicals, agricultural products, etc.), but also by the place of production (home bias). Armington suggests that products of the same kind but from foreign countries face imperfect substitution in demand. As we will see below, this idea is behind the utility function specification of Anderson and van Wincoop (2003), that serves as departure point in the aforementioned micro-foundation of the special structural gravity equation. Feenstra (2002), following Anderson (1979), derives the gravity equation with transport costs and trade barriers using a monopolistic competition model with a CES utility function, and evaluates three alternative methods to estimate it empirically. Anderson and van Wincoop (2003) proposed a theoretical grounded gravity equation much more complex than the previous one, which is able to account for the impact of both internal (within a country) and external (among countries) effects.

This equation also allows considering the three kinds of factors that the *special structural gravity* required: the bilateral barriers between origin *i* and destination *j*; *i*'s resistance to trade with all the rest regions; and *j*'s resistance to trade with the rest of the world.

Though there are various established theories that fulfill the two assumptions underlying the *special structural gravity*, we will focus on a theoretical approach that is very close to the Anderson and van Wincoop (2003) formulation. The especial worries of these authors are: the bias that can emerge from estimates of the simplest gravity equation, and the goal of getting an approach that allows for a comparative statics analysis to evaluate the border effect. Moreover, an interesting aspect of their work is that it extends McCallum (1995) seminal paper, which since its publication has been a benchmark in the estimation of national border effect.

- **Anderson and van Wincoop approach to the theoretical founded gravity equation**

The model that these authors developed is grounded on the Dixit-Stiglitz-Krugman model. More specifically, their approach builds on the monopolistic competition model by Dixit-Stiglitz (1977) with constant elasticity of substitution (CES) preferences. The advantage of combining these two concepts is that it allows for the consideration of transport costs and trade barriers across partners, accounting for the existence of different prices levels at all locations where trade takes place. The main drawback of the simplest version of the gravity equation is that it does not consider prices third party prices in bilateral trade flows, while in the special structural gravity equation Eq.(1.3) these terms appear through the "*multilateral resistant*" terms.

The first building block of their gravity model is based on the assumption that each firm produces and exports a unique variety from a single location, so each origin provides a single set of goods. This is the consequence of considering economies of scale, monopolistic competition and transport costs, what forces firms to produce only one variety at one specific location and export to all locations from there.

The second characteristic of their approach is the assumption of a modified Constant Elasticity of Substitution (CES) utility function, whose value does not only increase with the number of varieties consumed by individuals, but also it increases in the consumption of some products, depending on their origin.

$$U_j = \left(\sum_i \beta_i^{(1-\sigma)/\sigma} T_i^{(1-\sigma)/\sigma} \right)^{\sigma/(\sigma-1)}, \quad (1.13)$$

subject to the following budget constraint:

$$\sum_i p_{ij} T_{ij} = y_j \tag{1.14}$$

where T_{ij} represents the consumption by region *j* from region *i*, σ is the elasticity of substitution which is greater than 1, β_i is a (positive) parameter that weights the consumption of each origin specific product[8], y_j is the nominal income of region *i*, p_{ij} is the Cost, Insurance and Freight (c.i.f.) price paid in region *j* for products from region *i*. The c.i.f. prices are composed by the Free On Board (f.o.b) price and transport costs $\left(p_{ij} = p_i \tau_{ij}\right)$, where τ_{ij} represents the transport costs between two partners. The formulation[9] of the transport costs that Anderson and van Wincoop adopt is $\tau_{ij} - 1$, which offers the costs of shipping one unit from *i* to *j*.

Therefore, after some steps, the nominal demand associated to the optimization problem maximizing the utility function subject to the budget constraint defines as:

$$T_{ij} = \left(\frac{\beta_i p_i \tau_{ij}}{P_j}\right) y_j, \tag{1.15}$$

where P_j is a price index that regards the prices in region *j*, having the following form:

$$P_j = \left[\sum_i \left(\beta_i p_i \tau_{ij}\right)^{1-\sigma}\right]^{1/(1-\sigma)} \tag{1.16}$$

Anderson and van Wincoop follow Deardorff (1998) and Anderson (1979) in using the market clearing condition $\left(y_i = \sum_j T_{ij} p_i\right)$, and by choosing a f.o.b price that equals to one $\left(p_i = 1\right)$ it results in following market clearing condition:

$$y_i = \sum_j T_{ij} = \left(\frac{\beta_i p_i \tau_{ij}}{P_j}\right)^{(1-\sigma)} y_j \tag{1.17}$$

[8] Head and Mayer (2014) use $A_i = 1/\beta_i$, obtaining a direct interpretation of A_i in terms of perceived quality of country *i*'s products.

[9] Normally, in economic geography literature the trade costs adopt the "iceberg melting" form; nevertheless the transport costs formulation by Anderson and van Wincoop (2003) yields essentially the same model, as the authors recognize.

From this clearing market condition Eq.(1.17) the authors, who are interested in the equilibrium determination of prices and in comparative statics, firstly include this expression in the demand equation Eq.(1.15) to solve for β_i, and secondly they isolate the scaled prices $(\beta_i p_i)$ from the clearing market condition Eq.(1.17), so as to obtain the following specification of the demand equation Eq.(1.15).

$$T_{ij} = \frac{y_i y_j}{y^W}\left(\frac{\tau_{ij}}{\Pi_i P_j}\right)^{1-\sigma}, \tag{1.18}$$

where $y^W = \sum_i y_i$ is the world nominal income and Π_i has the form:

$$\Pi_i = \left(\sum_j \left(\frac{\tau_{ij}}{P_j}\right)^{(1-\sigma)} \theta_j\right)^{1/(1-\sigma)}, \tag{1.19}$$

where $\theta_j = y_j / y^W$ represents the income shares.

Substituting the scaled price term into the consumer price index, we obtain:

$$P_j = \left(\sum_i \left(\frac{\tau_{ij}}{\Pi_i}\right)^{(1-\sigma)} \theta_i\right)^{1/(1-\sigma)} \tag{1.20}$$

At this point Anderson and van Wincoop (2003) assume that $\tau_{ij} = \tau_{ji}$, implying that $\Pi_i = P_i$. But we will continue with the general form of Anderson and van Wincoop formulation of the gravity equation, which in terms of the special structural gravity equation's components Eq.(1.3) results in the next equivalence:

$$T_{ij} = \frac{Y_i}{\Omega_i}\frac{T_j}{\Phi_j}\phi_{ij} \tag{1.21}$$

$$\phi_{ij} = \tau_{ij}^{(1-\sigma)} \tag{1.22}$$

$$\Omega_i = \Pi_i^{(1-\sigma)} \tag{1.23}$$

$$\Phi_j = P_j^{(1-\sigma)} \tag{1.24}$$

The authors term the price index as "multilateral resistant" variables because these price indices depend on all bilateral trade costs (resistant terms) that partners faces ($\tau_{i.}$ or $\tau_{.j}$, respectively).

In summary, it is undoubted that international trade is on the increase, due to the proliferation of new trade agreements, the improvements in transport facilities and information technologies, etc. However, the empirical evidence has shown the persistence of the border effect, even inside of countries (internal border) or between countries (external border) which are members of the same common commercial area. Methodologically, the most efficient instrument to quantify said border effect is the gravity equation, whose more sophisticated version, the special structural gravity equation (henceforth, gravity equation) allows controlling for the omission of relevant variables and which is specifically designed for providing an adequate estimate of border effect. In the next section, addressing the empirical estimation of the border effect for the Spanish economy, chapter 3 estimates the gravity equation to quantify the internal and external border effect; Chapter 4 suggests alternative specifications of the gravity equation, to endow said equation of a more flexible treatment of non-linear relationship between trade and distance. To make these estimates we use a novel dataset that collects intra and international trade flows with origin in the Spanish regions. Chapter 2 describes the elaboration of this dataset and shows its main features.

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SECTION II: ESTIMATION OF THE BORDER EFFECT INSIDE OF SPAIN AND WITH ITS MAIN EUROPEAN PARTNERS

2 Toward a Region-to-Region International Trade Dataset for the Spanish Case[10]

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2.1 Introduction

To date, there is no data on region-to-region trade flows between different countries within the European Union (EU). Due to this limitation, several important questions regarding the dynamics of EU integration remain unsolved, both for scholars and policy makers. Thus, researchers are incapable of addressing relevant issues already tested in other countries like the United States (US) or China (Poncet, 2003).

For example, the analysis of business cycles co-movement for the EU regions suffers from a lack of information on the trading flows connecting each pair of regions. Consequently, those papers that are willing to analyze to what extent the EU integration process has led to an increase in the synchronization of the European economies, and therefore, to a decrease in the "asymmetric-shock risk" of a non-optimal monetary union, have had to substitute the actual bilateral flows connecting each pair of regions, with physical distance or trade potentials estimated by gravity equations (Fatás, 1997; Barrios y de Lucio, 2003).

Another example can be found in the field of the border effect literature. Conversely to what happens in the U.S. and Canada (McCallum, 1995; Helliwell, 1996; Anderson and van Wincoop, 2003; Feenstra, 2002), the estimation of the international border effect in Europe has been restricted to the analysis of country-to-country (Chen, 2004; Minondo, 2007) or region-to-country data (Gil et al., 2005; Requena and Llano, 2010; Ghemawat et al., 2010; Llano-Verduras et al., 2011). However, research on the internal border effect (home bias) using region-to-region has been confined to those countries where interregional trade datasets are available (Wolf, 2000; Combes et al., 2005; Requena and Llano, 2010), but without taking into account the international cross-border relations. Again, as in the case of the business cycle co-movements, the main restriction of these articles remains the data scarcity regarding the bilateral flows connecting pairs of regions located in different countries within the EU.

In this chapter, we develop a methodology to produce region-to-region trade flows between Spain and seven EU countries, by integrating trade data (to obtain trade prices at the region-to-country level) and transportation statistics (to obtain freight flows by road at the region-to-region level). The chapter focuses on the description of the methodology of estimation. A clear point of departure is that this methodology should be based on data already available for most of the EU countries, avoiding the use of "non-survey" methods for estimating interregional flows. By doing so, we want to produce "pure data" that can be analyzed afterwards with different econometric procedures and different gravity model specifications. Here, based on the new dataset, a number of analyses are conducted with the aim of testing the robustness of the figures as regards other official statistics already available.

To the best of our knowledge, our approach is the first attempt at producing and analysing such flows using region-to-region international flows within the EU. Although the case study focus on Spain against its 7 main EU partners, an additional virtue of the process described here is the possibility of extending it to a larger set of countries, with the goal of covering the widest possible sample of countries within the EU.

The structure of the rest of this chapter is as follows: section 2 describes a conceptual framework for decomposing the interregional trade flows between countries. This framework is described from the widest viewpoint, so it can be easily connected with modern international trade theory (Feenstra, 2004), recent articles on the geographical frictions to trade (Hilberry and Hummels, 2008), and the most common situation of other countries in the world, where trade and transport statistics are also available. Then, in section 3, we develop a methodology to obtain region-to-region international trade flows taking the Spanish regions as a reference. Finally, in section 4, we conduct an exploratory analysis, with the aim of analysing the spatial patterns of the Spanish international trade, with the region-to-region specific breakdown.

2.2 International trade flows in the EU: the link between trade and freight

This section describes the conceptual framework required to build a dataset on region-to-region trade data between EU countries. Before doing that, it is convenient to start saying that trade and freight flows are different concepts that should be treated carefully. In general terms, the concept of “international trade of goods” is used to denote a commercial transaction between two agents (exporter - importer), which, usually, implies the shipment of that good, from the exporting country to the importing one, crossing the national border. Let us assume that the transport service of delivering this product is done by a truck from the exporting country. Regardless the accounting specificities of the flows (value, time, taxes, etc.), this single trade operation could be registered similarly by the corresponding trade and transport surveys, which would ideally lead to a perfect coherence between records obtained by surveying to all the operating agents (exporter, importer, transporter, custom). Departing from this simplest situation, economic and logistic complexities could introduce differences when a single trade operation is declared by the exporting/importing agent, the customs located in the border (if there is so) or the truck delivering the product (Gallego et al., 2014; Diaz et al., 2013). Among the factors introducing such differences, one should consider the presence of the "headquarters effect", "transit flows" or "multi-modal trade flows"[11]. Being aware of this complexity, in the methodology we depart from assuming *a priori* a certain level of coherence between trade and freight statistics. This hypothesis is in line with a number of relevant papers that have been published recently using shipments by road as a good proxy for trade (McCallum, 1995; Anderson and van Wincoop, 2003; Combes et al, 2005; Hilberry and Hummels, 2008). In addition, as we will see later on by several tests, this assumption seems to be plausible for certain countries and types of flows like the ones considered here, and serve as a needed starting point when no better information is available.

In most of the EU countries, there are two main sources for bilateral flows: 1) Trade statistics on intra-EU trade, which register bilateral flows between pairs of countries within the EU, both in volume and monetary units (in some countries like Spain, trade data identify the exporting region or the importing region, but never both simultaneously); 2) Transport statistics on intra-national and inter-national freight flows, which -in some cases (road freight)- contain information on the type of product transported (just in volume), as well as on the specific regional origin and destination of the flows.

As it will be described with more detail in the next section (section 3), the methodology implemented to build the region-to-region trade dataset considers the combination of these two sources: one for estimating the region-to-region flows in volume (road freight statistics), and the other for estimating region-to-country specific trade prices (official trade statistics). The method is explained in such a way that could be replicated by any other EU country with access to the same statistics.

2.3 Method of estimation of a region-to-region international trade database

2.3.1 A theoretical decomposition of the flows

Let us start considering two European countries e and u, with I and J number of regions respectively. Without loss of generality, and considering the complete set of regions, all types of

[11] The headquarters located in the capital region may account for all the deliveries departing/arriving to establishments or branchs located in other regions; 2) International imports arriving by road to a region, are then re-shipped by road to another country; 3) International imports arriving by ship or railway, are then re-shipped by road to another region in the country or to another country.

bilateral trade flows from region *i* in country *e* to region *j* in country *u*, could be defined as T_{ijt}^{eu}. For simplicity, the time *t* subscript is omitted in some equations. Although a simpler notation is possible, the use of two alternative subscripts for countries and regions would allow differentiation between flows of different nature:

- If *i*=*j* and *e*=*u* we have intra-regional intra-national trade flows;
- If *i*≠*j* and *e*=*u* we have inter-regional intra-national trade flows;
- If *i*≠*j* and *e*≠*u* we have inter-regional inter-national trade flows (henceforth "international trade");

Note that the accounting relations described in Eq. (2.1) and (2.2) below refer to products delivered to the final and the intermediate demand. Therefore, this framework is coherent with the National Accounts and the Input-Output assumption of "total output = total demand" for a "closed system" (i.e., the intra-EU economy, just considering goods), excluding exports and imports from third countries. Thus, total output (*TO*) of a region *i* in country *e* could be decomposed as (2.1):

$$TO_i^e = T_{ii}^{ee} + T_{ij}^{ee} + T_{ij}^{eu} \tag{2.1}$$

While total demand (*TD*) in a region *j* of a country *u* will be decomposed as (2.2):

$$TD_j^u = T_{jj}^{uu} + T_{ij}^{uu} + T_{ij}^{eu} \tag{2.2}$$

Let us now consider that each bilateral aggregated flow can be decomposed in volumes (*Q*) and unit prices (*P*) of a set of *k* tradable varieties. These commodities could travel using 5 alternative transport modes: road (R), train (T), ship (S), airplane (A) and others (O). Therefore, for the most general case of aggregate international trade flows, T_{ij}^{eu}, and each of its spatial components defined in (2.1) and (2.2), they could be decomposed as follows:

$$T_{ij}^{euk} = \underbrace{\left(Q_{ij}^{eukR} P_{ij}^{eukR}\right)}_{\text{For Spain} \approx 80\%} + \underbrace{\left(Q_{ij}^{eukT} P_{ij}^{eukT}\right) + \left(Q_{ij}^{eukS} P_{ij}^{eukS}\right) + \left(Q_{ij}^{eukA} P_{ij}^{eukA}\right) + \left(Q_{ij}^{eukO} P_{ij}^{eukO}\right)}_{\text{For Spain} \approx 20\%} \quad (2.3)$$

where Q_{ij}^{eukR} is the bilateral trade flow in volume units (tons) of variety *k*, departing from region *i* in country *e* and arriving at region *j* in country *u*. The capital letters R, T, S, A and O, denote the transport mode used for the delivery. Similarly, each element P_{ij}^{eukR} defines the average prices (value/volume relations) for each dyad of regions, transport mode and type of commodity.

Next, we focus on element $T_{ij}^{eukR} = (Q_{ij}^{eukR} P_{ij}^{eukR})$, which captures the international exports of variety *k* delivered by road with origin in region *i* from country *e* to region *j* in country *u*. Since the rest of the chapter is mainly focused on the road mode, it is convenient to offer a first intuition about its relevance, as it represents about 80% of the international trade flows between Spain and the 7 countries considered (see **Table 2.1** for more detailed figures by regions and types of flows).

Again, this particular flow of road transportation can be decomposed depending on the nationality of the truck offering the transportation service (freight flow), which can be classified as an intra-national or an inter-national (cross-country) type of service (equation (2.4)). Due to data restrictions, we consider that the price P_{ij}^{eukR} of a variety *k* traded between a dyad *ij* of two specific regions is the same regardless of the nationality of the truck delivering the product.

$$T_{ij}^{eukR} = \underbrace{\left(Q_{ij}^{euk\_National\_Trucks} P_{ij}^{eukR}\right)}_{\text{For Spain} \approx 60\%} + \underbrace{\left(Q_{ij}^{euk\_International\_Trucks} P_{ij}^{eukR}\right)}_{\text{For Spain} \approx 40\%} \quad (2.4)$$

Departing from this theoretical decomposition of the international trade flows (equation (2.3)), and having in mind the final focus on the international trade flows by road (equation (2.4)), it is useful to have a look at the "real world", in order to know to what extent this framework can be completed with available data, for example, in an European country like Spain. Again, although the relevance of the "national trucks" will be analyzed afterwards, in equation (2.4) the percentage share of the Spanish international trade flows that are delivered by Spanish trucks is about (60%) (see **Table 2.2** for more detailed figures).

2.4 A region-to-region international trade dataset for Spain: method of estimation

In this section we describe the procedure to estimate a new database on region-to-region international commodity flows for Spain. The method is based on the available information on freight flows by heavy trucks (volume) with Spanish nationality (section: Spanish statistics on volumes: freight and trade data), as well as the estimation of unit value (value/volume) relations obtained from the official international trade data (section: Bridging the gap between trade and transport statistics).

2.4.1 Spanish statistics on volumes: freight and trade data

In Spain there are two main sources offering information on bilateral international flows between: trade and transport statistics (freight flows). Only the latter could potentially offer the region-to-region dimension.

- **The trade statistics in Spain**

The main statistics for intra-EU trade are based on the Intrastat system. Since the removal of the European boundaries, customs are no longer collecting data on intra-EU trade. Currently, trading operations produced in a year are declared by the firms themselves.

For the Spanish case –as for the rest of the EU countries-, intra-EU trade statistics do not fulfil all the requirements considered in equations (2.1), (2.2) and (2.3). At most, the information offered is like that in (2.5) for the international exports departing from region *i,* and in (2.6) for the international imports arriving in region *j*[12]:

$$T_{i.}^{euk} = T_{i.}^{eukR} + T_{i.}^{eukT} + T_{i.}^{eukS} + T_{i.}^{eukA} + T_{i.}^{eukO} \qquad (2.5)$$

$$T_{.j}^{euk} = T_{.j}^{eukR} + T_{.j}^{eukT} + T_{.j}^{eukS} + T_{.j}^{eukA} + T_{.j}^{eukO} \qquad (2.6)$$

[12] A "dot" (.) in the mathematical expressions means the aggregation of all the corresponding origins *i*, or destinations *j* for a specific country.

Consequently, for the official trade statistics for any region in the country, the information regarding the destination region of outflows and the origin region of inflows is not available. By contrast, it is possible to split the importing and exporting flows by the country of origin/destination, to have a great detailed sectoral classification (17,000 products for NC 8 digits) and the main transport mode used for the delivery. However, having (2.4) in mind, for a specific transport mode such as "road", the nationality of the carrier is also blinded[13].

- **The road freight flows statistics in the EU and Spain**

Alternatively, most of the EU countries collect data on freight flows by transport modes (freight statistics, from now). Regarding the road mode, all EU countries produce the same type of survey, which captures specifically the information on intra-national as well as inter-national deliveries. This set of parallel surveys is designed in a way that avoids double counting of the same delivery. Therefore, by the aggregation of all the operations declared by all the EU countries, one could estimate the total freight flows by road (in tons) departing from or arriving in each region of a country. Usually, Eurostat and each EU country publish the origin-destination specific intra-national freight flows F_{ij}^{eegR}, but just the aggregated international freight flows (aggregated volumes loaded $F_{i.}^{eugR}$ and unloaded $F_{.j}^{eugR}$ in each region for each type of product *g*) [14]. Currently, Eurostat restricts the access to detailed data on freight flows declared by carriers from other countries ($F_{ij}^{eugR\_International\_Trucks}$). In addition, national statistical institutions only have information on the freight flows delivered by their own national trucks $F_{ij}^{eugR\_National\_Trucks}$ [15]. As aforementioned, data from Eurostat corresponding to the Spanish case indicate that around 58%

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[13] Note also that we have used the notation $T_{i.}^{euk}$ and $T_{.j}^{euk}$, instead of their decomposition based on quantities and prices. By doing so, we want to emphasise that although customs statistics offered the "monetary value" for all transactions, the "volume units" ($Q_{i.}^{eukR}$ and $Q_{.j}^{eukR}$) are not always available. As we will see in brief, it will be possible to compute average unit value relations (volume/value), which could be used as proxies for the origin-destination-region-product-mode-year specific prices.

[14] Note that, although both sources (trade and freight statistics) offer data on trading volumes (tons), we prefer to use different notations for both: *Q*= volumes from trade statistics; *F*=volumes from freight statistics. Note also that we use different notations for the product disaggregation of trade statistics *(k)* and freight statistics *(g)*. As we explain in the next section, this option is motivated by the different level of disaggregation in the data. It also allows us to use the concepts of *"products"* (*g*) and *"varieties" (k)*.

[15] As an example, currently a researcher from Spain could have no access to Eurostat data on freight services between Spain and France declared by French trucks. This restriction holds for any other EU country.

of its international exports to EU27 and 56% for the imports from the EU27 are delivered using Spanish trucks (see **Table 2.2**). These shares would probably be higher if we just considered trade flows with the 7 selected countries in our dataset, instead of the EU27.

For the Spanish case, the Permanent Survey on Commodity Transport by Road (PSCTR), collected by the Ministerio de Fomento (Spanish Ministry of Public Works), is the main source offering data on intra-national and inter-national transport flows by road. Like its counterparts in the rest of the EU, this survey provides, for each year *t* and type of product (*G=24;* see detail in the Appendix 2.8), a rich set of variables covering origin and destination flows (in tons and in tons*km), for international shipments. Usually, this dataset is published on an aggregated basis. Exceptionally, in this study we are able to use an extended dataset, which specifies the region-to-region dimension of intra-national and inter-national flows with a large number of European countries. This rich and novel dataset contains a large number of international deliveries made by the surveyed trucks, which can be combined with the available data on international trade flows by road. On the other hand, for the sake of transparency, this dataset also presents some potential limitations: *Population figures* from the official survey on road freight flows are based on surveys to the transporters, without any additional robustness checking with other data on regional or business activity. As a consequence, a match between the freight flows (in tons) and the corresponding figures (in Euros) reported by national, regional and branch accounts in the corresponding countries cannot be assured. Finally, it is important to highlight that the survey just covers *volumes* transported by heavy trucks *based in Spain* ($Q_{ij}^{euk\_National\_Trucks}$ from equation (2.4)). Consequently, all the international exports and imports with origin/destination in a Spanish region, which are delivered by an international truck ("cross-country transport") are not covered by the survey (see Eurostat 2009, for a detailed definition of these concepts in transport and freight). Despite these potential limitations, as we will see in **section 2.5.1**, the data obtained at the end of the process performs very well, correlating with the official trade data usually employed in most of the analysis.

2.4.2 Bridging the gap between trade and transport statistics

Departing from the description of the previous two complementary sources, the target is to estimate a region-to-region international trade dataset, with the largest sectoral detail. This goal is to overcome two main limitations: 1) since freight flows just include shipments by Spanish carriers, we lose the Spanish international trade delivered by foreign carriers; 2) the freight flows have to be translated into monetary values, using international trade prices. As we will see in brief, this latter step is not straightforward.

Inspired by the notation in **section 2.2**, equation (2.7) describes an estimated trade flow of products *g* transported by Spanish trucks from region *i* in country *e* to region *j* in country *u*. Note that if *e= Spain*, equation (2.7) captures Spanish exports to EU countries, while if *u= Spain* it captures Spanish imports from the EU. In both cases, the products are transported only by Spanish trucks.

$$\hat{T}_{ij}^{eugR} = \left(F_{ij}^{eug\_National\_Trucks} \hat{P}_{ij}^{eugR} \right) \qquad (2.7)$$

The main difference between T_{ij}^{eukR} (equation (2.4)) and $\hat{T}_{ij}^{eugR}$ (equation (2.7)) is that the former is a "theoretical value" not included in the EU *trade statistics*, while the latter is an "estimated value" that could be obtained by the combination of estimated trade prices $\hat{P}_{i.}^{eugR}$ (or $\hat{P}_{.j}^{eugR}$ for imports, being *u=Spain*) and actual *freight flows* in tons, F_{ij}^{eugR}, delivered by Spanish trucks.

We now describe the procedure to obtain the corresponding set of "estimated trade prices". In theory, it is possible to calculate sector-region-country specific unit value prices of the Spanish regional exports $\hat{P}_{i.}^{eugR}$ (as well as the corresponding sector-country-region specific unit values for Spanish regional imports $\hat{P}_{.j}^{eugR}$) just by considering the international trade flows by road. However, several problems arise when dealing with the available information. Next we describe these problems and the solutions that have been devised.

- **Filtering raw prices from potential outliers**

The literature on "unit values" and "quality of products" in trade (Berman et al., 2009; Alcalá, 2009; Baldwin and Harrigan, 2007; Hallak, 2006; Hallak and Schott, 2008) has reported a number of problems when dealing with "value/volume" ratios obtained directly from raw trade datasets: omissions when reporting "volumes" (but not "values"); mistakes when registering prices and volumes, etc. These errors in the raw data can produce enormous variability in the "unit values" obtained for different origins and/or destinations for specific varieties. Therefore, it is convenient to conduct a first screening of the raw data in order to remove potential outliers. This filtering has also to be fine enough to keep reasonable price variability, which is expected to capture region-country specificities in terms of quality and product differentiation.

In order to eliminate potential outliers and produce a set of "clean" price vectors for each origin-destination-variety ($\hat{P}_{i.}^{eukR}$ for exports and $\hat{P}_{.j}^{eukR}$ for imports of variety *k* transported by road), the raw data was subject to the following filter:

a. First, for each year, regional origin (i_1), country destination (u_1) and product (g_1), which includes as many as *z* varieties of *k* ($\{k_1, k_2, \ldots k_z\} \in g_1$), the maximum "unit value" is eliminated ($\max \hat{P}_{i.}^{eukR} = [\,]$)[16].

b. Then, for the remaining "unit values" of varieties related to that product g_1 ($\{k_1,$ ~~$k_{2=max}$~~$,\ldots k_z\} \in g_1$), the median (*m*) and the standard deviation (*s.d.*) are computed.

c. All the "unit values" exceeding the following rule $(m-2s.d.) < \hat{P}_{i.}^{eukR} < (m+2s.d.)$ are also considered as outliers, and therefore eliminated.

- **Obtaining product prices *(g)* from varieties *(k)***

In addition, it is important to consider that the disaggregation of the freight flows (*G=24 products*) is considerably smaller than that from the international trade dataset (around *K=17,000 varieties*). This level of disaggregation can be easily described as a number of varieties (*k*) within a set of products (*g*) (see Davis and Wenstein, 2003, for a similar assumption). Therefore, if the goal is to obtain an "implicit price vector" for each region-country-product that would take into account the "quality" composition of the internal "variety-mix" within each product *g* $\{k_1, k_2, \ldots \in g_1\}$, the "value/volume" ratios should be computed using a weighted average of the "filtered variety price" (*k*) included in each product (*g*).

In order to solve this problem, we proceed in the following way:

[16] After different estimates, where the final unit values obtained became too high compared to official trade data, a first filter for the largest prices of varieties within each product was considered to be appropriate. Based on previous experience reported by different authors (Eurostat, 2006; Berthou and Emlinger, 2011), we decided to exclude the maximum unit price for each category-origin-destination specific price. Some additional filters were also tested. In fact for 2 products, a stronger filter was needed, eliminating all the unit values of the *z* varieties of *k* within the first percentile of the price distribution within *g*.

1. First, for each specific product (*g₁*) , international prices for the exports of product (*g₁*) with origin in region *i* (*e=Spain*) and destination in country *u* (regardless of the final region of destination in that country) are obtained as a weighted average of the filtered prices $\hat{P}_{i.}^{eukR}$ of the *z* varieties (*k*) included in that product g_1. This step can be expressed analytically as (2.8):

$$\hat{P}_{i.}^{eug_1R} = \frac{\hat{P}_{i.}^{euk_1R} Q_{i.}^{euk_1R} + \hat{P}_{i.}^{euk_2R} Q_{i.}^{euk_2R} + ...\hat{P}_{i.}^{euk_zR} Q_{i.}^{euk_zR}}{\sum_{k \in G} Q_{i.}^{eukR}} ; \{k_1, k_2 ... k_z\} \in g_1 \qquad (2.8)$$

2. Similarly, international prices for the Spanish regional imports of products (g_1) will be derived from (2.9), where now *u=Spain* and *e= any other EU country*:

$$\hat{P}_{.j}^{eug_1R} = \frac{\hat{P}_{.j}^{euk_1R} Q_{.j}^{euk_1R} + \hat{P}_{.j}^{euk_2R} Q_{.j}^{euk_2R} + ...\hat{P}_{.j}^{euk_zR} Q_{.j}^{euk_zR}}{\sum_{k \in G} Q_{.j}^{eukR}} ; \{k_1, k_2 ... k_z\} \in g_1 \qquad (2.9)$$

Finally, it is possible that some origin-destination-product specific flows in the *freight dataset* have no correspondence in the set of prices deduced from the *trade dataset*. In order to avoid missing data on observed "freight flows", and focusing on the case of export prices, any missing $\hat{P}_{i.}^{eug_1R}$ is substituted by the average price for a given year, origin region and product $\hat{P}_{i.}^{e.g_1R}$ if available, or by the average price for each specific year and product $\hat{P}_{..}^{e.g_1R}$ if it is not. This treatment is equivalent for the case of the import prices, except for the fact that instead of considering the origin region it is replaced by the destination region $\hat{P}_{.j}^{e.g_1R}$.

2.4.3 Description of the final dataset and the additional information

The outcome of this procedure is a unique dataset with information on several variables regarding region-to-region flows for international shipments departing from/arriving in the Spanish regions (Nuts 2). It is clear that the novel dataset is not a perfect substitute of the official trade datasets, or a more robust one built upon a complete set of freight statistics produced by each EU partner. However, it covers a great gap on the available information, and as we will see in section 2.5.1, it performs as the official datasets when both are used in an aggregate form. In addition, one of the great potentials of this dataset is that it can be directly connected with the same type of interregional trade flows within Spain (Llano-Verduras et al., 2011; Ghemawat et al., 2010), which contain not just interregional flows but also intraregional ones.

Spain is divided into 17 regions (Nuts 2). Due to the characteristic of our road flow dataset, we exclude flows where a Spanish island-region is a partner. After the final screening, the region-to-region dataset includes bilateral exports and imports of the Spanish regions against the regions (Nuts 2) for a group of selected European countries, disaggregated by G=24 manufacturing products (the list of Spanish regions, European countries and products is reported in the Appendix[17] 2.8); we will work with 22 products, discarding the most heterogeneous ones, related to energy (product 9) and miscellaneous (product 24). Although the original dataset on region-to-region freight flows includes data on the Spanish flows with 15 countries (imports) and 12 countries (exports) in Europe, a previous analysis of the flows was conducted in order to choose the most robust sample of countries[18]. Finally, the selected sample includes 7 European countries, and their corresponding Nuts 2 regions: Belgium, France, Portugal, Germany, Italy, The Netherlands and United Kingdom.

Regarding the distance variable, we use the mean actual distance covered by the Spanish trucks in the operations between each pair of trading regions. These data are also obtained from the Spanish Permanent Survey on Commodity Transport by Road (SPSCTR). This variable has the virtue of capturing the actual distance travelled by trucks between origins and destinations, and is superior to the one used by other authors, where the intra-national or the inter-national (or both) distances were built on a priori estimates based on the great circle distance (Head and Mayer, 2002). In theory, with the actual distance, we are able to take into consideration region-to-region links between countries that are not directly explained by their GDP or population (market potential), but also by some specific regional links induced by social networks, business networks or upstream-downstream intersectoral relations, which could be driven by specific factor endowments (geography, historical accident…) rather than the general accumulation of employment and economic activity.

[17] Note that although the text refers to the EU, the sample of countries considered does not specifically fulfill any administrative-political category, and indeed includes countries like Switzerland and Andorra. Due to data restrictions, these two latter countries have to be considered as single-region countries.
[18] For brevity, this analysis is omitted in the chapter. The interested reader can obtain a more detailed explanation upon request.

2.5 An exploratory analysis

The aim of this section is twofold: first, in **sub-section 2.5.1**. the coherence of our novel dataset is analyzed, by comparing it to the official trade flows that are used for standard trade analyses in Spain; second, in **sub-section 2.5.2** our dataset is analyzed with the aim of identifying some clear spatial patterns of the Spanish international trade with the main European partners, considering the novel dimension of the region-to-region breakdown. In this chapter we do not try to test any specific theory, but setting the statistical basis for the two next empirical chapters.

2.5.1 How representative is the dataset?

With the objective of analyzing the consistency of our dataset we will proceed in the following way. First, we will discuss the representativeness of the Spanish trucks when analyzing the Spanish international trade with the 7 main EU partners. With this purpose, we start by analyzing the structure of the Spanish trade by transport modes, as well as the available information regarding the nationality of the trucks delivering these goods. This analysis is based on official trade and freight data. Second, we will confront our dataset with the official trade data using a common level of spatial aggregation (region to country). This analysis is carried out in two steps, first regressing each flow vector *vis a vis* with its corresponding official one, and then, running a simple gravity model in both datasets with the aim of showing that using both sets of data result in very similar results at the region-to-country aggregate level.

We depart now from **Table 2.1,** which shows the distribution of the Spanish regional trade with the 7 European countries and G=22 selected products. The figures are expressed in volumes (tons) and monetary units (thousands of Euros), considering all the transport modes (total) as well as those transported by road. Since the data corresponds to the Spanish official *trade data* (http://datacomex.comercio.es/), and not to our own estimates based on *freight flows*, these figures correspond to the elements $T_{i.}^{e..R}$ (Spanish exports) and $T_{.j}^{.u.R}$ (Spanish imports) described before. Therefore, the label "road" (R) here includes all trucks, and not just Spanish ones ($\hat{T}_{i.}^{e..R}$ and $\hat{T}_{.j}^{.u.R}$).

Table 2.1: Spanish trade of goods with the 7 European countries considered, by region and transport mode. Aggregated data for 2004-2007, by tons and thousands of Euros.

	Exports				Imports			
	Tons	**Exports by road /Total exports (%)**	**Thousands of Euros**	**Exports by road /Total exports (%)**	**Tons**	**Imports by road /Total imports (%)**	**Thousands of Euros**	**Imports by road /Total imports (%)**
Andalucía	27.284.172	58%	30.928.246	74%	21.727.464	37%	19.708.731	64%
Aragón	7.969.226	84%	22.807.484	53%	10.306.798	85%	19.481.533	84%
Asturias	8.519.291	24%	7.485.372	47%	3.503.029	37%	3.763.335	76%
Balears (Illes)	118.715	58%	1.515.447	29%	1.372.922	11%	2.307.345	28%
Canarias	923.088	2%	1.097.792	6%	3.466.434	1%	5.267.479	2%
Cantabria	4.502.612	65%	4.759.408	87%	4.070.864	45%	4.016.991	65%
Castilla y León	11.107.527	70%	28.360.292	55%	12.166.975	72%	31.054.727	89%
Castilla-La	3.871.963	90%	7.912.228	92%	3.538.201	93%	17.923.223	96%
Cataluña	48.582.024	84%	112.206.057	88%	63.698.405	81%	151.930.800	90%
C.Valenciana	24.873.053	81%	42.278.797	67%	24.044.857	49%	37.270.306	71%
Extremadura	3.569.291	92%	3.186.074	94%	4.425.454	96%	2.434.833	93%
Galicia	17.662.172	60%	35.578.067	47%	20.668.102	52%	26.978.173	56%
Madrid	9.597.960	88%	41.405.582	92%	21.690.905	86%	130.868.603	78%
Murcia	9.058.320	90%	9.475.887	90%	5.641.601	37%	4.945.610	75%
Navarra	6.684.605	84%	14.475.897	75%	6.176.898	80%	14.003.805	94%
País Vasco	17.701.931	83%	36.867.919	90%	24.437.073	58%	26.819.645	79%
Rioja (La)	911.161	81%	2.999.824	79%	1.100.406	78%	2.267.846	83%
Spain	203.028.581	74%	404.041.874	76%	232.219.608	65%	501.364.372	80%
Spain(*)	201.895.309	75%	400.727.135	76%	227.197.031	67%	493.468.161	81%

Source: Datacomex DataBase. Ministerio Industria y Comercio
(*): excluding islands (Baleares and Canarias islands) and Ceuta and Melilla.

Figures in **Table 2.1** indicate that 76% of the Spanish exports are moved by road (74% in terms of volume), compared with 80% of the Spanish imports (65% in tons). By regions, although most of the regions show higher "shares" for this specific transport mode, there are some exceptions that clearly reduce the average. Obviously, the main exceptions are the islands (Canarias and Baleares). Then, some flows in peninsular regions located far from the border with France register lower shares than the average (Andalucía: 74% for exports and 64% for imports; Galicia: 60% for exports and 56% for imports), since they are more prone to use sea routes. In addition, regions located on the coast -or with intense imports of intermediate products due to their heavy industries such as metallurgy or chemicals- also account for a "road share" below the average (Cantabria and Asturias). In spite of these exceptions, it is clear that by analyzing Spanish international flows by road with these 7 selected European countries, we capture the bulk of the Spanish trade of goods with them.

Next, focusing on the international trade flows by road, **Table 2.2** offers an interesting picture of the spatial distribution of the countries offering transport services (carriers) to the Spanish traders (exporting and importing firms). This table is based on the data published by Eurostat on freight flows by road in the EU, which has 3 spatial dimensions: on the one hand, the figures represent the aggregation of all the freight flows in tons delivered (Spanish exports) or received (Spanish imports) to/from the rest of the EU27 countries (rows at the bottom of the table); on the other hand, the rows show the declaring country, or in other words, the nationality of the carrier that is delivering the transport service. Note that all the flows are registered in thousands of tons for years 2005 and 2007 (year 2004 is not available for all the reporting countries). Additionally, in the pro memory row, the table also includes, as a reference, the volume (in thousands of tons) of the Spanish exports and imports to the EU27 by road, published by an official Spanish trade data base (Datacomex). Note that although the total volume of trade reported by each source in each year is different, the coherence between the figures is considerably high. For example, while the official trade dataset reported 41,148 thousands of tons exported from Spain to the EU27 in 2005, the addition of the freight flows independently declared by the transporters through the 29 national surveys on freight flows recollected and consolidated by Eurostat (in rows) accounts for 47,013, that is, just 14.3% more. Taking into account that the coverage ratio between the aggregate figures offered by both sources is similar by years and flows, we can confirm the coherence between the *big (aggregate) numbers* in both datasets, at least for the Spanish case, and as regards to the international trade flows by road with the EU27. This coherence seems to water down one of the main potential limitations of using freight flows as a proxy to trade, that is, the presence of multiple stops transit flows and multimodal deliveries.

Table 2.2: Freight flows by road with origin (outflows) and destination (inflows) in Spain, which were generated in other EU27 countries, by year and "nationality of the carrier". Thousands of tons. 2005 and 2007

Country declaring the freight flows (carrier's nationality)	Spanish outflows to the EU by road				Spanish inflows from the EU by road			
	2005		2007		2005		2007	
Belgium	336	1%	268	1%	411	1%	368	1%
Czech Republic	610	1%	1,005	2%	472	1%	756	1%
Denmark	82	0%	57	0%	82	0%	47	0%
Germany	1,804	4%	2,022	4%	1,77	4%	1,985	4%
Ireland	84	0%	130	0%	51	0%	136	0%
Greece	34	0%	46	0%	24	0%	0	0%
Spain	**27,253**	**58%**	**29,78**	**57**	**28,5**	**60%**	**29,059**	**56%**
France	3,080	7%	3,395	7%	3,39	7%	3,624	7%
Italy	1,736	4%	1,055	2%	1,88	4%	1,128	2%
Latvia	69	0%	90	0%	81	0%	68	0%
Lithuania	179	0%	321	1%	211	0%	259	1%
Luxembourg	105	0%	156	0%	91	0%	164	0%
Hungary	258	1%	536	1%	263	1%	448	1%
Netherlands	680	1%	603	1%	862	2%	739	1%
Austria	263	1%	187	0%	268	1%	144	0%
Poland	1,020	2%	1,934	4%	794	2%	1,735	3%
Portugal	8,408	18%	9,133	18%	7,19	15%	9,780	19%
Slovenia	149	0%	138	0%	154	0%	159	0%
Slovakia	379	1%	693	1%	368	1%	576	1%
Finland	49	0%	37	0%	33	0%	30	0%
Sweden	67	0%	81	0%	74	0%	62	0%
United Kingdom	368	1%	413	1%	316	1%	335	1%
Norway	:		:		78	0%	0	0%
Total	**47,013**	**100**	**52,12**	**100**	**47,4**	**100**	**51,602**	**100%**
Pro memory: Trade data by road (Datacomex)	41,148	93%	43,641	79%	46,1 4	97%	46,143	89%
% coverage (Total freight flows/total trade flows)	114,3%		119,4 %		102, 8%		111,8%	

Sources:

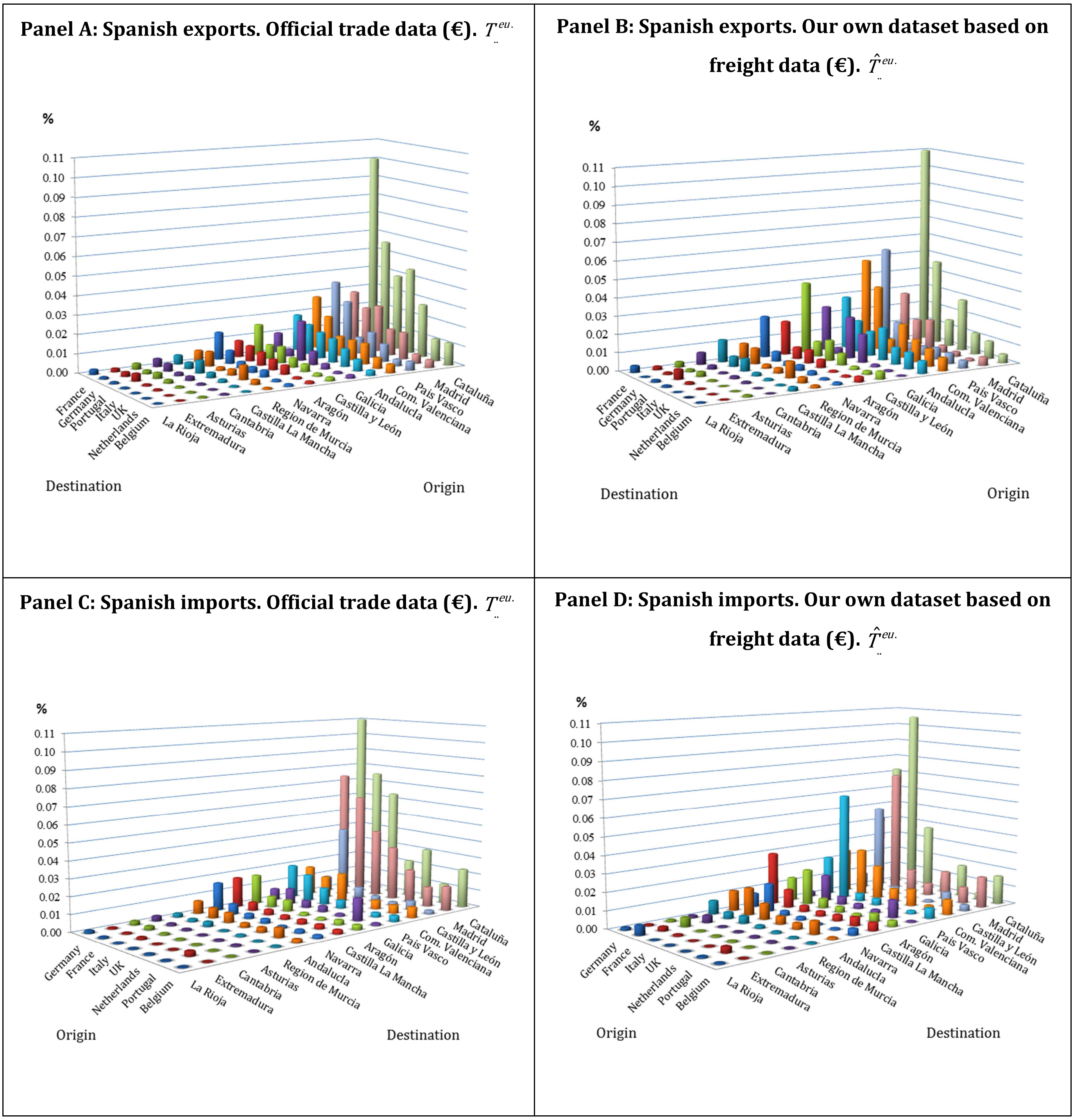
Road freight data: Own calculation based on data from Eurostat;
Trade data by road: Datacomex DataBase. Ministerio Industria y Comercio.

Besides this important point of reference, it is interesting to focus on the country share of carriers when serving Spanish trade operations. The Spanish carriers account for 58% of the outflows and 60% of the inflows (shaded in grey in **Table 2.2**), both measured in volume. As we will see later on, these shares are in line with the coefficient of determination obtained for our specific dataset on Spanish trucks when it is compared with the official trade statistics by road by computing a simple regression model (see **Table 2.3**), where the R^2 is 65% for the exports flows and 54% for the imports flows). Although the analysis of the share registered by the international carriers when transporting Spanish international exports and imports is out of the scope of this chapter, it is convenient to highlight the portion recorded by Portuguese carriers (18% for outflows and 15% for inflows), as well as those from France (7% for outflows and inflows), Italy and Germany (each with 4% for both types of flows).

After this first insight on the role played by Spanish trucks in the Spanish trade with the main EU countries (using official data from Eurostat in volumes), we now focus on our specific dataset (in volumes and monetary units), comparing our dataset (based on road *freight flows)* and the official *trade data* by road. Note that this comparison should be set at the common level of disaggregation for both sources, that is, the breakdown for product (g)- region (i)- country (e), both for volumes (tons) and monetary values (Euros), even if our methodology allows us to disaggregate it to a further level.

In order to illustrate the coherence between the two datasets, our dataset and the official trade statistics, **Figure 2-1** shows the spatial structure of the main aggregate flows (exports, imports) using average flows for the period 2004-2007. The bars for each pair of flows (exports and imports in Euros) are ranked according to the official trade flows T_{ijt}^{eugR}. Therefore, any variation in the shape of the graphs for two equivalent flows (panel A-B for exports; panel C-D for imports) will indicate heterogeneity between the two datasets. However, the shape of the two pairs of panels (A-B; C-D) is very similar, which can again be interpreted as a sign of coherence between the two datasets when they are compared at the higher common spatial level, not just on the levels, but also on the bilateral structure. Moreover, since the graphs are based on the estimated freight flows in Euros, $\hat{T}_{i.t}^{eugR}$, that is, on our own dataset, the similarity observed for the two pairs of flows also indicates that the process of estimating trade flows by combining freight flows and unit-values (prices) is adequate.

Figure 2-1: Spatial pattern of the Spanish international flows by road with the main European countries (average 2004-07)



Source: Own elaboration based on data from Datacomex and from our estimation of trade flows.

With the same purpose, we now estimate a regression model where the dependent variable is a vector with all the export flows from the trade statistics, $T_{i.t}^{eugR}$, for the period 2004-2007 (15 regions * 7 countries * 22 products * 4 years = 9,240 potential observations) and the independent variable is the equivalent vector of estimated flows obtained according to our methodology, $\hat{T}_{i.t}^{eugR} = \left(F_{i.t}^{eug\_National\_Trucks}\hat{P}_{i.t}^{eugR}\right)$. This model is expressed in equation (2.10) for the Spanish regional exports (*e= Spain*) and in equation (2.11) for the Spanish regional imports (*u= Spain*):

$$T_{i.t}^{eugR} = \beta_0 + \beta_1 \hat{T}_{i.t}^{eugR} + \varepsilon_{i.t}^{eugR} = \beta_0 + \beta_1 \left(F_{i.t}^{eug\_National\_Trucks}\hat{P}_{i.t}^{eugR}\right) + \varepsilon_{i.t}^{eugR} \qquad (2.10)$$

$$T_{.jt}^{eugR} = \beta_0 + \beta_1 \hat{T}_{.jt}^{eugR} + \varepsilon_{.jt}^{eugR} = \beta_0 + \beta_1 \left(F_{.jt}^{eug\_National\_Trucks}\hat{P}_{.jt}^{eugR}\right) + \varepsilon_{.jt}^{eugR} \qquad (2.11)$$

Note that variables $T_{i.t}^{eugR}$ and $\hat{T}_{i.t}^{eugR} = \left(F_{i.t}^{eug\_National\_Trucks}\hat{P}_{i.t}^{eugR}\right)$ - and the equivalent for imports- only account for the international trade flows transported by road. However, it is important to remember that they are not fully comparable: while trade statistics report all the flows transported by road, our estimated flows $\hat{T}_{i.t}^{eugR}$ only cover the Spanish carriers (with a share around 54-65% when the EU27 is considered, according to **Table 2.2**). Obviously, the aim of this model is solely to analyze the similarity of each pair of vectors (observed and estimated), without any other intention from the explanatory viewpoint. If each pair of vectors was identical, that is, the freight flows delivered by the Spanish trucks would be exactly the same than the trade flows reported by the official trade statistics; with the coefficient β_1 equal to 1.

As in the graphical analysis (**Figure 2-1**), the regression results shown in **Table 2.3** also confirm a strong relation between the 4 pairs of vectors compared, even when they are considered in the more disaggregated way (pooled data for 4 years and 22 products). As expected, the coefficients are close to the unity, indicating that the spatial and sectoral structure of the Spanish trade flows with these 7 EU countries delivered by Spanish trucks is very close to the observed structure of the official trade data. This result points out to an almost one-to-one relation between the two datasets at the highest common level of disaggregation. The determination coefficients, which quantify the total of variability captured by our dataset, are also relevant, between 54% and 65%. In general, the highest coefficients are observed in outflows when comparing quantities. In our view, the smaller R^2 obtained for the monetary flows are explained by the difficulty of measuring "aggregated prices for products (*g)*" departing from disaggregated variety unit-values (*k*). However, the high and significant coefficients found indicate a good performance of the methodology used for estimating such price vectors, as well as the effectiveness of the filters proposed for eliminating outliers.

Table 2.3. Regression (OLS) between equivalent vectors of international flows from trade and freight statistics: (T_{ijt}^{eugR} vs $\hat{T}_{ijt}^{eugR}$); (Q_{ijt}^{eugR} vs F_{ijt}^{eugR}). 2004 - 2007. Region-to-country sample considering: 7 EU countries; 22 products; 15 regions.

	Spanish Exports		Spanish Imports	
	(1)	(2)	(3)	(4)
VARIABLES	Euros	Tones	Euros	Tones
$\hat{T}_{ijt}^{eugR}$	0.712***		0.891***	
	(0.00693)		(0.00930)	
F_{ijt}^{eugR}		0.961***		1.045***
		(0.00843)		(0.0109)
Constant	1.558e+07***	7,606***	1.527e+07***	7,253***
	(1.025e+06)	(504.8)	(1.692e+06)	(564.7)
Observations	7,077	7,077	7,648	7,648
R-squared	0.599	0.648	0.546	0.545

Note: Standard robust errors (origin and destination regional partners clustered) in parentheses with ***, ** and * respectively denoting significance at 1%, 5% and 10%.

Before finishing this section, it is interesting to analyze the performance of the official trade statistics and our estimated datasets on a standard gravity equation like the one described in equation (2.12) for the Spanish exports and in equation (2.13) for the Spanish imports. Again, this exercise can be done only at the aggregate spatial level (region-to-country), for which both datasets are available.

$$Ln T_{i.t}^{e=Spain,u} = \beta_0 + \beta_1 Ln GDP_{it}^{Spain} + \beta_2 Ln GDP_t^{u} + \beta_3 Ln\left(dist_{i.}^{e=Spain,u}\right) + \mu_t + \varepsilon_{i.t}^{eu} \qquad (2.12)$$

$$Ln T_{.jt}^{e,u=Spain} = \beta_0 + \beta_1 Ln GDP_t^{e} + \beta_2 Ln GDP_{jt}^{Spain} + \beta_3 Ln\left(dist_{.j}^{e,u=Spain}\right) + \mu_t + \varepsilon_{.jt}^{eu} \qquad (2.13)$$

In equation (2.12) the endogenous variable $T_{i.t}^{e=Spain,u}$ are the Spanish exports from each region *i* to country *u* in year *t*. Conversely, in equation (2.13) the variable $T_{.jt}^{e,u=Spain}$ captures the Spanish imports in each region *i* from country *e* in year *t*. In both cases, the endogenous variables would be fed with the flows from our own dataset (columns 1, 2, 5 and 6 in **Table 2.4**) and from the official trade statistics (columns 3, 4, 7 and 8 in **Table 2.4**), separately. The rest of the variables are exactly the same, and correspond to the logarithms of the GDP of the exporting/importing location (region or country depending on the flow), while $ln(dist_{ij})$ is the logarithm of the distance between both locations, where the variable μ_t is the year fixed effect (one dummy variable per year).

Table 2.4. Comparative analysis of the performance of the gravity equation with alternative datasets. OLS and PPML pooled estimates for period 2004-2007. Region-to-country international flows (€).

	Spanish Exports to 7 EU countries				Spanish Imports to 7 EU countries			
	Our own dataset based on freight flows (€)		Official trade data (€)		Our own dataset based on freight flows (€)		Official trade data (€)	
	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	OLS	PPML	OLS	PPML	OLS	PPML	OLS	PPML
Variables	$\ln(T_{iJt})$	T_{iJt}	$\ln(T_{iJt})$	T_{iJt}	$\ln(T_{Ijt})$	T_{Ijt}	$\ln(T_{Ijt})$	T_{Ijt}
$\ln(GDP_{it})$	0.988***	0.828***	1.095***	0.997***	0.714***	0.834***	0.618***	0.731***
	(0.103)	(0.116)	(0.0650)	(0.0924)	(0.108)	(0.120)	(0.0743)	(0.0949)
$\ln(GDP_{jt})$	0.596***	0.697***	0.614***	0.526***	1.074***	0.938***	1.243***	1.262***
	(0.122)	(0.133)	(0.0767)	(0.132)	(0.0936)	(0.112)	(0.0730)	(0.123)
$\ln(dist_{ij})$	-1.832***	-1.607***	-1.800***	-1.385***	-1.45***	- 1.316***	-1.29***	- 0.868***
	(0.314)	(0.396)	(0.196)	(0.279)	(0.277)	(0.359)	(0.192)	(0.233)
Constant	-0.207	1.227	-2.802	-1.850	-6.658**	-5.341	-10.0***	- 14.70***
	(2.861)	(3.213)	(1.816)	(2.460)	(2.587)	(3.409)	(2.095)	(4.591)
Observations	379	416	416	416	387	417	417	417
R-squared	0.417	0.442	0.766	0.657	0.516	0.528	0.743	0.686

Note: Standard robust errors (origin and destination regional partners clustered) in parentheses with ***, ** and * respectively denoting significance at 1%, 5% and 10%. Fixed effects of year (μ_t) included. Considering just the selected sample (7 EU countries; 15 regions; Sectors: total).

Table 2.4 shows the results for equations (2.12) and (2.13) using the official trade ($T_{i.t}^{euR}$) data and our estimate based on freight flows ($\hat{T}_{i.t}^{euR}$), for both the Spanish regional exports and the Spanish regional imports with the 7 European countries (without considering their corresponding regions). The results are reported for two alternative estimators; namely, OLS and Pseudo Poisson

Maximum Likelihood (PPML). This latter estimator prevents problems of heteroskedasticity and zero value flows (Silva and Tenreyro, 2006). The results verify again the similarity of our dataset when it is tested –in parallel- to the official Spanish data on trade by road, in a simple gravity equation. The equivalence of the signs and elasticities, with the corresponding levels of significance, suggests a similar performance of the models when only the endogenous variable is changed. This result indicates that, for both datasets, the largest part of the bilateral flows (region-to-country) is explained by the level of accessibility by road (distance) and the size of the economies (GDPs).

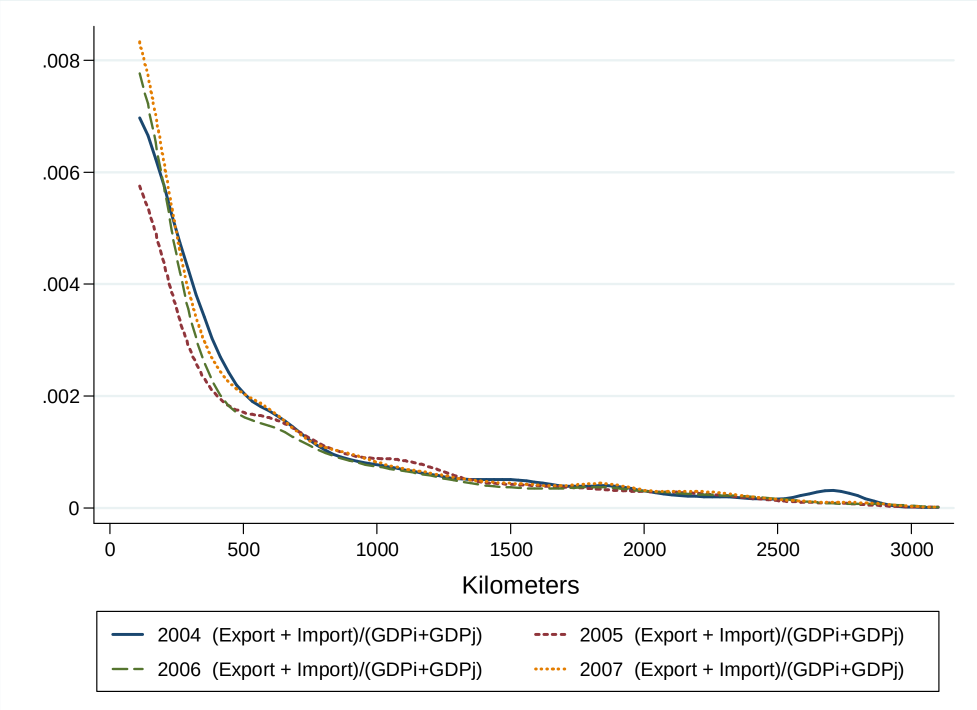
2.5.2 What does the dataset say about trade in Spain?

In this section, we briefly explore the new spatial dimension of our dataset using the region-to-region breakdown of the flows. First, following some recent works (Hillberry and Hummels, 2008; Llano-Verduras et al., 2011), we offer a first view of the distribution of trade depending on the distance travelled by the trucks in the international deliveries to the European regions considered. Like them, we use a kernel regression to provide a non-parametric estimate of the relationship between distance and the intensity of the Spanish regional trade flows[19]. In contrast to previous analysis based on cross-section data, we plot the kernel distribution of the consecutive years, obtaining a first intuition on the dynamics of the Spanish region's propensity to trade with further locations.

Figure 2-2 plots the distribution of the international flows (exports + imports) for each region against the rest of the European regions considered. Note that the trade flows are corrected by the GDPs of each exporting/importing flow. Therefore, the kernel distribution on the "corrected trade" on "the actual distance travelled by the Spanish trucks" is close to plotting a gravity equation. It is also worth mentioning that the highest concentration of the trade flows (in current monetary units) for each year occurs on the shortest distances, observing a downward trend of intensity in the first 700 km. This result is in line with those obtained in previous papers (Llano-Verduras et al., 2011), which analyzed all the Spanish flows (domestic and international), but considered all the flows (and not just the deliveries by Spanish trucks), without the region-to-region breakdown. We want also to emphasize that in most years, the highest intensity of international trade does occur on the shortest distance, among the first 100 kilometers. Behind this result is the fact that some important trading cities (Barcelona, Bilbao, Valencia, Valladolid, Vigo, etc) are not located on the frontier with Portugal or France, but at least 100 km away from it.

[19] We use the Gaussian kernel estimator in STATA, calculated on n=100 points, and allowing the estimator to determine the optimal bandwidth.

Figure 2-2: Kernel regression: Inter-national trade relative to the GDP on distance. NUTS-2 region-to-region data. Euros. 2004-07.

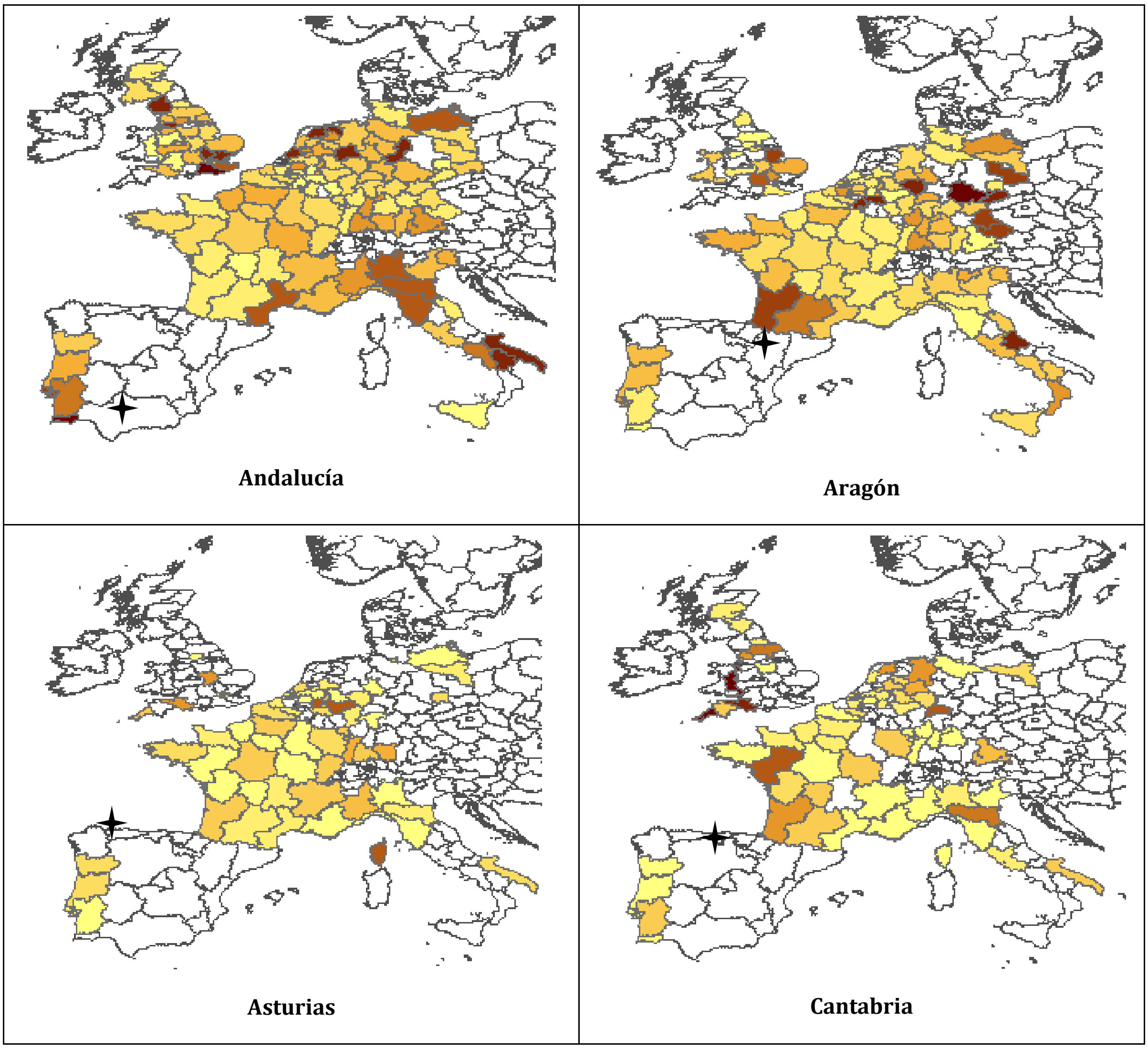


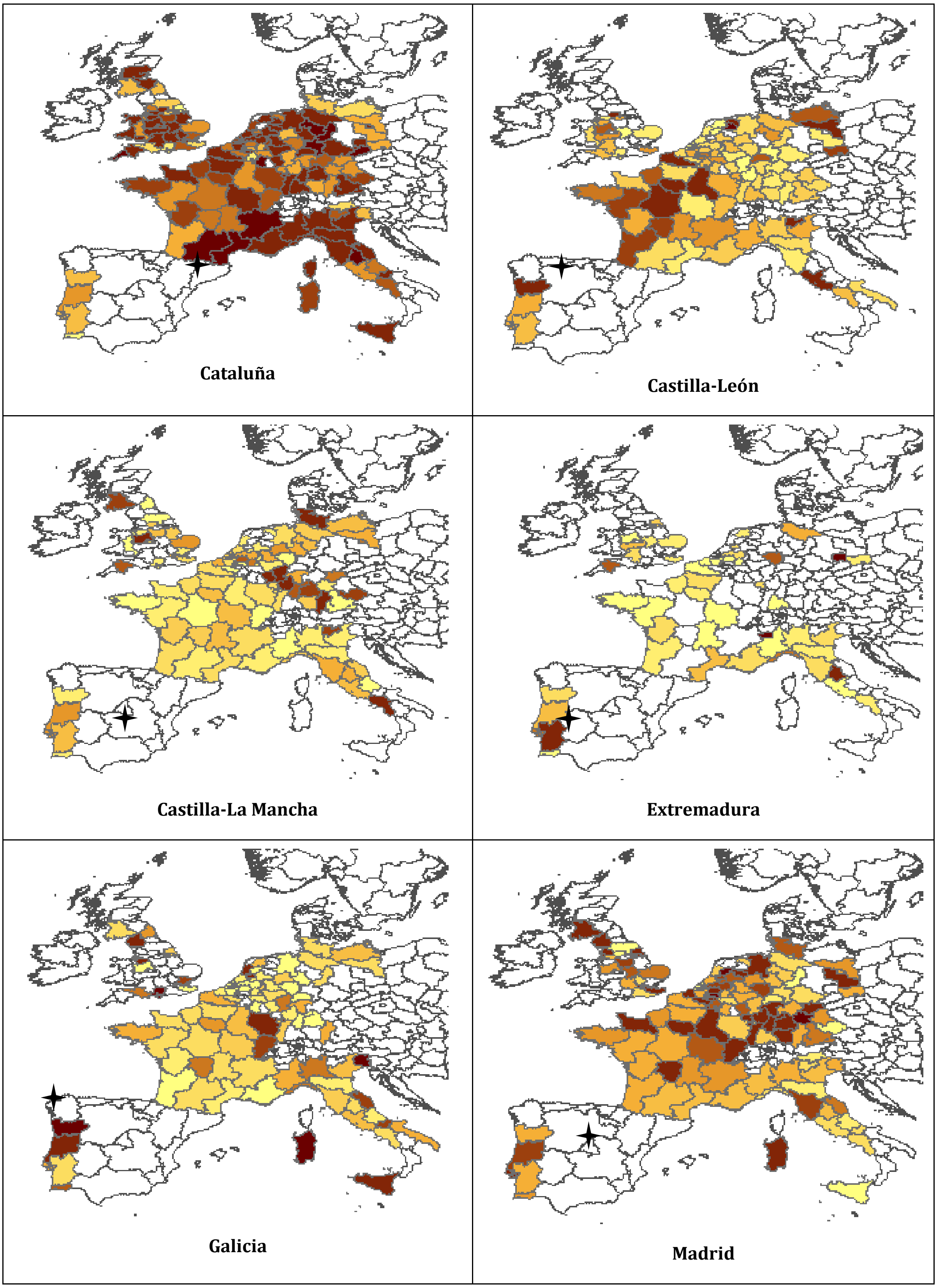
Next, we want to identify the main interregional and international aggregated flows. For the sake of brevity, we will define a comprehensive index based on that suggested by Streit (1969), which offers a condensed measure of the bilateral intensity of trade between any pair of regions. This index was computed using aggregate flows pooling the observations for the whole period. For clarity, the scripts for products (g) and time (t) are not included in equation (2.14).

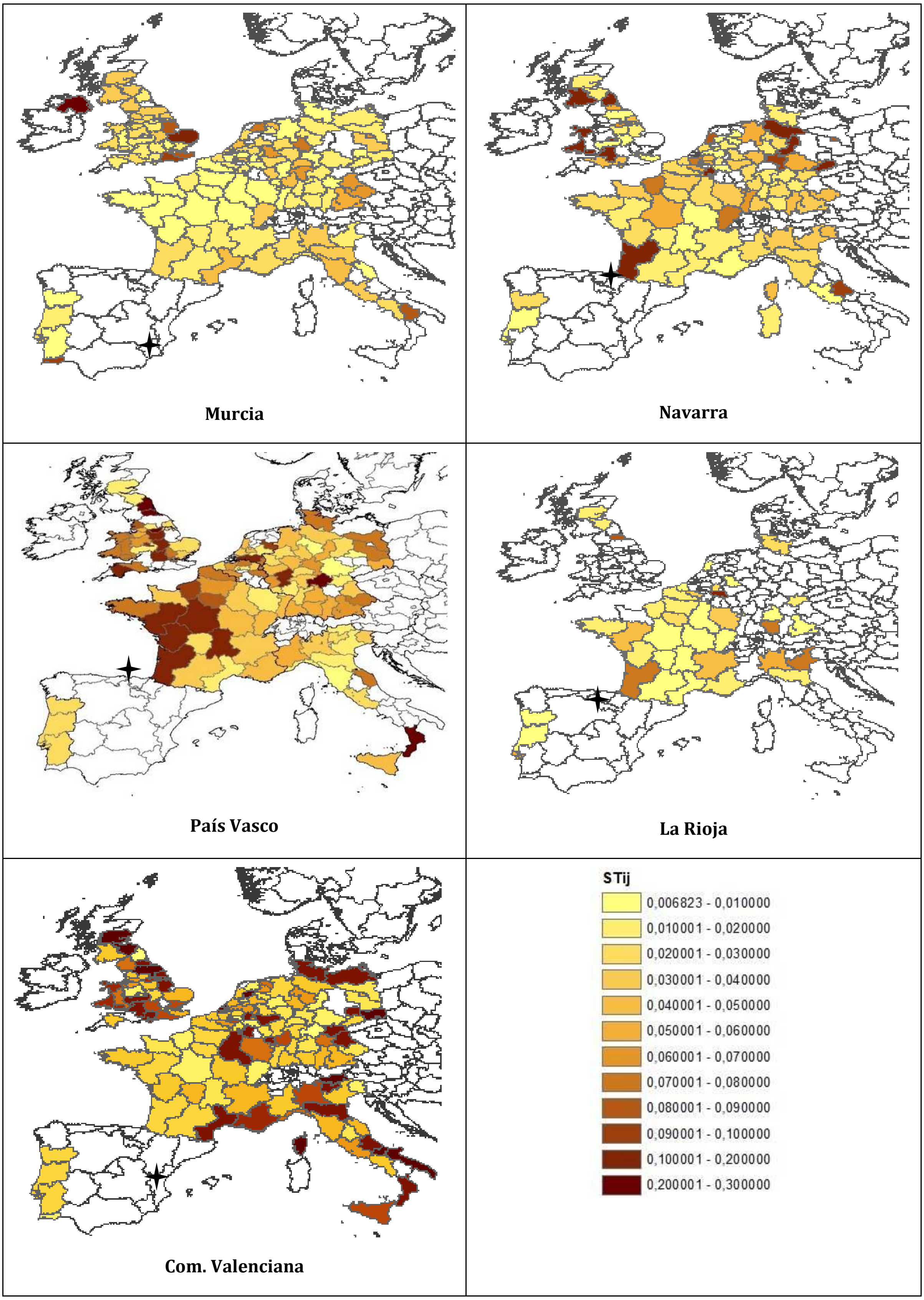
$$ST^{eu}_{ij\,Average(2004-07)} = \frac{1}{4}\left[\frac{\hat{T}_{ij}}{\sum_{i=1}\hat{T}_{ij}} + \frac{\hat{T}_{ij}}{\sum_{j=1}\hat{T}_{ij}} + \frac{\hat{T}_{ji}}{\sum_{j=1}\hat{T}_{ji}} + \frac{\hat{T}_{ji}}{\sum_{i=1}\hat{T}_{ji}}\right] \qquad (2.14)$$

The results obtained for the 15 Spanish peninsular regions are shown in **Figure 2-3**. First, it is worth mentioning the novelty of these maps, as well as the interesting spatial patterns *unveiled* by the new region-to-region dimension of our dataset. Then, it is important to highlight clear differences in the degree of spatial concentration of the trading partners (and their relative intensities) of the index obtained for each region. For example, the main exporting regions in the country (Cataluña, Madrid, Comunidad Valenciana, País Vasco, etc.), show a wider set of partner regions in the 7 countries considered. Also for this group of main exporters, the border regions with France tend to show a higher concentration of interactions with closer regions. In this regard, the spatial concentration of Cataluña's trade with the European regions located along the Mediterranean axis (within France and Italy), as well as the strong concentration of the País Vasco flows in the regions located along the Cantabric Coast-Axis (in France), seems to be mainly conditioned by "accessibility". By contrast, the lower level of spatial concentration observed in regions like Madrid, Andalucía or Comunidad Valenciana, points to alternative drivers, such as social and business networks, or more complex logistics' connections associated with the role of specific sectoral linkages, multinationals or intermediate products. In addition, one may want to consider a higher relevance of the airplane and maritime transport modes for the exports/imports of some regions with poorer road accessibility with regard to the EU core countries.

Figure 2-3: Main inter-national trade flows from selected regions by road (€). Streit Index. Average flows for period 2004-07.




Cataluña
Castilla-León
Castilla-La Mancha
Extremadura
Galicia
Madrid


Murcia
Navarra
País Vasco
La Rioja
Com. Valenciana
STij
0,006823 - 0,010000
0,010001 - 0,020000
0,020001 - 0,030000
0,030001 - 0,040000
0,040001 - 0,050000
0,050001 - 0,060000
0,060001 - 0,070000
0,070001 - 0,080000
0,080001 - 0,090000
0,090001 - 0,100000
0,100001 - 0,200000
0,200001 - 0,300000

Finally, based on the index computed in equation (2.14) we compute a gravity model using the region-to-region breakdown as well as different alternative specifications. The model is described by equation (2.15) and the results are reported in **Table 2.5**.

$$Ln ST_{ijt}^{eu} = \beta_0 + \beta_1 Ln\left(\frac{GDP_{it} GDP_{jt}}{\sum_{i=1} GDP_{it}}\right) + \beta_3 Ln\left(dist_{ij}\right) + \mu_t + \mu_i + \mu_j + \varepsilon_{ijt}^{eu} \qquad (2.15)$$

where ST_{ijt}^{eu} is the trade intensity index defined in equation (2.14) for each pair of region *i* in country *e* and region *j* in country *u* at year *t*. As an explanatory variable we introduce the distance *ln(dist$_{ij}$)* and a measure of the relative importance of the origin and destination region in terms of GDP with regard to the total GDP of all the regions considered. This variable labeled "share" $Sh_t = \left(\frac{GDP_{it} GDP_{jt}}{\sum_{i=1} GDP_{it}}\right)$ is related to the one used by other authors like Helpman (1987) and Feenstra (2004) in other contexts, where μ_t is the year fixed effect (one dummy variable per year). The terms μ_i and μ_j correspond, respectively, to the multilateral resistance fixed effects for each origin and destination region/country. These variables are introduced as a dummy for each Spanish region and for each of the European regions/countries considered. With the exception of the dummies, the rest of the variables are included in logarithms.

Table 2.5 shows the results for the estimation of equation (2.15) using the trade intensity index computed over our dataset with the region-to-region breakdown. The first 4 columns show the results for the pooled OLS with different combinations of spatial and temporal fixed effects[20]. In that specification, the trade index is regressed against the "share" and the distance variable. Then, the next 4 columns use a Random Effects (RE) Panel data model. The no rejection of the Hausman-test null hypothesis (reported almost at the bottom of the table), which is the absence of systematic relation between the dyadic estimators and the error term, points to the Random Effects model as the most efficient technique, rather than the Fixed Effects model, in addition of consistent. Comparing the results obtained for the two main variables in all the reported specifications, we can conclude that, in general and as expected, the average relevance of the outflows/inflows connecting any pair of regions is positively related with the corresponding

[20] Alternative specifications with PPML procedures were also estimated, obtaining similar results. These results are available upon request.

"share" in terms of the GDP of both regions (in the total of the regions considered), and negatively with the distance. The elasticities obtained for all the specifications are similar and coherent by pairs. It is worth mentioning that in the results obtained in columns (16) and (20), that is, with monodic fixed effects by regions (origin and destination) and by years, the "share" variable appears to be non-significant, probably because the fixed effects capture its effect.

Table 2.5. Results for the gravity equation based on Streit Index with region-to-region data. 2004 - 2007.

	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
	OLS	OLS	OLS	OLS	RE	RE	RE	RE
VARIABLES	$Ln(ST_{ijt})$	$Ln(ST_{ijt})$	$Ln(ST_{ijt})$	$Ln(ST_{ijt})$	$Ln(ST_{ijt})$	$Ln(ST_{ijt})$	$Ln(ST_{ijt})$	$Ln(ST_{ijt})$
$Ln(Sh_{ijt})$	0.198***	0.197***	0.448**	-0.702	0.150***	0.146***	0.480**	-0.643
	(0.0221)	(0.0221)	(0.226)	(1.317)	(0.0232)	(0.0234)	(0.221)	(1.222)
$Ln(dist_{ij})$	-0.69***	-0.69***	-0.99***	-0.988***	-0.569***	-0.567***	-0.830***	-0.827***
	(0.0947)	(0.0949)	(0.149)	(0.149)	(0.0762)	(0.0762)	(0.0957)	(0.0958)
Constant	-1.156	-1.179	-3.901	16.44	-2.009***	-2.012***	-5.792	14.04
	(0.770)	(0.771)	(4.198)	(23.25)	(0.666)	(0.667)	(4.061)	(21.64)
FE by origin country	YES	YES	NO	NO	YES	YES	NO	NO
FE by destination country	YES	YES	NO	NO	YES	YES	NO	NO
FE by origin region	NO	NO	YES	YES	NO	NO	YES	YES
FE by destination region	NO	NO	YES	YES	NO	NO	YES	YES
FE by year	NO	YES	NO	YES	NO	YES	NO	YES
Hausman test	-	-	-		2.81	2.51	0.33	2.65
					(0.245)	(0.774)	(0.847)	(0.754)
Observations	3,764	3,764	3,764	3,764	3,762	3,762	3,762	3,762
R-squared	0.141	0.142	0.374	0.374	0.138	0.138	0.370	0.370

Note: Standard robust errors (origin and destination regional partners clustered) in parentheses with ***, ** and * respectively denoting significance at 1%, 5% and 10%.

2.6 Conclusions

Researchers in empirical trade do not live in *a world with perfect traceability*, where products can be followed from the exact point of production to the exact final point of consumption. As a result, they usually confront the frustrating reality of a *world of incomplete information,* full of statistical gaps, disconnections and data constraints. For example, in the EU, there is a great need for datasets of the economic flows (goods, services, capital and people) that connect the regional economies of the corresponding countries. However, these variables are normally unavailable. Consequently, the spatial pattern of the EU single market at the sub-national level, and several important questions regarding the dynamics of its level of integration, are simply unknown.

In this chapter we describe a methodology to obtain region-to-region international flows by combining the trade and transport statistics usually produced by most of the EU countries. Then, we develop the corresponding dataset that captures intranational flows and international shipments by truck between the Spanish regions and other regions in the EU, both in volume and monetary units. The chapter focuses on describing the methodology used for estimating the Spanish flows, but it also points to straightforward extensions to other EU countries with similar statistics. Then, based on the new dataset obtained for Spain, a number of analyses are developed with the aim of testing the robustness and coherence of the figures, as well as for the identification of the main spatial patterns of Spanish international trade, with a region-to-region specific breakdown. Among these analyses, a bilateral trade intensity index between regions has been computed, plotted and regressed against the product of GDPs and distance. These analyses try to offer a compact characterization of the flows obtained, exemplifying their potential for the analysis of a wide range of issues related to the structure and dynamics of the European integration process at the subnational level. Thus, the ambition of this chapter is to serve as a methodological “hub” for further investigations and provide the first set of data based on it; i.e., the novel dataset between Spanish regions and those in the 7 EU counterparts. The main advantage of this framework lies in the fact of disaggregating the intra EU trade into nested spatial scales (national, Nuts 0; regional Nuts 2; and provincial, Nuts 3) with the possibility of controlling for the effect of their corresponding borders.

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2.8 Appendix

Appendix Table 2.1: Countries and regions included in the sample.

Countries	NUTS 0	Spanish Regions	NUTS 2
Andorra	AD	Andalucía	ES61
Belgium	BE	Aragón	ES24
Germany	DE	Asturias	ES12
Spain	ES	Baleares	ES53
France	FR	Canarias	ES70
Italy	IT	Cantabria	ES13
Netherlands	NL	Castilla y León	ES41
Portugal	PT	Castilla La Mancha	ES42
United Kingdom	UK	Cataluña	ES51
		Comunidad Valenciana	ES52
		Extremadura	ES43
		Galicia	ES11
		Comunidad de Madrid	ES30
		Región de Murcia	ES62
		Navarra	ES22
		País Vasco	ES21
		La Rioja	ES23

Appendix Table 2.2. Products (g) included in the sample. Based on the NST classification.

Code	Description	Code	Description
1	Cereals.	16	Natural or manufactured fertilizers.
2	Potatoes, other fresh or frozen	17	Coal chemicals, tar products.
3	Live animals, sugar beets.	18	Chemicals, except coal chemicals and tar
4	Wood and cork.	19	Pulp and waste.
5	Textiles and residuals, other raw	20	Vehicles and transport equipment,
6	Food and fodder.	21	Metalware.
7	Oil.	22	Glass, glassware, ceramic products.
8	Solid mineral fuels.	23	Leather, textiles, clothing, miscellaneous
9	Crude oil.	24	Various items.
10	Petroleum products.		
11	Iron ore, scrap, blast furnace dust.		
12	Minerals and non-ferrous residuals		
13	Iron products		
14	Cement, lime, manufactured building		
15	Raw or manufactured minerals		

Source: Permanent Survey on Road Transport of Goods, Ministerio de Fomento.

Note: shaded sectors are not considered in the empirical analysis of this chapter.

3 Thin and Thick Borders in the EU Single Market: How Deep Internal Integration is within Countries, and How Shallow between them[21]

[21] This research was developed in the context of the following projects: the C-intereg Project (www.c-intereg.es); the TransporTrade Program S2007/HUM/497, from the Comunidad Autónoma de Madrid; and ECO2010-21643 and ECO2013-46980-P from the Spanish Ministry of Economics and Innovation. I express my gratitude to the UAM for the FPI scholarships. Much-appreciated comments from various colleagues have served to improve the manuscript and get its publication in The World Economy (Gallego and Llano, 2014). Thank you Francisco Alcalá, David Weinstein and Jonathan I. Dingel; Francisco Requena; Asier Minondo; Rosella Nicolini, J.P. Lesage and Roberto Patuelli. Any errors herein are entirely the responsibility of the authors.

3.1 Introduction

But what, in economic terms, is a nation? As we move across geographical space, what is special about crossing a national boundary?

Fujita, Krugman and Venables, 1999, pp. 239.

As the main economic journals and newspapers have reported, several regions in Europe are demanding greater political autonomy or openly calling for independence. Such is the case with Cataluña and País Vasco in Spain (*Economist*, 2012a; *New York Times*, 2012), Flanders in Belgium (*Economist*, 2011) and Scotland in the UK (*Economist*, 2012b). What are the costs and benefits for the new economies to come and for the countries to which they belong? What would the overall consequence be for citizens and the European project as a whole? The aim of this chapter is not to answer these questions but adding first some *stylized facts* to the discussion.

If the EU moves towards a "Europe of regions", or any of the current sub-national units become a new member state, it would be critical to have a better knowledge of the level of integration (expressed in similar spatial units) that each has now—or could have in the future—with every other region of the Single European Market. In addressing the previous questions abstractly, we join other economists in wondering what, in economic terms, a nation actually is, and how national and regional boundaries differ as impediments to economic integration. The border-effect literature offers a valuable basis for discussion, since it allows us to quantify, after controlling for a set of factors, the higher intensity of trade within a certain spatial unit in comparison with the intensity in other markets.

For the European Union (EU), certain papers have estimated the relevance of international borders by comparing a European country's domestic trade volume with its international trade volume (Head and Mayer, 2000; Minondo, 2007; Chen, 2004). Similar analyses have been produced at the sub-national level so as to compute external border effects. These have taken a country's regions (or provinces) as their point of reference and counted how many more times they traded with the rest of the country (as a whole) than with other countries (Gil et al., 2005; Ghemawat et al., 2010).

In parallel, we also find estimates of internal border effects, defined as how much more trade a region (province) of a given country conducts with itself than with any other region (province) of the same country. Wolf (1997, 2000), for example, while investigating market fragmentation in the United States (US), found intra-state trade unduly high in relation to inter-state trade. Later, Hillberry and Hummels (2008) analyzed the impact of geographical frictions on trade, using truck deliveries within U.S. at different spatial levels. They found that internal border effects would disappear in the U.S. as the spatial units became very fine. Similarly, Combes et al. (2005) and Garmendia et al. (2012), taking into account social and business networks, investigated the narrowing of internal border effects at the province level (Nuts 3) for France and Spain, respectively.

To the best of our knowledge, no one has yet produced an initial estimate of border effects in Europe. No one, that is, has estimated how much more trade a particular region of a European country conducts with another region of the same country than with a third region in another European country. The reason is lack of data on region-to-region trade flows between Europe's countries. Thus the most ambitious attempts to measure the effect of international borders on inter-regional trade structures in the European Single Market are either indirect or restricted to border regions with intense bilateral trade relations (Lafourcade and Paluzie, 2011; Helble, 2007).

Moreover, whenever an external border effect has been computed—on the basis of flows between sub-national units on both sides of a national border (McCallum, 1995; Anderson and van Wincoop, 2003; Feenstra, 2002, 2004)—only inter-regional flows between contiguous countries (e.g., Canada-US.) have been considered. The actual effects of a national-border crossing have thus been mixed with those of high economic integration and cultural and historical similarities. It would therefore be most interesting to have an alternative estimate of Anderson and van Wincoop's border effect, one between the Canadian provinces and the regions of a non-contiguous country: the Mexican states, for example. Space being non-neutral, we should keep in mind that a Canadian province wishing to deliver a product by truck to regions in another country must either trade with the U.S. or send the truck across it. The U.S., on the other hand, can deliver products by truck to two contiguous countries, Canada and Mexico. Similarly, Spain can trade with three contiguous countries (Portugal, France and Andorra), and with many others once its trucks have crossed France. Since competing destinations so thoroughly condition international trade (Anderson and van Wincoop, 2003), and different European countries share such different levels of economic and cultural integration, it would be interesting to compute external border effects *à la* McCallum—but to do so for region-to-region trade between non-contiguous European countries as well. This would give us a first insight into the true roles played by various national borders.

In this chapter, using a unique dataset that captures region-to-region intra- and inter-national trade, we estimate internal and external border effects, contrasting the intra- and inter-regional trade between Spanish regions (Nuts 2) against their inter-regional trade and those of the most important 7 European trade partners (and using the methodology described in the previous chapter to compile the robust and novel database of these flows). To do so, we test several specifications of the gravity model (McCallum 1995; Feenstra 2002, 2004; Anderson and van Wincoop 2003; Gil et al, 2005), producing benchmarks for the results of our novel dataset. Then, in line with some recent papers (Head and Mayer, 2000, 2002; Hillberry and Hummels, 2008; Llano-Verduras et al., 2011; Garmendia et al., 2012) we also consider the non-linear relationship between distance and trade that appears when the analysis is conducted at a low spatial scale. Like in these previous papers, we obtain border effects that shrink along with the size of the exporting unit, simply by dividing up the spatial unit of the importer (from country to regions). This result probably masks the mismeasurement of the external border effect in region-to-country data, a mismeasurement due to an inappropriate assumption about the distribution of trade within the importing country's regions.

In sum, in this section we contribute to the previous literature in the following ways: (1) It produces the first estimates for the external border of European regions by means of region-to-region flows, just as McCallum, Feenstra or Anderson and van Wincoop did for Canada and the U.S.. These estimates confirm that trade integration is even higher between European regions than between North America's equivalent spatial units; (2) It computes external and internal border effects for inter-regional, intra-national and inter-national flows between one country (Spain) and its seven main European partners. Whereas previous papers considered only inter-regional trade between two contiguous countries, this approach sheds new light on the effect of different national borders; (3) It analyzes in detail the external border effect for each Spanish exporting region, as well as for the seven EU countries considered. We thus shed new light on the *relative integration of regions* (corrected by distance and market potential) of these seven countries with regards to the Spanish exporting regions. Surprisingly, the analysis points a greater integration of the Spanish regions with the richer and more distant European regions of the so-called *"blue banana",* than with closer foreign locations; e.g., french regions. We therefore part ways with previous papers (Lafourcade and Paluzie, 2011) and conclude that the intensity of trade in border regions, although clearly above average, is significantly less than what we would expect given their greater market potential (per capita income/distance) with respect to the European core. The analysis concludes, finally, with an interesting extrapolation exercise, where we compute the "trade potentials" that would be expected in a fully integrated Europe—that is, assuming a non-external border effect for the Spanish regions when they export to the regions of these seven countries. We then estimate how long each Spanish exporting region would take to reach full integration, considering two alternative scenarios with regards to the pace of penetration in those markets. The first scenario considers the pre-crisis evolution of the Spanish exports to these seven countries, taking into account the growth rates observed in the exports of each region from 2001 (the introduction of the euro) until 2008 (the last year before the sharp downturn in trade). The second scenario is based on the evolution of the Spanish exports to these seven countries during the period of recovery (2011-2013). The result shows that, for the two scenarios, it will take from 30 to 1,337 years to achieve the same level of integration with the EU than with the other Spanish region. Moreover, the results suggest that in some cases (Asturias), it will take between 400 and 1,000 years to reach that level of integration assuming the exporting dynamic observed before or after the crisis. In our view such dramatic figures, generated even with prudent hypotheses, clearly illustrate the role of internal and external borders, and provide some insight for the debate on what a nation is in economic terms.

The rest of the chapter is organized as follows. Section 2 describes the alternative specifications of the gravity equation used in our analysis. Section 3 briefly summarizes our method for estimating a region-to-region intra-national trade dataset for the Spanish case, the process used for re-scaling the region-to-region international flows to make them coherent with the official levels (region-to-country), and offers a descriptive analysis of new trade flows. Section 4 presents the results obtained with different specifications of the gravity equation. Our analysis explores new dimensions of the dataset, offering detailed results by exporting Spanish regions and importing EU regions. The final section summarises the main conclusions of our work.

3.2 The Empirical Model

The backbone of our investigation is the gravity equation, which was reviewed in the first chapter of this thesis (**Section 1.4**). Under this equation the intensity of trade between any two locations (regions or countries) is positively related to their economic size and inversely related to the trade cost (proxy by geographical distance) between them. However, we depart from previous literature by redefining specific border effects to be measured. By internal border effect we denote the number of times a Spanish region trades more with itself than with any another region in the sample. By external border effect we denote the number of times a Spanish region trades more with another Spanish region than with a foreign region elsewhere in Europe, controlling for a set of factors.

First, we define our specifications by taking inspiration from some classic papers on the estimation of border effects with sub-national spatial units in Canada and the U.S. (McCallum, 1995; Anderson and van Wincoop, 2003; Feenstra, 2002, 2004). We will thus for the first time estimate the real value of border effects in an EU country as measured with homogeneous spatial units on both sides of the national border (region-to-region, instead of country-to-country or region-to-country). Next, we use our dataset to replicate the specifications used to generate previous estimations of region-to-country trade flows in Spain (Gil et al., 2005). We thus highlight for the Spanish case the difference between these benchmark results, and the results obtained with our new dataset. It is important to note, however, that despite our efforts to keep close to the benchmark assumptions, certain important differences in the datasets will limit the comparability of the results. These differences are laid out in **Section 3.4**.

For the sake of brevity, we here define two equations that contain all the models used in this article. They include variables that will be *switched on* or *off* depending on the model in use at a given time. For example, equation (3.1) formulates a general specification for estimating the external border effect using the inter-regional flows (intra excluded) along with GDPs, distance and other standard control variables:

$$LnT_{ijt}^{eu} = \beta_0 + \beta_1 LnGDP_{it} + \beta_2 LnGDP_{jt} + \beta_3 External\_Border + \beta_4 Ln(dist_{ij}) + \beta_5 External\_Contig + \mu_i + \mu_j + \alpha_{ij} + \mu_t + \varepsilon_{ijt} \quad (3.1)$$

where LnT_{ijt}^{eu} [22] is the logarithm of the flow from region *i* in country *e* to region *j* in country *u* in year *t*. Note that: (a) if *e = u = Spain* and *i = j*, equation (3.1) will capture intra-regional trade flows for a Spanish region *i*; (b) if *e = u = Spain* and *i ≠ j*, equation (3.1) will capture inter-regional trade flows for a pair of regions within Spain; (c) if *e ≠ u*, equation (3.1) will capture inter-regional flows between Spain and another European country in the sample. It is then clear that this chapter focuses on flows originating in Spanish regions, *e = Spain*, but the model could be used in any other country. The variables $lnGDP_{it}$ and $lnGDP_{jt}$ are the logarithms of the nominal gross domestic product (GDP) of the exporting and importing region, respectively. The variable $lndist_{ij}$ is the logarithm of the distance between region *i* and region *j.*

The variable *External_Border* is a dummy that takes the value one for inter-national flows, when the trade flow crosses over an international boundary (*u ≠ Spain*), and zero otherwise. The

[22]In order to alleviate notation, henceforth, we refer to T_{ijt}^{eu} as the "*estimate value*", and not as the "theoretical value" which is unobservable, of trade flows obtained in the previous chapter ($\hat{T}_{ij}^{eugR}$ according to the notation of said chapter, and described in Eq. (2.7)).

anti-log of the parameter associated with this variable measures the size of the external border effect.

To capture the positive effect of adjacency, we introduce the dummy variable *External_Contig*, which takes the value one when trading partners are contiguous, but do not belong to the same country. This variable conveniently controls for higher concentration of trade between border regions of different countries (Spain-Portugal, Spain-France). It is in line with the results of Lafourcade and Paluzie (2011), who have shown that border regions in countries like France and Spain tend on average to capture larger shares of bilateral trade and FDI flows. The terms μ_i and μ_j correspond to multilateral-resistance fixed effects for the origin and the destination region, respectively. Their inclusion follows Anderson and van Wincoop (2003) and Feenstra (2002, 2004) and they are meant to control for competitive effects exerted by the non-observable price index of partner regions and by other competitors. They are also meant to capture other particular characteristics of the regions in question. The variable α_{ij} is the region-pair effect and μ_t the time fixed effect.

We next define an additional set of models based on equation (3.2):

$$Ln\frac{T_{ijt}^{eu}}{GDP_{it}GDP_{jt}} = \beta_0 + \beta_1 Internal\_Border + \beta_2 External\_Border + \beta_3 dist_{ij} + \beta_4 dist_{ij}^2 + \beta_5 Internal\_Contig + \beta_6 External\_Contig + \mu_{it} + \mu_{jt} + \mu^u + \mu_t + \varepsilon_{ijt} \qquad (3.2)$$

where $\frac{T_{ijt}^{eu}}{GDP_{it}GDP_{jt}}$ represents bilateral flows originating in Spanish regions and corrected by the GDPs of the trading regions. Anderson and van Wincoop (2003) have shown that the inclusion of bilateral trade corrected by unitary income elasticity does not greatly affect the other parameters.

This specification includes the variable *Internal_Border*[23], which controls for flows that cross a domestic frontier, i.e. it takes the value one when the origin and the destination are different

[23] Although the concepts of "border effect" and "home bias" are different, they are sometimes used synonymously in this literature. Papers using the "home bias" label emphasize the uneven intensity of trade within a region (or a country), which can be the result of a "bias" in preferences toward domestic goods, whereas those using the "border effect" label tend to remark the negative effect that borders exert on flows delivered to the other regions (or countries), given the same preferences. Here, to make clear that we are interested in the negative effect of the boundaries, we have defined the dummies in terms of how much lower is trade when partners are separated by a frontier (regional or national). Although the papers that we adopt as references (McCallum (1995), Anderson and van Wincoop (2003) and Gil et al. (2005)), define the dummies of interest in the opposite way, it must be noticed that the only difference in the results is the sign of the the parameter, negative in our estimates and positive in theirs.

regions but both belong to the same country (interregional flows within Spain trade *e=u=Spain* and *i ≠ j*) and zero otherwise. In addition, the variable *External_Border* is a dummy that controls for flows that cross an international boundary, i.e. it takes the value one for inter-national flows (*e*=Spain*; u* =any of the 7 European countries considered) and zero otherwise. The anti-log of the parameter associated with these two variables measures the size of the effect that regional and national borders respectively exert on trade. It also includes certain refinements in the treatment of distance. It thus includes, apart from the traditional variable $dist_{ij}$, a new variable $dist_{ij}^2$. As in Hillberry and Hummels (2008), Llano-Verduras et al. (2011) and Garmendia et al. (2012), the variable $dist_{ij}^2$ is defined as the square of the distance between trading regions, and it is expected to capture the non-linear relationship between trade and distance that is observed for kernel regressions in **Figure 3-2**. Also in line with these papers, we split the interpretation of these two variables (capturing the negative but non-linear effect of distance on trade) into two parts: (i) a negative and direct effect of distance on trade, and (ii) a positive effect for the square of the distance, to capture the high concentration of trade over the shortest distance as observed in the kernel regressions. Note also that the contiguity variable is also split into two variables: *Internal_Contig* and *External_Contig*. This allows us to consider (simultaneously or independently) the different effects that *adjacency* exerts on trade flows between two contiguous regions in Spain or between a Spanish region and a contiguous foreign one. The terms μ_{it} and μ_{jt} correspond to the multilateral-resistance fixed effects for each origin and destination region interacted with time, respectively. It is worth mentioning that the initial origin and destination fixed effects of Anderson and van Wincoop (2003) and Feenstra (2002) did not consider their interaction with time, because they used a cross-section dataset, instead a pool of data. To account for the likely heterogeneity between countries and its effect on the estimate of a single border effect, we have also added a fixed-effect term for each destination country (μ^u). Finally, to consider the time dimension, we have included a time fixed-effect term which regards the global shocks that may affect the estimate of the structural border effect over the period considered.

Having defined all the variables and specifications, we now briefly explain the models used for our empirical analysis and the ways they include our variables and specifications. The estimation methods and data types used for the first set of models are as similar as possible to those of the benchmarks. For models 1 and 2 (M1 and M2), the estimation of equation [1]—as in McCallum (1995) and Anderson and van Wincoop (2003)—is based on cross-section datasets (2011) for region-to-region flows, and it takes into account only non-zero values (zero values represent 44% of our sample; 2004-2011). For comparability with previous authors (Gil et al., 2005), in models M3 and M4 we incorporate the dataset broken down in region-to-country level, we use a specific econometric technique (panel random effects) and define the same distance measure. This distance is a weighted average of geodesic distance between the main cities within each region. Estimates for the other models are based on equation (3.2) (**Table 3.2**) and use a pool of data (2004–2011). For models estimating the external border effect, intra-regional trade flows are excluded (and *Internal_Border* therefore drops). For models focusing on the internal border effect, international flows are excluded (and *External_Border* drops).

Ordinal Least Square (OLS) estimators are used when the gravity equation is applied to a dataset with no zero values. When zeros are included[24], we use instead the Poisson pseudo-maximum likelihood technique (PPML). It was Santos Silva and Tenreyro (2006) who proposed using the PPML approach, which also sorts out Jensen's inequality (note that the endogenous variable is in levels) and produces unbiased estimates of the coefficients by solving the heteroskedasticity problem. For M3 and M4—as in Gil et al. (2005)—we use a panel random effect estimator (REM) with time fixed effects.

3.3 The data

In the previous chapter, we laid out a method for estimating region-to-region international flows between Spain and seven European countries[25], by doing this we got a first estimation of international trade flows at region-to-region level. It combines region-to-region freight statistics for Spanish trucking with international price indices (deduced from official trade data[26]) for each year region-country variety. In the previous chapter, we evaluated our dataset in terms of its variability in comparison with the variability of the official data (both in terms of region-to-country product), being the results satisfactory. Nevertheless, one should keep in mind that our database only includes international flows transported by Spanish trucks, and although relevant,

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[24] The zero values considered in our dataset correspond to region dyads that had non-zero values in at least one year of the period 2004–2011. Zeros corresponding to regions that did not receive any exports from a Spanish region during that period are not considered in our sample.

[25] Although for the sake simplicity we use the label EU, our sample of countries does not fall under any specific administrative category.

[26] As discussed in the previous chapter, for most of our EU countries, two main sources for the inter-national bilateral flows of goods exists: (1) Trade statistics on intra-EU trade, which register bilateral flows between pairs of countries, both in volume and in monetary units; for certain countries, like Spain, the trade data identify the exporting or the importing region but never both simultaneously; (2) Transport statistics on intra-national and inter-national freight flows, which in some cases (e.g., road freight) provide information on the type of product transported (quantity) as well as on the regional origin and destination of the flows. Our method aims to build up a region-to-region trade dataset by combining these two sources: (1) Region-to-region flows in quantities (road-freight statistics), and (2) specific region-to-country trade prices (from the official trade statistics).

they do not encompass the full population of possible carriers (see **Table 2.2** for a description of the share that the main carriers show in the Spanish exports and imports to the EU). Thereby, the dataset does not have to match the value of the official data (region-to-country). Note, in advance, that in this chapter we attempt to estimate the border effect for the case of Spain, therefore levels matter, as they might result in biased border effect estimates. Then, in order to improve the quality of our international flows, the levels are rescaled to reconcile them with the official information available on international trade by road (customs). This match is set at the lowest common level of disaggregation available for both sources of annual region-to-country international trade by road for each specific product (NSTR-3 digits). Therefore, the final database keeps the region-to-region dimension and is coherent with the official levels on Spanish exports by road to these countries. In sum, this process of harmonization has two main advantages: i) First, it rises the level of representativeness of our dataset in levels, due to the fact that our region-to-region original dataset on freight flows only includes deliveries developed by Spanish trucks, while the official trade levels -used now as constraint- include all deliveries by road (regardless of the nationality of the transporter)[27]; ii) Second, having in mind that the purpose of our analysis is the quantification of the border effect, i.e. the measure of differences in levels of trade depending on the final destination, it is crucial to assure the comparability between the levels of the Spanish deliveries within Spain and the ones to the EU countries. After this harmonization with the official flows by road, most of the potential biases are avoided.

The other novelty of this dataset respect to the one estimated in the first chapter is that this covers a wider period, from 2004 until 2011, instead from 2004 until 2007, what allows us to evaluated in deeper detail the effect of the current crisis.

This unique dataset for region-to-region international trade flows was connected with equivalent data on (intra- and inter-regional) trade flows within Spain. This second dataset is similar (but not exactly the same) to the ones used in previous analysis (Garmendia et al., 2012; Llano-Verduras et al., 2011; Ghemawhat et al., 2010; Requena and Llano, 2010; Llano et al., 2010). The result is a unique dataset on region-to-region flows for intra-regional, inter-regional and inter-national flows into and out of the regions of Spain (Nuts 2) and the regions of Spain's seven main European partners.

Our distance variable gathers the *actual distance* covered by Spanish trucks between each pair of trading regions, as reported in the survey published by Spain's Ministry of Public Works and

[27] It is important to remark that, since Spanish trucks account for the main share in the Spanish exports by road to these seven EU countries, we can assume that the region-to-region structure observed for the Spanish trucks (observable in the freight statistics) is similar to the (non-observable) structure corresponding to the non-Spanish trucks.

Transport (Ministerio de Fomento). This variable has the virtue of capturing the *real distance* travelled by trucks between actual points of departure and destinations. In this sense, it is superior to the variables used by other authors, where intra-national and/or inter-national distance is either a-priori estimate based on the great circle distance between main cities weighted by population or an ad-hoc estimate by mathematical approximation. By using actual distance, we should, in theory, be able to account for region-to-region inter-country links that are not attributable to the mere allocation of population. There are specific regional endowments or specificities that weighted distances tend to mask. The Ministry's survey also includes the actual distance travelled by trucks for intra-regional deliveries. Crucially, this allows us to avoid choosing alternative ad-hoc intra-regional distances, which alter results on border effects (Head and Mayer, 2002). Because the actual distance travelled by each truck between each pair of regions may vary in every year, and with the aim of eliminating the risks of endogeneity, we have arrived at our intra- and inter-regional distances by averaging the distances observed in all deliveries from 2004 to 2011 for each specific dyad i-j[28]. Regional GDPs for the EU regions under consideration are published by Eurostat.

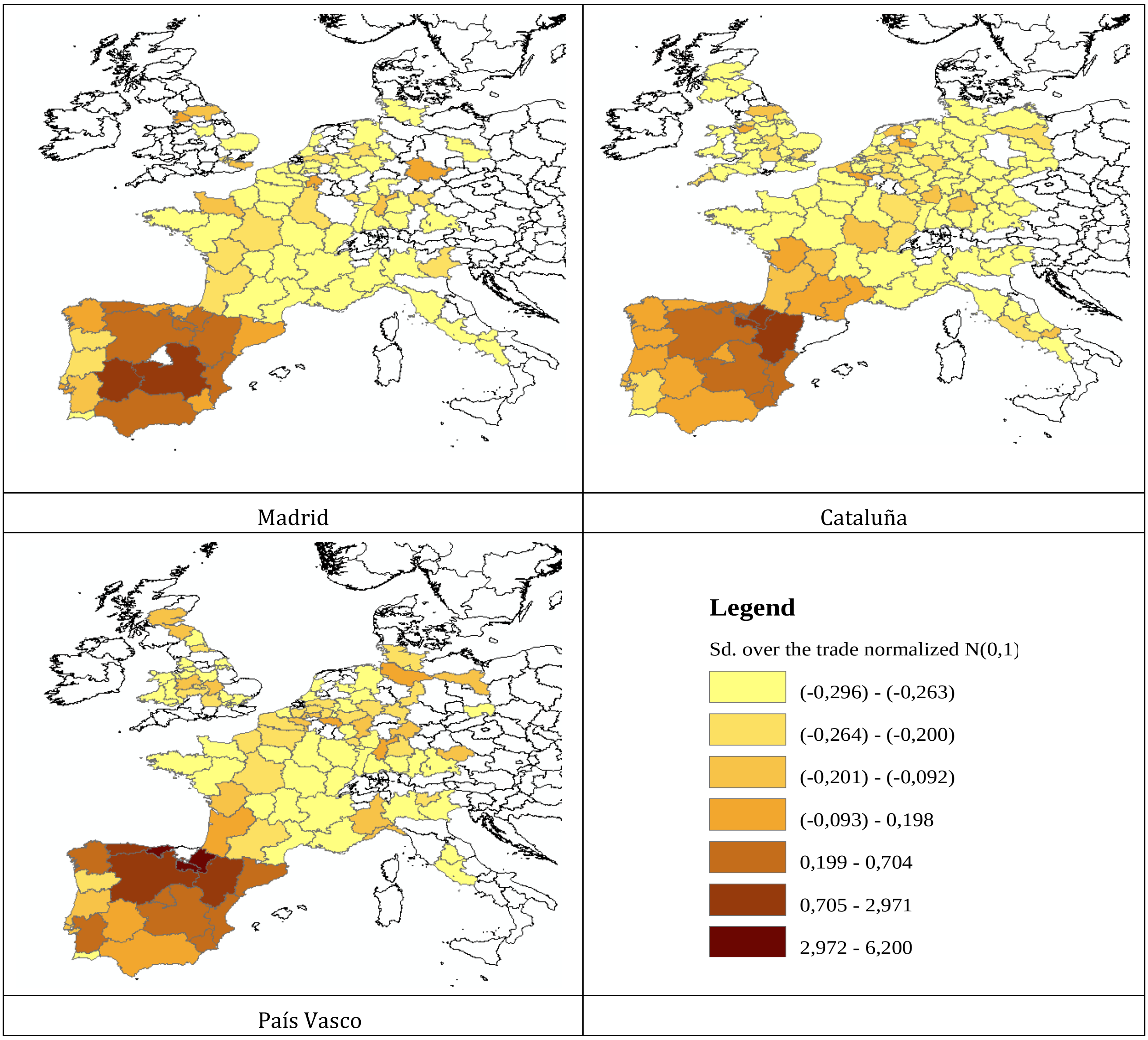
3.3.1 Descriptive analysis: the non-linear relation between distance and trade

Before proceeding to the econometric analysis, we will briefly analyze the novel dataset. **Figure 3-1** plots the spatial concentration of exports delivered from three important Spanish regions, corrected by the product of the GDPs of the trading partners and expressed in terms of standard deviations. The maps are referred to the average of the largest period available (2004-2011). It is worth mentioning the novelty of these three maps, which reveal the hitherto unknown region-to-region dimension of Spanish trade relations with seven European partners. It is important, also, to highlight that in all three cases intra-national trade flows are clearly greater than inter-national flows. The intensity of the color shows a clear discontinuity in the relevance of trade flows between Spanish and European markets, even when three of the country's main exporting regions are considered. As we will see in the next sections, this result leads to significant external border effects for all exporting regions and all importing countries. Note that for all three regions the most intense interregional trade flows within Spain are concentrated in the closest regions. This will be tested by contiguity dummies.

[28] More precisely, we obtained the actual distances used in this thesis by first screening out outliers: i.e., distances that are too great for a specific dyad. We then computed the actual distance for each regional dyad (aggregate) for each year, starting from the most disaggregated level (micro-data at the municipality level for the Spanish exporting unit). Finally, we obtained intra- and inter-regional distances by averaging the distances observed in all deliveries from 2004 to 2011 for each specific dyad *i-j*.

In addition, like some recent papers (Garmendia et al., 2012; Llano-Verduras et al., 2011; Hillberry and Hummels, 2008), we offer here a first view of the distribution of trade (always region-to-region) as it depends on distance travelled by trucks, for both domestic and international deliveries. Like them, we also use a kernel regression to generate a nonparametric estimate of the relationship between distance and the intensity of Spanish regional export flows[29]. One novelty of this approach is that we plot the kernel distribution for consecutive years in the same graph.

Figure 3-1 : Main Intra-and Inter-National trade Flow by Road from Selected Regions (standard deviation over the full sample normalized) Data: average dyadic flows for 2004-2011



[29] We use the Gaussian kernel estimator in STATA, with n = 100 points and the estimator calculating optimal bandwidth.

Figure 3-2: Kernel Regression: Intra- & Inter-National Trade Relative to GDP (NUTS-2 Region-to-Region) on Distance. Zero Flows Excluded. (€). 2004–2011.

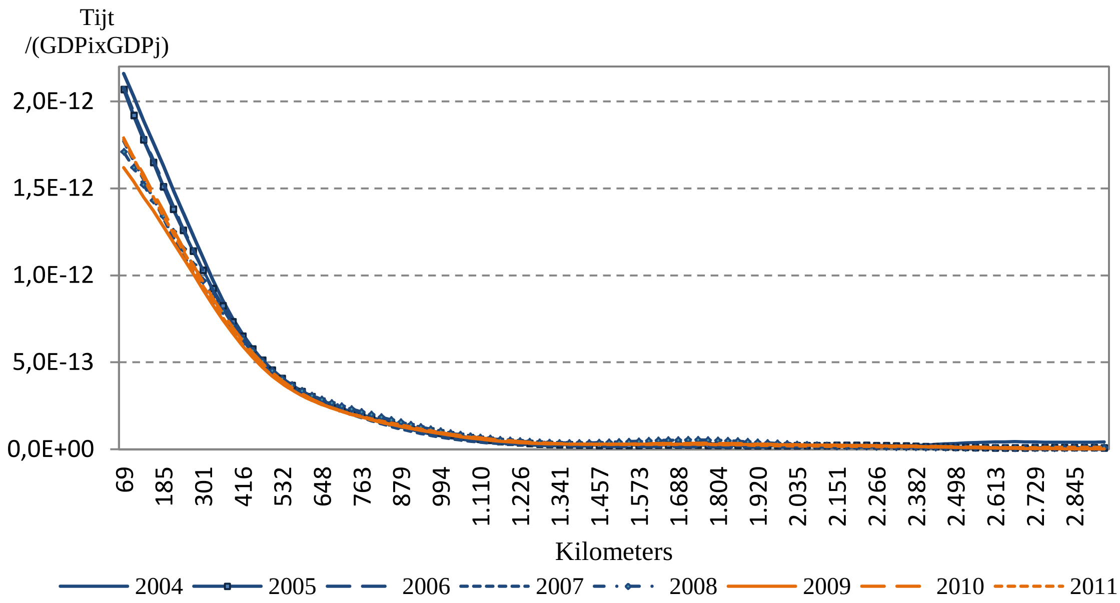


Figure 3-2 plots the distribution of domestic and international flows (exports) for each region against those for the rest of Spain's regions and the seven European countries. Note that trade flows are corrected by the GDP of each exporting/importing region.

Therefore, the kernel distribution for the corrected trade over the actual distance travelled by the Spanish trucks is close to plotting the endogenous variable considered in the gravity equation (3.2) against the distance. It is also worth mentioning that, even when intra-regional trade flows are not included, the highest concentration of trade flows (in current monetary units) for each year occurs over the shortest distance, and follows a decline in intensity in the first 700 km. This result is in line with the results of previous papers (Llano-Verduras et al., 2011), which also analyzed all Spanish flows (domestic and international), considering all the flows (and not just the deliveries by Spanish trucks) but without the region-to-region breakdown we study here. Before discussing the econometric results, it is convenient to remark a slight variation in the shape of the kernel regression during the period. Such variation is clearer in the thicker part of the distribution, that is, the one that corresponds to the largest intensities of trade observed in the shortest distance. To this regard, the volume of trade in the shortest distance is larger at the beginning of the period (2004) than at the end (2011). To make this point clear, the lines corresponding to the pre-crisis / post-crisis are plotted with two different colours. In our view, this result is connected with the two paradigmatic patterns of trade observed in Spain before and after the crisis, something that will be analyzed with some detail in section 3.4.1.

3.4 Results

We begin our empirical analysis by revisiting some classic specifications for the estimation of border effects, so as to test the performance of our new dataset against them. This will afford us some measure of comparability with previous results and thus allow us to determine which of our results derive from new specifications and which from our dataset itself. **Table 3.1** lays out the results for four models.

The first two models (M1 and M2) mirror those of McCallum (1995), Anderson and van Wincoop (2003) and Feenstra (2002, 2004)30. As reported in the first column (M1), when considering our dataset the McCallum-like specification generates an external border effect of 24 (vs. McCallum's 22 for Canada-US). The coefficients and signs for the rest of the variables align with expectations. There is, however, a slightly lower coefficient for GDPs than the normal values in our benchmarks, which use all trade flows and not just truck deliveries. Similarly, results for model 2 (M2) were generated by our novel dataset and a specification similar to that defined by Anderson and van Wincoop (2003) and Feenstra (2002, 2004). The results once again align with expectations. As in the benchmark papers, we find a significant decrease in the external border effect (now of factor 14) when multilateral resistance terms are taken into consideration.

Table 3.1: Estimations with Classic Specifications from Previous Papers.

[30] Before comparing results, we should point out some relevant differences between our dataset and the dataset used by these authors: (i) We must emphasize that values obtained for the external border effects in a country like Spain in its trade with seven European countries can hardly be compared with the figures for Canada and the US. (ii) Our distance variable for intra- and inter-national flows measures the actual distance travelled by trucks delivering commodities, whereas the distance used by McCallum (and in papers published thereafter) was either the linear distance between the main cities in each province and state or the weighted distance. (iii) In our sample we consider seven different "international borders", and two contiguous countries (France and Portugal), whereas McCallum and all subsequent articles replicating his work with similar datasets considered only one "international border": between Canada and the US.

Based on Eq. (3.1).

	M1	M2	M3	M4
	OLS	OLS	REM	REM
	Mc	AvW	Gil et al. 1	Gil et al. 2
	ln T_{ijt}	ln T_{ijt}	ln T_{iJt}	ln T_{iJt}
ln GDP_{it}	0.577***		0.990***	0.977***
	(0.0782)		(0.0566)	(0.0572)
ln GDP_{jt}	0.546***		0.677***	0.658***
	(0.0876)		(0.0681)	(0.0689)
ln $dist_{ij}$	-0.988***	-1.174***	-1.626***	-1.439***
	(0.134)	(0.182)	(0.171)	(0.209)
External Border	**-3.190*** **	**-2.650*** **	**-2.594*** **	**-2.772*** **
	(0.192)	**(0.666)**	**(0.179)**	**(0.210)**
External Contig				0.406*
				(0.221)
Constant	-0.977	28.56***	-10.73***	-11.02***
	(3.067)	(1.165)	(2.205)	(2.250)
External Border	24	14	13	16
Observations	898	898	877	877
R-squared	0.400	0.549		
P-seudo R2	-	-	0.878	0.881
Multilateral resistance	NO	YES	NO	NO
Time fixed effect	NO	NO	YES	YES
Period	2011	2011	2004-2011	2004-2011

Note: Standard robust errors (origin and destination regional partners clustered for M1 and M2) in parentheses with ***, ** and * respectively denoting significance at 1%, 5% and 10%. Models M3 and M4 use the same region-to-country distance variable than Gil et al. (2005).

In the **Table 3.1** models 3 (M3) and 4 (M4) report the results generated by a specification similar to the one used by Gil et al. (2005) but with our novel dataset. To reduce data differences, we aggregate our region-to-region dataset to the data structure used in their paper—flows between each Spanish region to the rest of Spain (ROS) or to other countries—and use their distance measure[31]. Like them, we also omit data on intra-regional flows and focus on the estimation of the external border effect. According to the distance variable in model 3 (M3) we find a negative elasticity of –1.626 and an external border effect of 13 [exp|-2.594|] for Spanish exports. Similarly, Gil et al. (2005) obtained a negative elasticity for distance of –1.28 when using GDPs and –1.26 when using Population and Surface (columns (1) and (3) in **Table 3.1** of their paper). With these two specifications, which do not control for contiguity, they obtained an external border effect of 20 [exp(2.99)] for exports and of 24 [exp(3.18)] for imports. With model 4 (M4), where they controlled for contiguity (as we have done), they obtained a lower negative coefficient for distance (–0.88, vs. –1.439 in our estimates). They obtained a similar external border effect than ours (13) for exports to other contiguous countries and member states of the EU and the EFTA, but clearly larger (54) for neither contiguous nor member of the EU or EFTA32.

We now revisit more recent specifications that have considered alternative spatial units and discussed the nonlinear relationship between trade and distance (Hillberry and Hummels, 2008; Llano-Verduras et al., 2011; Garmendia et al., 2012). These models use equation (3.2) and the full dimensions of our novel region-to-region dataset. For comparability with previous papers, external and internal border effects are estimated separately.

Table 3.2 reports results for a first set of models estimating the external border effect (M5-M7) and the internal border effect (M8-M9), considering the full sample (2004-2011). All of these models use the corrected trade flows $\frac{T_{ijt}^{eu}}{GDP_{it}GDP_{jt}}$ as an endogenous variable as well as all the fixed effects described above. However, each uses a different estimation procedures and treatment of the distance variable. M5 includes zero flows, use the PPML estimator and the distance in logs. M6 includes zero flows and use the PPML estimator including the distance and the square of distance, both in levels. M7 excludes zero flows, use OLS estimators and include the distance and the square of distance also in levels. M8 and M9, which are related to the domestic trade (intra-regional and

[31] Some important differences nevertheless hold. For example: (1) Gil et al. (2005) used a different database on inter-regional trade flows within Spain for 1995–1998, considered international flows by all transport modes for twenty-seven OECD countries, and included Spain's two island regions. Our estimate uses data for 2004–2011, considers only inter-regional and inter-national flows by Spanish trucks to seven European countries, and excludes the islands. (2) Gil et al. (2005) used trade flows and GDPs in real terms; we use them in current terms.

[32] In our view, the differences in the border effect estimation can be explained by the differences between the two datasets. Gil et al. (2005) used total flows (not just truck deliveries) and a wider range of countries. Although the number of deliveries by trucks could be taken as representative of all internal trade flows (trucks accounting for more than 90% of Spain's internal transport flows), the international truck deliveries in our sample fall away short of the total trade considered in their all-modes sample for twenty-seven OECD countries.

inter-regional flows) just include one zero value, for which the OLS estimator procedure is adequate, and also include the log-transformation of distance and its quadratic form, respectively.

Table 3.2. Alternative Estimates for Internal and External Border Effects. M5- M10 are based on Eq (3.2).

	M5	M6	M7	M8	M9
	PPML	PPML	OLS	OLS	OLS
VARIABLES	Tijt corr	Tijt corr	ln Tijt corr	ln Tijt corr	ln Tijt corr
$\ln dist_{ij}$	-0.977***			-1.411***	
	(0.125)			(0.0596)	
$dist_{ij}$		-2.938***	-0.733**		-6.108***
		(0.335)	(0.299)		(0.401)
$dist^2_{ij}$		0.839***	-0.0212		2.761***
		(0.0972)	(0.0960)		(0.286)
Internal Border	**-**	**-**	**-**	**-0.324**	**-1.642*** **
				(0.309)	**(0.278)**
External Border	**-1.912*** **	**-2.104*** **	**-2.318*** **	**-**	**-**
	(0.172)	(0.185)	(0.293)		
Internal Contig	0.407**	0.662***	1.255***	-0.0427	0.0294
	(0.208)	(0.190)	(0.137)	(0.0988)	(0.114)
External Contig	0.0726	0.120	1.319***	-	-
	(0.338)	(0.333)	(0.375)		
Constant	-22.74***	-27.50***	-28.15***	-19.23***	-24.29***
	(0.798)	(0.188)	(0.195)	(0.360)	(0.200)
Internal Border	-	-	-	1	5
External Border	7	8	10	-	-
Observations	12,165	12,165	6,995	1,792	1,792
R-squared	0.821	0.809	0.652	0.851	0.850
Multilateral resistance	YES	YES	YES	YES	YES
FE by destination	YES	YES	YES	YES	YES
FE by year	YES	YES	YES	YES	YES

Note: Standard robust errors (origin and destination regional partners clustered) in parentheses with ***, ** and * respectively denoting significance at 1%, 5% and 10%. Fixed effects of origin-region by year (μ_{it}), destination-region by year (μ_{jt}), destination-country (μ^u) and year (μ_t) included. Period: 2004-2011. $T_{ijt}\_corr = T_{ijt}/GDP_i x GDP_j$.

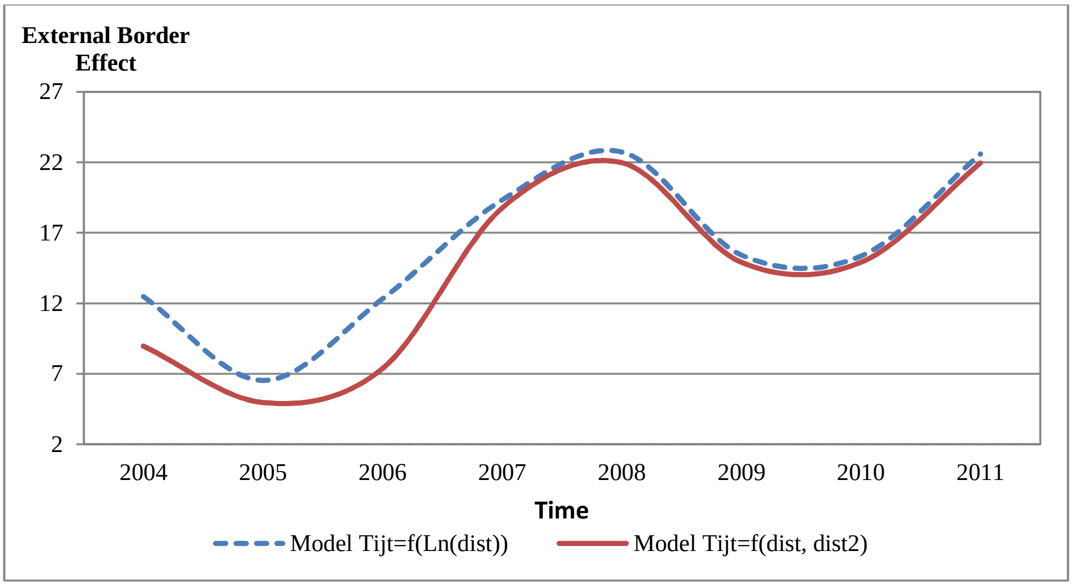
First, we analyze the results obtained for the external border (M5-M7). The first three models generate significant coefficients with the expected signs for all variables except External_Contig in M5 and M6, becoming non-significant. This result suggests that the difference in the intensity of trade between a Spanish region and a foreign border region, on the one hand, and between non-adjacent Spanish regions, on the other, is non-significant, whether the intensity is higher or lower. Note, in fact, that the coefficient for the Internal_Contig variable is positive and significant. Moreover, the results for distance variables that control for the non-linear relationship between trade and distance in M6 and M7 suggest that distance acts as a clear impediment to trade (negative coefficient for $dist_{ij}$), but an impediment that tapers off as distance increases (positive coefficient for the square of distance). As for the external border effect, the three models reach similar factors: 7 for M5, 8 for M6, and 10 for M7. Thus, seems to be persistent and robust to alternative specifications, subsamples and estimation procedures. This persistent external border effect around 8 is slightly larger than that obtained by Llano-Verduras et al. (2011) with region-to-country [3.3 = exp(1.2)] and province-to-country [4.9 = exp(1.6)] data. Note that the papers use different datasets but similar specifications for distance and the same estimation procedures as in M6 and M7. However, the external border effect for Spanish exports is smaller than the 13 and 16 obtained when the same dataset is applied in a region-to-country aggregated format (M3 and M4), as in Gil et al. (2005).

We now focus on our results for the internal border effect, reported in the last two columns of **Table 3.2**. Both models are estimated using OLS due to the very few zero flows observed during the period for the intra-national deliveries. Thus, the only difference between the two specifications is the treatment of distance. The most surprising result is the low factor of the internal border effect in M8 (1), whereas in M9 it reaches a significant factor of 5. The latter internal border effect is greater than the one obtained by Garmendia et al. (2012) with province-to-province data, using OLS [3.7 = exp(1.31)] and PPML [2.4 = exp(0.88)] procedures and with similar specifications for the distance variable (square of distance). Now, as in Llano-Verduras et al. (2011), the contiguity dummy becomes non-significant for the two models, and even negative for M8.

3.4.1 The evolution of the external border effect before and after the crisis

In this section we focus on the evolution of the external border effect during an eight year period, including the largest economic crisis observed in the Spanish Economy since the Great Depression. This analysis has the additional interest of showing to what extent the evolution of the external border effect just reflects a monotonic increase of trade integration of the Spanish regions with the ones of the main European partners, or, as it is the case, if this effect is sensitive to the evolution of the demand of the two main markets under analysis, namely, the rest of the country and other EU countries considered in the sample. By doing so, we will shed new light on how the external border effect is sensitive to the cycle. To this regard, the Spanish case is paradigmatic. Before the crisis, the Spanish economy was based on the real estate and the service sector, recording huge growth rates in the internal demand, which generated intense levels of intra-national trade (mainly in the short distance). The evolution of international exports during that period of boom was also very intense, and in fact, with a strong concentration in the EU countries. However, after the crisis (2010-2013), the Spanish economy followed a completely different pattern of growth, based on a strong increase in their international exports and a weak evolution of the domestic demand (intra-national trade).

Figure 3-3. Temporal evolution of the Spanish external border effect.
PPML. Results are reported in Appendix Table 3.1 (Appendix). Period: 2004-2011.



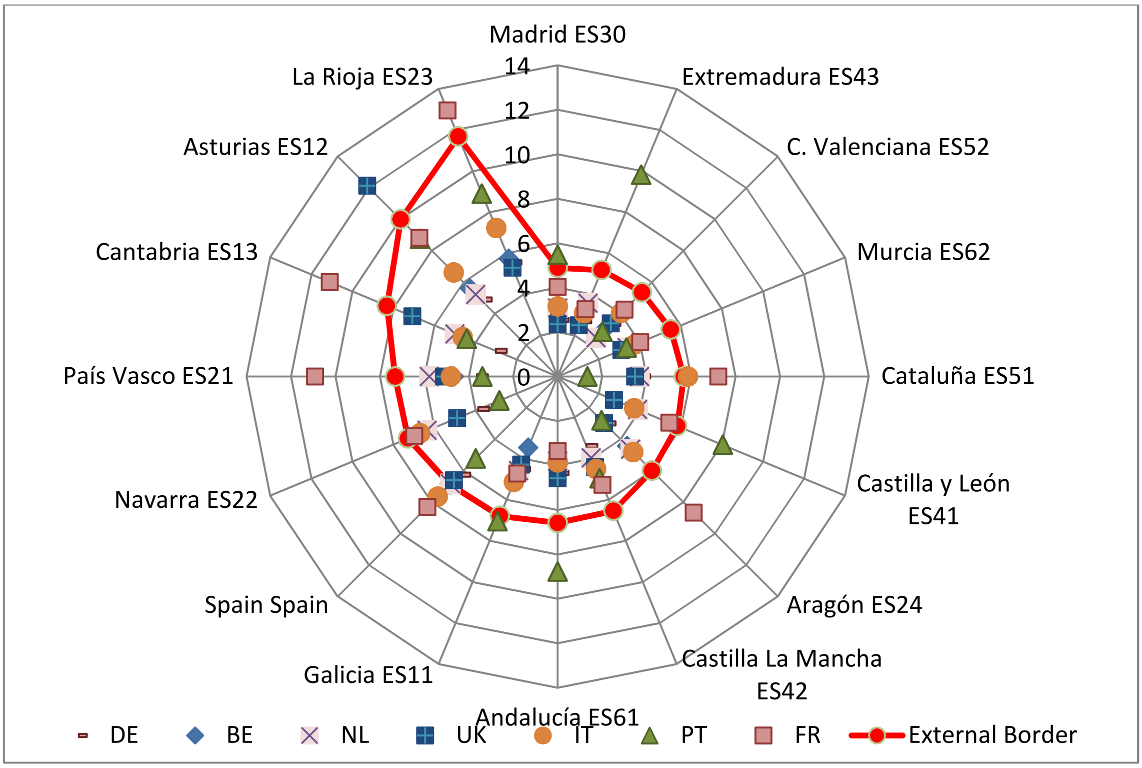
Departing from this context, **Figure 3-3** plots the evolution of the border effect during the whole period. The specific results are described in **Appendix Table 3.1** in the Appendix. Note that, in order to isolate the effect of the evolution of trade (goods) and the GDPs (goods + construction + services), whose composition was especially different before and after the crisis, for this analysis the product of GDPs are included in the right hand side of the equation rather than as a denominator of the endogenous variable. Regarding the results, as expected, the evolution of the Spanish external border effect is far from monotonic, and it is coherent with the evolution of the internal/external demand. Thus, the results point out to a pro-cyclical external border effect for the Spanish economy with regards to their seven main European partners, since it expands during the boom previous to 2009 and it contracts during the recovery. However, for several reasons, the pattern observed is not as clean as expected. The external border effect starts with a slight decrease from 2004 to 2005; then, it rises up to a maximum factor of 19 (27 for the specification using the log of distance) in 2008. This is a year when the international trade contracted, while the Spanish internal demand was fueled by expansive fiscal policies. After this year, the Spanish external border effect decreased continuously until 2011 (with factors of 14 and 11, respectively). In our view, this evolution is connected with the relative evolution of the internal European demand, than with the process of integration promoted by the EU Commission through the elimination of external barriers to trade. As said before, after 2009 the Spanish international exports experienced an unknown expansion while its internal demand remained extremely weak due to strong cuts in public expenses, a sharp reduction in the loanable funds offered by the commercial Banks (several subject to external intervention) and the largest unemployment rate ever recorded in the Euro Area (26%). All these factors collapsed in a clear reduction of the external border effect. Finally, it is worth mentioning that although this effect decreased from 2008 (19) to 2011 (11), it remained higher than in 2005 (5). Although further research is needed, such result can be connected with the fact that the recent expansive period for the Spanish exports (2010-2011) was not specifically oriented towards the European markets (also affected by the strong recession) but to third countries. This fact will be discussed in the last section of this chapter.

3.4.2 Results by exporting region and importing country

Next, we focus on the spatial dimension of the external border effect, decomposing the overall effect by exporting region and importing country simultaneously. This will shed new light on the heterogeneous level of trade integration between Spanish regions and those of Spain's main European partners. Note that with this analysis we examine the thickness of seven heterogeneous national borders— two with contiguous countries (Portugal and France) and five with non-adjacent ones (Belgium, Germany, Italy, the Netherlands and the United Kingdom). We compute equation (3.2) with a single regression, but controlling, by means of dummies, the exporting region and the importing country. We generate these estimates with the PPML procedure and the pre-crisis sub-sample (2004–2007), with zero flows included. Note that intra-regional flows and the *Internal_Border* are not included in the analysis. We present our results in two complementary ways: the detailed results obtained from the regressions are reported in **Appendix Table 3.2**

(Appendix), while **Figure 3-4** uses a spider-web graph for a more visual report of the corresponding external border effects.

Figure 3-4. External border effect by destination country for each Spanish region. PPML. Period: 2004-2007.



The border effects plotted in this graph are based on Appendix Table 3.2 Procedure: PPML, equation (3.2); region-to-region data (intra-regional flows excluded). The graph is ordered for the value of the global external border for each Spanish region.

As reported in **Appendix Table 3.2** (Appendix), the external border effects in ascending order are obtained for Portugal (5.22), Germany (6.25), the UK (6.6), Belgium (6.83), the Netherlands (6.83), Italy (7.64) and France (8.27). From these results, it is remarkable that the rankings do not coincide with what one might expect when considering only the absolute intensity of trade (corrected by GDPs), as plotted in **Figure 3-1**. It is clear that distance (and the square of distance) is playing an important role, together with other non-observable fixed effects. As our results suggest, the border effect is a relative measure of integration between each European region and each exporting Spanish region, with respect to their market power (GDPj) and the distance between them. Therefore, our specification for the external border effect by country calls for a higher intensity of exports from a given Spanish region (e.g., Cataluña) to a French border region (e.g., Languedoc-Roussillon) than from the same Spanish region to an Italian region (e.g., Milan) of the similar size and idiosyncratic demand. If this intensity does not reach the level suggested by equivalent "inter-regional" flows from the same exporting region to other Spanish regions (internal trade), then the French region (e.g., Languedoc-Roussillon) is punished with a higher external border effect than the more distant Italian region (e.g., Milan). If we keep this in mind, the previously described ranking suggests that the highest external border effects under these specifications correspond to France, which is contiguous to two strong Spanish regions, with intense interregional flows to the rest of the country. Conversely, the lowest border effects are found in Portugal, which is also contiguous to Spain, but shares frontier with the poorest Spanish regions (Extremadura, Andalusia, the two Castillas and Galicia). Low border effects are also obtained for rich but more distant countries, such as Germany, the UK, Belgium, and the Netherlands. These non-evident results are in line with those of other papers, which have also found lower external border effects for Germany than for France when using region-to-country flows for specific Spanish regions like Cataluña and País Vasco (Ghemawat, 2010; Gil-Pareja et al., 2006)[33]. However, our results may differ from those papers using alternative specifications and datasets. The smaller border effect obtained for Belgium is striking and requires further research, perhaps into the effects of Belgium's business networks, hub-spoke structure, tax system, or status as the seat (via Brussels) of the EU government. Before entering upon a detailed analysis of the border effect by region and country, we should comment on the other variables reported in **Appendix Table 3.2** (Appendix). To control for the enhancing effect of border regions (Lafourcade and Paluzie, 2011), we consider two Contiguity dummies, finding that just the Internal_Cont is positive and significant.

We focus now on the border effects reported in **Figure 3-4** for each exporting region and each importing country, as obtained with region-to-region trade flows. The overall ranking of the Spanish border effect with respect to the seven EU countries is the same as previously stated. The thick red line tracks the external border effect for each Spanish region with respect to the European importing countries. It is easy to see that the lowest external border effects are obtained for Madrid (4.85 = exp[1.58]), while the largest are obtained for La Rioja (11.6 = exp[2.45]), Asturias (9.97 = exp[2.3]) and Cantabria (8.3 = exp[2.11]). Pais Vasco and Cataluña can be considered as special cases. Both are contiguous to France, and have intense trade with the EU and

[33] Note that the results are not fully comparable, because of notable differences in the data and specifications used in each paper. Thus Ghemawat et al. (2010), using total trade flows (exports + imports by all transport modes), found a low and shrinking external border effect for Cataluña in its trade with France. Another case in point is Gil-Pareja et al. (2006), who also found—using regional balance-of-payment data and region-to-country data—that the external border effect for País Vasco exports was lower for trade with countries such as Portugal, Belgium, Germany, Finland and the Czech Republic, than it was for trade with France.

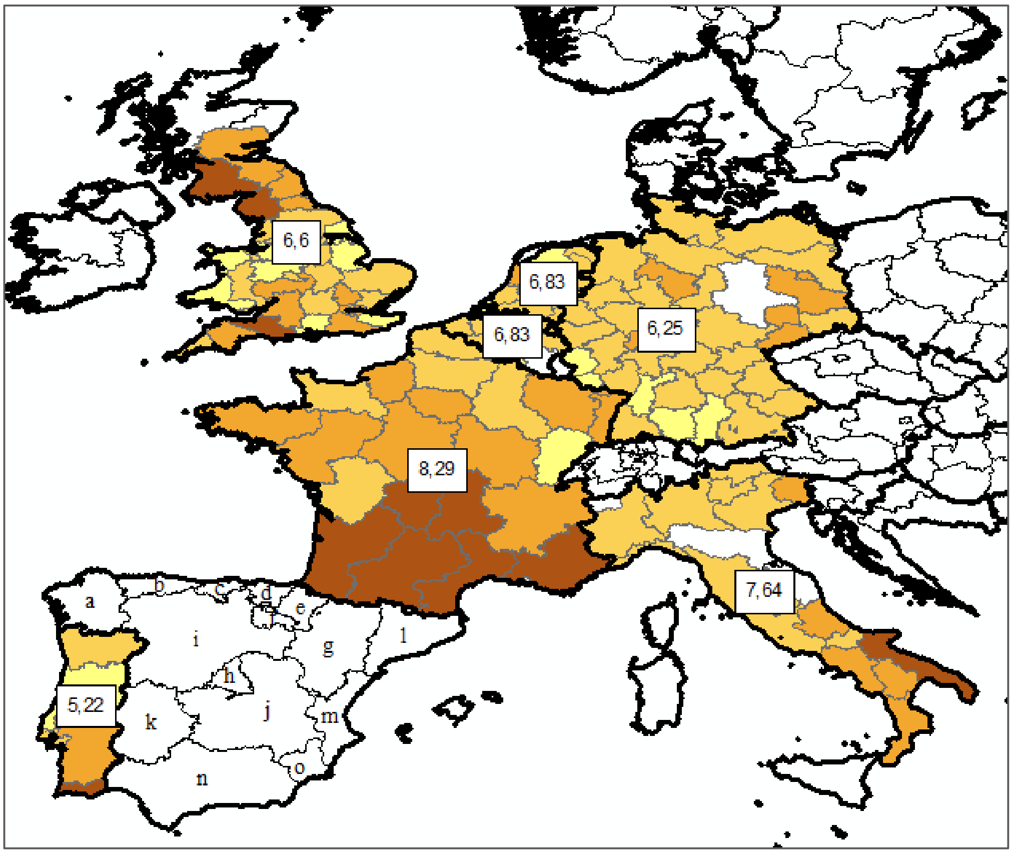
the internal market. At first sight, when we consider the Cataluña high intensity of trade with the seven EU countries (see **Figure 3-1**), one may expect the lowest border effect. However, by taking into account its huge intensity of trade with the rest of Spain (Ghemawat et al, 2010), we see that the model demands much higher international trade flow from Cataluña with the nearest French regions than is actually the case. Cataluña's large external border effect is thus induced by its high GDP, its relative orientation towards the Spanish market and its geographical advantage as the main "gateway" to the European core. Something similar may happen with País Vasco. It seems clear from this analysis that the strong intensity of interregional trade over the shortest distances within Spain calls for the same intensity of trade for exports to the bordering regions of France. To the best of our knowledge, this is the first time that this puzzling result is observed in Europe, due to the lack of information on region-to-region international trade flows. Further research is needed to get an explanation of this discontinuity in the intensity of trade with the crossing of the national border, getting a sectoral, geographical and historical refined characterization of each region.

3.4.3 Results by importing region

We now complete the previous analysis with an alternative focus on the external border effect of Spain as a whole with respect to each specific region in the seven EU countries. Note that a complete region-to-region breakdown of the external border is not possible because of a lack of degrees of freedom (a maximum of four observations for each region-to-region dyad is available). For brevity, the results are presented in **Figure 3-5** in a map, which captures the external border effect for each EU region along with the border effect obtained in the previous analysis for its corresponding country. This breakdown, new to the literature, helps us to identify EU regions that are relatively integrated with the Spanish regions (as exporters). It also shows a remarkable variability of the relative integration within each country. Note again that, in this map, the intra-country variability of the border effect with respect to Spanish exports is driven by: (1) the high intensity of trade within Spain, (2) the size of the importing EU region and (3) the importing region's accessibility (by road) from Spanish exporting regions.

With this in mind, we identify two great patterns in the variability of the external border effect within each importing country in **Figure 3-5**: (i) for France, the largest border effects are obtained in some of the regions closest to Spain (some of them border regions), while the lowest border effects are obtained in the most distant ones (northeastern France); (ii) for other countries, the darkest regions within each country (highest border effects for importers from Spain) are the furthest regions from Spain (by road) while the lightest (lowest borders effects for importers from Spain) correspond to the nearest. The pattern is perfectly clear for Italy, the UK and Germany. Belgium and the Netherlands obtain very low border effects in all their regions. To verify this pattern, **Figure 3-6** shows the scatterplot of the external border effect against the market potential of the destination region (per capita income of the importing region / distance from Spain). For clarity, the observations for each importing country are plotted in different colors, and the market potential of the sub-sample (2004-2007) is standardized to 100%. The sample is then divided into two groups by average market potential with respect to Spain, and two trend lines (both significant) are added for each group. The figure thereby shows clearly that the trend line for regions with the lowest market potential with respect to Spain (the UK, Italy, the Netherlands, Belgium, and Germany) has a negative slope. Within these countries, then, the regions with the highest market potential (the richest ones, located near the "blue banana") register the lowest border effects with respect to Spain. Conversely, in the other group—regions with above-average market potential (mainly regions from France)—the trend line has a positive slope, which confirms that the Spanish external border effect is higher for the closest regions in France than it is for the most distant regions within these same countries.

Figure 3-5: Map of the Spanish External Border Effect by importing region (colour) and country (numbers). Equation (3.2), PPML. Period: 2004-2007.



Note: The figures in the map represent the border effect for the destination countries; the lowercapital letters in the map represent the Spanish regions.

External Border Effect

Natural Breaks

- 1,16 - 3,63
- 3,63 - 4,96
- 4,96 - 6,63
- 6,63 - 10,83
- 10,83 - 19,74

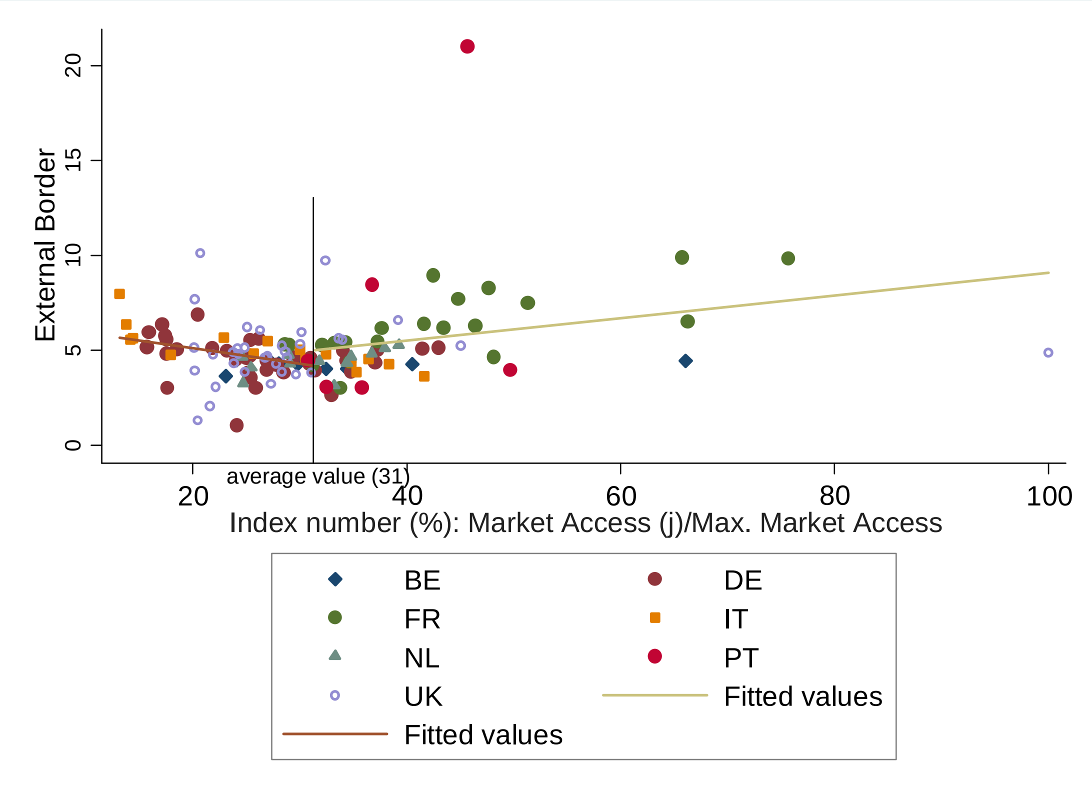
Code	Name	Eurostat
a	Galicia	ES11
b	Asturias	ES12
c	Cantabria	ES13
d	País Vasco	ES21
e	Navarra	ES22
f	La Rioja	ES23
g	Aragón	ES24
h	Comunidad de Madrid	ES30
i	Castilla y León	ES41
j	Castilla La Mancha	ES42
k	Extremadura	ES43
l	Cataluña	ES51
m	Comunidad Valenciana	ES52
n	Andalucía	ES61
o	Región de Murcia	ES62

Again, in order to better understand this interesting result, we may wish to think of the border effect as a relative measure of integration. If actual trade between Spanish regions (internal trade) is greater than trade over equivalent distant regions between Spanish and French, then the French regions bear a large border effect. Why? Because their actual trade with Spanish regions should have a level similar to that observed within Spain. This "penalty effect" over the border affects mainly French regions, which should have a much higher level of imports from Spain than is observed, at least if we consider a unified single market. Conversely, the low border effect obtained for Portugal suggests that its actual trade with Spain is similar to that expected, given its market potential with respect to Spain. By contrast, when we consider regions of more distant countries (the UK, Italy, and Germany), the ratio between actual interregional international flow and Spanish internal trade is smaller (lower border effects). The explanation is that, assuming the distance decay of interregional trade within Spain, the expected trade with a further region in Germany is not that far from the actual one, even if that German region is richer –on average- than a Spanish region.

One of the main conclusions of this analysis is that Spanish exports in general seem to have a reasonable penetration in the main EU markets, when we consider the internal distance decade and the great distance at which such wealthy European markets lie. At the same time, although the intensity of Spanish exports is greater over the shortest distance (to border regions in France), it is much smaller than what we should expect if they were as integrated as any other Spanish region.

Figure 3-6: Scatterplot of Spanish External Border Effects (EBE) against the "market potential" (standardized to 100%) of EU regions ($GDPpc_j/D_{ij}$).

The EBE is obtained from Equation (3.2), with PPML procedure. 2004-2007.



3.4.4 How far are we from a full integrated market

To add a more insightful corollary for policymakers, we would like to conclude with a relevant extrapolation exercise. We begin with a question: how intense would be exports from Spanish regions to their EU counterparts in a world of perfect integration? That is, in an EU market where the external border effects of the Spanish regions were null. To find out, we estimate previous models using Spanish interregional trade flows alone; i.e., using a perfectly integrated market (trade within a country, without intra-regional flows). Then, with the estimated coefficients for each Spanish region, we predict region-to-region flows with respect to our seven EU countries.

As in previous sections, two alternative specifications are used, both with zero flows and PPML procedures for the period before the high increase of the external border effect in 2008 (2004–2007). The first includes the square of distance: the estimation is defined by equation (3.3), the prediction by equation (3.4).

$$T_{ijt}^{ee} = \beta_0 + \beta_1 Ln(GDP_{it} GDP_{jt}) + \beta_2 dist_{ij} + \beta_3 dist_{ij}^2 + \beta_4 Contig + \mu_{it} + \varepsilon_{ijt} \qquad (3.3)$$

$$\hat{T}_{ijt}^{eu} = \hat{\beta}_0 + \hat{\beta}_1 Ln(GDP_{it} GDP_{jt}) + \hat{\beta}_2 dist_{ij} + \hat{\beta}_3 dist_{ij}^2 + \hat{\beta}_4 Contig + \mu_{it} \qquad (3.4)$$

In equation (3.3) the model is estimated with only interregional trade flows within Spain (T_{ijt}^{ee}) as dependent variable, while equation (3.4) predicts the interregional exports from Spanish regions to other EU regions ($\hat{T}_{ijt}^{eu}$) assuming the elasticities $(\hat{\beta}_0, \hat{\beta}_1, \hat{\beta}_2, \hat{\beta}_3, \hat{\beta}_4)$ obtained in (3.3). The right-hand side in both equations includes the log for the multiplication of the corresponding GDPs, the distance variables, the contiguity dummy and the fixed effects for the origin and year (μ_{it}). The fixed effects for destinations are not included since the importing regions in the estimation sample (regions within Spain) and the forecast sample (regions in the other seven EU countries) are different.

At this point, it is convenient to briefly discuss a potential drawback to the quadratic approach. Although widely used for dealing with non-linear functions, the quadratic model suffers from a potential limitation: the reversal of the effect's direction. Normally, the quadratic model is used under the assumption that the turning point lies outside the sample (Gould, 1993). In order to compute the point at which the effect changes direction, we use the following expression: $-\beta_2 / (2\beta_3) = (-(-4.062 / 2(1.974)) = 1.028$, where β_2 and β_3 are, respectively, the coefficients for the distance and the square of distance in our equation (3.3), being the distance variable expressed in thousands of kilometers. Thus, when estimating (3.3) with only interregional flows within Spain, the turning point arises at 1,028 km. Although this value is not problematic for the modeling of flows within Spain (the largest trip within Spain is around 1,120.422 km), **Figure 3-7** shows how harmful it would be for the prediction of exports to the other EU regions (with a maximum distance of 3,100 km in our sample)[34].

For this reason, we use an alternative specification described in equation (3.5) and (3.6), where the non-linear relationship between trade and distance is captured by a specification equivalent to the one considered before; i.e., one that takes logarithms for the distance variable. The rest of the variables and samples are exactly the same as in equations (3.3) and (3.4):

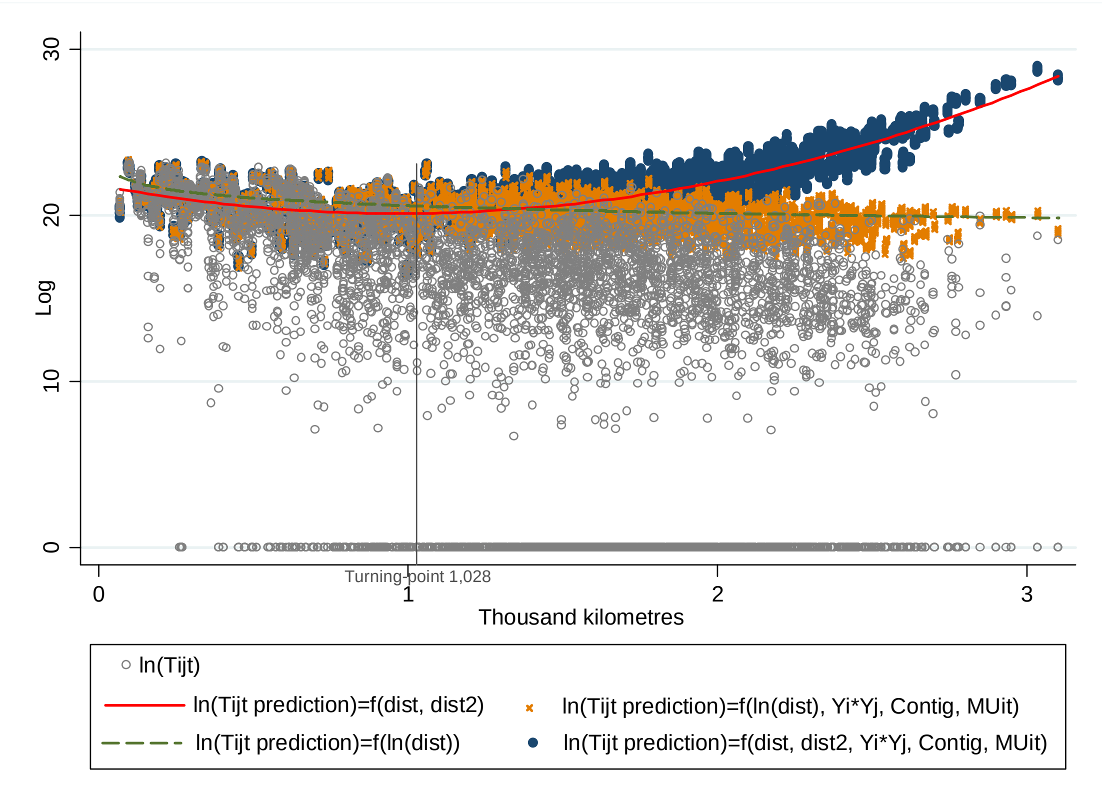
$$T_{ijt}^{ee} = \alpha_0 + \alpha_1 Ln(GDP_{it} GDP_{jt}) + \alpha_2 Ln(dist_{ij}) + \alpha_3 Contig + \mu_{it} + \varepsilon_{ij} \qquad (3.5)$$

[34] Note that this effect will not be problematic with the equation (3.2), that is used to estimate external border effects in previous sections. Because the estimation there mixes intra-national and inter-national flows, the turning point varies by specification for each Spanish origin region, whose value is about 1,750 kms for the average estimate in which all origin regions are included.

$$\hat{T}_{ijt}^{eu} = \hat{\alpha}_0 + \hat{\alpha}_1 Ln(GDP_{it}GDP_{jt}) + \hat{\alpha}_2 Ln(dist_{ij}) + \hat{\alpha}_3 Contig + \mu_{it} \quad (3.6)$$

Figure 3-7 plots the two alternative predictions (one based on equation (3.4) and the other on equation (3.6)) for Spanish exports to regions of the seven European countries under full integration, along with the actual flows. Three points are worth mentioning: (i) as expected, the level of predicted flows in both predictions is clearly above the actual level; (ii) although a large number of actual flows are null, the predicted values for the dyads are clearly positive regardless of the specification used in the forecast (we will explore this result to some extent later); (iii) the gap between flows predicted with the quadratic specification and actual flows clearly expands as distance from Spanish exporting region to European importing region increases. The reason, as previously discussed, is the turning point of the quadratic form. We now use the log specification (equation (3.6)) as a benchmark, to compare predicted flows with actual flows, and compute the corresponding "trade potentials". The results are reported in **Table 3.3**.

Figure 3-7: Scatterplot of Predicted and Actual Spanish Exports to the rest of Spain and to EU regions. Predictions based on Equations (3.4) and (3.6), using PPML and the sub-sample 2004-2007 and with zeros.



The first seven columns of **Table 3.3** report the ratio of predicted flows over actual flows between each Spanish region and each of our seven European countries. This ratio reflects the increase necessary for actual flows (AV) to reach the trade value predicted (PV) for a no-boundaries scenario. Note that both the actual and the predicted values are initially inter-regional flows. For the sake of brevity, however, we report the results in terms of region-to-country aggregation. At the same time, for this analysis we have used the sub-period (2004–2007), whose values are annual trade-flow averages. Column (8) reports the same ratio as the previous columns but for total international Spanish outflows for each region. Columns (9–10) split the previous total into two components: (i) on the one hand (column 9), the predicted trade flow can exceed the actual flow because the latter is zero[35] ; (ii) on the other (column 10), the actual flow can be positive but lower than expected. Column (9) is related with the percentage of actual zero flows (plotted and described in **Figure 3-7**) Note that this approximates the "extensive margin" of trade, since it implies that a Spanish region should start exporting to a new market (and thereby increase the number of importing regions within the seven countries considered)[36]. By contrast, column (10) is related with the percentage of non-zero flows observed, which approximates the "intensive margin" of trade, because it relates to the increase in positive actual flows from each Spanish region necessary for full integration with the regions of the seven European countries.

Finally, using the ratio of predicted values of trade flows (PV) over the actual flows (AV) (columns 1–7), and considering each Spanish region's different pace for export penetration into each of the seven countries, this last information reported by the official Spanish trade statistics[37], we present in column 11 and 12 the average number of years[38] that it would take each Spanish region to achieve full integration with the seven countries, for two alternative scenarios. More specifically, the two alternative scenarios are described as follows: i) in column (11) we report the number of years that it would take each Spanish region to achieve full integration if the Spanish

[35] Note that the origin-destination pairs included in the sample report trade for at least one year in the period; therefore their trade can be zero for the rest of the years.

[36] It is important to remark that all zero trade flows considered in this thesis correspond to European regions that have had a positive flow with any Spanish region during the period 2004–2007. Thus, we do not consider the "effort" of entering into regions where non-trade flows were observed at all in this period. In this sense, we consider our calculation to be cautious.

[37] For comparability, the rhythm of each Spanish exporting region's penetration into each of the seven European countries considered is computed with official trade statistics (http://datacomex.comercio.es/), but only with trade flows by "road".

[38] The formula used to compute the number of years required to achieve the predicted volume of trade in a full integration scenario is based on the compound-interest expression, where, according to an interest rate (i: annual average growth rate of the international trade), the final value (PV: predicted value of trade flow) is related to the initial value (AV: actual value of trade flow) during a period of time (n: number years) through the following equation: $n = Ln\left(\frac{PV}{AV}\right) / Ln(1+i)$.

exports to these seven countries follow the same rhythm than that observed between 2001 (the introduction of the euro) and 2008 (the last year before the sharp downturn in 2009); ii) the second scenario reported in column (12) corresponds to the number of years to achieve full integration if the Spanish exports continue on the same trend than in the period of recovery (2011-2013)[39]. All the calculations are available upon request. These averages give a better idea of the path to full integration. Note that although all these numbers are considerably large, they can be considered as a potential timeline for full regional integration if trade growth were equivalent to that observed during these two paradigmatic periods described in **section 3.4.1**.

From the results we can see that the expected value exceeds actual value in all cases, but especially for some regions and countries (i.e.: the United Kingdom). At this point, we must remark that our naïve prediction does not take into account the geography of destination countries, which is essential in the case of the UK when considering trade flows by road. Although our results are thus gross approximations, they provide an opportunity to explore what would happen, hypothetically, in a scenario with no political frontiers and no obstacles other than distance.

It is worth mentioning that, as per the results in column (11), all Spanish regions would take more than 30 years—on average— to attain a level of integration with these other countries similar to the level they enjoy nowadays with the rest of Spain. The lowest period (30 years) is obtained for Galicia when one assumes its exporting dynamics for the period 2001-2008 (column 11). The longest periods of adjustment occur in regions with the lowest international trade growth and/or highest proportion of zero values. Among these regions are Asturias (400 years on average in column 11 and 1,095 in column 12), Aragón (270 years on average in column 11, and 1,344 in column 12) La Rioja (50 years on average in column 11, but 603 in column 12), Comunidad Valenciana (93 years on average in column 11, but 535 in column 12) or Madrid (277 years on average in column 11, and 440 in column 12). Full integration is also a long way off for other important Spanish regions, such as Cataluña (84 years on average in column 11, and 306 in column 12) or the País Vasco (47 years on average in column 11, and 397 in column 12)[40].

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[39] Note that the growth rates used for computing this second scenario of full integration take into account the period 2011-2013, which is slightly different than the one considered in section 3.4.1 for analyzing the evolution of the border effect. The reason is that in latter analysis the growth rates are computed using the official data, which is available at the region-to-country level until 2013. By contrast, the former analysis, included in section 3.4.1, uses our dataset with region-to-region flows, which ended in 2011.

[40] Note that these calculations are intended only to suggest a reference timeline for discussion, and are therefore open to much criticism. For example, our estimates do not consider any kind of trade-off between internal integration within Spain and external integration with European regions. This assumption implies that the difference between predicted and actual trade intensity should be fully explained by a pure "creation effect", with no deviation of trade from the internal Spanish market to the European market. Moreover, we do not take into account competing effects stemming from equivalent attempts by other

Table 3.3 Trade differentials in the case of full integration (no-external border effect) Predictions based on equations (3.5) and (3.6): PPML with zero values. Period: 2004-2007.

	Trade potential with the regions in a specific country "u". Period: 2004-2007							Total trade potential			Average number of years to full integration	
	BE	**DE**	**FR**	**IT**	**NL**	**PT**	**UK**	**Total (PV/ AV)**	**Share of PV when AV is zero**	**Share of PV when AV is NOT zero**	Scenario 1	Scenario 2
	(1	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Asturias	28	39	36	16	65	7	115	27	62%	43%	400	1,095
La Rioja	11	53	20	50		7	23	21	70%	43%	52	603
Castilla La Mancha	40	28	25	20	25	4	29	19	51%	50%	39	31
Castilla y León	21	29	12	18	40	7	17	16	42%	58%	54	211
Aragón	18	15	22	21	23	3	14	15	41%	59%	270	1,344
Cantabria		9	25	13	42	6	24	15	53%	48%	47	423
Andalucía	19	20	15	12	12	7	24	15	25%	75%	69	244
Extremadura	13	14	25	26	103	7	8	14	53%	51%	39	49
C. Valenciana	13	17	12	20	13	4	21	14	22%	79%	93	535
País Vasco	12	10	13	9	20	5	23	12	33%	67%	47	397
R. de Murcia	16	13	15	13	9	7	10	12	29%	71%	262	148
Navarra	17	12	11	14	22	4	17	12	43%	57%	400	60
C. de Madrid	15	14	13	10	19	3	12	11	48%	53%	277	440
Galicia	13	25	15	10	25	3	20	10	42%	58%	30	43
Cataluña	10	12	8	13	11	2	17	10	23%	78%	84	306

Note: PV=predicted value; AV= actual value. Columns (11-12) report the average number of years that each Spanish region should spend in order to reach full integration with these countries considering the bilateral "trade differentials" reported in columns (1-7) and the bilateral growth rates of the international exports by road from each of the Spanish regions to the seven European countries considered. The observed periods estiamtions correspond to two structurally differentiate moments, one before the crises, scenario 1 (from the 2001 to 2008), and the other after, scenario 2 (from 2010 to 2013). Note that 2001 is one year ahead the introduction of the "euro" as a common currency in all these countries. It was during our selected period that the European Market was closest to our hypothesis of "full integration" (non-external border).

regions (and countries) to enter and increase their export shares in these same importing European regions. Consequently, we are assuming that trade potentials will be absorbed by importing regions without constraint from their demand capacity. Moreover, our estimates are always constrained to road-delivery flows. Although this mode of transport represents around 80% of Spanish exports to these countries (see section 2.3.1 for more detail), it should be completed with extended datasets (unavailable at present in any country).

Focusing on the difference obtained between the two scenarios (column 11 vs. 12), the result shows that during the second period (2010-13), the average number of years obtained were higher than in the previous one (the range varies between 31 in Castilla-La Mancha and 1,344 in Aragón). This result seems to be contradictory with our previous comments regarding the evolution of the border effect during the cycle. However, as it was mentioned at the end of **section 3.4.1**. it is important to remark that, although the Spanish exports boosted after 2009, they tended to have non-EU countries as destinations. Note that during this period some of the seven European economies considered in the sample were also trapped into a deep recession; a fact that limited its potential demand capacity. Therefore the results obtained suggest that the exporting effort made during the recovery period by the Spanish exporting firms, did not have a special effect on an increase in the regional integration with the main partners in Europe, since the bulk of this exports were delivered to further and more dynamic markets. Instead, when the pre-crisis growth rates are used in the first scenario (column 11), the range of years decreased, from a minimum of 30 years in Galicia to a maximum of 400 years in Asturias and Navarra.

The conclusion of this analysis is threefold: i) a full integration scenario is still very far away for every region; ii) the observed differentials and integration schemes are relative to the location and size with respect to potential importers; iii) Thus, it is important to highlight that our approach imposes a greater effort of integration to those regions with larger intensities of trade within Spain and locational advantages towards the European core.

3.5 Some conclusions

In this article we aim to measure the internal and external trade integration of Spanish regions by quantifying the corresponding internal and external border effects in Spain, taking into account intra- and inter-national trade between Spanish regions (NUTS 2) and the regions of Spain's seven main European partners. The lack of information on inter-regional flows, both domestic and international, has made it difficult to obtain clear estimates of border effects like those reported for Canada and the U.S. by McCallum (1995), Anderson and van Wincoop (2003) and others. Until now, external border effects in Europe have been computed with country-to-country or region-to-country flows. We can thus suppose there has been a loss of relevant information, because of aggregation and the use of non-homogeneous spatial units. The computation of distance as well, both for intra-national trade and for region-to-country dyads, has being a source of bias in previous border-effect estimates.

In this chapter we have made use of a novel dataset for inter-regional trade flows by road, including intra-national and inter-national flows, and considered actual distance for the shipments. From this starting point we have borrowed classic specifications previously used to compute external and internal border effects both between Canada and the U.S. and between Spain and other countries. As our results attest, the new dataset generates similar but not identical figures when channeled into these classic specifications. For one thing, we find a higher level of integration (i.e., a lower external border effect) between our region pairs than previous authors have found between Canadian provinces and U.S. states (14 vs. 22). When we aggregate our dataset to a format of region-to-country Spanish flows, we obtain a lower border effect than the benchmark paper found. Moreover, when we use the dataset with full disaggregation (with zero and region-to-region flows) and alternative estimation procedures, the external border effect estimates decrease, and in the case of the internal border effect, it becomes non-significant in one estimate. We also observe a certain variation of the internal and external border effects due to the non-linear relationship between distance and trade. With most of the specifications considered here we obtain internal and external border effects that are positive and significant, although smaller than in previous papers that do not consider region-to-region international flows. Finally, we repeat the analysis for region- and country-specific border effects, obtaining relative measures of integration between Spanish regions and their main partners. We conclude with an extrapolation exercise, where we predict trade potentials assuming a scenario of full integration between Spanish regions and the regions of the seven European countries considered. With this final analysis we find, on the basis of the recent dynamics of exports to these countries, that it would take between 30 and 400 years, on average, for Spanish regions to attain such a level of integration, under the best scenario, i.e., turning back to pre-crises (2001-2008) growth rates of export penetration. Nevertheless, the extreme large values found seem to point out that some regions are moving against integration with some specific European countries.

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3.7 Appendix

Appendix Table 3.1. Evolution of the Spanish external border effect during the period 2004-2011. Procedure: PPML. Data: region-to-region (intra-regional flows are excluded).

	M10		M11	
	PPML	$e^{\lvert External\ Border \rvert}$	PPML	$e^{\lvert External\ Border \rvert}$
VARIABLES	T_{ijt}		T_{ijt}	
ln GDP_i *GDP_j	0.747***		0.734***	
	(0.0264)		(0.0284)	
ln $dist_{ij}$	-1.067***			
	(0.0803)			
$dist_{ij}$			-3.212***	
			(0.221)	
$dist^2_{ij}$			0.771***	
			(0.0740)	
External_Border_04	-2.524***	12	-2.193***	9
	(0.239)		(0.272)	
External_Border_05	-1.876***	7	-1.602**	5
	(0.613)		(0.628)	
External_Border_06	-2.511***	12	-1.998***	7
	(0.581)		(0.601)	
External_Border_07	-2.962***	19	-2.932***	19
	(0.871)		(0.876)	
External_Border_08	-3.124***	23	-3.090***	22
	(0.740)		(0.742)	
External_Border_09	-2.736***	15	-2.702***	15
	(0.582)		(0.594)	
External_Border_10	-2.731***	15	-2.705***	15
	(0.678)		(0.691)	
External_Border_11	-3.118***	23	-3.089***	22
	(0.677)		(0.684)	
Internal_Contig	0.123		0.273***	
	(0.0967)		(0.0929)	
External_Contig	0.306		0.255	
	(0.220)		(0.205)	
Constant	-9.318***		-13.48***	
	(1.328)		(1.449)	
Observations	12,165		12,165	
R-squared	0.892		0.886	

Note: Standard robust errors (origin and destination regional partners clustered) in parentheses with ***, ** and * respectively denoting significance at 1%, 5% and 10%. Fixed effects of origin-region by year (μ_{it}), destination-region by year (μ_{jt}), destination-country (μ^u) and year (μ_t) included.

Estimates are obtained using the following equations (3.7) and (3.8):

$$T_{ijt}^{eu} = \beta_0 + \beta_1 Ln(GDP_{it} GDP_{jt}) + \beta_2 External\_Border + \beta_3 Ln(dist_{ij}) + \beta_4 Internal\_Contig + \beta_5 External\_Contig + \mu_i + \mu_j + \gamma_t + \varepsilon_{ij} \quad (3.7)$$

$$T_{ijt}^{eu} = \beta_0 + \beta_1 Ln(GDP_{it} GDP_{jt}) + \beta_2 External\_Border + \beta_3 dist_{ij} + \beta_4 dist_{ij}^2 + \beta_5 Internal\_Contig + \beta_6 External\_Contig + \mu_i + \mu_j + \gamma_t + \varepsilon_{ij} \quad (3.8)$$

Appendix Table 3.2. Main coefficients obtained for each origin region by importing country.

		$dist_{ij}$	$dist^2_{ij}$	BE	DE	FR	IT	PT	NL	UK	Internal Contig	External Contig	**External Border**
Galicia	ES11			-1.243***	-1.506***	-1.555***	-1.635***	-1.953***	-1.524***	-1.456***			**-1.916*** **
Asturias	ES12			-1.720***	-1.586***	-2.175***	-1.890***	-2.170***	-1.649**	-2.495***			**-2.302*** **
Cantabria	ES13				-1.100***	-2.406***	-1.531***	-1.488***	-1.611**	-1.957***			**-2.118*** **
País Vasco	ES21			-1.539***	-1.290***	-2.390***	-1.571***	-1.217***	-1.754***	-1.632***			**-1.990*** **
Navarra	ES22			-1.878***	-1.353***	-1.944***	-1.901***	-1.042*	-1.849***	-1.588***			**-1.986*** **
La Rioja	ES23			-1.746***	-1.712***	-2.561***	-1.977***	-2.186***		-1.667***			**-2.458*** **
Aragón	ES24			-1.487***	-1.099***	-2.159***	-1.570***	-1.031**	-1.535***	-1.087***			**-1.792*** **
Madrid	ES30	-4.008***	1.050***	-1.009**	-0.928***	-1.393***	-1.149***	-1.700***	-1.123**	-0.851**	0.360*	0.419	**-1.586*** **
Castilla y León	ES41			-1.332***	-1.206***	-1.696***	-1.318***	-2.085***	-1.363***	-1.010***			**-1.762*** **
Castilla La Mancha	ES42			-1.494***	-1.219***	-1.662***	-1.508***	-1.601***	-1.378***	-1.484***			**-1.878*** **
Extremadura	ES43			-1.195**	-0.984**	-1.184***	-1.126***	-2.284***	-1.273**	-0.914*			**-1.645*** **
Cataluña	ES51			-1.266***	-1.300***	-1.979***	-1.768***	-0.295	-1.304***	-1.250***			**-1.736*** **
C. Valenciana	ES52			-1.123***	-1.198***	-1.449***	-1.396***	-1.048**	-0.899**	-1.217***			**-1.678*** **
Andalucía	ES61			-1.290***	-1.471***	-1.213***	-1.353***	-2.172***	-1.336***	-1.524***			**-1.885*** **
Murcia	ES62			-1.356***	-1.184***	-1.391***	-1.319***	-1.212***	-1.221***	-1.135***			**-1.706*** **
Spain	**ES**	**-3.196*** **	**0.894*** **	**-1.922*** **	**-1.833*** **	**-2.115*** **	**-2.033*** **	**-1.652*** **	**-1.921*** **	**-1.887*** **	**0.610*** **	**0.223**	

Note: Standard robust errors (origin and destination regional partners clustered) in parentheses, with ***, ** and * respectively denoting significance at 1%, 5% and 10%. Fixed effects of destination-region by year (μjt) and year (μt) included. The results in the (last column) are region-specific border of a unique gravity equation, which includes destination-region by year (μjt), destination-country (μu) and year (μt) fixed effects. The results for Spain (bottom row) are obtained by a gravity equation that also considers all the origin regions and includes origin-region by year (μit), destination-region by year (μjt), and year (μt) fixed effect. Endogenous variable is Tijt_corr = Tijt/GDPixGDPj. Procedure: PPML. Data: region-to-region (intra-regional flows are excluded). Period: 2004-2007

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4 The Border Effect and the Non-linear Relationship between Trade and Distance[41]

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4.1 Introduction

After McCallum (1995) found that the border effect between two similar countries as Canada and the United States was 22, i.e. any Canadian provinces tends to trade 22 times more with another Canadian province than with a similar state of the U.S., many authors have repeated the exercise with other countries[42] and different spatial units. Some have estimated the relevance of *international frontiers* by comparing the domestic trade volume of one country (region) with its international trade volume (Head and Mayer, 2000; Gil et al., 2005; Minondo, 2007; Chen, 2004), while others have measured the relevance of *internal borders*, estimating how much more trade a region (province) of a given country conducts with itself than with any other region (province) of the same country (Wolf 1997, 2000; Hillberry and Hummels, 2008; Combes et al., 2005; Garmendia et al., 2012).

Besides the pure estimation of the border effect, many authors have tried to find out the variables that determine the higher intensity of trade within some political barriers; i.e., those factors that can solve the puzzle. Chen (2004) classified them into two broad groups by their exogenous/endogenous nature. The exogenous factors have a direct effect as frictions changing relative prices and inducing substitution towards proximate products. They are considered exogenous because they artificially alter free trade between the partners. Therefore, under this kind of factors there could be room for a greater integration, what would entail gains in terms of welfare. The endogenous factors emerge from the own decisions of economic agents. As an example, when individual or companies seek to locate in places with better access to markets, in order to avoid information or transport costs, among others trade costs, this results in an increase of trade flows in the short distance, what in turns increases the border effect. Another example is when firms closely linked in the input-output structure make the decision of locating nearby so as to minimize transport costs, so that it also generates a higher level of trade in short distances.

However, apart from the endogenous and exogenous factors that can generate the border effect, there are also other worrying elements that can entail the over-estimation of the border effect. These factors have been identified in relation with the own formulation of the gravity equation, and with the correct measure of the distance variable. As it was previously noticed in the introduction of this thesis, Anderson and van Wincoop (2003) argue that the misspecification of econometric models based on the naïve McCallum (1995) gravity equation lead to the upward bias

[42] Japan (Okubo, 2004), United States (Wolf, 2000; Hillberry, 2002; Hillberry and Hummels, 2003; 2008; Millimet and Osang, 2007), the European Union (Chen, 2004; Nitsch, 2000, 2002; Evans, 2003), Germany (Shultze and Wolf, 2009), Russia (Djankov and Freund, 2000) and Brazil (Daumal and Zignago, 2008), among others.

of the border effect. The problem of this specification is the omission of relevant variables, the multilateral resistance effects, what increases the actual effect of national borders. Another limitation often found in the literature is the presence of zero trade values and their inappropriate treatment. Silva and Tenreyro (2006) proposed an econometric procedure (PPML) to solve this problem, as it was described in the previous chapter. Head and Mayer (2002) suggest that *"the border effects may have been mismeasured in a way that leads to a systematic overstatement"*. The authors reveal that the standard methods used to measure intra-national and inter-national distance tend to show an illusionary border effect (Wei, 1996; Nitsch, 2000; Head and Mayer, 2000). Especially, the overestimation of the internal distance penalizes the border effect estimates; insofar as only a large border effects can be able to explain the high concentration of trade within artificially distant national boundaries. Finally, some authors have argued that the border effect may arise from an inadequate treatment of distance variable given its non-linear relation with the trade. Sometimes, we should be aware that the lack of information of trade flows in a high enough scale disaggregation, like the range comprising region-to-region and zip-to-zip spatial units, makes it impossible to considerate this non-linearity, since the sharp negative effect of distance takes place in the first kilometers (e.g., see the kernel density functions of trade flows presented in the previous chapter and those that follow here). Nevertheless, some studies have tried to embed this non-linear relation in the econometric specifications. As far as we know, it has been through the inclusion of the quadratic form of the distance in the gravity equation (Hillberry and Hummels, 2008; Llano-Verduras et al., 2011).

Related to the last approach (the treatment of the non-linear relationship between trade and distance) that intends to solve part of the border effect puzzle, the objective of this chapter is to make a methodological contribution to the literature when flows are observed at a sufficiently fine spatial level[43]. In this regard, this chapter presents a few novelties: (1) It computes the effect of two different types of borders (*Ownregion*, *Owncountry*) simultaneously for inter-regional flows between one country (Spain) and its seven main European partners; and using region-to-region national and international flows. We obtain robust results for alternative specifications of the gravity model, based on the fixed effect approach (Anderson and van Wincoop, 2003). (2) Like other papers reporting border effects that shrink along with the size of the exporting unit (Hillberry and Hummels, 2008; Llano-Verduras et al., 2011), we observe this reduction using a

[43] This non-linearity can be induced by at least the same factors (endogenous/exogenous) suggested before for the border effects. It can be also explained by, for example: (i) non-linear relationships between (observable) geographic distance and (usually unobservable) actual trade costs; (ii) different levels of product transportability between each pair of regions; and (iii) different transport-mode mixes for shipments to/from certain locations due to geographical advantage/disadvantage (i.e., remoteness, presence of a coast, landlock locations, etc.).

lower spatial scale for the importer (foreign regions instead of countries); (3) Finally, it suggests three new alternative strategies for tackling the non-linear relationship between trade and distance that has been previously discussed by others (Eaton and Kortum, 2002; Henderson and Millimet, 2008; Hillberry and Hummels, 2008). Our specification begins by incorporating a quadratic distance term, so as to capture the fast decrease in trade flows over the shortest distances. It then suggests an alternative strategy, which considers three sub-divisions of the sample by distance travelled. Furthermore, we develop a robust analysis using two innovative approaches—the linear and cubic piecewise regression and a semi-parametric regression—so as to add flexibility without imposing a specific functional form to the non-linear relation between trade and distance. These strategies produce interesting results: (i) a low but persistent internal border effect, which reaches a factor of 4, robust to several specifications; (ii) a persistent external border effect that is also about 4; (iii) a variation in the elasticity of distance when it is segmented by alternative criteria; especially by the well-known power series known as the *Fibonacci sequence* (to the best of our knowledge, this is the first time that these complementary approaches have been used for this purpose in trade analysis); (iv) finally, a tackling of the endogeneity problem by means of alternative specifications based on Hausman and Taylor (1981), who find, with respect to our previous estimates based on Anderson and van Wincoop (2003) and Silva and Tenreyro (2006), a small remarkable variation in the estimation of the external border effect, with a factor around 5, and the reduction of the internal border effect estimation, with a factor around 2.

The rest of the chapter is organized as follows. Section 2 briefly summarizes the literature on the non-linear relationship between trade and distances and its effect on the estimates of border effects. Section 3 offers a descriptive analysis of new trade flows in relation with distance. Section 4 describes the alternative specifications of the gravity equation used in our analysis. Section 5 presents our results, and the final section summarizes our conclusions.

4.2 Brief review of the non-linear treatment of the distance

Some recent papers describe the border effect as an artifact of "spatial aggregation" (Hillberry and Hummels, 2008; Llano-Verduras et al., 2011) or of a mismeasurement of the distance variable (Head and Mayer, 2000, 2002). Hillberry and Hummels (2008) used a micro-dataset on truck shipments of U.S. firms in 1997, which offered several spatial levels corresponding to states and zip codes. Investigating the non-linear effect of distance on the extensive and intensive margin of U.S. internal shipments, they found no border effect on internal shipments at certain spatial levels (*Ownzip*). The non-linear relationship between trade and distance was controlled for with a quadratic term for the distance variable. Similarly, Llano-Verduras et al. (2011) revised the estimated effect that national boundaries (*Owncountry*) exert on Spanish domestic and international trade (at the country level) by using flow data at two different spatial scales for the exporting unit: namely, the Spanish regions (Nuts 2) and provinces (Nuts 3). They found that the size of the border effect depended largely on the unit of spatial measurement. This paper—although varying the spatial scale for Spanish units: from regions (Nuts 2) to provinces (Nuts 3)—always scaled the foreign partner at the country level. A complementary study, Garmendia et al. (2012), estimated the effect of the regional borders (*Ownregion*) on truck shipments within Spain at the province level (Nuts 3), taking into account social- and business-network effects.

Although the econometric treatment of non-linearities has been widely considered in fields such as labor economics or growth, it has received little attention in the literature of international trade and gravity equations. One of the exceptions, Mukherjee and Pozo (2011) used a gravity model to analyze the impact of exchange-rate volatility on the volume of bilateral international trade through a semi-parametric regression for a panel of 200 countries. This model considers a non-linear relationship between volatility and trade, avoiding the need to superimpose any linearity restriction on the underlying relationship between exchange-rate volatility and trade. Another interesting example is Mundra (2005), who studied the relationship between U.S. bilateral trade and the stock of immigrants from different countries using a semi-parametric regression, where some variables enter the model linearly and there is no functional form for the proxy of social networks (immigration stock). De Benedictis et al. (2008) investigated the empirical relationship between overall specialization and per capita income using the Balassa Index of Revealed Comparative Advantages and non-parametric regression models. Finally, Ruiz et al. (2009) studied the non-linear relationship between remittances, institutions and growth, and, like Chami et al. (2005), discussed the advantages of semi-parametric approaches over quadratic terms. Moreover, piecewise regression (spline models), another benchmark approach for dealing with non-linearities, has also been neglected in trade analysis. In fact, we have found no remarkable examples in the field of bilateral flows, and just one on the use of spline techniques when modeling time series of product-specific exports (Martín Rodriguez and Cáceres Hernández, 2010).

As noted above, an interesting reference for our approach is Henderson and Millimet (2008), who used different parametric and non-parametric methods to discuss the nonlinear relationship between trade and distance. They specifically questioned two main assumptions of the literature: (i) that the relationship between trade and unobserved trade costs is (log) linear and (ii) that the effects of trade costs on trade flows are constant across country pairs. They then estimated gravity models both in levels and logs using two datasets and different parametric and nonparametric methods. Their paper concluded by suggesting two lines for future research that are worth repeating here: first, their exclusion of zero-trade observations; second, their observation that "while the parametric models outperform their nonparametric counterparts, all of the models perform relatively poorly using cross-country data […]. As a result, there is substantial room for improvement in modeling cross-country trade flows".

A more classical reference is Eaton and Kortum (2002), where a Ricardian model was tested by means of structural equations with bilateral flows for 19 OECD countries in 1990. In some of their specifications, the distance variable is divided into six intervals, as an alternative to the quadratic form. The length of such intervals is ad-hoc, and its effects on the results are not subject to a robust check against alternative spatial units or division criteria.

At this point, we stress how our work differs from the previous literature. With respect to Hillberry and Hummels (2008), our main contribution lies in the discussion of alternative specifications for dealing with the non-linear relationship between trade and distance when the dataset combines domestic and international flows (both at the region-to-region level), any of which may cross up to seven different borders. Whereas Hillberry and Hummels (2008) were able to disentangle the effect of internal borders (*Ownregion* and *Ownzip*) on internal flows within the U.S. at very fine spatial units, they remained silent on the equivalent puzzle for international deliveries. Similarly, Garmendia et al. (2012) focused on the effect of regional and provincial borders (*Ownregion* and *Ownprovince*) and networks on domestic shipments within Spain, but did not consider the effect of national borders on international flows. Conversely, Llano-Verduras et al. (2011) focused strictly on the effect of national borders (*Owncountry*), leaving aside intra-regional flows and own-region borders.

In this chapter, all flows and borders are considered simultaneously. Moreover, by using Nuts 2 regions (and not Nuts 3) we are able to obtain shrinking external border effects. Unlike Llano-Verduras et al. (2011), we do this not by changing the "spatial scale of the exporting region" (from Nuts 2 to Nuts 3) but by using regions instead of countries as the importing spatial units.

4.3 Descriptive Analysis

Before proceeding to the econometric analysis, we will briefly analyze the novel dataset to show the non-linear relation between trade and distance when the spatial grid is sufficiently fine[44]. With this purpose, we offer a first view of the distribution of trade (always region-to-region), as it depends on the distance travelled by trucks, for both domestic and international

[44] It must be notice that this chapter just focus on the pre-crisis period (2004-2007) in order to avoid structural changes that may alter erratically the results.

deliveries. Like in Garmendia et al. (2012), Llano-Verduras et al. (2011) and Hillberry and Hummels (2008), we also use a kernel regression to generate a nonparametric estimate of the relationship between distance and the intensity of Spanish regional export flows[45].

Figure 4-1: Kernel Regression: Intra- & Inter-National Trade Relative to GDP (NUTS-2 Region-to-Region) on Distance. Zero Flows Excluded. (€). 2004–2007.

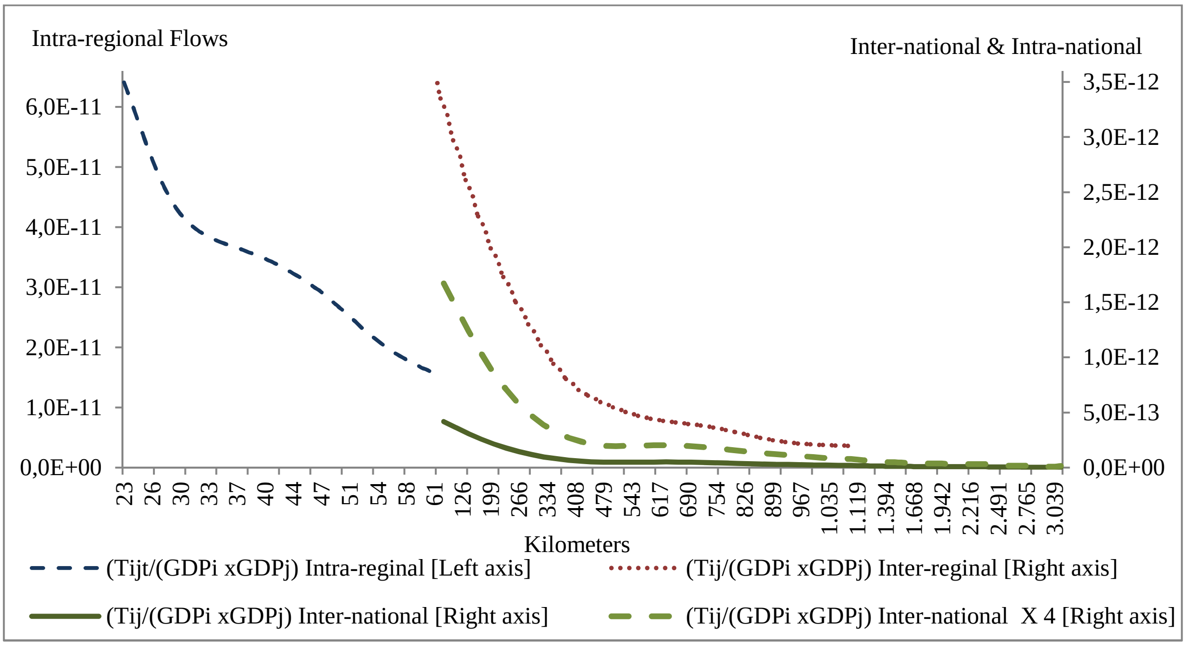


Figure 4-1 plots the distribution of domestic and international flows (exports) for each region against those for the rest of Spanish regions and the seven European countries. Note that trade flows are corrected by the GDP of each exporting/importing region. To illustrate the *multi-level dimension of the non-linear relation between trade and distance*, the figure depicts a separate plot for the kernel regression of each kind of trade flow: i.e., intra-regional flows within Spain, inter-regional flows within Spain and inter-regional exports from Spanish regions to regions in the seven countries. To bring out the great differences in intensity, the graph displays two different scales: one for intra-regional flows (left axis) and one for the remaining flows (right axis). Moreover, to emphasize the similar shape of each kernel distribution, the *international flows* kernel is plotted twice: with its natural scale and re-scaled at a factor of “x4” (in line with the largest external border effect reported in this chapter). In distinguishing the great differences in the relative intensity of the flows, we can also see the *regularity* of the non-linear relationship

45 We use the Gaussian kernel estimator in STATA, with n = 100 points and the estimator calculating optimal bandwidth.

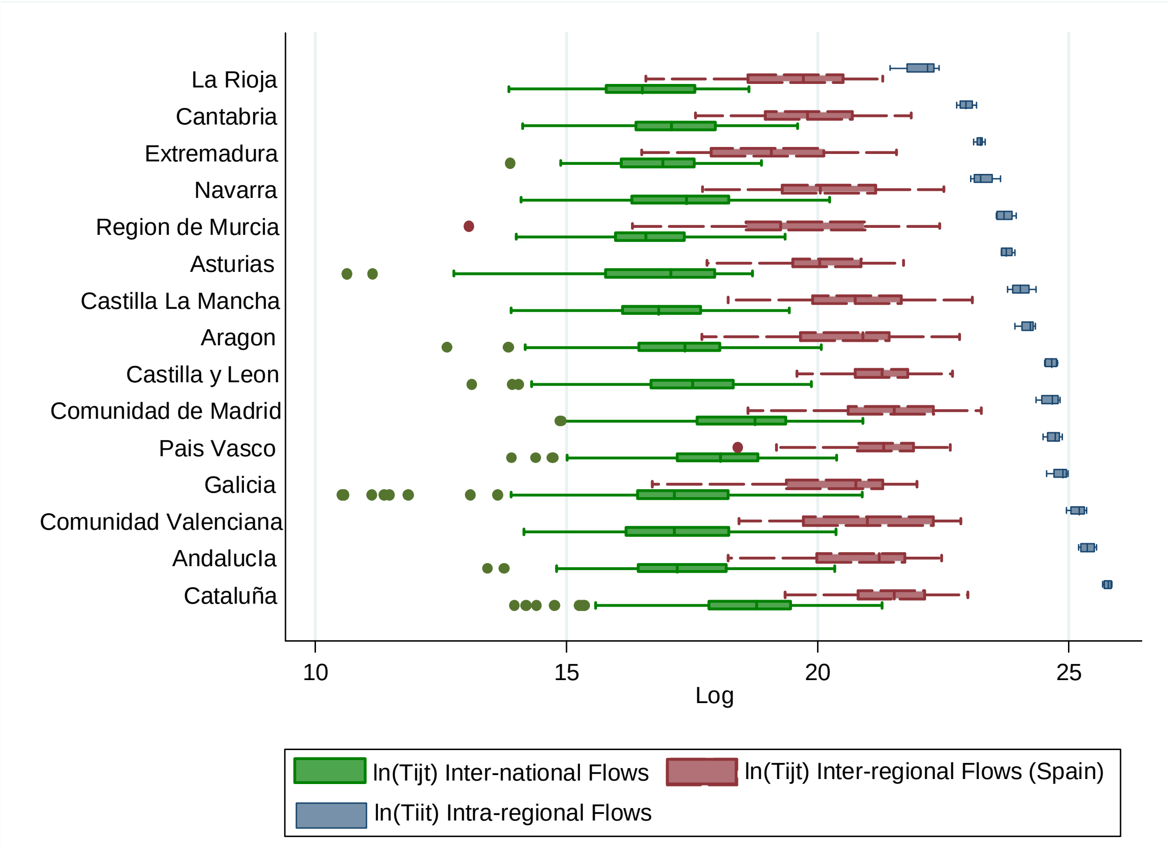
between trade and distance over the shortest distance. By mixing together different types of flows, other papers have emphasized the sharp decrease on the intensity of trade over the shortest distances (e.g., 700 km). Our approach shows how distance varies by kind of flow.

From this analysis we can conclude that regardless the flow type, the bulk of trade takes place over short distances, while beyond a certain threshold the negative effect of distance falls off deeply. Hence the relevance of territorial disaggregation, Llano-Verduras et al. (2011) and Garmendia et al. (2012) have shown that, with insufficient territorial disaggregation of trade, the gravity equation may lead to an overestimation of the border effect and an underestimation of the distance effect. As we will see in the next section, this overall effect can arise not just when regions are used instead of provinces, but also when countries are used instead of regions. Because of this non-linearity, moreover, sharp decreases in trade intensity may or may not coincide with the administrative units where the flows are allocated (and even where borders are!). It would thus be interesting to consider econometric procedures flexible enough to control for that.

Complementarily,

Figure 4-2 shows the distribution of each type of flow (in logs and without controlling for GDPs) by exporting region. To interpret this, it is critical to take into account that the figure plots the distribution of observations around the corresponding mean rather than aggregate magnitudes. The aim of this graph is threefold: First, to illustrate the variability of trade in each market (intraregional, interregional within Spain and interregional with the rest of Europe), and show that, although there are some rare small international exports, the intensities for each category are quite stable (structural). Second, as with the kernel regressions, to confirm a clear discontinuity in the intensity of trade in the presence of both regional and national borders. Note that in almost all regions, there is little overlap between the intensities of interregional flows within Spain and with Europe, and none at all between intra-regional trade and the other two categories. Third, to demonstrate the remarkable variability in the range of trade intensity by region. For the sake of clarity, the exporting regions are ranked by largest flows (intra-regional). Cataluña has the largest intensities for each category, showing outstanding values for intraregional and international flows. Other cases are also worth mentioning: Galicia and Asturias, for example, show wide ranges of flows, with several outliers in the bottom part of their distribution; conversely, the Madrid region shows a shorter and more compact range (no outliers in the bottom part of the distribution) together with intense flows in all categories.

Figure 4-2: Distribution of trade flows by nature and exporting region. 2004–2007.



Note: The box records the second and the third quartiles of the variables, being the line that divides the box between these two quartiles the average. The first and the second whiskers correspond to the first and the fourth quartiles, respectively. The dot values are usually interpreted as outliers, but in this case we consider them as extreme values.

4.4 The Empirical Model

4.4.1 Baseline models

As in most of the articles cited previously, the backbone of our investigation is the gravity equation, where the intensity of trade between any two locations (regions or countries) is positively related to their economic size and inversely related to the trade cost (proxy by geographical distance) between them. Here again (as in the previous chapter), according to our definition of the border effects: Internal border effect (exp|*Internal_Border*|) denotes the number of times a Spanish region trades less with any other domestic region in the sample than with itself; and the external border effect [46] (exp|*External_Border-Internal_Border*|) denotes the number of times a Spanish region trades less with a foreign region elsewhere in Europe than with another Spanish region, controlling for a set of factors.[47]

For the sake of brevity, we define two equations that contain the benchmark models:

$$Ln\frac{T_{ijt}^{eu}}{GDP_{it}GDP_{jt}} = \beta_0 + \beta_1 Internal\_Border + \beta_2 External\_Border + \\ \beta_3 Internal\_Contig + \beta_4 External\_Contig + \beta_5 Ln\left(dist_{ij}\right) + \mu_{ij} + \mu_{jt} + \mu^u + \varepsilon_{ijt} \quad (4.1)$$

where $\frac{T_{ijt}^{eu}}{GDP_{it}GDP_{jt}}$ represents bilateral flows originating in Spanish regions and corrected by the GDPs of the trading regions[48]. More specifically, T_{ijt}^{eu} is the flow from region *i* in country *e* to region *j* in country *u* in year *t*. The variables GDP_{it} and GDP_{jt} are the nominal gross domestic product (GDP) of the exporting and importing regions, respectively. The variable $Ln\left(dist_{ij}\right)$ is the logarithm of the distance between region *i* and region *j.*

The variable *Internal_Border* controls for flows that cross a domestic frontier; i.e., it takes the value one when the origin and the destination are different regions but both belong to the same country (interregional flows within Spain: *e=u=Spain* and *i ≠ j*) and zero otherwise. In addition, the variable *External_Border* is a dummy that controls for flows that cross an international boundary; i.e., it takes the value one for inter-national flows (*e*=Spain*; u* =any of the 7 European countries considered) and zero otherwise.

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[46] It is worth mentioning that the main difference between the baseline specification of this chapter and the specification of the previous chapter, when estimating the two kinds of border effects (internal and external), is that here both barriers are estimated simultaneously. That is, we use the full sample and the two border dummies, what entails a certain change in the direct interpretation of the *External_Border* dummy, which does not match with the external border effect anymore.

47 Note that with these definitions, the addition to the two border effects (External_Border + Internal_Border) we denote the number of times a Spanish region trades less with a foreign region elsewhere in Europe than with itself.

48 In order to save notation, it must be notice that, in the tables of results, we refer to this term as T_{ijt}_corr (trade flow corrected for the GDPs' product), instead of $T_{ijt}^{eu} / GDP_{it}GDP_{jt}$.

To capture the positive effect of adjacency, we introduce two dummy variables: *Internal_Contig* and *External_Contig*. This allows us to consider (simultaneously or independently) the different effects that *adjacency* exerts on trade flows between two contiguous regions in Spain, or between a Spanish region and a contiguous foreign one. *Internal_Contig* takes the value one when trading regions *i* and *j* are contiguous and are both located in Spain, and zero otherwise. Similarly, *External_Contig* takes the value one when region *i* is a Spanish region exporting to a foreign contiguous region *j* and zero otherwise. These variables conveniently control for higher inter-regional trade flows between contiguous Spanish regions, as well as for the higher concentration of trade between border regions of different countries (Spain-Portugal, Spain-France). It is in line with the results of Lafourcade and Paluzie (2011), who have shown that border regions in countries like France and Spain tend, on average, to capture larger shares of bilateral trade and FDI flows.

The terms μ_{it} and μ_{jt} correspond to the well-known multilateral-resistance fixed effects for each origin and destination region interacted with time, respectively (Anderson and van Wincoop, 2003; Feenstra, 2002). These fixed effects are meant to control for competitive effects exerted by the non-observable price index of partner regions and by other competitors. They are also meant to capture other particular characteristics of the regions in question. To account for the likely heterogeneity between countries and its effect on the estimate of a single border effect, we also add for each destination country a fixed-effect term (μ^{u}). In addition, a time fixed-effect term (μ_t) is included, which controls for cyclical factors that are common to all the European countries (global cycle, developments in the integration process, exposure to external economic shocks, etc.).

Eq. (4.2) describes an alternative specification with certain refinements in the treatment of distance.

$$Ln\frac{T^{eu}_{ijt}}{GDP_{it}GDP_{jt}} = \beta_0 + \beta_1 Internal\_Border + \beta_2 External\_Border + \beta_3 Internal\_Contig + \beta_4 External\_Contig + \beta_5 dist_{ij} + \beta_6 dist^2_{ij} + \mu_{it} + \mu_{jt} + \mu^{u} + \mu_t + \varepsilon_{ijt} \quad (4.2)$$

It thus includes, apart from the traditional variable $dist_{ij}$, a new variable $dist^2_{ij}$. As in Hillberry and Hummels (2008), Llano-Verduras et al. (2011) and Garmendia et al. (2012), the variable $dist^2_{ij}$ is defined as the square of the distance between trading regions and it is expected to capture the non-linear relationship between trade and distance that is observed in the kernel regressions in

Figure 4-1. Also in line with these papers, we split the interpretation of these two variables (capturing the negative but non-linear effect of distance on trade) into two parts: (i) a negative and direct effect of distance on trade and (ii) a positive effect for the square of the distance, to capture the high concentration of trade over the shortest distance as observed in the kernel regression.

4.4.2 Alternative specifications

- **Gravity equation with segmented distance**

Next, as an alternative way to deal with the non-linear relationship between trade and distance, we introduce a flexible approach that controls for changes in the slope of our linear estimation for different "segments" of the sample, these segments corresponding to different distances traveled by trucks. Although purely non-parametric techniques such as kernel regressions offer certain flexibility, they cannot quantify the border effects under discussion. As we present in the next section, this new approach produces different results from those of the square of distance. In our view, the variation is due to the differing capacities of the alternative strategies to deal with the non-linear relationship shown in **Figure 4-1**, which repeats itself at different levels of aggregation, perhaps as flows cross certain thick borders[49]. For each regression using this approach we proceed as follows: (1) we rank the whole sample by increasing distance; (2) we divide the entire range of distance traveled (max-min distance observed in the sample) into "segments" (stretches). For purposes of rigor, we define the "segments" in three alternative ways:

i. **"Naïve":** The first way simply divides the entire range of actual distance traveled into four stretches of equal length (in kilometers). We call it "naïve" because it ignores the expected higher intensity of flows over the shortest distance.
ii. **"Fibonacci":** The second way follows the *Fibonacci sequence*, a "magical" mathematical relation that appears in several natural phenomena (the reproduction of rabbits, the internal structure of sunflowers, etc.). The sequence has been used in architecture and in certain fields of economics and finance but, to the best of our knowledge, never before in trade. One benefit of the sequence is that it produces "segments" of increasing length.

[49] Two examples of thick borders (i.e., administrative borders coinciding with specific forces that cause considerable agglomeration of trade at a short distance) are: (a) Internal borders defining large metropolitan areas; these may coincide with the space where the forces of economic agglomeration around cities are at work, causing a great volume of intra- and inter-regional flow between contiguous regions. (b) International frontiers, coinciding with disproportionate divisions in terms of legal, cultural, historical and political barriers to trade.

Another is that the sequence, although completely exogenous, fits perfectly with the non-linear intensity of trade at the nearest distance, dividing the entire range of distance as follows: first stretch: 8% of distance; second stretch: 8%; third stretch: 17%; fourth stretch: 25%; fifth stretch: 42% (100% in total).

iii. **"Quartile":** The third way assures an equal distribution of the number of observations per segment. It arranges them into quartiles of observation distribution, ranked by distance traveled.

This novel strategy is formally expressed in Eq.(4.3):

$$Ln\frac{T_{ijt}^{eu}}{GDP_{it}GDP_{jt}} = \beta_0 + \beta_1 Internal\_Border + \beta_2 External\_Border + \beta_3 Internal\_Contig + \beta_4 External\_Contig + STRETCH^S Ln\left(dist_{ij}\right)\theta + \mu_{it} + \mu_{jt} + \mu^u + \mu_t + \varepsilon_{ijt} \quad (4.3)$$

$STRETCH^S Ln\left(dist_{ij}\right)$ denotes the interaction between the log of the distance and a matrix *STRETCH*, which contains a set of dummy variables identifying each "segment". By including such interactions, we essentially introduce a set of "semi-dummy" variables, where $Ln\left(dist_{ij}\right)$ replaces the value one of a normal dummy for the corresponding stretch. θ is a vector containing the coefficients for each distance stretch. Superscript *s* indicates the three alternative ways of splitting the sample (Naïve, Fibonacci, and Quartile). The rest of the variables are the same as those used in previous specifications.

- **A look at the effect of the national border**

Before considering alternative treatments for the non-linearities, it is appropriate to analyze the heterogeneity of the external border effect for each destination country. This analysis relies on equation (4.4). As in equation (4.3), we still consider the distance variable divided into different stretches. In addition, the *External_Border* effect is split according to the European destination country. Thus, the variable is renamed accordingly, using the label *Border_Country*.

$$Ln\frac{T_{ijt}^{eu}}{GDP_{it}GDP_{jt}}=\beta_0+\beta_1 Internal\_Border+\beta_2 Border\_Country+STRETCH^S Ln\left(dist_{ij}\right)\theta+$$
$$\mu_{it}+\mu_{jt}+\mu^u+\mu_t+\varepsilon_{ijt}$$

(4.4)

Border_Country represents a set of dummies, one for each European country, that take the value one when the destination of the flow is a non-Spanish region located in each one of the countries of the sample. The country destination fixed effect, which considered the particular resistance/propensity of each country to import Spanish products is now redundant and drops from the equation.

- **A Piecewise regression approach**

As a robust check, three alternative piecewise regressions—namely, two linear and one restrictive cubic spline models—have been estimated. Piecewise models are also known as spline regressions and are described in the literature as efficient ways to approximate true non-linear relationships in data. Their main advantage is that the shape of the estimated function acquires a larger flexibility and is data driven, since no form is imposed a priori. A piecewise linear function is composed of linear segments—straight lines—separated by a number of *knots*. In some econometric software (i.e., Stata) the number of knots as well as the specific location of each can be set a priori by the researcher, or be automatically assigned by the procedure to find the best fit for the data. In keeping with our previous models, we consider four segments in every one of them. In our case, the three spline models can be described by Eq. (4.5), where element $f\left(Ln\left(dist_{ij}\right)\right)$ corresponds to the three alternative segment definitions:

$$Ln\frac{T_{ijt}^{eu}}{GDP_{it}GDP_{jt}}=\beta_0+\beta_1 Internal\_Border+\beta_2 External\_Border+f\left(Ln\left(dist_{ij}\right)\right)+\mu_{it}+\mu_{jt}+\mu^u+\mu_t+\varepsilon_{ijt}$$

(4.5)

For the first linear spline (M13 in **Table 4.4**), three equally spaced knots were set. For the second linear spline (M14 in **Table 4.4**) the three knots were assigned according with the sample's quartiles. Finally, we estimated a restricted cubic spline to better capture the strong non-linearity observed in the shortest distance (M15 in **Table 4.4**), here we also set four segments (knots=3) a priori, although the size of each segment was automatically determined.

- **A semi-parametric regression approach**

We have also applied a semi-parametric approach (Pagan and Ullah, 1999; Yatchew, 1998) for the same purpose of achieving some flexibility in modeling the non-linearity as well as in estimating our desired parameters (internal and external border effects). We have followed Robinson (1988),[50] who described a general model of the type in Eq.(4.6):

$$Y_{ijt} = \beta_0 + X_{ijt}\beta + f\left(dist_{ij}\right) + \varepsilon_{ijt} \tag{4.6}$$

Where Y_{ijt} is the dependent value expressed in dyadic terms *ij* (bilateral flows divided by the corresponding income levels), and $X_{ijt}\beta$ is a matrix including the explanatory variables whose parameters are to be estimated (internal and external border effects among others); $dist_{ij}$ is the explanatory variable that enters the equation non-linearly following a non-binding function *f*. This model can be estimated using Robinson's (1988) double residual method, which starts by applying a conditional expectation to both sides of (4.6). This leads to:

$$E\left(Y_{ijt}\middle|dist_{ij}\right) = \beta_0 + E\left(X_{ijt}\middle|dist_{ij}\right)\beta + f\left(dist_{ij}\right) + \varepsilon_{ijt} \tag{4.7}$$

By subtracting (4.7) from (4.6), we obtain Eq. (4.8)

$$Y_{ijt} - E\left(Y_{ijt}\middle|dist_{ij}\right) = \left(X_{ijt} - E\left(X_{ijt}\middle|dist_{ij}\right)\right)\beta + \varepsilon_{ijt} \tag{4.8}$$

If the conditional expectations are known, the parameter vector β can be estimated by means of OLS. If they are unknown, they can be estimated with a non-parametric kernel estimator, as in Robinson (1988).

4.4.3 A final robust check on endogeneity

Finally, we would like to address an econometric issue that has been analyzed with panel data and gravity equations in previous papers (Egger, 2002; Mitze 2010; Brun et al., 2005; Belke and

[50] Verardi and Nicolas (2012) have described this approach and developed the corresponding Stata routine (*semipar*) for implementing it. We are grateful for this contribution.

Spies, 2008; Serlenga and Shin, 2007). The advantage of panel data is that they allow controlling for unobservable bilateral fixed effects, whose existence implies bias in Pooled Ordinary Least Square (POLS) estimates. The Random Effects Model (REM) approach yields consistent estimates only when the regressors are uncorrelated with the unobservable dyadic fixed effect. However, it is likely to find correlation among some exogenous variables and the unobservable pair-individual effects, which is termed as right-hand side endogeneity, in this case the REM approach is not valid. This correlation can be verified with the Hausman Test, whose null hypothesis indicates that they are uncorrelated. Although the use of Fixed Effects (FE) estimators is a straightforward way to tackle such a problem while giving unbiased estimates of time-varying variables, when applied to gravity equations it impedes the analysis of important time-invariant variables, such as distance, contiguity and border-effect dummies. As an alternative, several authors have favored the Hausman-Taylor (1981; hereinafter HT) approach, which provides estimates of both time-varying and time-fixed regressors. Departing from some of the following references (Egger, 2002; Mitze 2010; Belke and Spies, 2008), the HT approach can be expressed as a model of the form described in Eq. (4.9):

$$Y_{ijt} = \delta_0 + \delta_1 X1_{ijt} + \delta_2 X2_{ijt} + \gamma_1 Z1_{ij} + \gamma Z2_{ij} + \mu_{ij} + \varepsilon_{ijt} \tag{4.9}$$

where Y_{ijt} is the dependent variable; μ_{ij} corresponds to the unobservable bilateral fixed term, i.i.d. N(0,σ_μ); ε_{ijt} is the residual of the model, i.i.d. N(0,σ_ε); $X1_{ijt}$ and $X2_{ijt}$ represent vectors of time-varying variables; and $Z1_{ij}$ and $Z2_{ij}$ contain vectors of time-invariant variables. $X1_{ijt}$ and $Z1_{ij}$ are doubly exogenous variables[51]. $X2_{ijt}$ and $Z2_{ij}$ denote vectors of endogenous variables, which produce a bias under the REM approach. It is worth mentioning that one advantage of the HT estimator is its hybrid nature[52], which allows for endogenous and exogenous regressors.

The HT strategy is a two-step estimation procedure based on the Instrumental Variable (IV) technique, where the second step considers the GLS transformation of the variables. The instruments come from the own specification of the model, exploiting the double dimension of

[51] In the context of panel data, some authors employ the terminology of doubly exogenous regressors, when they refer to regressors non-correlated neither with the error term nor with the unobservable dyadic fixed effect term, and employ the term of singly exogenous regressors, when they refer to regressors correlated with the unobserved heterogeneity term. Here we employ interchangeably the terms: exogenous regressors and doubly exogenous, and endogenous and singly exogenous regressors.

[52] In the opposite side, the FEM assumes the correlation of all the variables with the unobservable term, and the REM assumes non-correlation between regressors and the unobservable term.

regressors in a panel (time and individual). More specifically, the instruments for time-varying variables are their *within-group* transformation. In this way the estimator achieves consistent estimates of parameters the δ_1 and δ_2. The choice of instruments for the time-fixed regressors depends on their exogenous status. The exogenous regressors, $Z1_{ij}$, serve as a valid instrument of themselves, whereas the endogenous, $Z2_{ij}$, need the *between* information of the exogenous time-varying variables $\left(\overline{X}1_{ij}\right)$ as instruments. Accordingly, the number of time-fixed endogenous variables should be lower or equal to exogenous time-varying regressors.

To re-estimate Eqs. (4.1) and (4.3) under this last constraint, we follow Carrère (2006) passing the variable of GDP's product to the right-hand side, which will be considered as endogenous variable for the HT procedure. *Internal_Border*, *External_Border*, *Internal_Contig*, *External_Contig* and *Distance* $\left(Ln\left(dist_{ij}\right)\right)$ are classified as dyadic time-fixed variables, $Ln\left(GDP_{it}GDP_{jt}\right)$ as the only dyadic time-varying variable, and the multilateral resistant terms $\left(\mu_{it},\mu_{jt}\right)$ and destination country $\left(\mu^{u}\right)$ and year $\left(\mu_{t}\right)$ fixed effects are considered as exogenous monadic variables.

Empirically, the main problem for the HT approach is deciding whether a variable should be considered a-priori as correlated or uncorrelated with the individual effects. We consider different options depending on the economic meaning of the assumption: (i) as a starting point, we consider the non-existence of heterogeneity in the model, and apply a POLS estimator; (ii) we assume the existence of unobservable heterogeneity but with zero correlation with the rest of the regressors, and use the REM estimator; and, finally, (iii) after rejecting the null hypothesis of Hausman's test, we follow Carrère (2006) in considering GDP as a significant source of endogeneity.

4.5 Results

In this section we analyze the main results for the twenty-four models estimated with our novel region-to-region dataset. The first specifications to be considered use *corrected trade* flows $\frac{T_{ijt}^{eu}}{GDP_{it}GDP_{jt}}$ as the endogenous variable, as well as all the fixed-effects approaches described above. However, each uses a different treatment of the distance variable. In contrast to previous papers in the literature, the effects of external (*External_Border*) and internal (*Internal_Border*) borders are estimated simultaneously in all specifications; i.e., with the whole sample considered at the same time. We are thus able to determine whether the two border effects are at work; i.e., when certain (international) flows are crossing two borders (one internal, the other external) or more[53]. Note that such results would not be fully comparable with those previously reported, since with just two dummies we would have to control for three types of flows (intra-regional, inter-regional within Spain and inter-regional with other EU countries). However, this approach is close to computing the internal border effect (*Internal_Border*) within a single country (*Euroland*) with two nested administrative borders, as Hillberry and Hummels (2008) did for the U.S.. Our analysis and interpretation of the results will therefore be close to theirs.

The results generated by Eqs. (4.1) to (4.3) are reported in **Table 4.1**. Ordinary Least Square (OLS) estimators are used when the gravity equation is applied to a dataset with no zero values, in this case we are modeling only the intensity of flows between regions, not the drivers behind the existence or non-existence of said flows. When zeros are included[54], we use instead the pseudo-maximum likelihood technique (PPML). It was Santos Silva and Tenreyro (2006) who proposed using the PPML approach, which also sorts out Jensen's inequality (note that the endogenous variable is in levels) and produces unbiased estimates of the coefficients by solving the heteroskedasticity problem.

Table 4.1 reports the results for the first six models. M1 includes the endogenous variable and the distance in logs (OLS without zero flows). M2 includes zero flows and use the PPML estimator. Thus the endogenous variable is expressed in levels and distance in logs. In M3 *distance* and the *square of distance* are included in levels. Next, to shed more light on the non-linear relationship between trade and distance, M4–M6 report the corresponding results for three alternative models based on our alternative strategies (Eq. (4.3)), which segments the sample in three ways by trucking distance. This procedure estimates the elasticity of distance in each interval. Note that in these models the distance variables for each "stretch" are also expressed in logs.

The first three models (M1-M3) generate significant coefficients with the expected signs for all variables except *External_Contig*. This result suggests that the difference in the intensity of trade between a Spanish region and a foreign border region, on the one hand, and between non-adjacent Spanish regions, on the other, is non-significant. However, the coefficient for the *Internal_Contig* variable is positive and significant. In the three models the coefficient for the distance variable is negative and significant, with elasticities that are within normal range. Moreover, the results for distance variables that control for the non-linear relationship between trade and distance in M3

[53] Note that in some cases (e.g., exports from Spain to Germany) a Spanish truck may cross three or four different national borders. As described in the introduction, this could induce additional "jump" in the intensity of trade.

[54] The zero values considered in our dataset correspond to region dyads that had non-zero values at least in one year in the period 2004–2007. Zeros corresponding to regions that did not receive any exports from a Spanish region during that period are not considered in our sample.

suggest that distance acts as a clear impediment to trade (negative coefficient for $dist_{ij}$), but an impediment that tapers off as distance increases (positive coefficient for $dist_{ij}^2$).

Table 4.1. Alternative Estimates for External Border Effects.
M1–M2 are based on Eq. (4.1), M3 on Eq. (4.2), M4–M6 on Eq. (4.3).

VARIABLES	M1 OLS Ln(T_{ijt}_corr)	M2 PPML T_{ijt}_corr	M3 PPML T_{ijt}_corr	M4-Naïve PPML T_{ijt}_corr	M5-Fibonacci PPML T_{ijt}_corr	M6-Quartile PPML T_{ijt}_corr
Ln($dist_{ij}$)	-1.035***	-0.908***				
	(0.0769)	(0.104)				
$dist_{ij}$			-2.025***			
			(0.284)			
$dist_{ij}^2$			0.541***			
			(0.0787)			
Ln($dist_{ij}$ stretch1)				-1.179***	-1.104***	-1.195***
				(0.158)	(0.215)	(0.146)
Ln($dist_{ij}$ stretch2)				-1.129***	-1.151***	-1.116***
				(0.145)	(0.193)	(0.136)
Ln($dist_{ij}$ stretch3)				-1.082***	-1.128***	-1.082***
				(0.140)	(0.177)	(0.132)
Ln($dist_{ij}$ stretch4)				-1.044***	-1.048***	-1.046***
				(0.136)	(0.166)	(0.129)
Ln($dist_{ij}$ stretch5)					-1.002***	
					(0.159)	
Internal_Border	-1.373***	-2.031***	-3.513***	-1.380***	-1.339***	-1.289***
	(0.231)	(0.385)	(0.302)	(0.482)	(0.488)	(0.471)
External_Border	-2.055***	-3.155***	-4.541***	-2.566***	-2.600***	-2.498***
	(0.352)	(0.456)	(0.391)	(0.534)	(0.534)	(0.523)
Internal_Contig	0.396***	0.570***	0.997***	0.312	0.199	0.243
	(0.0922)	(0.193)	(0.181)	(0.218)	(0.238)	(0.221)
External_Contig	0.249	-0.186	0.270	-0.398	-0.471	-0.493
	(0.157)	(0.325)	(0.318)	(0.339)	(0.345)	(0.344)
Constant	-20.60***	-21.25***	-24.50***	-20.26***	-20.53***	-20.20***
	(0.313)	(0.466)	(0.258)	(0.646)	(0.845)	(0.605)
Internal Border Effect	4	8	34	4	4	4
External Border Effect	2	3	3	3	4	3
Null hypothesis†	Ln($dist_{ij}$ stretch1)-Ln($dist_{ij}$ stretch2)=0, $\chi 2$			5.5**	1.09	15.57***
	Ln($dist_{ij}$ stretch2)-Ln($dist_{ij}$ stretch3)=0, $\chi 2$			16.52***	0.67	9.05***
	Ln(distij stretch3)-Ln($dist_{ij}$ stretch4)=0 $\chi 2$			7.57***	15.22***	10.94***
	Ln($dist_{ij}$ stretch4)-Ln($dist_{ij}$ stretch5)=0, $\chi 2$				16.23***	
Observations	3,688	6,376	6,376	6,376	6,376	6,364

R-squared	0.812	0.905	0.882	0.906	0.906	0.905

Note: Standard robust errors (origin and destination regional partners clustered) in parentheses with ***, ** and * respectively denoting significance at 1%, 5% and 10%. Fixed effects of origin-region by year (μ_{it}), destination-region by year (μ_{jt}), destination-country (μ^{u}) and year (μ_{t}) included. Wald test was calculated to evaluate significant differences between the coefficients associated to the stretches of distance in models M4, M5 and M6. $T_{ijt}\_corr = T_{ijt} / GDP_{it}GDP_{jt}$.

Regarding the external border effect, model M1 reaches a value of 2 (exp|2.055-1.373|) while the other two (M2–M3) reach a factor of 3. Note that the latter two stand up robustly to alternative specifications (M4-M6), subsamples, estimation procedures and treatments for the non-linear relationship between trade and distance. This persistent value between 3 and 4 for external border effect is very close to the one obtained by Llano-Verduras et al. (2011) with region-to-country [3.3 = exp(1.2)] and province-to-country [4.9 = exp(1.6)] data. Note that these papers use different datasets and definitions of the border dummy, but similar specifications for distance and the same estimation procedures as in M2 and M3 (PPML). By contrast, the results for the internal border effect are more puzzling, showing a larger variation with respect to the econometric approach used to control for the non-linearity. On the one hand, the factor obtained for the internal border effect for M1, M4, M5 and M6 is exactly the same (4) and in almost all cases is very close to the external border effect. On the other, the internal border effect slightly rises for M2 (factor of 8) and skyrockets to a factor of 34 in M3. Note that this jump just occurs when the PPML is used with the whole sample (zero flows included) and the quadratic term of the distance. Similar results have not been reported in articles where the internal border effect was estimated alone (Garmendia et al., 2012); i.e., with the external border effect and international flows excluded.

If we compare the results reported in **Table 4.1** for models M2 (with logarithmic transformation of distance) and M3 (with the quadratic form of distance) with those estimated in the previous chapter using the same specifications (**Table 3.2:** M5 and M6 for the external border effect, and M8 and M9 for the internal border effect) we find significant differences. There are two main reasons behind these differences: on the one hand, the period considered here only covers the pre-crisis years (2004-2007), while the previous estimates covered the entire period available (2004-2011). Note that the temporal analysis of the external border effect (section 3.4.1) showed as in 2008 it peaked, gathering since then estimates higher than during pre-crisis period. On the other hand, though less important, the estimation method used for estimating the internal border effect in the former chapter (**Table 3.2:** M8 and M9) was OLS—since there were no zeros in the sub-sample selected, PPML was not required. Additionally, it is remarkable that the estimates in

Table 3.2 calculate separately the internal and external border effect. That is, the estimation of the internal border effect does not consider the international trade flows, and the estimation of the external border effect does not include the intraregional trade flows. Therefore, for each sub-sample we got an estimation of the distance and contiguity effects. In fact, we observed a more negative coefficient of the distance for the estimation of the internal border effect (in **Table 3.2** model M8 for $Ln(dist_{ij})$ is - 1.411 and for model M9 is -6.108 and 2.761 for $dist_{ij}$ and $dist_{ij}^2$, respectively) than for the estimation of the external border effect (in **Table 3.2** model M5 for $Ln(dist_{ij})$ -0.977 and for model M6 -2.938 and 0.839 for $dist_{ij}$ and $dist_{ij}^2$, respectively), meanwhile the contiguity factor was only positive and significant for the estimation of the external border effect in the case of the domestic adjacency (**Table 3.2** 0.407 for M5 and 0.662 for M6).

In this chapter, however, all the specifications include simultaneously the two kinds of border effects (and therefore the three types of trade flows). So now it is estimated a unique coefficient for the effect of distance and adjacency. Compared to the results of the previous chapter, these estimates remain close to the ones obtained when international trade flows (more numerous) were included, but not the intraregional trade flows. The coefficients of distance here are -0.908 in M2 for the log-transformation of distance and -2.025 and 0.541 in M3 for its square form (**Table 4.1**). The internal contiguity effect is also significant, but lower than in **Table 3.2** (**Table 4.1** in M2 is 0.570 and in M3 is 0.997). These results, closer to those obtained when the external border effect was estimated isolated, lead to a overestimation of the internal border effect (8 for M2 and 34 for M3 in **Table 4.1**) with respect to its former estimate (1 for M8 and 5 for M9 in **Table 3.2**). The explanation for this comes from the fact that the previous estimates modeled the high discontinuity between the intraregional (trade in the shortest distances) and the interregional (for longer distances) trade flows through the estimation of a strong negative effect of the distance, so that the difference between the intraregional trade and the interregional trade that remains unexplained by the distance effect is smaller; difference that eventually constitutes the internal border effect. Therefore, only with the introduction of the distance variable in a more flexible way, especially for the first kilometers, the internal border effect will be more similar to that estimated without the international flows. The external border effect also showed changes in its values, decreasing from a coefficient of 7 (M5) and 8 (M6) in **Table 3.2** to around 3 in **Table 4.1** (M2 and M3), but probably they are more related to the period considered that to the changes on the coefficients of the distance and the contiguity dummy.

Table 4.1 reports promising results for models M4 to M6, which employ our new controls for non-linearity. The coefficients for STRETCH $Ln\ (dist_{ij})$ in each of the segments are negative and highly significant for these three alternative models. More interestingly, in M4 (Naïve) and M6

(Quartile) the negative elasticity for each stretch decreases, which is consistent with a segmentation where the distance variable is sorted in increasing order. In M5 (Fibonacci), however, the negative elasticity of distance increases in the first two segments (from −1.104 to –1.151) and decreases thereafter (from −1.151 to −1.002). The last part of **Table 4.1** shows the results for the Wald test applied to the Null-hypothesis of equal elasticity between consecutive stretches of distance. The results show that the differences between the stretches are statistically significant, with the exception of the first three consecutive segments in the Fibonacci division. For the external border effect, the three alternative procedures for segmenting the sample reach significant factors that in absolute terms vary across 3 and 4, close to those obtained in M2 and M3. Moreover, the results for the internal border effect also result in a factor around 4, which is significant in all cases. Therefore, we can conclude that the internal border effect increases when zero flows are included and PPML is used (M2–M3), but this effect is controlled for when segmented distance is used (M4–M6). Finally, it is interesting to note that the coefficients for *Internal_Contig* and *External_Contig* become non-significant. This suggests that when the non-linear relationship is controlled for by segmentation of the sample into stretches, the alternative control for the higher intensity of trade over the shortest distance (contiguity) becomes redundant.

If we now compare the results obtained in the M4-M6 models in **Table 4.1** (where the logarithmic transformation of the distance divided into several stretches feeds the specifications), with those obtained in the previous chapter for the specification with distance in logarithmic terms (**Table 3.2:** M5 for the external border effect and M8 for the internal border effect), there are still differences, but these are smaller than when the distance variable entered non-split. As it was expected, the more significant change is in the internal border effect, which shrinks to a factor of 4. The external border also achieves a factor around 4. Among the three alternatives used to divide the effect of distance, we believe that the *Fibonacci*'s division fits best the data, since the increasing segments of distance are the shortest at the beginning, and presents the highest R^2 (90%), together with the *quartile* criterion.

To bring home the previous results, **Table 4.2** summarizes the main features of the three alternative segmentations and provides measures of overall fitness for each segment. Several points are worth mentioning: (i) The three sequences have been defined not by volume or nature of trade but, instead, by distance range and number of observations (zero flows included). Thus the *Fibonacci* and *Quartile* sequences consider segments of different length; (ii) The percentage of zero values for each stretch and each criterion is different. Zero values are highly concentrated in the longest trips (mainly international flows); (iii) For a complementary view, we show the close fit obtained with the models run separately for each segment of the sample[55]. **Table 4.2** reports the R^2 for regressions that use $(Ln(dist_{ij}))$ or $(dist_{ij}, dist_{ij}^2)$; i.e., for the counterparts to the specifications used in M2 and M3. Note that, although the three alternative segmentation criteria generate the same R^2 $(Ln(dist_{ij}))$ and R^2 $(dist_{ij}, dist_{ij}^2)$ for the whole sample (TOTAL column), which correspond to models M2 and M3, respectively, the quality of the fit is different for each segment and sequence. Throughout the sample (TOTAL), R^2 is always higher with $Ln(dist_{ij})$ (90.5%) than with $dist_{ij}$ or $dist_{ij}^2$ in levels (88.2%). The *Fibonacci* sequence (followed by *Quartile*) shows the best fits when the model is regressed for the last subsamples (largest distances) and generates the highest R^2 $(Ln(dist_{ij}))$ and R^2 $(dist_{ij}, dist_{ij}^2)$. Conversely, although the *Naïve* sequence performs well for the first two stretches, it fails for the last two.

Table 4.2. Characterization for three Alternative Segmentations.

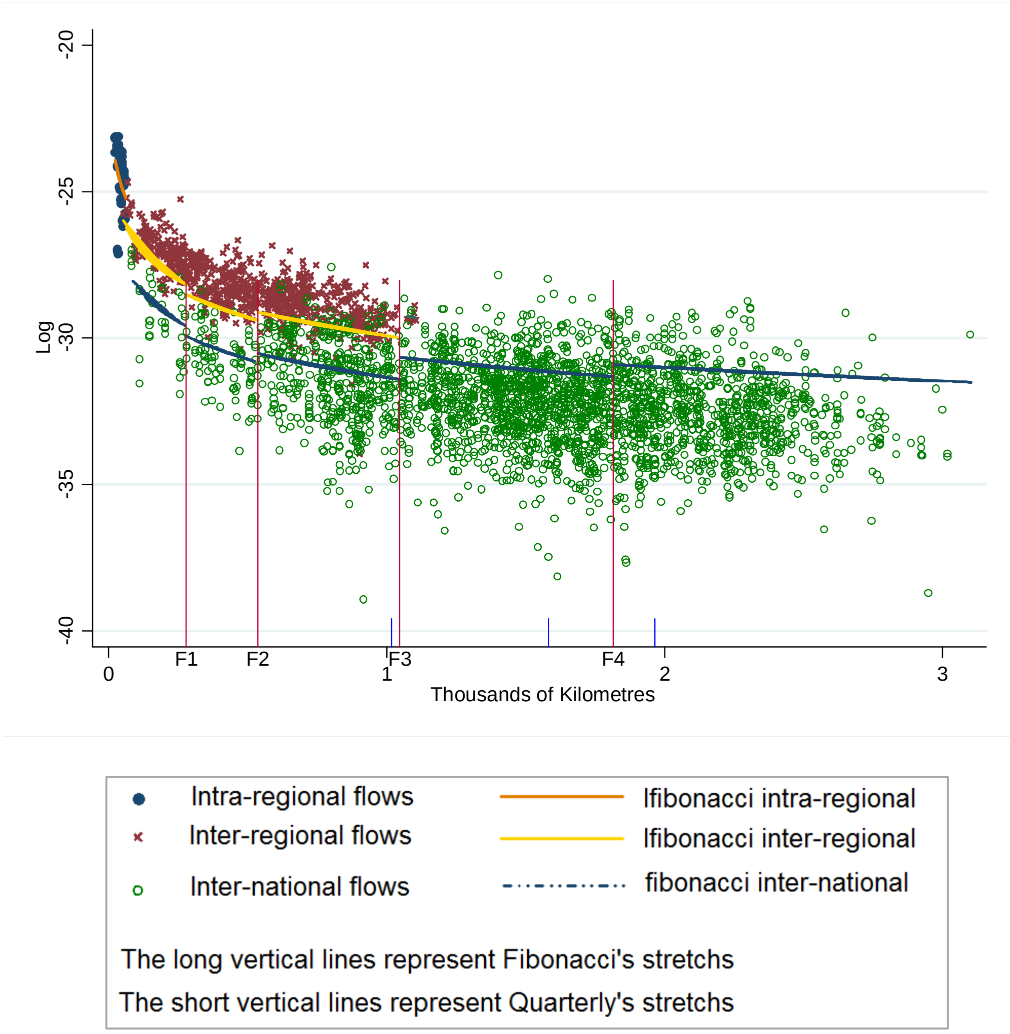
Naive	Km. (thousands)	0.0229 -	0.7946 -	1.5618 -	2.3318 - 3.1		TOTAL
	Range	25%	25%	25%	25%		100%
	obs. (%)	18%	31%	42%	9%		100%
	zeros (%)	1%	12%	24%	5%		44%
	R2 (Ln(dist$_{ij}$))	**90%**	**68%**	**16%**	**23%**		0.905
	R2 (dist$_{ij}$, dist$_{ij}^2$)	**88%**	**68%**	**18%**	**23%**		0.882
Fibonacci	Km. (thousands)	0.0229 -	0.2802 -	0.5366 -	1.0488 -	1.8193	TOTAL
	Range	8%	8%	17%	25%	42%	100%
	obs. (%)	5%	6%	15%	42%	33%	100%
	zeros (%)	0%	0%	2%	22%	18%	44%
	R2 (Ln(dist$_{ij}$))	**89%**	**75%**	**62%**	**34%**	**18%**	0.905
	R2 (dist$_{ij}$, dist$_{ij}^2$)	**90%**	**75%**	**62%**	**34%**	**18%**	0.882
Quartiles	Km. (thousands)	0.0229 -	1.0231 -	1.5825 -	1.9648 - 3.1		TOTAL
	Range	32%	18%	12%	37%		100%
	obs. (%)	25%	25%	25%	25%		100%
	zeros (%)	2%	12%	15%	14%		44%
	R2 (Ln(dist$_{ij}$))	**90%**	**48%**	**34%**	**0.24%**		0.905
	R2 (dist$_{ij}$, dist$_{ij}^2$)	**88%**	**47%**	**33%**	**0.24%**		0.882

Note: Fixed effects of origin-region by year (μ_{it}), destination-region by year (μ_{jt}), destination-country (μ^{u}) and year (μ_t) included. The endogenous variable is $T_{ijt\_}corr = T_{ijt}/GDP_{it}GDP_{jt}$.

[55] Note that the results in Table 4.2consider the sample subdivided according to the *Naïve*, *Fibonacci* and *Quartile* criteria and use the strategy for Eq. (4.1) and (4.2).

To complement the previous table, **Figure 4-3** shows the distribution of the dependent variable (in logs) in regards to distance. It uses three different colors for identifying the main categories of trade flows (intra-regional; inter-regional within Spain; inter-regional exports to the seven EU countries). It also includes full-vertical lines in red for identifying the five stretches of the Fibonacci sequence, and short-vertical-lines in blue for the Quartile. The plot shows a clear "jump" in the intensity of intra-national (red-crosses and blue-bullets) and inter-national (green hollow circles) flows. The non-linear relationship is also clear.

Figure 4-3: Trade flows by nature and distance stretches. Period:2004–2007.



4.5.1 Specifications for a country-specific analysis

We would now like to discuss the national border effect in greater detail, taking each country separately. As described in **section 4.4.2**, this analysis is based on Eq. (4.4). **Table 4.3** reports our results with three alternative specifications according to the three alternative segmented-distance variables proposed (*Naïve, Fibonacci*, and *Quarterly*) to treat the non-linearity in distance. The external border effect is now broken-down into each destination country. Observe though that here the interpretation of the external border effect keeps being the same as so far; e.g., how much less a Spanish region exports to a non-adjacent foreign region than to a non-adjacent Spanish region, ceteris paribus. Taking into account the non-significant results obtained for the contiguity variables in models M4–M6, henceforth we exclude these variables when the distance variable displays a more flexible role.

The results are ranked by increasing order of *Country_Border* coefficients in M8 (the ranking is pretty homogeneous for the two last specifications, *Fibonacci* and *Quartile* criteria). The lowest effects for border with M8 used as a benchmark are obtained for Portugal (3.9), and Germany (4.5), followed by UK (4.7), Netherlands (4.7), Italy (4.7) Belgium (4.7), and France (5.3). At this point, it can be useful to take as benchmark the findings obtained in regards to the country-border specification in the previous chapter. Nevertheless, firstly, we must recall two features that characterize those estimations. On the one hand, in the previous chapter we include the distance variable in the quadratic form, while here we offer three more flexible alternatives. On the other hand, in the previous chapter we did not include the intra-regional flows, while here we can estimate the internal border effect. Conversely, both estimates cover the same period (2004-2007). Thus, besides the consideration or not of the intraregional trade flows, we should stress that the main differences come from the way of modelling the non-linear distance effect. According to the rank of the results, it is remarkable that both results remain close, however, the values of the border effect under the square distance specification are always above: Portugal (5.2), and Germany (6.8), followed by UK (6.6), Netherlands (6.8), Belgium (6.8), Italy (7.6) and France (8.2).

Consider border as a measure of integration between Spanish regions and the regions of the seven European partners—with size and bilateral distance previously controlled for—; then it is notable to find that the highest levels of integration are not always with the regions of the nearest countries, but with further regions, like German regions. In fact, as it was highlighted in the preceding chapter, it is remarkable the high border effect obtained for France, which is the country with the most intense trade relation with Spain. Just as a reminder, this result was explained by the fact that, although actual trade is large, it is far from what the model would yield taking into account the huge trade potential of this country with regards to the Spanish regions (large GDP and high accessibility by road). This fact is reinforced by the circumstance that two important Spanish regions in terms of interregional exports to the rest of Spain (Cataluña and País Vasco) are indeed neighboring regions to France. Thus, since the model yields a much larger trade than the observed one, the border effect of France will be larger than the one for Portugal (with a high accessibility, but a lower GDP), or further destinations such as Germany or the Netherlands. Segmented distance performs similarly here, where in some cases the first segments show a lower negative elasticity than the next.

Table 4.3. External Border Effects by Country. PPML Procedure. Region-to-Region Spanish exports 2004–2007. M7–M9 are based on Eq. (4.4)

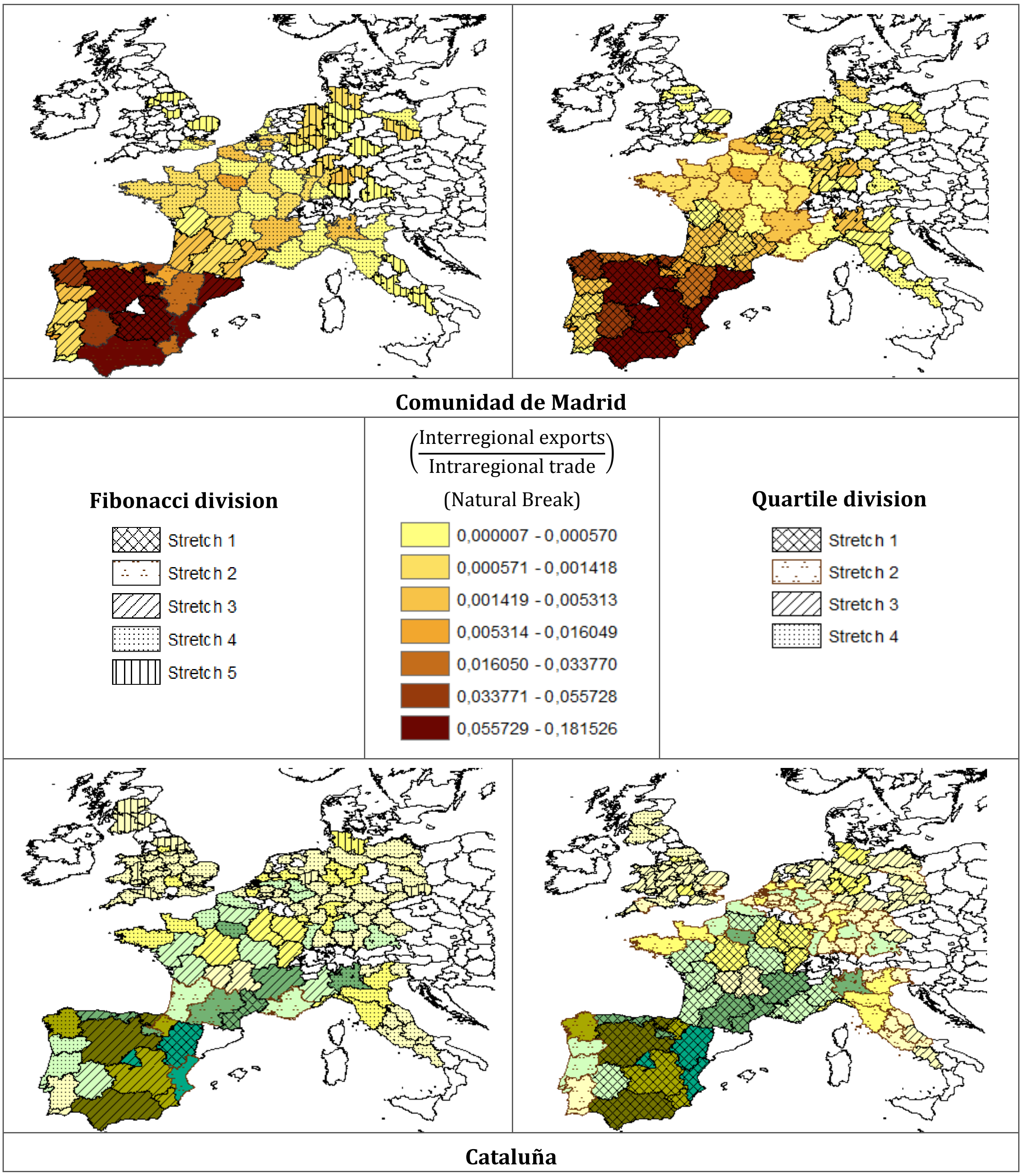
VARIABLES	M7 T_{ijt}_corr	M8 T_{ijt}_corr	M9 T_{ijt}_corr
Ln($dist_{ij}$ stretch1)	-1.317***	-1.112***	-1.303***
	(0.113)	(0.215)	(0.0979)
Ln($dist_{ij}$ stretch2)	-1.254***	-1.173***	-1.213***
	(0.102)	(0.188)	(0.0914)
Ln($dist_{ij}$ stretch3)	-1.203***	-1.152***	-1.179***
	(0.0980)	(0.170)	(0.0889)
Ln($dist_{ij}$ stretch4)	-1.161***	-1.065***	-1.143***
	(0.0955)	(0.159)	(0.0862)
Ln($dist_{ij}$ stretch5)		-1.019***	
		(0.153)	
Internal_Border	-0.944**	-1.171***	-0.959***
	(0.367)	(0.423)	(0.352)
Border_BE	-2.224***	-2.728***	-2.435***
	(0.430)	(0.483)	(0.416)
Border_DE	-2.170***	-2.686***	-2.392***
	(0.425)	(0.482)	(0.408)
Border_FR	-2.494***	-2.841***	-2.543***
	(0.401)	(0.452)	(0.390)
Border_IT	-2.259***	-2.744***	-2.471***
	(0.422)	(0.481)	(0.407)
Border_PT	-2.357***	-2.521***	-2.251***
	(0.395)	(0.447)	(0.389)
Border_NL	-2.213***	-2.739***	-2.444***
	(0.434)	(0.489)	(0.418)
Border_UK	-2.228***	-2.716***	-2.434***
	(0.423)	(0.482)	(0.408)
Constant	-19.75***	-20.51***	-19.80***
	(0.495)	(0.846)	(0.448)
Internal Border	3	3	3
Portugal	4.1	3.9	3.6
Germany	3.4	4.5	4.2
United Kingdom	3.6	4.7	4.4
Netherland	3.6	4.7	4.4

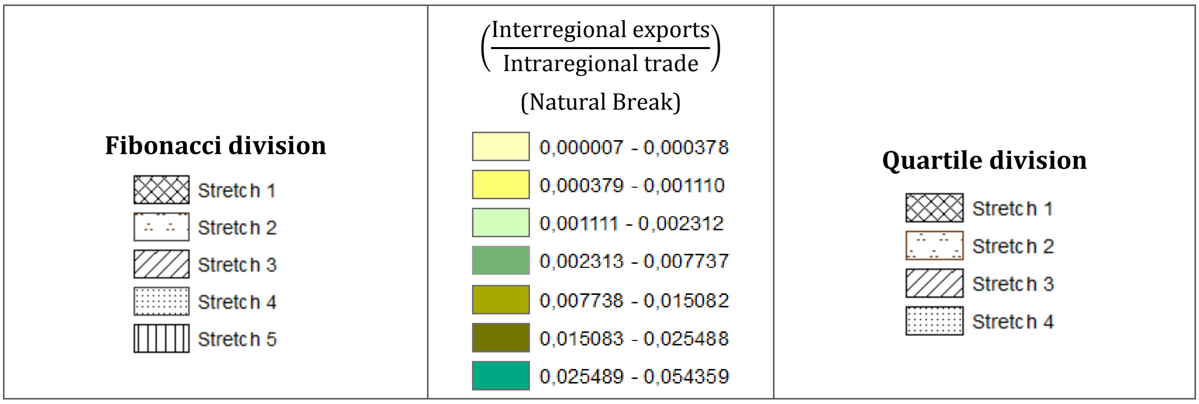
Italy	3.7	4.7	4.5
Belgium	3.6	4.7	4.4
France	4.7	5.3	4.9
Observations	6,316	6,316	6,302
R-squared	0.904	0.906	0.896

Note: Standard robust errors (origin and destination regional partners clustered) in parentheses with ***, ** and * respectively denoting significance at 1%, 5% and 10%. Fixed effects of origin-region by year (μ_{it}), destination-region by year (μ_{jt}) and year (μ_t) included. $T_{ijt}^{eu} / GDP_{it}GDP_{jt}$.

Getting further into this analysis, **Figure 4-4** plots the spatial concentration of exports delivered from two key Spanish regions, Cataluña and Madrid, divided by their corresponding intra-regional flows. In the four maps, the *palette* corresponds to the intensity of flows, with seven color intensities automatically determined by the ArcGis's "natural break" option. We use this representation so data can speak for themselves. The first two are for Madrid, the others for Cataluña. We then use different frames to identify the regions included in the corresponding *Fibonacci* and *Quartile* stretches. It is worth mentioning that the color intensity shows a clear discontinuity in the relevance of trade flows between Spanish and European markets, even for a highly open border region such as Cataluña. It is also interesting to note which regions are included in each stretch for the two cases considered here: in the case of Madrid, the first stretch of the *Fibonacci* division (completely exogenous to our dataset) perfectly matches the two contiguous regions (Castilla y León and Castilla–La Mancha), while the second stretch captures the rest of the Spanish regions with the sole exceptions of Cataluña and Galicia. By contrast, the first stretch of the *Quartile* division is now broader, including all the Spanish regions as well as the Portuguese and the nearest French ones. However, if we consider the regions classified in every stretch for Cataluña, we see that the stretches for national and international markets do not match exactly. We should thus emphasize that the composition of each stretch will naturally depend on the specific location of each Spanish exporting region.

Figure 4-4. Interregional exports (divided by the intra-regional trade) and main distance stretches. Madrid versus Cataluña. Average Flows for 2004–2007.





(*) The variable represented in these graphs represents the average across the whole period of the interregional export divided by the intraregional flows. $\sum_t \overline{T}_{ijt} / T_{ii,t}$

4.5.2 Robust checks with alternative procedures

Before we conclude, we analyze in this section the results obtained for a last set of specifications based on the last two alternative econometric methods described in section 4.4.2: namely, the spline and semi-parametric regressions. It is now worth considering that these flexible procedures play a competing role against the contiguity dummies, which also tend to control for discontinuities in the relationship between trade and distance. Taking our cue from their non-significant results in certain cases of the previous section, we therefore now exclude adjacency dummies.

Table 4.4 reports alternative results for *Internal_Border* and *External_Border* effects when they are computed by the methods described in Eqs. (4.3), (4.5) and (4.6). The first three models—M10, M11 and M12—correspond to the PPML estimates applied to the whole dataset (with zeros) once the sample has been controlled by the three sets of semi-dummies containing the segmented distance (*Naïve*, *Fibonacci* and *Quarterly*, respectively). The results vary slightly from those reported in **Table 4.1**, as the internal border effect remains significant but decreases to a factor of 3, while the external border effect reaches a factor of 4. The next models (M13, M14, and M15) correspond to three alternative procedures for estimating the spline regression. In M13 the knots of the spline regression are equally spaced over the range of the distance variable; in M14 they are placed at the quartiles of the distance variable, while in M15 the "natural spline" (i.e., where the spline regression creates variables containing a restricted cubic spline) is applied.

Table 4.4. Alternative Estimates for the *External* and *Internal Border Effect*.
M10–M12 are based on Eq. (4.3), M13–M15 on Eq. (4.5) and M16–M17 on Eq. (4.6).

	M10	M11	M12	M13	M14	M15	M16	M17
	Naïve	Fibonacci	Quartile	Naïve	Quartile	Cubic		
	PPML	PPML	PPML	SPLINE-OLS	SPLINE-OLS	SPLINE-OLS	SEMI-PAR	SEMI-PAR
VARIABLES	Tijt_corr			Ln(Tijt_corr)				
Ln($dist_{ij}$ stretch1)	-1.318***	-1.132***	-1.303***	-0.891	-1.287***	-1.36***		
	(0.110)	(0.210)	(0.0961)	(0.647)	(0.0591)	(0.0842)		
Ln($dist_{ij}$ stretch2)	-1.255***	-1.191***	-1.215***	-1.25***	-0.850***	0.467*		
	(0.0988)	(0.184)	(0.0895)	(0.135)	(0.203)	(0.252)		
Ln($dist_{ij}$ stretch3)	-1.204***	-1.166***	-1.181***	-1.233***	-1.509***	-3.966		
	(0.0954)	(0.166)	(0.0870)	(0.0912)	(0.379)	(3.008)		
Ln($dist_{ij}$ stretch4)	-1.162***	-1.080***	-1.145***	-1.089***	-1.315***	8.703		
	(0.0930)	(0.156)	(0.0844)	(0.190)	(0.454)	(16.84)		
Ln($dist_{ij}$ stretch5)		-1.033***						
		(0.150)						
Internal_Border	-0.943***	-1.143***	-0.960***	-0.997**	-0.692***	-0.576**	-1.45***	-1.66***
	(0.362)	(0.417)	(0.349)	(0.403)	(0.225)	(0.238)	(0.354)	-0.3367
External_Border	-2.361***	-2.606***	-2.380***	-1.797***	-1.508***	-1.396***	-2.27***	-2.29***
	(0.447)	(0.486)	(0.435)	(0.485)	(0.365)	(0.367)	(0.419)	-0.497
Constant	-19.75***	-20.43***	-19.80***	-21.14***	-19.66***	-19.37***		
	(0.485)	(0.828)	(0.443)	(2.501)	(0.306)	(0.393)		
Internal Border Effect	3	3	3	3	2	2	4	5
External Border Effect	4	4	4	2	2	2	2	2
Observations	6,376	6,376	6,364	3,688	3,688	3,688	3,688	3,688
R-squared	0.904	0.906	0.896	0.811	0.812	0.811	0.322	0.501
FE origin-region x time	YES	YES	YES	YES	YES	YES	NO	YES
FE destination-region x time	YES	YES	YES	YES	YES	YES	NO	YES

Note: Standard robust errors (origin and destination regional partners clustered) in parentheses with ***, ** and * respectively denoting significance at 1%, 5% and 10%. Fixed effects of destination-country (μ^{u}) and year (μ_t) included. Models M16 and M17 use the distance variable in levels (kilometers). $T_{ijt}^{eu}\_corr = T_{ijt}^{eu} \Big/ GDP_{it} GDP_{jt}$.

Although the spline models (M13–M15) resemble our previous approach (M10–M12), there are several differences worth mentioning: (i) the three spline models are based on the OLS estimator and are applied to our restricted sample with no zero flows; (ii) conversely, our previous approach used the PPML estimator and the complete sample. The consequences are twofold: First, the number of observations considered for the PPML-STRETCH approach is 6,376, whereas that for the SPLINE-OLS is 3,688; i.e., the segment length in each is therefore different under the quartile criterion. Second, the PPML gives more consideration to the largest-value observations: that is, the ones taking place within Spain. That said, the two approaches rely on similar assumptions and reach coherent results: in both cases the internal and external border effects are low and significant, with a factor that ranges from 3 to 2 for the internal border and from 4 to 2 for the external border. Moreover, negative elasticity for the distance variable also varies by stretch: in contrast to our findings when the semi-dummy variables were used for segmenting the distance (M10–M12), the negative elasticities for the first and subsequent stretches of distance in models M13–M15 do not show a clear decreasing pattern (in absolute terms); now, for example, the largest negative elasticity corresponds to the third segment in all cases; besides, in some of them the coefficient becomes non-significant or even positive (stretch 2, 3 and 4 in M15-Cubic spline).

The last two columns correspond to the results obtained with the semi-parametric regression. In M16 the model is estimated with country fixed effects and time fixed effects, while in M17 time-origin region and time-destination region fixed effects are also added. The idea here, as in Benedictis et al. (2008), is to test to what extent our results are affected by the inclusion of a large number of fixed effects. Note that elasticity for distance is excluded, since its effect is captured by the corresponding kernel distribution, and removed from both sides of the function as expressed in Eqs. (4.7) and (4.8). Now, when this highly flexible approach is applied, the internal border effect becomes significant and positive again with a factor around 4 and 5, while the external border effect decreases to a factor of 2.

Finally, to illustrate the performance of these three highly flexible approaches when dealing with the non-linear relationship between trade and distance, we report two informative plots. **Figure 4-5** shows the scatterplot of the dependent variable (in logs) with respect to distance (levels), along with the trade predicted with the cubic spline regression and the model using the *quadratic* term ($dist_{ij}^2$). Similarly, **Figure 4-6** shows the scatterplot of the dependent variable against the prediction based on the semi-parametric approach (M17).

Figure 4-5. Spline regression scatterplot. 2004–2007.

In this regression the zero values and contiguity dummies are not included

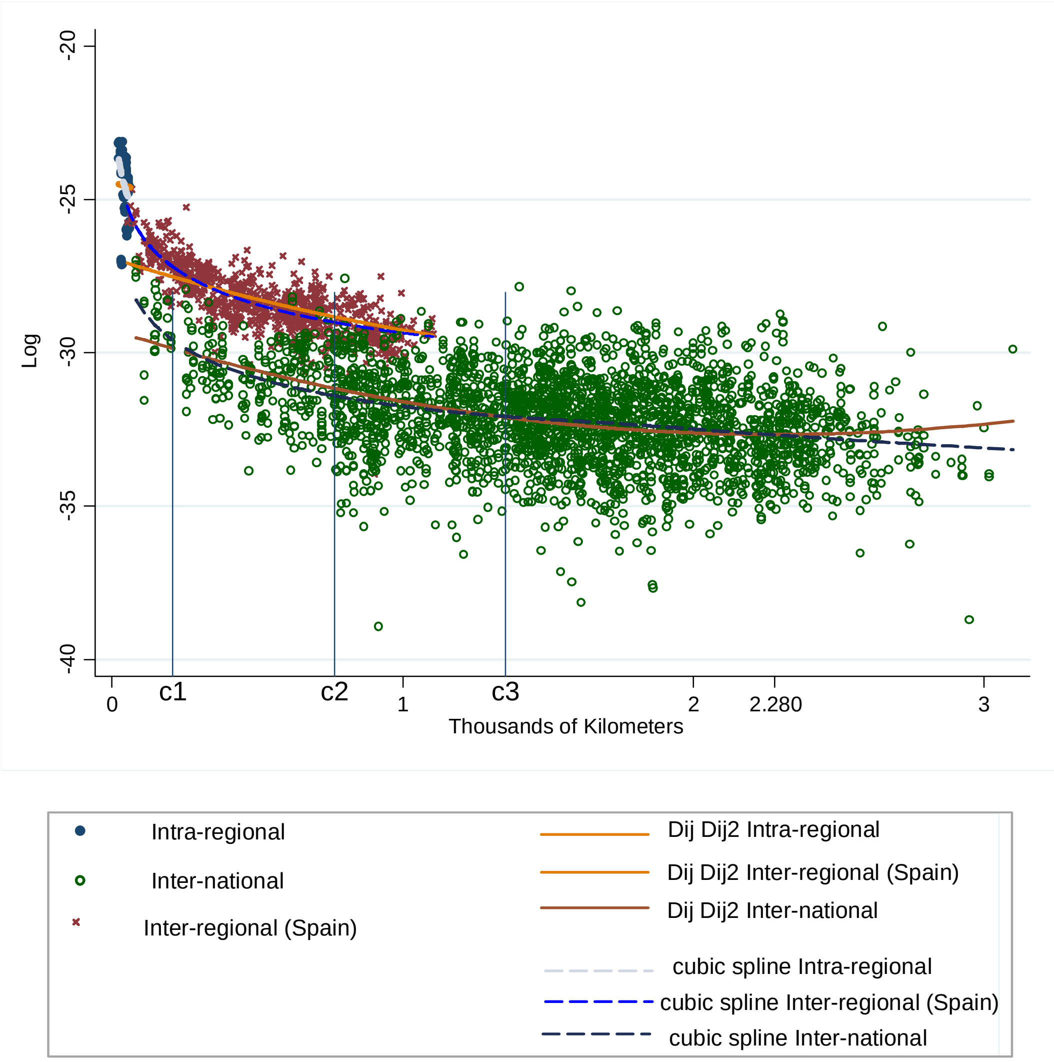
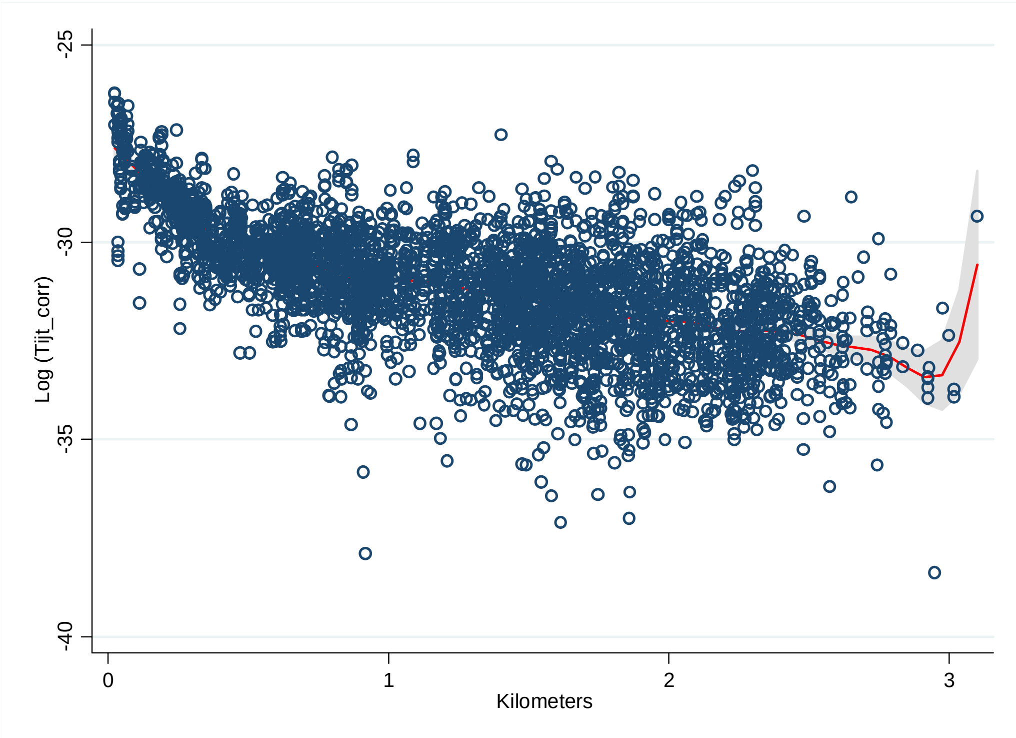


Figure 4-5 tries to shed some light on the alternative performance of the spline model versus the quadratic form and, more specifically, on the atypical high internal border effect obtained in M3 versus that under any other specification. The blue vertical lines indicate segments automatically set by the cubic spline (C1, C2, and C3). A vertical black line indicates the distance 2,280 km, which is the distance at which the quadratic term of the distance variable is reverted: the turning point where the parabola's slope becomes positive[56]. Several results are worth

[56] Although widely used for dealing with non-linear functions, the quadratic model suffers from a potential limitation: the reversal of the effect's direction. Normally, the quadratic model is used under the assumption that the turning point lies outside the sample (Gould, 1993). In order to compute the point at which the effect changes direction, we use the following expression: $(-\beta_5/2\beta_6)$, where β_5 and β_6 are, respectively, the coefficients for the distance and the square for distance in Eq. (4.2): 2,280km [–(–2.98523)/(2*0,654596)], corresponds to the estimate plotted in the graph, which was based on OLS and the sub-sample with non-zero flows (equivalent to the spline estimates plotted in the same graph). If

mentioning. First, although the scale of the graph does not show this clearly, the spline-model prediction is a better fit than the quadratic-model prediction for the largest flows over the shortest distance (intra- and inter-regional within Spain over the shortest distance). Second, the shape of the predictions based on spline and square-of-distance models for international flows (in green) is very similar. Moreover, if we consider that our sample consists of seven EU countries and relatively short distances (< 3,000 km), the number of flows going beyond the parabola's minimum (2,280 km) is not especially high for non-zero values. However, this could point to a stronger limitation in **Table 4.1**, where PPML and zero flows are included, since the turning point occurs at 1,873 km.

Figure 4-6. Semi-parametric regression scatterplot. 2004–2007.



At this point, it is worthwhile to sum up our results, which might have something to do with the nature of the two border effects considered here. On the one hand, the internal border, far from being explained by external barriers to trade (division or fragmentation), seems most closely related to the economics of agglomeration around metropolitan areas (Diaz-Lanchas et al., 2013), as well as to the spatial spillover of the strongest regions and their neighbors. It thus seems sensitive mostly to mismeasurement, spatial-unit definition (modifiable area unit problem, MAUP)

the analysis were repeated with a specification equivalent to that in model M3 (Table 4.1)—i.e., with the PPML and zero flows—then, the turning point would be 1,873 km [–(–2.012/ (2*0.537))= 1,873].

and aggregation bias. The external border, on the other hand, seems harder to budge (Wei, 1996). First, region-to-region international flows lead to lower external border effects than do region-to-country datasets. However, even when we include zero flows (which tend to increase the external border, since most zero flows correspond to international flows) and control for the non-linear distance-trade relationship, we obtain a positive and significant factor of 4. Finally, according to our results, we find no strong variations in border effects when using alternative treatments for non-linearity (log-log; quadratic terms; and more flexible approaches based on segmented distance, and non-parametric approaches) with the exception of M3 for internal border. Nevertheless, our results show larger variations in the elasticity of distance (by segment) and in the role played by (external and internal) contiguity than in the border effects.

4.5.3 Endogeneity

In this section we focus on the additional robust checks on endogeneity, which are based on the HT procedure. The results are reported in **Table 4.5**.

The first three models (M18–M20) are based on Eq. (4.1), and the next four (M21–M24) on Eq. (4.3), but both equations include the GDP product on the right-hand side. No zero values are included. M18 and M24 report the results for the POLS estimator, which assumes the inexistence of unobservable bilateral fixed effects. The latter uses a segmented distance variable, in keeping with the Fibonacci criterion, and excludes contiguity variables. Both estimates bring out the expected signs on the parameters, which are highly statistically significant, except for the external contiguity in M18. In M24, the negative effect of the distance variable decreases along the stretches and reveals a drop in the internal border effect, from 5 to 3. The external border effect, on the other hand, keeps constant around 4.

M19 assumes zero correlation between the unobservable dyadic heterogeneity and the regressors (REM approach). The results show some differences with the POLS estimates. The main significant changes occur in *the* internal border effect, which takes the value 4 (5 in POLS). The end of the M19 column reports results for the Hausman test, whose null hypothesis of non-correlation among regressors and unobservable bilateral effect is rejected.

M20 corresponds to a Hausman and Taylor's (1981) approach, which considers GDP products as endogenous regressors. In relation with the RE approach (M19), M20 shows the same External Border (4), but a significant smaller coefficient for the internal border estimate, which passes from 4 in M19 to 3 in the HT approach. Following Carrère (2006), we report at the end of the M20 column our results for the Hausman test between the HT estimates and the RE (GLS) estimates. The rejection of the null hypothesis suggests that the HT approach improves the estimate: in other words, the instrumented variable is actually, in some degree, an endogenous component in the regression.

Table 4.5. Border Effect Estimates by the Hausman-Taylor (1981) Procedure. Region-to-Region Spanish Exports 2004–2007. M18–M20 are based on Eq. (4.1) and M21–M24 on Eq. (4.3).

	M18	M19	M20	M21	M22	M23	M24
	POLS	REM (GLS)	HT(†)	HT	HT	HT	POLS
VARIABLES				Naïve	Fibonacci	Quarterly	Fibonacci
Ln(GDPi x GDPj)	0.646***	0.622***	0.637***	0.635***	0.635***	0.633***	0.641***
	(0.0372)	(0.0303)	(0.0415)	(0.0414)	(0.0414)	(0.0416)	(0.0375)
Ln($dist_{ij}$)	-0.981***	-1.034***	-1.088***				
	(0.0955)	(0.0955)	(0.145)				
Ln($dist_{ij}$ stretch1)				-1.224***	-1.504***	-1.196***	-1.312***
				(0.151)	(0.304)	(0.167)	(0.148)
Ln($dist_{ij}$ stretch2)				-1.198***	-1.482***	-1.188***	-1.267***
				(0.135)	(0.266)	(0.148)	(0.135)
Ln($dist_{ij}$ stretch3)				-1.221***	-1.443***	-1.186***	-1.244***
				(0.130)	(0.240)	(0.142)	(0.127)
Ln($dist_{ij}$ stretch4)				-1.237***	-1.391***	-1.209***	-1.195***
				(0.128)	(0.224)	(0.138)	(0.120)
Ln($dist_{ij}$ stretch5)					-1.404***		-1.199***
					(0.215)		(0.117)
Internal Border	-1.513***	-1.377***	-1.239**	-0.847*	-0.391	-0.897*	-1.020***
	(0.307)	(0.332)	(0.536)	(0.497)	(0.589)	(0.515)	(0.345)
External Border	-2.902***	-2.865***	-2.722***	-2.419***	-2.046***	-2.470***	-2.478***
	(0.421)	(0.538)	(0.756)	(0.738)	(0.792)	(0.753)	(0.439)
Internal Contig	0.438***	0.400**	0.365				
	(0.116)	(0.161)	(0.262)				
External Contig	0.319	0.298	0.237				
	(0.216)	(0.267)	(0.448)				
Constant	-3.623**	-2.298	-2.780	-2.197	-1.125	-2.194	-2.142
	(1.781)	(1.501)	(2.070)	(2.089)	(2.328)	(2.077)	(1.851)
Internal Border Effect	5	4	3	2	1	2	3
External Border Effect	4	4	4	5	5	5	4
Hausman test(i)		822.39***					
Hausman test between HT and RE estimates(ii)			658.4***				
Observations	3,688	3,688	3,688	3,688	3,688	3,676	3,688
R-squared(iii)	0.777	0.770	0.742	0.742	0.743	0.742	0.779

Note: Standard robust errors in parentheses with ***, ** and * respectively denoting significance at 1%, 5% and 10%. Fixed effects of origin-region by year (μ_{it}), destination-region by year (μ_{jt}), destination-country (μ^{u}) and year (μ_{t}) included. The dependent variable is the log-transformation of regional trade flows ($Ln(T_{ijt})$). In Hausman and Taylor estimates the dyadic exogenous variable valid to be an instrument is distance, while the likely endogenous variable is the product of GDP's.

(i) Hausman test between the FE and RE estimations.
(ii) Hausman test between HT and RE(GLS) estimates.
(iii) In the calculation of R^2 for Hausman & Taylor estimation, we follow to Carrere (2006) which corresponds to 1-[Sum of Square Residuals]/[Total Sum of Square].

Models M21, M22 and M23 record the results of the HT approach when the distance variable is segmented under different criteria (Naïve, Fibonacci and Quarterly, respectively). For our benchmarks, we take estimation M20 for the three models M21, M22 and M23 and the last column M24 (POLS, with the distance variable split in accordance with Fibonacci criterion) for the second, M22. Out of the three models, only that under the Fibonacci criterion displays a "monotonous" decrease of the negative effect of distance along the stretches. In comparison with M20, the M22 (Fibonacci) estimates show the greatest reduction in the internal border estimation: from 3 in M20 to a statistically non-significant 1. Regarding the external border estimates, the three segmented specifications (Naïve, Fibonacci and Quarterly) increase smoothly from a value of 4 in M20 to 5.

Comparing M22 with the POLS estimation where the distance variable is also divided (M24), we find that, once the endogeneity problem is tackled, the new border estimations yield a bit more dispersed values: the internal border in M22 turns non-significant, while for the POLS estimator it gets a significant factor of 3; instead, the external border effect leads to a somewhat higher estimate in M22 (5) against the POLS (M24) factor (4).

In general, the results reveal a big variability in the internal border parameter (from 3 to 5 under POLS approaches, and from 1 to 4 under HT approaches). Meanwhile, the other parameters lie on a narrow range along the different specifications. More research, beyond the scope of this study, is no doubt needed in this field, but our testing of a vast range of specifications can serve as a benchmark.

4.6 Conclusions

In this chapter we aim to shed new light on the *non-linear relationship between trade and distance* and its effect on the regional and national border effects of a country. With this purpose in mind, we have made use of a novel dataset for inter-regional trade flows by Spanish trucking, including intra-national and inter-national flows between Spanish regions (NUTS 2) and the regions of Spain's seven main European partners, and considering the actual distance of shipments.

In line with previous papers, we have considered three classic ways for dealing with non-linearity (log-log OLS; log-PPML; quadratic terms and PPML). In addition, we have developed a new strategy to deal with this *non-linearity*. Namely, we segment the sample, considering alternative stretches of the distance variable. Moreover, we have applied two additional estimation methods (piecewise regression and semi-parametric approaches) to estimate the desired parameters while managing the non-linearity in the most flexible way. The results obtained with these alternative strategies are quite robust: the internal border effect stays around 4, reaching lower significant values (2) for some specifications. The effect of the national border reaches a significant factor that oscillates between 3 and 5. We consider that these novel results support the call of Henderson and Millimet (2008) for further research on the appropriate gravity equation functional form, using parametric and non-parametric procedures. We have contributed here by using inter-national and inter-regional flows simultaneously.

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SECTION III: THE EFFECT OF TRADE OPENNESS ON THE DOMESTIC LOCATION OF THE ECONOMIC ACTIVITIES

5 Trade Openness, Transport Networks and the Spatial Location of Economic Activity

5.1 Introduction

Currently, economic geography literature on the effects of trade openness on the location of economic activity is regaining interest for both scholars and policy makers, due to recent changes in political boundaries (particularly in Eastern Europe), and the attempt of some Western European regions to claim independence, which may leave them out of the EU: Flanders in Belgium, Scotland in the United Kingdom or the Basque Country and Catalonia in Spain. The topic is also making the headlines as more countries are getting involved progressively in new or existing free trade agreements or common commercial areas, with implications not just for new members, but also for the incumbents. One example is the 2004 EU enlargement, which integrated ten Central and Eastern European Countries (CEECs) into the EU's internal market, and has shifted Europe's economic center of gravity eastwards (Brülhart et al., 2004). Moreover, globalization processes are reinforcing the reduction in trade frictions related to economic and commercial barriers such as declining transport costs (result of the technological progress and improvements in transport networks), and the previously mentioned non-transport related impediments such as tariffs, quotas, etc. All these changes on international market accessibility of countries are generating prominent changes not only between countries, but also, and most importantly within countries; i.e., in the internal structure of the spatial location of economic activities in the countries involved in trade openness.

A liberalization process in the form of trade openness implies different gains depending on the territorial scale of analysis: *between* countries, resulting in the reallocation of economic activity at the international level, and *within* countries resulting in a complementary and simultaneous reconfiguration at the regional level. Focusing on the analytical framework based on Helpman and Krugman (1987) and Krugman (1991), characterized by Dixit-Stiglitz preferences, iceberg transportation costs, and increasing returns, along with computer simulations, two complementary sets of models have addressed these two issues. On one hand, between countries effects using a multi-country analytical framework have been addressed with the so-called New Trade Theory (NTT) models, which study the reallocation of economic activity as a consequence of changes in trade frictions, particularly non-transport related costs, and considering explicitly a spatial network configuration but without allowing for an internal dimension; e.g., Behrens et al. (2007a), Behrens et al. (2009) and Barbero et al. (2015). On the other, within countries effects and the internal redistribution of economic activity are the research matter of New Economic Geography (NEG). Allowing also for a multi-country configuration, this literature studies how transport related costs determine the distribution of economic activity at the regional level, but is not suited to study the effects of trade liberalization as the international dimension is not considered; for a set of results for different transport network configurations of the core-periphery model see Ago et al. (2006), Castro et al. (2012), Akamatsu et al. (2012), and Barbero and Zofío (2015).

Both NTT and NEG models share a common structure. Indeed, on the preferences side they rely on an upper tier Cobb-Douglas (CD) utility function with homogenous and differentiated products, with the latter corresponding to a Constant Elasticity of Substitution (CES) specification, which yields a suitable price index. Also, from a technological perspective, firms are characterized by increasing returns, and the market equilibrium is solved within a monopolistic competition market structure. Based on these assumptions, these models set the theoretical grounds so as to explain why economic activity may end up agglomerating in some countries (NTT) or regions (NEG), even if departing from a situation where all are initially identical from the consumers and producers perspective. The final result regarding the agglomeration or dispersion of economic activity depends on the net effect of counterbalancing centripetal and centrifugal forces. In these models agglomeration forces are driven by: i) the price index effect by which areas with large manufacturing sectors enjoy lower prices; ii) the so called home market effect (Krugman, 1980) by which locations with larger markets have more than proportionally larger manufacturing sector, paying larger nominal salaries; and iii) the existence of economies of scale in production that result in lower average costs at the single plant level. Dispersing forces are led by transport costs because the larger they are, the more difficult it is to supply other markets while competing with local firms, complemented with an immobile share of workers in one of the sectors, normally the one producing a homogenous product, ensuring that a sizable amount of final demand expenditure is territorially fixed[57]. Both centripetal forces incentive producers to locate as close to market demand as possible.

While the theoretical frameworks share a common structure resulting in equivalent centripetal and centrifugal forces, the main difference between NTT and NEG models is the assumption about inputs mobility, particularly the labor force; i.e., the relevant difference when solving for the equilibrium is whether workers are immobile. While in NTT models it is firms mobility (so as to meet the zero profit condition) and the exports/imports trade balance what clear the market, and the spatial equilibrium can be characterized in terms of equal relative market potentials (RM), in NEG models the equilibrium is defined under the same conditions but it is workers mobility what

[57] The homogenous good sector, characterized by constant returns to scale, is normally associated with agriculture as in Krugman (1991), Krugman (1993a), and Krugman (1993b).

clears the market so as to equalize real wages across locations (i.e., the instantaneous equilibrium). Therefore, market equilibrium through RMP equalization in NTT and real wage equalization in NEG summarize the main difference between both types of models.

Even if most of the literature with multiple countries and multiple regions models between and within country effects independently, without considering the complementary and simultaneous effects that trade openness has at both levels, a few contributions have considered jointly both the international and national dimensions; e.g., Krugman and Livas-Elizondo (1996), Alonso-Villar (1999), Behrens et al (2007b). These authors allow for a limited number of countries, which consist of several regions. The key feature of these contributions with respect to the spatial equilibrium is that labor is mobile within countries but not between countries, thereby combining the assumptions of both models about labor mobility. The main idea put forward in these theoretical contributions based on the NTT/NEG structure is that the removal of national barriers increases the pressure of competition in domestic economies. But at the same time, it is well known that, in a context of imperfect competition and scale economies, trade openness yields global gains from international trade specialization, giving firms the opportunity of serving larger markets. As already introduced, and from a policy perspective, one of the main concerns of trade openness is its spatial implications in terms of regional inequalities. In fact, it is easy to realize that when an economy behaves as an autarky (respect to trade but also input factors mobility, particularly workers that are not allow to migrate internationally), and therefore only serves own domestic market, production and population will tend to agglomerate in the better connected location to supply the whole domestic market, as border regions do not offer a locational advantage in terms of international trade. However, once this economy starts a trade openness process, these once dead end locations start becoming attractive to firms as there is a tradeoff between supplying domestic and foreign markets. If this economy starts to address international markets, producers seek to locate closer to the border, in order to reduce transport costs and be more competitive, and consequently they will leave inner locations, which may result in lower regional inequalities.

In this study we formulate a proposal based on this NEG/NTT structure that allows for the agglomeration and dispersion forces, but considering a more complex model that those already proposed in the literature by allowing for two sectors, both producing and demanding differentiated goods and subject to sector specific transports costs, and allowing for complex trade network topologies corresponding to a homogenous space (where no country or region has a locational advantage) or a heterogeneous space (related to hub-spoke structures). This model allows us to study the implications that trade openness has on the spatial configuration of the economic activity within countries trading with each other. By doing this we follow three key contributions: Fujita et al. (1999, chapter 7), who consider a single country closed economy with two symmetric regions producing two differentiated sectors (each with a different degree of elasticity of substitution) and different transport costs; Krugman and Livas-Elizondo (1996), who develop an international model with two countries to evaluate the process of international trade openness where the domestic economy is modeled by a homogeneous space; and Alonso-Villar (1999) who introduces a heterogeneous space.

The structure of the paper is organized as follows. Section 2 reviews briefly the literature on this field. Section 3 introduces the model assumptions, the general notation for any network topology representing the world economy, and the spatial conditions characterizing the so-called instantaneous equilibrium. Section 4 presents some simulations that illustrate the analytical potential of our analysis when establishing the effects of trade openness on the location of economic activity within countries and depending on two opposed network topologies in terms of their centrality. And Section 5 concludes.

5.2 Related literature

As it was pointed out in the motivation, the spatial situation and distribution of economic activity within a country, and the access to the rest of the world play an important role in its international relationships. Geography matters, because countries are not dimensionless entities in space as in many New Trade Theory and New Economic Geography models with two countries or two regions. Simply following the gravity equation, both the bilateral and multilateral distances within and between countries matter and determine trade flows, as well as the existence of non-transport related trade barriers depending on whether a common trade area exists or not.

This section examines the main empirical and theoretical contributions that study the effects of international trade openness on the internal economic geography in a country. From abroad perspective, these contributions study this issue from three complementary dimensions: i) the sectoral dimension, which was the first focus of interest, it is more linked with the old theory of trade motivated for the gain of comparative advantage and the distribution of resources to reap the benefits of international specialization; ii) the firm dimension, which has been a more recent application, it is linked with the NTT where the intra-industry trade and heterogeneous firms have changed the configuration of countries; and finally, iii) the space dimension, which represents a relevant issue for policy making in terms of transport infrastructure because unveils regional inequalities implication of the liberalization process.

Related to the spatial dimension that drives the present study, Brülhart (2011) describes two main concerns about trade liberalization, which literally are: "that trade liberalization increases within-country spatial inequalities, and that it favours regions with better access to international trade routes". In the literature, there are two the main approaches that evaluate the spatial implications of removing international barriers within a country: the urban system approach, based on scale economies that are exogenous at regional level and on perfectly competitive markets, and the NTT/NEG approach, which considers endogenously scale economies at the firm level and monopolistically competitive markets. Additionally, another distinction between the models of both approaches is related to the ex-ante assumption of locations of the regions in a country. Some models consider regions as geographical featureless units, i.e. regions are identically geo-referenced with respect of the foreign economy (homogeneous space) (Henderson, 1982), while others consider that some regions enjoy from a locational advantage in the international relationship (heterogeneous space) (Rauch, 1991). This study addresses the two previous concerns as hypotheses to be posited through a theoretical perspective, adopting the NTT and NEG analytical framework and explicitly modelling the trade topology (geography, allowing for both homogenous and heterogeneous configurations) by way of network theory.

5.2.1 Empirical references

From an empirical perspective, and under the inspiration of Mexico's integration with United States and Canada in the North American Free Trade Agreement (NAFTA), several authors have studied the within-country spatial implications of this trade liberalization agreement under the prism of the NTT and NEG literature. Here we are interested in those contributions whose results can be interpreted in terms of the greater or lower regional (in)equality; i.e., whether economic activity has spread across the domestic regions, included the lagging locations (a spatial convergence effect), representing a more balanced situation than that existing previous to trade openness. Hanson (1992, 1997, 1998) examines the effect of trade reform on regional employment in Mexico. He focuses on three key factors driving the regional distribution of firms and, consequently, employment: transport costs, which pull firms to locate close to large foreign markets; backward and forward linkages, which encourage sellers to locate close to buyers, and vice versa; and agglomeration economies, which reinforce the initial industrial pattern configuration. The pieces of the NTT and NEG workhorse model are there, but without considering the full-fledge general equilibrium framework that they offer. He found a significant effect of the trade reform, changing the previous agglomeration from Mexico DF manufacturing belt toward the formation of new industrial clusters near the United States.

Other authors have studied the consequences of European integration, where the existing research does not provide a clear answer. In general, it seems that EU integration has promoted the convergence among countries, while regional inequality growth is country specific. Egger et al (2005) found that for the Central and Eastern European countries, export openness brought an increase of regional inequalities in terms of real wages. Puga (2002) claims that "despite large regional policy expenditure, regional inequalities in Europe have not narrowed substantially over the last two decades, and by some measures have even widened". On the other hand, there are also evidences suggesting that trade integration promote regional convergence, such Redding and Sturm (2008). They studied the effect of German division (during 1945-1990) and later reunification, concluding that the iron curtain (representing both an ideological and socioeconomic conflict and a physical boundary) had a strong negative impact on border regions, so that disintegration leads to a core-periphery pattern. By contrast, with the reunification, they found signs of economic recovering in border regions. Therefore we can observe different results in term of regional inequalities depending on where a specific country is located in Europe, but also within of countries it seems that border regions are favored by trade liberalization. The European Union integration process implies a more complex mechanism than the more limited NAFTA trade agreement; as the former involved many countries, free trade of commodities, but also labor as a mobile input factor, which must be considered in theoretical models trying to explain reality; i.e., those jointly considering NTT and NEG assumptions.

Hu and Fujita (2001) examined the trends of regional inequality in China, in terms of income distribution and production agglomeration during the period 1985-1994. They choose this period because it captures the effects of globalization and economic liberalization in the Chinese economy. They found that income disparity between inner and coastal regions increased, with industrial production agglomerating in the coastal area. So while the disparities increased at a country level, the convergence of coastal provinces increased. These results concur with those of Kanbur and Zhang (2005), where trade openness favored the already-richer regions in the coast.

In sum, the empirical results reveal that trade liberalisation entails a bias in the location of production toward those regions with better access to international trade markets (bordering regions, region with ports, hub regions with good international connectivity, etc.). From a spatial (in)equality perspective, if the bordering regions were already richer than inner regions, then trade opening processes would reinforce the spatial reallocation of economic activity toward these regions; on the contrary, if the nearest regions to the rest of the world were less developed, trade openness process contributes to a reduction in spatial inequality. This shows that a caveat is necessary here, as divergence or convergence processes, understood as lower or higher regional inequalities, respectively, depend on the initial configuration of the economy. For instance, if departing from an autarky scenario economic activity is initially agglomerated in an internal region, like in the case of Mexico DF, a liberalization process weakens the agglomeration forces and pushes part of the economic activity toward bordering regions, so the initial openness triggers a convergence mechanism. In Mexico, where most of the activity was concentrated on Mexico DF, the trade liberalisation agreement resulted in a prominent part of the production being relocated to the northern border, thereby reducing regional inequalities. As a consequence we can conclude that a precise representation of the trade network between countries and across regions within countries in theoretical models is a necessary condition to appropriately study a particular reality or case, as it conditions agglomeration and dispersion forces, and their interaction shaping spatial equilibria.

5.2.2 Theoretical references

Driven by these empirical evidences, Krugman and Livas-Elizondo (1996), Alonso-Villar (1999), Brülhart et al. (2004) and Hanson (2001), propose a series of models based on the NTT and NEG analytical framework that allow the study of dispersion processes as a consequence of trade openness, and by which peripheral locations draw economic activity as a result of the change in the economic conditions that favored the pre-openness agglomerated equilibrium. By contrast, other researchers have found that these results are subject to subtle modelling choices which may qualify the previous results (Brülhart et al., 2004; Brülhart, 2011), including the actual trade network topology (i.e., the geographical features of each specific country and its place in it). Consequently, in this review we focus our attention in the specific assumptions adopted by these authors and their workings within the model. Particularly, we consider the main assumptions and conclusions from the NTT and NEG approach under three likely scenarios: i) a closed economy; ii) an open economy with two countries composed of several regions and where space is neutral so no region has locational advantage (i.e., homogeneous space), and iii) the same open economy but including locational advantages for some regions with respect to the international trade or in the domestic market (i.e., heterogeneous space).

In the literature, the first theoretical contribution addressing the effects of trade openness in the location of economic activity between and within countries is Krugman and Livas-Elizondo (1996), who consider an economy composed by a domestic economy and a foreign one ("the rest of the world"), whereas international transport and non-transport related costs (tariffs) become progressively lower between countries while domestic transport costs keeps constant or is costless. Their model explains the existence of large cities in some developing countries as a consequence of the strong forward and backward linkages that appear in a context of a relatively small closed economy with a strong manufacturing sector. They assume a homogenous space where locations are identically distributed; i.e., none of them enjoy a location advantage with respect to the "rest of the world". In their research these authors study how the agglomeration equilibrium breaks up once a country starts a trade liberalization process. They argue that in nearly closed developing countries, characterized by significant economies of scale and high trade barriers, where manufacturing production is basically addressed to domestic demand, the agglomeration forces prevail over the disadvantages of overcrowded locations (congestions costs which they model through the typical land-rent approach). Instead, as the degree of openness of the country increases, "centripetal forces" weakens against "centrifugal forces", and the production tends to become evenly spread across domestic regions, even when none of them initially agglomerates the entire mobile sector[58]. An alternative model to Krugman and Livas-Elizondo (1996) is by Behrens et al. (2007a). These authors adopt a model based on the monopolistic competition framework of Ottaviano et al. (2002), where, instead of including congestion costs, they consider two dispersion forces *à la* NEG (Krugman, 1991): on the one hand, part of the labor force is immobile -farmers; and on the other, local agglomeration increases competition resulting in a reduction of revenues. They reach the same conclusions: In so far an economy removes its barriers to international trade, agglomeration forces weaken while dispersion ones begin to play a more important role.

Alonso-Villar (1999) enhances Krugman and Livas-Elizondo's (1996) model, by introducing the more realistic assumption about the existence of a heterogeneous location of regions with respect to the rest of the world and among themselves. Thus, in international terms, some regions enjoy better access to foreign markets than others, since they are located closer to the national border. More specifically, she considers a world economy composed by three countries along a line (a star topology), where the country in the middle has three regions (yet another star configuration with two external and one interior location), while the other two countries consist of one single region (1+3+1). All regions are equidistant of their neighbors. In a situation of no international trade barriers (full economic integration), where only transport costs (proxied by distance) matter as impediment to trade (there are no trade barriers), she finds that if one foreign countries is large enough (acting as global attracting force), the agglomeration in the internal region of the central

[58] Building on Krugman and Livas-Elizondo (1996), Fujita et al. (1999, chap. 18) explore the sectoral dimension. They introduce an additional agglomeration force, by including input-output linkages between production sectors, therefore becoming more profitable being closer to other suppliers or client firms. They conclude that with trade openness appears a tendency toward the agglomeration among some sectors (clustering).

country would never be a stable equilibrium. Instead, the activity of the country would tend to agglomerate in the border region with better access to the foreign rich region. However, the final solution is more involved, since under this model both agglomeration forces and dispersion forces might be weakened. From the side of agglomeration forces, domestic producers can find more attractive to locate their firms close to foreign demand; however, on the other side, if foreign competitors exert a strong competition, domestic producers might look for less exposed locations while serving their own domestic market, where they have a privileged position. Therefore, the final equilibrium is not cut clear and once again depends on various initial features, as where is economic activity concentrated prior to trade liberalization (i.e., its distribution resulting from historical reasons), the relative size of the foreign demand, and the productive efficiency of foreign competitors (e.g., technological features).

Another interesting version of a NEG model in evaluating the effect of the trade openness of an economy is Brülhart et al. (2004). In this case, their model is inspired on the 2004 EU enlargement, under which ten Central and Eastern European Countries (CEECs) were integrated into the EU's internal market. They study how changes in market access with the new members affect the peripheral regions of the pre-enlargement incumbents (i.e., new border regions). In doing this, they formulate a model of two countries (domestic and foreign countries) and three regions. Two of the regions belong to the domestic country while the other just contains one. The agglomeration forces are the usual backward and forward linkages. The dispersion force arises from the fact that one of the sectors (agriculture) only uses the immobile factor (farmers), while the other (manufacturing) employs also a factor (human capital) that is mobile. The results of their model remain relatively close to those found by Alonso-Villar (1999) in so far as, for most of the parameters, when the domestic economy is increasingly opened, the mobile industry tends to locate closer to the foreign region. However, this does not happen always. If, for instance, the internal region of the domestic country exhibits a sufficiently high industry concentration, then, this agglomeration can result in a stable equilibrium. This model presents two advantages in comparison to Alonso-Villar's (1999) approach: On one side, it allows the evaluation of the progressive effect of trade liberalization (in spatial networks characterized either by a homogeneous or a heterogeneous topology); on the other, it can be resolved analytically.

5.3 Model

The model that we introduce to address the issue of trade openness and the location of economic activity enhances these proposals in three distinctive ways, so as to gain more insight of the agglomerating and dispersing forces driving the spatial equilibria. Firstly, following Krugman and Livas-Elizondo (1996) we intend to capture the effect of trade openness on the internal distribution of production and population adopting a suitable NTT/NEG analytical framework, while considering a more general and realistic assumptions. Secondly, following Alonso-Villar (1999) we formulate our model for a multi-country multi-regional setting that allows us to study the role of the spatial topology on the spatial distribution of economic activity. We propose a flexible setting based on a bilateral distance matrix that allows us to consider any type of network topology, including the homogenous space where no region has a locational advantage, or a heterogeneous space with locations enjoying better accessibility both within countries (e.g, central regions) or between countries (e.g., border regions). Thirdly, as the model does not have closed form solutions, we solve the model computationally to perform suitable simulations that allow us to address the research hypotheses for specific topologies of interest, and test under what condition would trade liberalization increase or reduce within-country spatial inequalities (section 4).

Therefore, we combine and extend the existing literature. Adapting the NTT/NEG analytical framework we consider the usual centripetal forces, associated to the forward and backward linkages and centrifugal forces associated to transports costs and some fixed demand associated to an immobile factor. Therefore, in contrast to Krugman and Livas-Elizondo (1996) we do not consider congestion costs (commuting costs, land rent costs, etc.) as the centrifugal force of the model, but rely on the immobile demand associated to labor employed in one of the production sectors. Adopting congestion costs as a dispersion force, though valid in a context of urban and city analyses, we believe that it does not conform to the regional prism. Inspired in Fujita et al. (1999, chapter 7), our multi-country, multi-regional model includes two differentiated sectors, one produced under constant returns to scale and the other under increasing returns to scale. The degree of substitutability perceived by consumers (as more or less homogeneous goods) is sector-specific, while the nature of the different commodities characterize their transportability, thus transport costs are also sector-specific[59].

5.3.1 A general New Economic Geography analytical framework

We assume a world economy with a number of regions situated in different countries that are denoted by way of a double subscript R_{ik}, with the first one referring to the specific region $i = 1,...,j,...,n$, and the second one to the particular country they belong to $k = 1,...,l,...,m$. Within countries we consider a NEG framework with two differentiated sectors, $s = 1,2$, with preferences

[59] Davis (1998) proved that the home market effect depends on the relative size of transport costs in the differentiated and homogeneous goods, insofar when both industries incur the same level of transport costs the home market effect disappears.

characterized *à la* Dixitz and Stiglitz (1977). Production is subject to increasing returns to scale within a monopolistic competition market structure in the first sector and constant returns to scale in a perfectly competitive setting in the second. Trade takes place over a transportation network connecting all regions and countries. Trade costs between regions are of the iceberg form and include both distance related cost over the transport network, and *ad valorem* tariffs when trade takes place between regions of different countries —to study the effect of trade liberalization. Each region i of a given country k is endowed with an exogenously given mass of $L_{ik} = L_{1ik} + L_{2ik}$ workers-consumers, each supplying one unit of labor— thereby coinciding country population and country labor. In each country labor is fixed and normalized to one for each sector, $\sum_i L_{sik} = 1$. Labor in the first sector is mobile within countries, i.e., workers can migrate across regions, but immobile across countries due to immigration restrictions. It is also assumed that labor is immobile in the second sector as it is based on local resource endowments (e.g., agriculture). Labor is the only production factor in the economy.

5.3.2 Preferences

Preferences of a representative consumer in region j and country l are defined over a continuum of varieties of two horizontally differentiated goods (Ω_{si}):

$$U_{jl} = D_{1jl}^{\mu_1} D_{2jl}^{\mu_2}, \tag{5.1}$$

where D_{sjl} stands for the aggregate consumption of each differentiated good in sector $s = 1,2$; $0 < \mu_s < 1$ is the share of income spent on each differentiated good, and $\mu_1 + \mu_2 = 1$. The aggregate consumption of each differentiated good is given by a constant elasticity of substitution (CES) subutility function

$$D_{s(jl)} = \left[\sum_k \sum_i \int_{\Omega_{si}} d_{s(ik,jl)}(\phi)^{(\sigma_s - 1)/\sigma_s} d\phi \right]^{\frac{\sigma_s}{\sigma_s - 1}}, \tag{5.2}$$

where $d_{s(ik,jl)}(\phi)$ is the individual consumption in region j country l of sector-s variety ϕ produced in region i situated in any country k including that to which i belongs; and Ω_{si} is the set of sector-s varieties produced in i. The parameter $\sigma_s > 1$ measures the constant price elasticity of demand and the elasticity of substitution between any two varieties. Let $p_{s(ik,jl)}(\phi)$ denote the price of sector-s variety ϕ produced in region i in country k and consumed in in region j in country l; and let w_{jl} denote the wage rate in region j in country l. Maximization of Eq.(5.1) subject to the budget constraint:

$$\sum_k \sum_i \left[\int_{\Omega_{1i}} p_{1(ik,jl)}(\phi) d_{1(ik,jl)}(\phi) d\phi + \int_{\Omega_{2i}} p_{2(ik,jl)}(\phi) d_{2(ik,jl)}(\phi) d\phi \right] = w_{jl}, \quad (5.3)$$

yields the following individual demands:

$$d_{s(ik,jl)}(\phi) = \frac{p_{s(ik,jl)}(\phi)^{-\sigma_s}}{g_{sjl}^{1-\sigma}} \mu_s w_{jl}, \quad (5.4)$$

where

$$g_{s(jl)} = \left[\sum_k \sum_i \int_{\Omega_{si}} p_{s(ik,jl)}(\phi)^{1-\sigma_s} d\phi \right]^{\frac{1}{1-\sigma_s}} \quad (5.5)$$

is the CES price index in sector s and region j of country l.

5.3.3 Technology, trade costs and networks

Technology is symmetric between firms, regions and countries, thus implying that, in equilibrium, firms differ only by the region they are located in. We thus henceforth suppress the variety index ϕ to alleviate notation. Production of any variety in the first sector involves a fixed labor requirement, F, and a constant marginal labor requirement, c. The total labor requirement for producing the output $x_{1ik} \equiv \sum_l \sum_j x_{1(ik,jl)}$ is then given by $l_{1ik} = F + c\, x_{1ik}$.[60] Increasing returns to scale, costless product differentiation, and the absence of scope economies yield a one-to-one equilibrium relationship between firms and varieties. For the second sector, constant returns and perfect competition ensure that the price of the variety in each region equals the salary in this sector. Trade of the differentiated goods is costly. We follow standard practice and assume that trade costs are of the *iceberg* form: $\delta_{s(ik,jl)} \geq 1$ units must be dispatched from region i in country k in order for one unit to arrive in region j in country l. We further assume that trade costs are symmetric, i.e., $\delta_{s(ik,jl)} = \delta_{s(jl,ik)}$. Besides transport costs, shipping goods between countries is normally subject to *non-transport frictions*. These normally include tariff barriers, non-tariff barriers (red tape, administrative delays, different product standards), and other

[60] For the sake of simplicity, in our simulations we consider that the technological parameters F and c are also the same across regions and countries. This assumption could be relaxed to explore the effects of different sectoral productivities on the spatial location of economic activity.

barriers (language, currency, accounting,...). Contrary to transport frictions between all regions, regardless the country they belong to, these non-transport barriers are country pair specific, and we denote them by $\rho_{s(ik,jl)}$, with $\rho_{s(ik,jl)} = 0$ if i and j belong to the same country $k = l$, or both countries belong to a free trade area; otherwise $\rho_{s(ik,jl)} > 0$ —we also assume reciprocity in tariffs: $\rho_{s(ik,jl)} = \rho_{s(jl,ik)}$. These barriers are considered as an *ad valorem* tariff in addition to transport costs, and therefore, total trade frictions between any two pair of regions are given by $\tau_{s(ik,jl)} = (1+\rho_{s(ik,jl)})\delta_{s(ik,jl)}$, with $\tau_{s(ik,ik)} = 1$, since $\rho_{s(ik,ik)} = 0$ and $\delta_{s(ik,ik)} = 1$.

Departing from the standard approach in international trade that considers two regions in a single country and the rest of the world, with the latter being either a single location as in Krugman and Livas-Elizondo (1996), or symmetrically located on both sides of the country as in Alonso-Villar (1999), implies the introduction of the *transport network* to the world geography. The transport network represents a specific configuration of the spatial topology both between countries and within countries. When shipping goods it is assumed that firms minimize the transport costs between any two regions choosing least cost itineraries, Zofío et al. (2014). According to the latter premise, if, for simplicity, the distance between any two neighboring regions is normalized to one: $r_{(ik,jk)} = 1$ (regardless of whether they belong to the same country or they are border regions between two countries), and the unit transport cost corresponds to a single and common value of $t_s > 1$, then the overall transport cost between any two regions separated by a distance $r_{(ik,jl)}$ is given by $\delta_{s(ik,jl)} = t_s^{r_{(ik,jl)}}$.[61]

The whole trade cost structure including transport (network related) and non-transport frictions can be described by way of the following symmetric matrix T_s where each element represents trade frictions between a specific pair of regions:

[61] Therefore, our transport cost metric δ corresponds to an exponential network metric as in Behrens et al. (2005, 2007a) or Barbero and Zofio (2015).

$$T_s = \begin{bmatrix} 1 & \dots & \delta_{s(11,n1)} & \dots & (1+\rho_{s(11,1m)})\delta_{s(11,1m)} & \dots & (1+\rho_{s(11,nm)})\delta_{s(11,nm)} \\ \delta_{s(21,11)} & \dots & \delta_{s(21,n1)} & \dots & (1+\rho_{s(21,1m)})\delta_{s(21,1m)} & \dots & (1+\rho_{s(21,nm)})\delta_{s(21,nm)} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ \delta_{s(n1,11)} & \dots & 1 & \dots & (1+\rho_{s(n1,1m)})\delta_{s(n1,1m)} & \dots & (1+\rho_{s(n1,nm)})\delta_{s(n1,nm)} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ (1+\rho_{s(1m,11)})\delta_{s(1m,11)} & \dots & (1+\rho_{s(1m,n1)})\delta_{s(1m,n1)} & \dots & 1 & \dots & \delta_{s(1m,nm)} \\ \dots & \dots & \dots & \dots & \dots & \dots & \dots \\ (1+\rho_{s(nm,11)})\delta_{s(nm,11)} & \dots & (1+\rho_{s(nm,n1)})\delta_{s(nm,n1)} & \dots & \delta_{s(nm,1m)} & \dots & 1 \end{bmatrix} \quad (5.6)$$

This is a both a symmetric and partitioned matrix, where the elements in the diagonal correspond to the intra-regional transport costs, that is why they are always equal to 1, which is equivalent to costless trade and therefore origin and destination prices are the same. The first and last elements of the transport cost matrix are related to the transport costs within countries 1 and m. The off-diagonal elements of the up-right corner and down-left matrices represent the cross-country transport costs between countries 1 and m, and m and 1, respectively, which are equivalent. Therefore the topological properties of the spatial network characterize the transport cost part δ_{sij} of the trade frictions matrix T_s, while the non-transport related costs have no relationship whatsoever with the topology.

5.3.4 Market outcome and spatial equilibria

For the first differentiated sector, a firm in region i and country k has to produce $x_{1(ik,jl)} \equiv L_{jl} d_{1(ik,jl)} \tau_{1(ik,lj)}$ units to satisfy final demand in region j in country l.

$$x_{1ik} \equiv \sum_l \sum_j L_{1jl} d_{1(ik,jl)} \tau_{1(ik,jl)}. \quad (5.7)$$

Using the previous expression Eq.(5.7), each firm in i maximizes its profit

$$\pi_{1ik} = \sum_l \sum_j \left(\frac{p_{1(ik,jj)}}{\tau_{1(ik,jl)}} - cw_{1ik} \right) x - Fw_{1ik}, \quad (5.8)$$

with respect to all its quantities $x_{1(ik,jl)}$, and taking wages w_{1j} as given. Because of CES preferences, profit-maximizing prices display the standard constant-markup pricing rule

$$p_{1(ik,jl)} = \frac{\sigma_s}{\sigma_s - 1} c w_{1ik} \tau_{1(ik,jl)}. \tag{5.9}$$

Free entry and exit implies that profits are non-positive in equilibrium which, using the pricing rule Eq.(5.9) into the total production function that satisfies final demand Eq.(5.7), yields the standard condition:

$$x_{1ik} \equiv \frac{F(\sigma_s - 1)}{c}, \tag{5.10}$$

and the associated labor input is $l_{1ik} = F + cx_{1ik}$.

For the second sector, constant returns and perfect competition result in the price of the variety produced in region i equaling the salary $p_{2ik} = w_{2ik}$, while the delivered price in other regions is $p_{2(ik,jl)} = w_{2ik}\, \tau_{2(ik,jl)}$.

5.3.5 The world spatial equilibria

Extending Fujita et al. (1999, chapter 7), and adopting a suitable set of normalizations, it is possible to determine the system of equations corresponding the so-called instantaneous equilibrium, characterizing both unstable short-run and stable long-run spatial equilibria. Within a country k, labor in each region is shared between both sectors, $L_{ik} = L_{1ik} + L_{2ik}$, and adding across regions: $\sum_i L_{sik} = 1$. We denote by λ_{1ik} the share of labor supply in region i of the country k in the first sector where labor is mobile, and assume an even distribution of the labor force for the second sector for which labor is immobile: $\lambda_{2ik} = 1/n$.

We present the spatial equilibrium that exists within each country in the case of an open economy where trade between countries take place; i.e., $0 < \rho_{sij} < \infty$. The spatial general equilibrium is completely defined by the system of equations including the income, y_i, price equations, g_{si}, and nominal wage, w_{si}, which are complemented with the real wage equations, ω_{si}, see appendix for details:

$$y_{ik} = \mu_1 \lambda_{1ik} w_{1ik} + \frac{\mu_2}{n} w_{2ik}, \quad i = 1,...,n, \quad k = 1,...,m \tag{5.11}$$

$$g_{1ik} = \left(\lambda_{1ik} w_{1ik}^{1-\sigma_1} + \sum_{j \neq i}^{n-1} \lambda_{1jk} \left(w_{1jk} \delta_{1(jk,ik)} \right)^{1-\sigma_1} + \sum_{j=1}^{n} \sum_{l \neq k}^{m} \lambda_{1jl} \left(w_{1jl} \tau_{1(jl,ik)} \right)^{1-\sigma_1} \right)^{1/(1-\sigma_1)}, \quad i=1,...,n, \quad k=1,...,m \tag{5.12}$$

$$g_{2ik} = \left(\lambda_{2ik} w_{2ik}^{1-\sigma_2} + \sum_{j \neq i}^{n-1} \lambda_{2jk} \left(w_{2jk} \delta_{2(jk,ik)} \right)^{1-\sigma_2} + \sum_{j=1}^{n} \sum_{l \neq k}^{m} \lambda_{2jl} \left(w_{2jl} \tau_{2(jl,ik)} \right)^{1-\sigma_2} \right)^{1/(1-\sigma_2)}, \quad i=1,...,n, \quad k=1,...,m \tag{5.13}$$

$$w_{1ik} = \left(y_{ik} g_{1ik}^{\sigma_1 - 1} + \sum_{j \neq i}^{n-1} y_{jk} g_{1jk}^{\sigma_1 - 1} \delta_{1(ik,jk)}^{1-\sigma_1} + \sum_{j=1}^{n} \sum_{l \neq k}^{m} y_{jl} g_{1jl}^{\sigma_1 - 1} \tau_{1(ik,jl)}^{1-\sigma_1} \right)^{1/\sigma_1}, \quad i=1,...,n, \quad k=1,...,m \tag{5.14}$$

$$w_{2ik} = \left(y_{ik} g_{2ik}^{\sigma_2 - 1} + \sum_{j \neq i}^{n-1} y_{jk} g_{2jk}^{\sigma_2 - 1} \delta_{2(ik,jk)}^{1-\sigma_2} + \sum_{j=1}^{n} \sum_{l \neq k}^{m} y_{jl} g_{2jl}^{\sigma_2 - 1} \tau_{2(ik,jl)}^{1-\sigma_2} \right)^{1/\sigma_2}, \quad i=1,...,n, \quad k=1,...,m. \tag{5.15}$$

Both the sectoral price g_{sik} and wage w_{sik} equations include the variables referring to region i itself in the first term of their RHS, those related to the rest of the regions within the same country K in the second term, and the interactions with the regions of the rest of the countries in the last term. As for the income equations (5.11), they are the sum of the workers' incomes in both sectors (depending on the share of the production in the first sector λ_{1ik} and the proportional labor force in the second sector, $1/n$). Regarding the price indices (5.12) and (5.13), representing a weighted average of delivered prices, they are lower: 1) the larger are the shares of the production in the first sector in region i (which is domestically produced), 2) the larger the imports from nearby regions rather than distant regions within the same country as transport costs $\delta_{s(jk,ik)}$ are lower with the former that the latter, and 3) the larger the trade with both nearby countries and those with existing trade agreements as tariffs ρ_{sij} will be smaller— part of $\tau_{1(jl,ik)}$. With respect to the wage equations (5.14) and (5.15), they show that they will be higher if incomes in other regions and countries with low transport costs and tariffs from i are high, as firms pay higher wages if they have inexpensive access to large markets. Finally, from the price and wage equations one obtains real salaries as the cornerstone of the model driving the migration of the workers of the first sector across regions in a country:

$$\omega_{1ik} = w_{1ik}\, g_{1ik}^{-\mu_1}\, g_{2ik}^{-\mu_2}, \quad i=1,...,n, \quad k=1,...,m \tag{5.16}$$

Comparing the real salaries within a country, an equilibrium is observed if they are equal across regions $\omega_{1ik} = \omega_{1jk}\ \forall i, j \in k$. Otherwise, and following standard NEG migration rules, if there are differences between real salaries, simple dynamics ensure that regions with higher salaries draw workers from below-average salaried regions until real wages equalize. Note that real salaries could be different between countries but not across regions in each country. This is because of the restrictive migration laws and physical barriers (e.g., US-Mexico wall, Spanish-North African fence...) preventing people movements across the borders.

5.3.6 Autarky and trade-openness equilibria

Looking at the system of non-linear equations representing the instantaneous equilibrium, it is easy to see that when $\rho_{s(ik,jl)} = \infty$, the last sets of terms in the RHS corresponding to other countries tend to zero, and therefore the spatial location of economic activity corresponds to a standard NEG model without a multi-country dimension—i.e., from a trade perspective a situation of autarky, and each country presents a specific locational patterns depending on how its geography and transport network shape its spatial topology, as well as the existing transport cost levels.

5.4 The effects of trade openness on the distribution of economic activity within a country

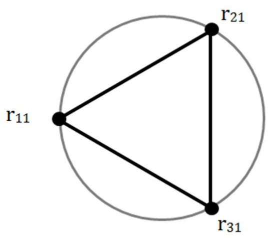
As argued before, it is very difficult to obtain general results in the multi-region setting, because the equilibrium allocation of economic activity in the first mobile manufacturing sector is determined by a complex trade-off between the inherent NEG centrifugal and centripetal forces, model's parameters, network topology and transport and non-transport related costs. This is particularly true for our model as any world trade network both within and between countries can be defined. However we can gain more systematic insights into how trade liberalization and the structure of the trading network influence the equilibrium distribution of economic activity by choosing some relevant configurations and resorting to systematic numerical simulations aimed at determining the critical break point and sustain-point values. The research strategy is as follows. First, we study the standard NEG results for a single country, and determine the long run-equilibria of economic an activity in its regions by way of the bifurcation diagram (tomahawk). This is equivalent to study a closed economy (autarky) within a world trading network. Subsequently, we allow for trade openness with a second country, and study how the possibility of international trade flows alters the distribution of economic activity within our first reference country; i.e., a systematic 'comparative statics' exercise. In doing so, we consider for our first benchmark country two different topologies that are completely opposed; namely a homogenous topology where all regions are equally located with respect to each other and there are no locational advantages (geometrically represented by an equilateral polygon—known as the race-track economy in the literature), and a heterogeneous topology where one central region enjoys a comparative advantage (geometrically represented by a star—hub and spoke—topology). While other alternative network topologies are possible, our results for these two extreme cases of network centrality allow us to set lower and upper bounds (range) for the results that would be obtained for intermediate topologies, see Barbero and Zofío (2015).

Once the research strategy has been laid out, we illustrate the effects of trade liberalization for the particular case of two countries consisting of three regions each, and focusing the analysis on the two opposed topologies already mentioned: a triangle topology (all regions are equidistant and there are not transport related advantages), and a line topology (a region is in the center of the network). In the next subsection we recall the long-run equilibria results corresponding to a situation of autarky for the homogenous space as summarized in the bifurcation diagram (tomahawk) of the reference country[62]. The main results refer to the usual critical values determining the disperse or agglomerated outcomes; i.e., that identify the transport cost thresholds for the mobile sector for which full dispersion is no longer stable (break-points), and for which full agglomeration is unfeasible (sustain-points). Therefore we first asses these scenarios in the context of autarky, and afterwards once the economy is fully opened to international trade. In doing so we change the transport cost of sector 1 and trade barriers to determine a wide range of scenarios, and identify the stable and unstable equilibria for each degree of openness.

[62] Additionally, these two extreme topologies for three regions have been already studied in the NEG literature by Ago et al. (2006) and Castro et al. (2012), even if for the simpler seminal model of Krugman (1991) that consider a homogenous and a differentiated sector.

5.4.1 A closed economy with homogenous space

Figure 5-1. Homogeneous topology (triangle) and the equivalent matrix of distances.



$$r_{(ik,jk)} = \begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \end{bmatrix}$$

Figure 5-1 depicts the homogeneous or symmetric space. Given this spatial configuration, no region has a geographical advantage in its trade relationship with the others. Graphically, this corresponds to the figure of the equilateral triangle (triangle topology), which may be embedded on a circumference. Since here we refer only to one country, we can omit the subscript l, referring to a second country. Thus we can define the distance matrix as $r_{(ik,jk)}$, where i and j are any two regions within the same country k. Alike the T matrix including the total cost of transportation between regions, it only includes as elements these bilateral distances, which are normalized to one.

Figure 5-2. Bifurcation with two differentiated sectors, $t_2 = 1.275$. Autarky economy composed of 3 regions. Triangle topology.

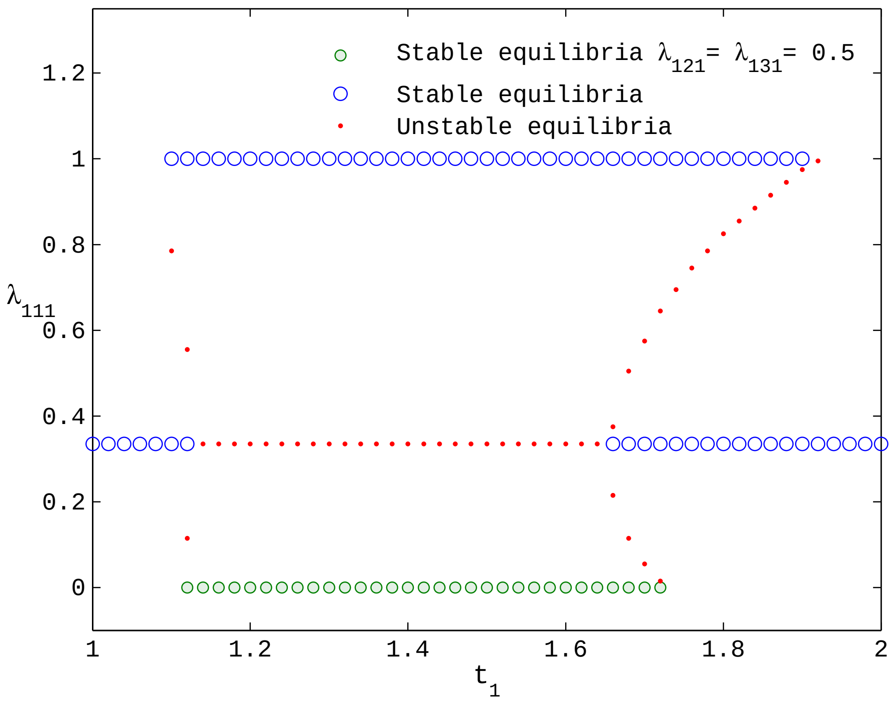


Figure 5-2 represents the tomahawk of a closed economy characterized by a homogeneous network topology (triangle) with respect to the transport costs of sector 1 (mobile sector) comprised between the values 1 and 2. In other words, it draws all the population shares which are in equilibrium, distinguishing whether they are long-run stable (blue or green hollows) or are short-run unstable; i.e., sensitive to small changes (red dots), for the different transportation costs of sector 1. For comparison purposes, the values of the rest of parameters considered henceforth, unless indicated otherwise, correspond to those employed by Fujita et al. (1999) (Chapter 7), where $\mu = 0.4$, $\sigma_1 = 5$, $\sigma_2 = 10$, $t_2 = 1.275$, and where we assume that workers of the immobile sector 2 are evenly distributed; i.e., $\lambda_{2i1} = 1/3$ for each region. Also, we assume that the labor force in both sectors, in the second country, is also evenly distributed: $\lambda_{sj2} = 1/3$, s=1, 2, j=1, 2, 3[63]. The results show that at relatively low levels, and from relatively high levels of transport costs borne by sector 1, the symmetric equilibrium is stable; i.e., each region would have a third of the working population of the mobile sector, $\lambda_{1i1} = 1/3$, i=1, 2, 3. However, for intermediate values of transport costs, agglomeration forces prevail, resulting in a stable core-periphery equilibrium or, for a smaller range of trade costs, in a semi-core-periphery equilibrium. We refer for core-periphery equilibrium to the situation where one region concentrates all the labor in sector 1, and therefore the entire industry of sector 1. Whereas we talk about a semi-core-periphery equilibrium when two regions concentrate all the industry in sector 1. The symmetric balance becomes unstable for this rank of intermediate transport costs. Between the two extreme solutions, core-periphery and flat-earth, just arise some unstable equilibria that collect different degrees of population. These are between the critical values of break-point (which breaks up the stable symmetric equilibrium) and sustain-point (which breaks up the stable core-periphery equilibrium). This result generalizes the well-known NEG outcome to three regions, concluding that under a symmetric topology and given the agglomeration and dispersion forces considered in the model, for sufficiently high or sufficiently low transport costs for sector 1, the homogeneous distribution of the mobile sector appears as a stable equilibrium. However, for intermediate transport costs, the stable equilibrium corresponds to a core-periphery structure, where all the activity of sector 1 is concentrated in a single location. In the next section we analyze the effect of trade liberalization on these results, identifying which regions gain/lose from the opening up process.

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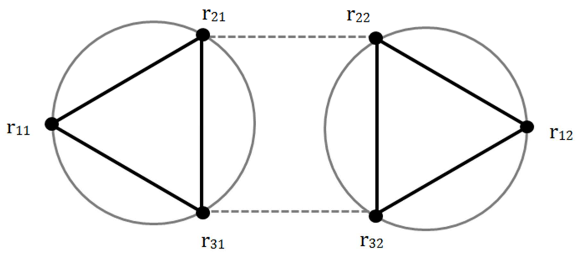
[63] Clearly, the location of the first sector activity in the second country: λ_{1l2}, is also subject to the forces that shape that of the reference country; i.e. real salaries in the regions of the second country will be affected by the same trade openness process. We shall take into account these feedback effects associated to changes in the distribution of the first sector in the second country when they result in different equilibria for the location of economic activity in the first country: λ_{1i1}.

5.4.2 How trade openness favours bordering regions by changing the trade network topology

Figure 5-3. Graphical representation of two countries characterized by a homogenous topology and the equivalent matrix of distances (within and between countries).



$$r_{(ik,jl)} = \begin{bmatrix} \begin{bmatrix}0&1&1\\1&0&1\\1&1&0\end{bmatrix} & \begin{bmatrix}3&2&2\\2&1&2\\2&2&1\end{bmatrix} \\ \begin{bmatrix}3&2&2\\2&1&2\\2&2&1\end{bmatrix} & \begin{bmatrix}0&1&1\\1&0&1\\1&1&0\end{bmatrix} \end{bmatrix}$$

Figure 5-3 shows the complete topology including two countries, each consisting of three regions with a homogenous network (triangle topology). Both countries are connected through two of its regions situated at their shared border (at the same distance as that between the regions of each country)[64]. The corresponding distance matrix shows the distance between all partners, which can be decomposed into 4 sub-matrices: the upper-left and lower-right sub-matrices correspond to the distances inside each country, while the upper-right and bottom-left off-diagonal sub-matrices represent distances between regions of both countries. It is among the regions belonging to the different countries where one finds the extended distances, which are no longer the same for all regions, thereby altering the neutrality of space as a force shaping the location of economic activity through transport costs. In fact, the distance between region 1 country 1 and region 1 country 2 is the largest: $r_{(11,12)} = 3.$ In sum, we go from two homogeneous topologies to a single heterogeneous network, where two groups of regions arise: those four situated at the border with better accessibility, and two remote regions in the *cul-de-sac* of the two countries.

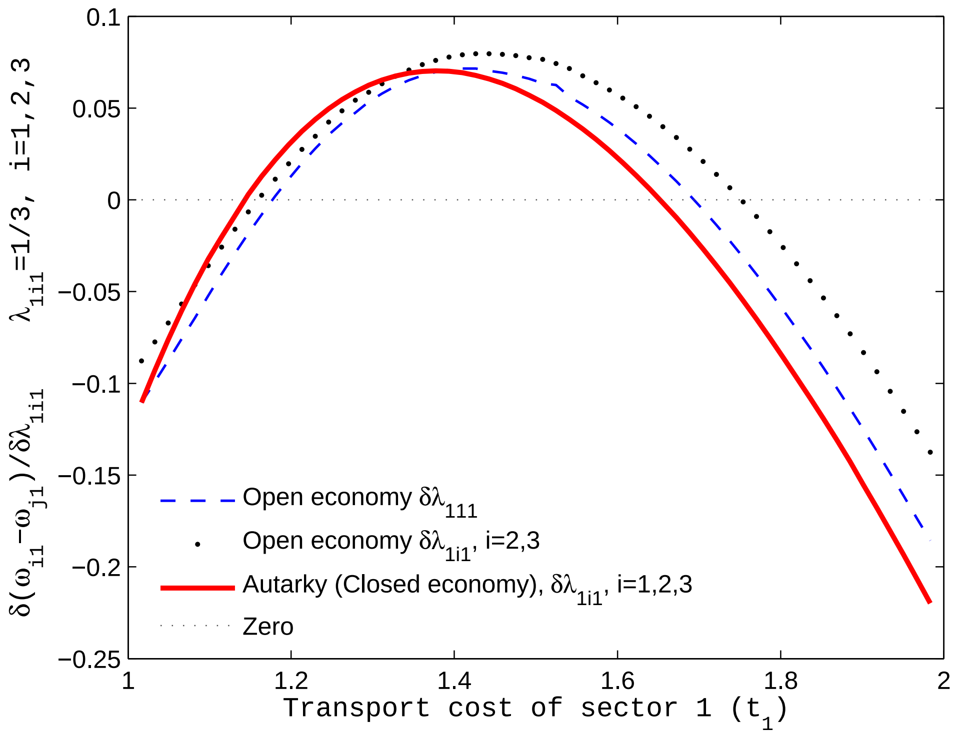
[64] Clearly, there could be other possible connections or links, such as: the union of a single region of each country; or one region of one country with two regions of the other country. In order to simplify matters, in this paper we focus on only one of them, which resembles the network configuration of Spain; where Madrid would be region 1 and Cataluña and the País Vasco would be regions 2 and 3.

The stability of the dispersed (flat-earth) equilibrium: Triangle topology in both countries

To study the break-points **Figure 5-4**plots the variation in the difference in real wages between workers of sector 1 across regions of the same country ($k = 1$) under autarky: $\rho_{s(ik,jl)} = \infty$, and complete trade openness: $\rho_{s(ik,jl)} = 0$, when a marginal change in population (and therefore in the share of manufacturing activity) takes place. Note that only workers of sector 1 move across regions of a given country, being drawn by the region(s) with the highest real wage(s); i.e., workers respond to changes in real wage differentials. This **Figure 5-4**, known as the wiggle diagram, depicts the transport costs values for which the symmetric distribution of workers is stable. As typical break-point exercise, the starting point is the symmetric—flat-earth—distribution of workers across regions ($\lambda_{1i1} = 1/3$, in our case). Therefore, the graph records the change in real wage differentials under marginal changes in the population, $\delta(\omega_{i1} - \omega_{j1}) / \delta(\lambda_{1i1})$, along the range of transport costs of said sector 1 comprised between the values 1 and 2. Thus the symmetric equilibrium will only be stable if an increase of population brings a lower real wage in the incoming (receiving) region. Graphically, this is observed for transport costs where the wage differentials are below zero, corresponding to a stable condition; by contrast, when they are above, we face reinforcing agglomeration dynamics.

The solid line recalls the previous break point results for the case of a closed economy, an autarky. Note that since this is a closed economy characterized by the triangle topology, the results between two regions will be independent of which two regions are chosen. On the opposite side, when the economy is in a liberalization process, the triangle topology does not longer prevail, emerging the two aforementioned groups of regions: central (r_{21} and r_{31}) and peripheral (r_{11}), given the new network configuration. This means that under the same characteristics, in terms of population and transport costs (here, in sector 1), there are different reactions of wage differentials to population shocks. That is, the marginal increase in the population will have a different effect depending on whether the increase occurs in a region closer or further away from the new market. The dashed line includes the case in which the most peripheral region suffers a positive immigration shock. Whereas the dotted line reports the change in the real wage differential when it is one of regions closest to the new market which sees its population increased. The dashed and dotted line corresponds to complete openness, and therefore the difference between these curves and the solid line, which corresponds to closed economy, delimit the bounds for the long-run symmetric equilibrium for all other intermediate degrees of trade openness: $0<\rho_{s(ik,jl)}<\infty$.

Figure 5-4 Break point in region 1 and region 2 (or 3) in country 1 before and after the openness of the economy, $t_2 = 1.275$. Triangle topology in both countries, where $\lambda_{1ik} = 1/3$, i=1, 2,3 and k=1, 2.

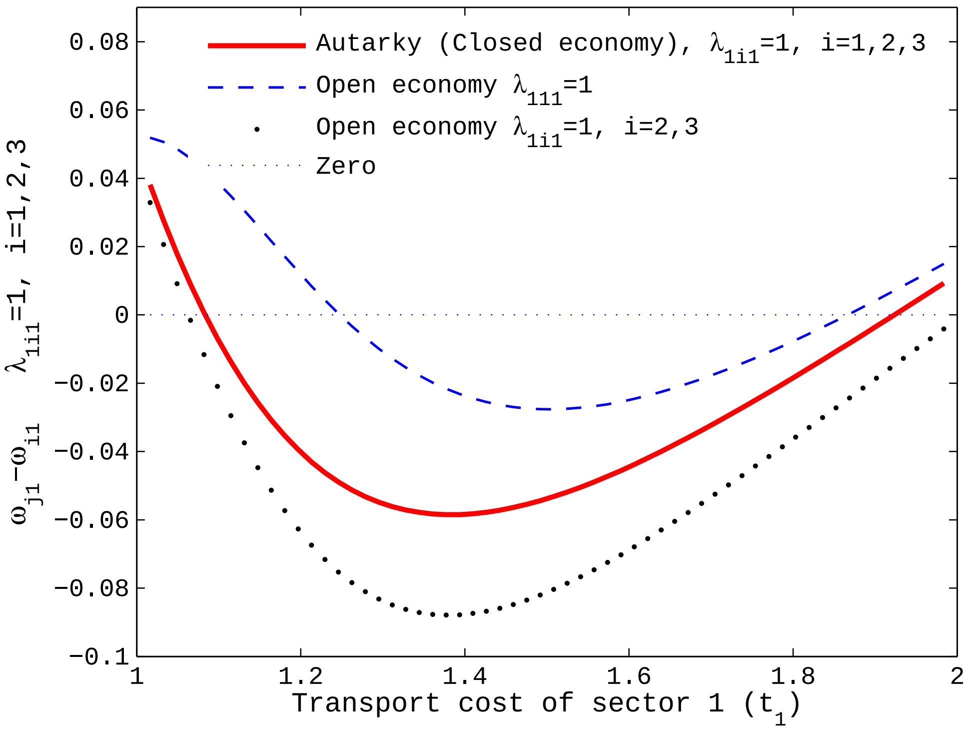


The study of the **Figure 5-4** shows that for low values of transport costs in sector 1, the break point comes first under the scenario of a closed economy, followed by the situation of an almost fully integrated trade area when the positive shock of migration affects one of the new core locations. So the break-point arises later when, in an open situation, it is the peripheral region (r_{11}) which receives immigrants. This means that the transport costs that keep sustainable the homogenous distribution have to be higher when we study a more peripheral region in an open economy, than in the other extreme scenarios; i.e., in an open scenario it is easier for peripheral regions to depopulate and lose economic activity. At the other end, when transport costs are high enough to make sustainable the even distribution of the population/economic activity, this becomes stable first in the situation of closed economy. The opposite case is when a region closest to the outside border begins to agglomerate, which requires the highest transport costs to make stable the flat-earth distribution; i.e., it is easier for better located regions to start agglomerating by drawing economic activity from the peripheral regions. An alternative way to analyze this is to note that the dotted curve (for a border region, such as r_{21}) is always above the dashed (for a more internal—peripheral—region, such as r_{11}), which means that under the same circumstances (migratory shock and transport costs), the change in the real wage differential in the frontier region is always greater than for the new periphery, in an open economy. This also means that the range of values for which the homogeneous space is unstable is greater when the incoming or receiving region has a locational advantage in an open economy, since it is more probable that it generates a self-reinforcing agglomeration effect.

The stability of the agglomeration (core-periphery) equilibrium: Triangle topology in both countries

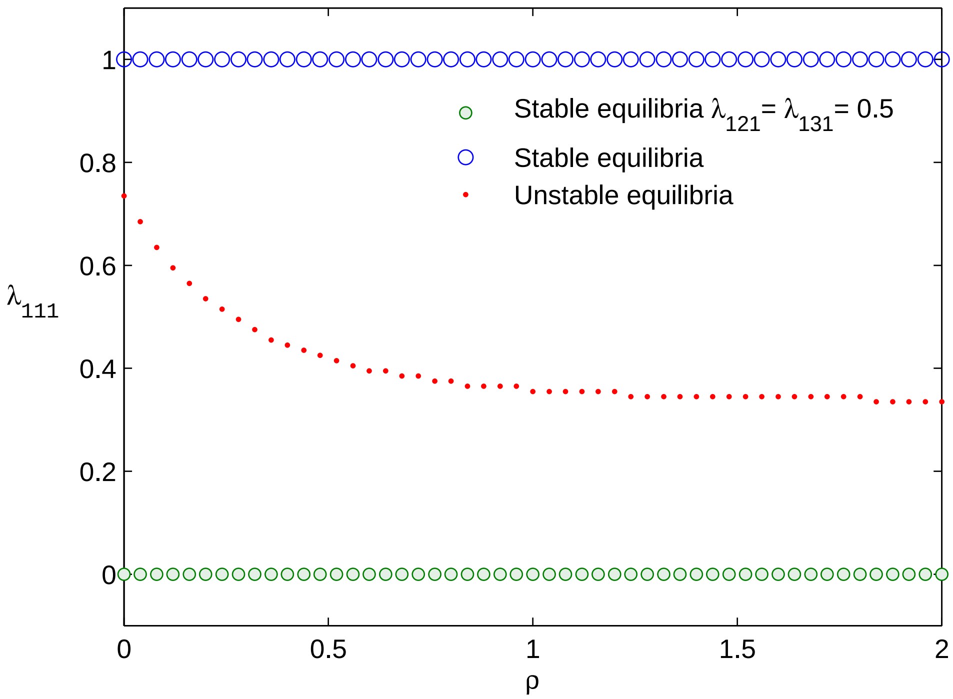
Figure 5-5 shows the levels of transport cost in sector 1 for which a situation in which one of the regions agglomerates all the economic activity is stable. As in the previous case, we take as reference two extreme scenarios: a closed economy: $\rho_{s(ik,jl)} = \infty$ (solid line) and an open economy: $\rho_{s(ik,jl)} = 0$ (dashed and dotted lines). The values shown in the graph are the differences in real wages between an empty region j, in terms of workers from sector 1, and a region that agglomerates all the workers, i: $\omega_{j1} - \omega_{i1}$, for each value of transport costs between 1 and 2. Thus, the core-periphery equilibrium is stable if the wage difference is negative, i.e. the curve is below zero, meaning that the region that holds all workers also shows the higher real wages. In all cases this only occurs among intermediate values of transport costs. Once again consistent with the bifurcation diagram in **Figure 5-2** for the autarkic economy, we recall the well-known centrifugal effect that breaks the core-periphery equilibrium when transport costs reach a high enough value, as a result of the existence of an immobile demand associated to the workers of the second sector. The fact that no agglomeration is fully stable at very low transport costs is uncommon. Just to clarify, this is due to two features of the second sector that go against the agglomeration (besides the aforementioned fixed demand): On one hand, it produces differentiated products, what makes more attractive those products; on the other hand, its trade incurs in transportation costs, which increases the consumption index price, especially in areas with high demand (large population). In other words, this result does not appear if the second sector was to produce perfectly homogeneous goods, $\sigma_2 = \infty$, and did not incur transport costs $t_2 = 0$. This result is also observed for the open economy. However, the graph shows that the results for a closed economy situate between the extreme cases in which, in an open economy, all mobile workers agglomerate in the peripheral region (with worse accessibility than any region in the homogenous autarky network) and the better located border regions (with better accessibility in this case); being the region that becomes remote after the full commercial opening the one that shows the lowest real wages. On the opposite side, there is the case of an open economy where the working population is located in a region near the foreign market; in this case, it is greater the range of intermediated transport costs for which this situation is stable. That is, compared to a closed economy situation where no region has a geographical advantage, trade openness polarizes the effects of transport costs, being more stable the agglomeration in regions closer to the new trading partner. Graphically, the lower the wage differential curve, the larger the wages in the agglomerating region, leaving a wider range of transport costs for which the initial agglomeration is sustainable.

Figure 5-5. Sustain Point in region 1 and 2 (or 3) in country 1: before and after the openness of the economy, given $t_2 = 1.275$ and $\lambda_{1j2} = 1/3$. Triangle topology in both countries, where $\lambda_{1j2} = 1/3$, j=1, 2, 3.



We now explore the results for different degrees of trade openness in the form of alternative values of the non-transport frictions—ad valorem tariffs ρ. **Figure 5-6** shows the distribution patterns of the mobile sector that represent an equilibrium, for relevant ranges of openness: $\rho = [0, 2]$. These equilibria may be stable (symbolized with hollows); i.e., robust to small changes in population, or unstable (symbolized by dots); i.e., sensitive to small changes in the population, which would lead to one of the stable equilibria. The results show that, given transportation costs $t_1 = 1.4$ and $t_2 = 1.275$, the core-periphery structure $\lambda_{111} = 1$ or $\lambda_{1i1} = 1/2$, i=2, 3 is a stable equilibrium for any degree of trade openness, regardless of whether the region that agglomerates is a bordering region or the most inner region. When the economy is an autarky; i.e., rho tends to infinity, the perfect distribution of the mobile sector between the three regions emerges as unstable equilibrium. However, when a process of opening starts (ρ tends to zero), only those combinations in which the farthest region to the external market (r_{11}) progressively increases its population are equilibriums, otherwise a process of relocation will begin toward the other regions. In short, if a closed economy starts from a symmetric distribution, the openness process will tend to agglomerate the mobile sector in one of the bordering regions. Only if the inner region were to increase the share of population with the integration process, the core-periphery equilibrium would not emerge. Therefore we note then that having large share of population allows offsetting the locational disadvantages of the inner region emerging from the new network, through the home market effect and the productive advantage of the economies of scale.

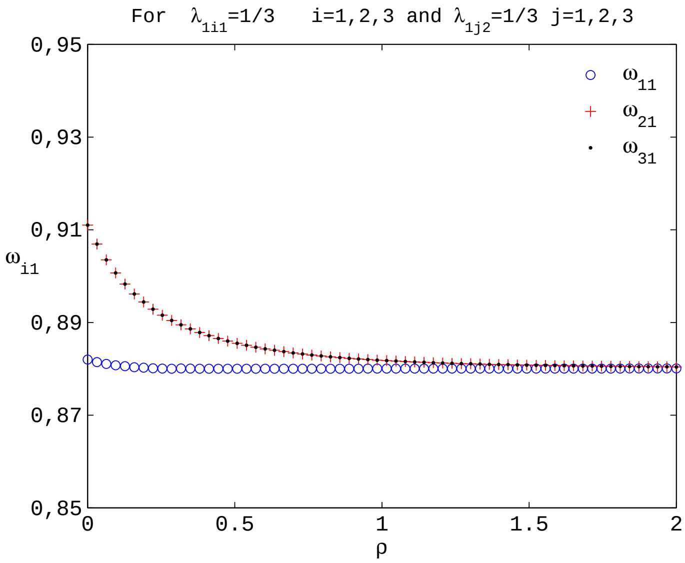
Figure 5-6. Core-Periphery bifurcation in region 1 in country 1 respect to the degree of openness of the economy, $t_1 = 1.4$ and $t_2 = 1.275$. Triangle topology in both countries, where $\lambda_{1j2} = 1/3$, j=1, 2, 3.



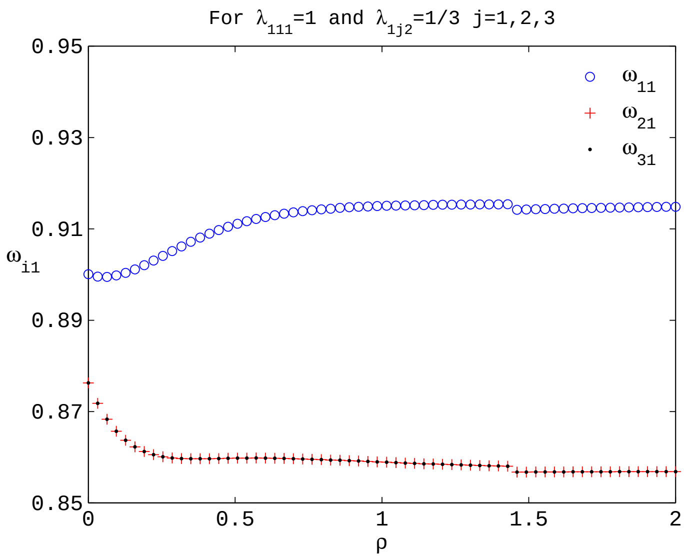
The set of graphics in **Figure 5-7** illustrates a detailed analysis of the indirect utility of individuals (hereafter real wages) in each region under the two traditional spatial distributions studied for the mobile sector: core-periphery and full dispersion configurations. This analysis complements those that took place when searching of the break points and sustain points of **Figure 5-4** and **Figure 5-5**. In those figures the comparative statics analysis between the wages was dyadic; i.e., only between two regions (real wage in the central region versus real wage in one of the peripheries), and for extreme values of tariff costs ($\rho = 0$, which approaches the case of full openness and $\rho = 2$, which leads to the autarky scenario). Here we analyze simultaneously the salaries for the three regions and we do it for all values of ρ comprised in the selected range. The transport costs assumed are $t_1 = 1.4$ for sector 1 and $t_2 = 1.275$ for sector 2, given these intermediate transport costs we observed a rich range of equilibria. Moreover, given that the range of real wages in the y-axis is the same, we can compare the three cases analyzed (full dispersion, agglomeration in region 1 and agglomeration in one of the regions closely located to the other country), and see under what circumstances regional wages reach higher values.

Figure 5-7. Real wage in each domestic region for different degrees of openness ρ in [0,2], $t_1 = 1.4$ and $t_2 = 1.275$. Triangle topology in both countries.

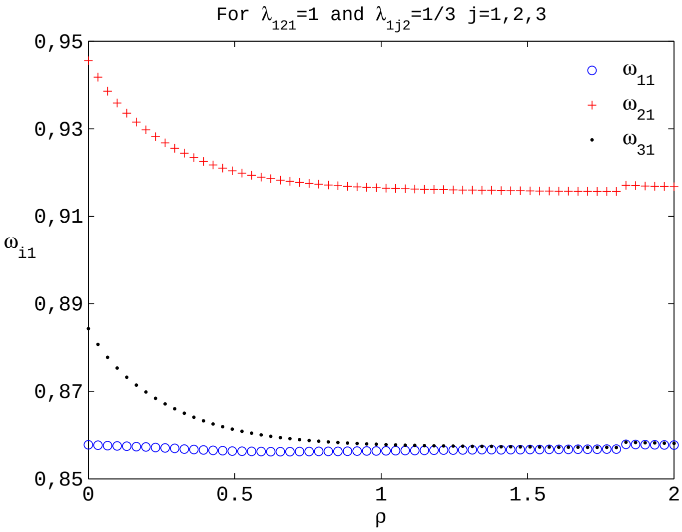
[a]



[b]



[c]



The first panel [a] depicts the case in which economic activity is equally distributed across the three domestic regions ($\lambda_{1i1} = 1/3$, in our case). For high values of ρ ($\rho = 2$, in this case) we get similar results to the ones obtained under the symmetric network economy in autarky. We know from the analysis of the autarky that under these circumstances all regions have the same wage and this is a stable equilibrium distribution for transport costs in sector 1 lower than 1.1 ($t_1 < 1.1$) or above 1.7 ($t_1 > 1.7$), approximately, and unstable for the intermediate costs (**Figure 5-2**). With the opening up process; i.e., the smaller are the tariff costs (ρ), a significant increase is observed in real wages in the peripheral regions, and only when ρ is sufficiently small, region 1 also yields a slight growth. In conclusion, trade liberalization appears to cause in the short term a clear real wage increase in border regions, which in the long run suggests that people would tend to agglomerate in them. According to the results of the tomahawk (**Figure 5-6**), we know that this is a stable equilibrium distribution.

The following panel [b] shows the scenario in which the entire population working in the mobile sector is in the furthest region to the foreign country ($\lambda_{111} = 1$, $\lambda_{1i1} = 0$, i=2, 3). Whereas panel [c] reflects the opposite scenario, where the economic activity of sector 1 is concentrated in one the frontier regions ($\lambda_{111} = 0$, $\lambda_{1i1} = 1$, i=2 or 3). In the case of autarky ($\rho = 2$), as expected, results in both graphs are equivalent, accruing from the triangle topology. However, with trade liberalization (reduction of ρ) the evolution of real wages differs. In both cases, the regions that agglomerate the economic activities of the mobile sector show the highest salary for the whole range of tariff costs considered, but when the economic activity of sector 1 is concentrated in the furthest region to the foreign country (r_{11}), the opening process means a progressively reduction in the wages in this region and an increase in the peripheries. By contrast, when the agglomeration takes place in the frontier, the opening up process to international market entails the increase in wages in this location and in the other border region, while in the new periphery (r_{11}, after the openness) hardly there exist changes[65].

In general, we have observed that behind a triangle topology, trade liberation increases real wages in the case of the border regions. This result aligns with the expectation, given the expressions that define the real wage (5.16), which is composed by: on the one hand, the positively related nominal wage (5.14); and on the other hand, inversely related price indices (5.12) and (5.13). In the case of the nominal wage, if we assume that all regions face a similar price index, then its value would be larger as higher is the income of the closest neighbors (lower transport costs). In the case of price indices, both for the sector 1 and 2, if we assumed a nominal wage similar across the different locations, these indices would be lower as higher is the share of said sectors that are in regions with low transport costs. Therefore, through the reduction of tariff barriers, the emergency of new trading partners will benefit more the border regions, since they are closely located to them, having 3 direct neighbors with trade openness instead of 1 in autarky.

Through the analysis of these three scenarios one can perform a comparative study of the wage levels (in a certain way, of welfare) in each case (full dispersion, agglomeration on the furthest region to the foreign market or agglomeration in one of the border regions).[66] In autarky it follows that the most favorable situation for workers in the mobile sector would be one in which all economic activity is concentrated in one region, regardless which particular one it is. Instead, once the process of removing tariff barriers gets sufficiently large, the setting with the highest real wages comes up when the activity of sector 1 agglomerating in one of the border regions, followed by the scenario in which the economic activity is distributed evenly between the two border regions, and being the worst result when agglomeration takes place in the new periphery (r_{11}).

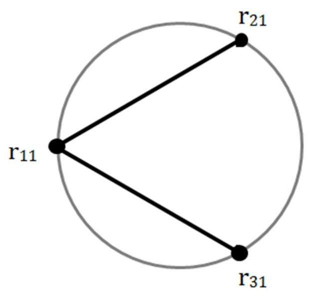
[65] These results are robust to alternative distributions of the economic activity of sector 1 in the second country, that in our base simulation is set evenly across regions; i.e., $\lambda_{1j2} = 1/3$, j=1, 2, 3. Real wages in all three regions as trade liberalization increases for alternative distributions of economic activity are shown in the **Appendix (5.7.4)**; these alternative scenarios agglomerate economic activity either in the farthest region: $\lambda_{112} = 1$, or symmetrically in the border regions: $\lambda_{1j2} = 0.5$, j=2, 3. Real wage patterns and differences between regions are unaffected by these changes.

[66] Nevertheless, it is worth mentioning some issues among others that keep off this analysis from one of welfare. On the one hand, it does not consider what happens with the real wages of workers in the immobile sector and, on the other hand, it does not take into account the negative externalities, in terms of regional inequality, that appears from the full concentration of mobile sector in a unique location. For different definitions of welfare in the NEG model see Charlot et al. (2006).

5.4.3 A closed economy with heterogeneous space

Figure 5-8 shows the graphical representation of the star topology for the previous 3-region economy case. This particular network, completely opposed to the homogenous topology of **section 5.4.1** in terms of centrality, gives a locational advantage to the central region (r_{11}, in this case). Their graphical representation could be a straight line or, as here, an open equilateral triangle[67]. Next to the graphical representation is the equivalent matrix of distances. Numerically, the differences in the home network come for the fact that the distance between the peripheral regions r_{21} and r_{31} is twice the distance between any of them and the central region r_{11}.

Figure 5-8. Heterogeneous topology (star) and the equivalent matrix of distances.



$$r_{(ik,jk)} = \begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 2 \\ 1 & 2 & 0 \end{bmatrix}$$

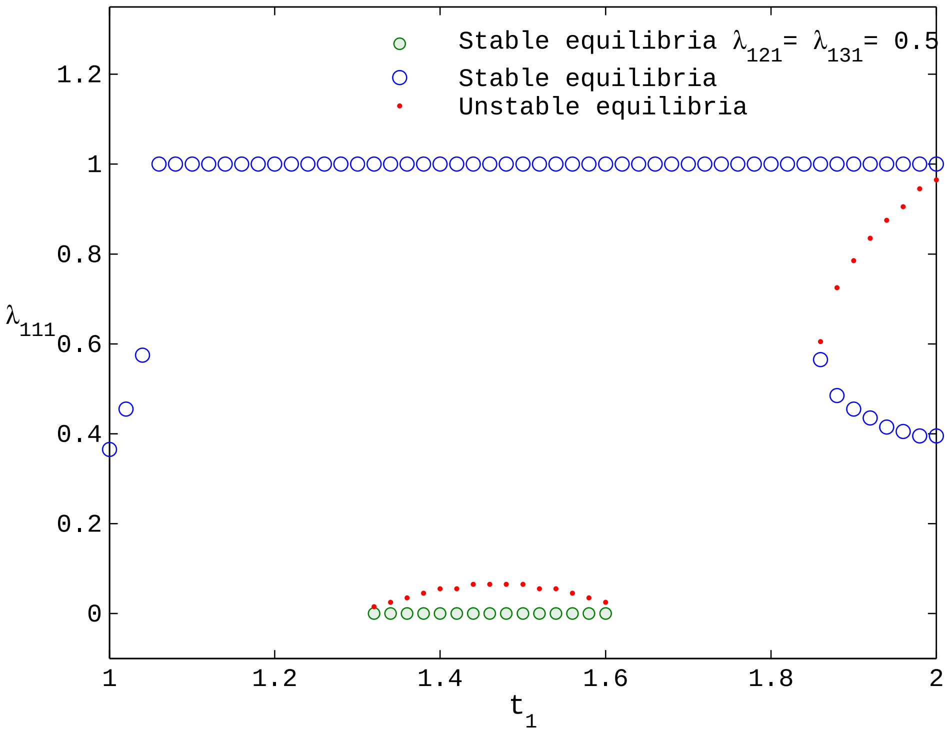
Figure 5-9 represents the tomahawk diagram of the 3 region closed economy characterized by the star topology, regarding alternative transport costs of sector 1 (mobile sector). This graph draws the shares of the population in the central region 1, being the rest of the population perfectly divided among the other regions, for which the economy is in equilibrium. As in **Figure 5-2**, the stable equilibria are represented by blue circles while the unstable equilibria by red dots. The results point out that from relatively low transport costs the core-periphery configuration, where the entire population is agglomerated in region 1, emerges as stable equilibrium—indeed much earlier that for the homogenous topology in **Figure 5-2**. By contrast, the symmetric distribution of the whole population between the two peripheral regions, leaving the central location without manufacturing sector, it is now only stable for a relatively small range of intermediate transport costs, in contrast to the larger range for the fully connected triangle topology. The symmetric distribution of the population is only stable for extremes transport costs. Instead, for relatively low or high transport costs the stable equilibrium arises when the share of

[67] Here we have chosen the triangular representation, looking for a twofold goal: first, to keep the triangle representation by simply removing the link between regions r_{21} and r_{31}; and second, to reflect spatial differences with respect to the rest of the world once we allow for trade openness, by which the two most peripheral regions in the home network will be the closest to the rest of the world.

population in region 1 gathers levels above 0.33 (which represents the homogeneous distribution of the population); more precisely these are between 0.3 and 0.6.[68] And only for relatively high transport costs (greater than 1.8), shares of population in region 1 above 0.6 appear as unstable equilibrium. In conclusion, the central region (r_{11}) tends to agglomerate the entire economic activity for a wider range of transport costs or concentrate a higher share of the population for extreme transport costs.

In **Figure 5-10** we observe a panel of graphics that present the real wages of the three regions that compose the country of interest, which is characterized by the star topology, for each value of transport costs of sector 1 comprised between 1 and 2. The first graph [a] considers the homogenous distribution of the population ($\lambda_{1i1} = 1/3$, in our case). In this scenario it is observed that the real wage in the central region (r_{11}) is always higher than in the other regions, except in the trivial case where transport is costless ($t_1 = 0$)—in that case all regions exhibit the same level of real wages. Therefore, the perfect dispersion of the population is never a stable equilibrium.

Figure 5-9. Bifurcation with two differentiated sectors ($t_2 = 1.275$). Autarky economy composed of 3 regions. Star topology.



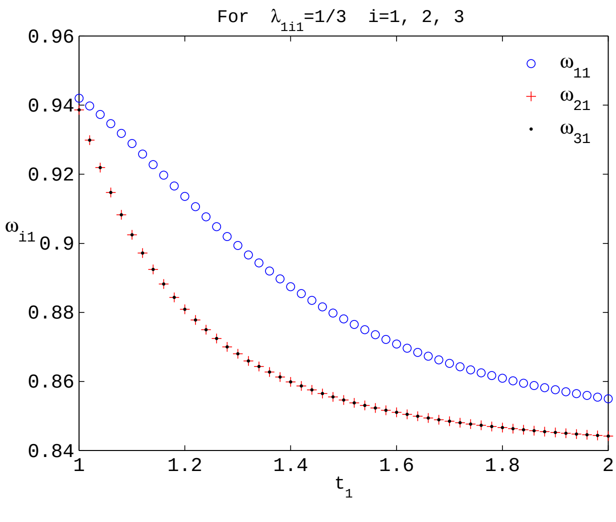
[68] This corresponds to the concept of *pseudo* flat-earth introduced by Barbero and Zofío (2015), as that distribution of manufacturing activity that represents a long-run equilibrium with all regions holding manufacturing activity, $\lambda_i > 0$, but in different proportions.

The following panel [b] shows the analysis for case when the entire activity of sector 1 is agglomerated in the central region ($\lambda_{111} = 1$, $\lambda_{121} = \lambda_{131} = 0$). The results show that the real wage is much higher in region 1 for almost all transport costs of this sector (between 1.05 and 2, approximately, with the latter representing a sustain point). The evolution of the chart indicates that as transport costs increase beyond 2 real wages in other regions exceed that of the central region, triggering dispersion toward the peripheral regions and more balanced equilibrium—even if full symmetry cannot be sustained. As mentioned above, this has been shown in classic NEG models (chapter 5 of Fujita et al. 1999), where the dispersion force arises from the immobile farmers. In turn, at very low levels of transport costs (lower that 1.05), wages in the peripheral regions become higher than in the central region. This result comes from a twofold motivation: on the one hand, workers in the locations 2 and 3, which do not need to import products of sector 2, start to face a lower price in their imports of products from sector 1. On the other hand, workers in region 1 have to import products of sector 2, which are also attractive since they are heterogeneous, but whose shipment is costly (chapter 7 of Fujita et al. 1999).

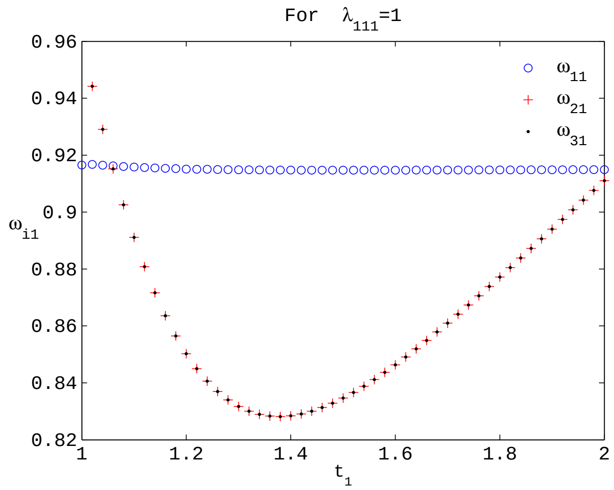
Finally, panel [c] represents real wages when all the activity of sector 1 is symmetrically concentrated in the two border regions ($\lambda_{111} = 0$, $\lambda_{1i1} = 0.5$, i=2, 3), which constitutes a feasible equilibrium, though only for a range of transport costs t_1 between 1.3 and 1.6, approximately as shown in **Figure 5-9**. For transport costs t_1 out of the above range, the activity of sector 1 would be concentrated in the central region (r_{11}). The dynamics suggest that workers migrate toward the central region, with more balanced long-run equilibrium emerging.

Figure 5-10. Real wage in each domestic region for different degrees of transport costs for sector, 1, $t_1 \in [1,2]$, $t_2 = 1.275$. Star topology.

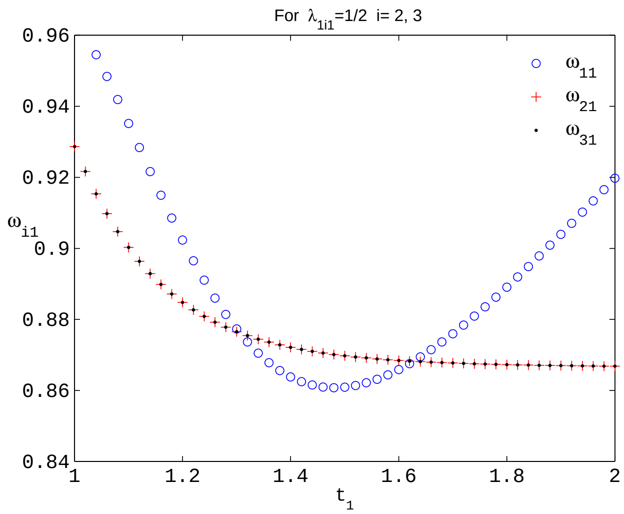
[a]



[b]



[c]



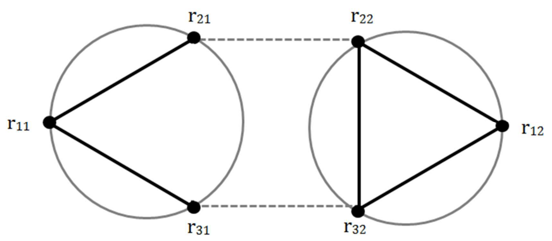
5.4.4 How trade openness offsets the locational advantage of the central region by changing the world trade network topology

Figure 5-11 shows the trade network of two countries with three regions each, where we consider the two autarkic topologies already studied but integrated in a single world economy. Both countries are connected by two of its regions. One country, the country of interest, presents the star topology, where the central region is that located further away from the foreign economy, so their exports must go through another domestic (border) region.[69] The second country

[69] This situation can be associated with the situation of Landlocked Developing Countries (LLDCs); i.e., r_{11} could considere as a third country on its own, facing difficulties to develop economically through foreign trade. See the reports by the UN Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States, http://unohrlls.org/about-lldcs/.

presents the topology of the connected triangle, discussed in **section 5.4.1**, so for this latter country we can recall previous results to discuss the effects of trade openness on it. Next to the world trade network is the distance matrix defining its topology, which is partitioned in four sub-matrices: Again the upper-left matrix represents the internal topology of the country of interest (the star), the lower-right matrix represents the internal topology of the second country (the triangle), and the off-diagonal matrices represent symmetrically the distance between regions in different countries.

Figure 5-11. Graphical representation of two countries: country 1 with the star topology and country 2 with the triangle topology. And the equivalent matrix of distances (within and between countries).



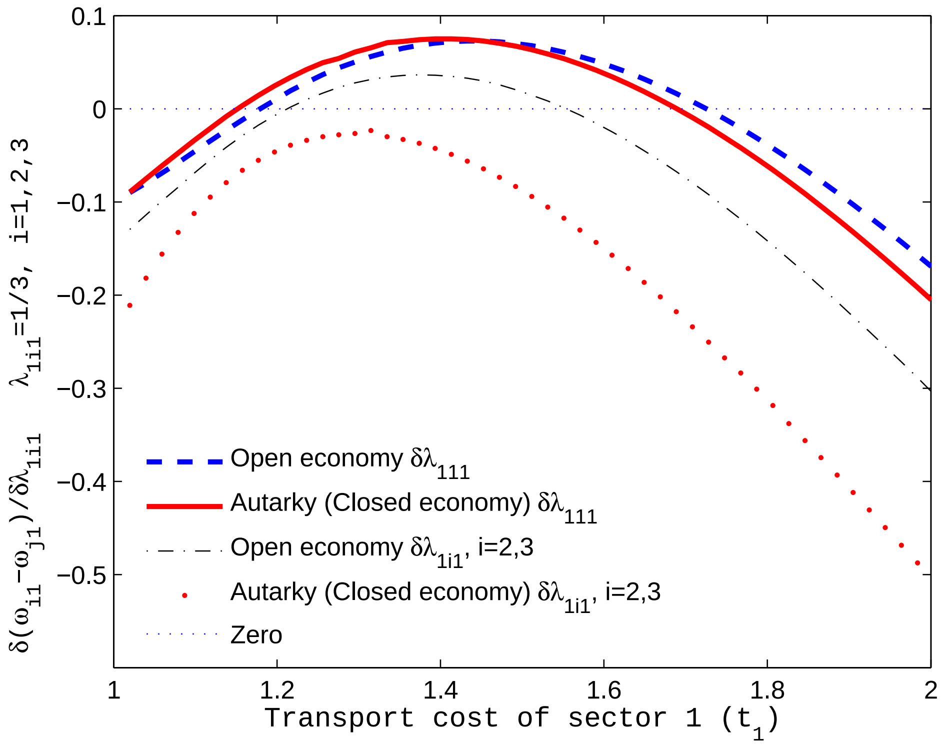
$$r_{(ik,jl)} = \begin{bmatrix} \begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 2 \\ 1 & 2 & 0 \end{bmatrix} & \begin{bmatrix} 3 & 2 & 2 \\ 2 & 1 & 2 \\ 2 & 2 & 1 \end{bmatrix} \\ \begin{bmatrix} 3 & 2 & 2 \\ 2 & 1 & 2 \\ 2 & 2 & 1 \end{bmatrix} & \begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \end{bmatrix} \end{bmatrix}$$

The stability of the dispersed (flat-earth) equilibrium: Star and triangle topologies for each country, respectively.

Figure 5-12 again shows an analysis of the stability of the symmetric equilibrium in the mobile sector (sector 1), taking as starting point the even distribution of this sector's activity among the regions of the country of interest. As in previous cases the symmetric distribution is a stable equilibrium whenever the real wage in the region receiving immigrants becomes smaller than in the origin regions. Therefore, the graph records the change in real wage differentials under marginal changes in the population, $\delta(\omega_{i1} - \omega_{j1}) / \delta(\lambda_{1i1})$, along the range of transport costs of said sector 1 comprised between the values 1 and 2. Graphically, this occurs when the change in the differential wage curve is negative, below zero. The main novelty of this graph with respect to **Figure 5-4**, is that here the topology of the country is not homogeneous (triangle), but heterogeneous (star). That means that, for the scenario of a three region country in autarky, the central region enjoys a privileged locational advantage (r_{11}), as the other regions (r_{21} or r_{31}) must ship their products through it. However, as in the previous case, once the trade openness processes take place it results, ceteris paribus, in uneven effects across regions, with a growth in economic activity in those regions whose geographical location improves in relative terms, and the opposite for those whose location worsens. Therefore, departing either from an even distribution of population (flat-earth) or full agglomerated (core-periphery), it is necessary to study the existence of break-points and sustain-points at the individual level, since they are different for each region. For the break points, whether a positive migration shock takes place in a central region or a peripheral one. Note that under the chosen world topology, the once privileged central region becomes a peripheral one with a locational disadvantage with respect to the foreign economy, what leads to conflicting forces without an obvious result.

If we analyze the case of the closed economy and compare it with **Figure 5-4** (triangle topology), the central region (r_{11}) provides higher (relative) salaries than any of the other regions poorly positioned in the home network (r_{21} or r_{31}), even when it is one of the peripheral region which receives a positive migration shock. Graphically the curve that refers to a peripheral region is *always* below zero, thus for any level of transport cost a small increase in population will never trigger an agglomeration process in the periphery, breaking up the symmetric equilibrium. On the other hand, when the best located region receives the immigration inflow, the results are more similar to those obtained in the closed economy with the homogeneous topology (triangle), being at intermediate values of transport costs when the symmetric equilibrium ceases to be stable, thereby triggering a process of agglomeration.

Figure 5-12. Break point for region 1 and region 2 (or 3) in country 1 before and after the openness of the economy, $t_2 = 1.275$. Star and triangle topologies, respectively, where $\lambda_{1ik} = 1/3$, i=1, 2, 3 and k=1, 2.



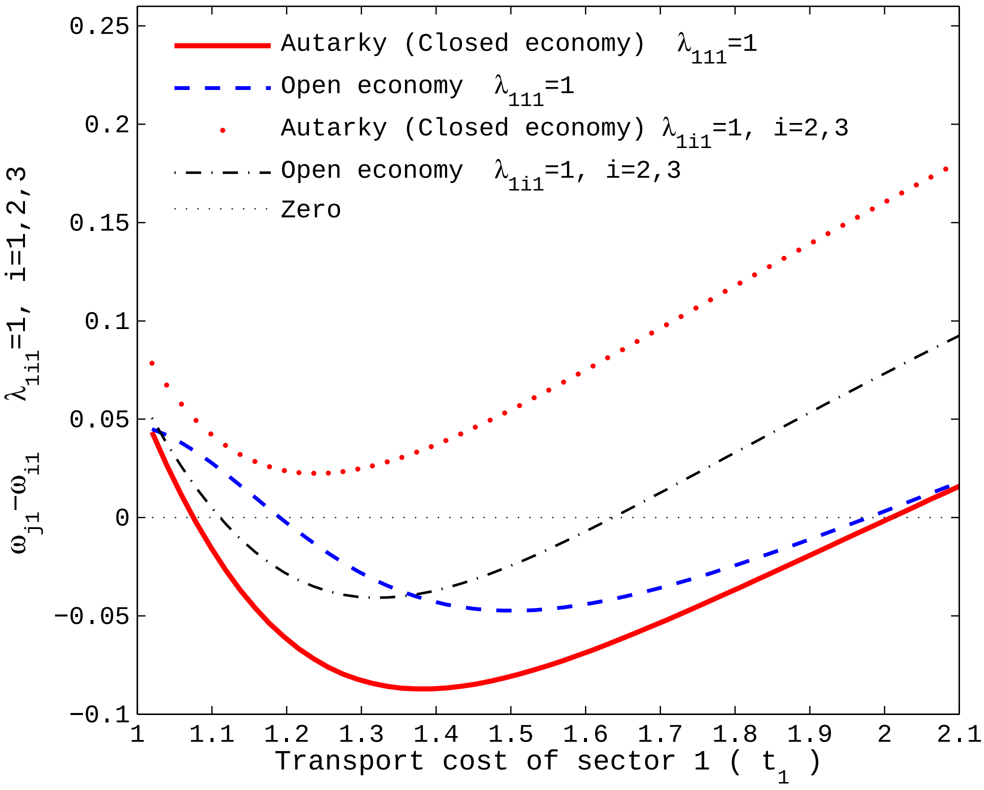
Given the world trade network in **Figure 5-11**, trade liberalization reverses the asymmetric effects that arise in autarky due to the star topology. So that regions that were originally peripheral (r_{21} and r_{31}), before the openness to the new market, switch to show higher real wages that break the symmetric equilibrium for intermediate transport costs; i.e., r_{21} or r_{31} can now agglomerate all the economic activity of sector 1 either individually or jointly. Nevertheless, their range of transport costs for which the symmetric equilibrium is broken in their favor is still narrower than for the domestic central region, even in a context of full trade liberalization. The results for region r_{11} suffer a small change with full opening, as the curve is shifted slightly to the right, which means that this region will begin to agglomerate, and therefore to break the homogeneous equilibrium, for higher transport costs. This suggests that for this network, although trade liberalization favors the border regions, the internal network still weighs considerably. These results go against those in **Figure 5-4** (triangle topology), where bordering regions passed to present higher real wages in relative terms with the full opening process, than the “new” inner region, for all levels of transport costs. Note that the only difference with the previous topology is the absence of the link between r_{21} or r_{31}, whose existence would reinforce the locational advantage of the bordering regions by easing trade between them instead of having to use r_{11} as corridor, since it is still the minimum distance between the two: $r_{(21,31)} = 2, via\ r_{11}$. If such link existed by way of transport infrastructure policy, the results in the previous section could be compared to those obtained in this one.

Regarding the new results where the internal advantage prevails over the external one, it is worth mentioning that we impose strong assumptions, such as the neighboring country having the same size of the domestic economy, sector 2 being evenly distributed in both countries, sector 1 being also homogenously laid out across foreign regions, and the foreign network corresponding to a triangle configuration. Therefore, it is likely that, besides changes in the trade network as the link between r_{21} or r_{31} already mentioned, simple changes in other assumptions like model parameters, uneven population sizes or industrial distribution (e.g. more dense in the bordering regions), particularly in the neighboring country, could reverse or reinforce the results. However, we prefer to undertake a simple analysis to draw clear cut conclusions.

The stability of the agglomeration (core-periphery) equilibrium: Star and triangle topologies for each country, respectively.

Figure 5-13 gathers the sustain points. Thus, as in **Figure 5-5**, this figure shows the differences in real wages between an empty region j, in terms of workers from sector 1, and a region that agglomerates all the workers, $i: \omega_{j1} - \omega_{i1}$, for each value of transport costs between 1 and 2. Thus, the core-periphery equilibrium is stable if the wage difference is negative, i.e. the curve is below zero, meaning that the region that holds all sector 1 economic activity also shows the higher real wages. Even for the case of autarky, since we analyze a heterogeneous space (star topology), we study separately the stability of the core-periphery results when it is the central region (r_{11} or a peripheral region, r_{21} or r_{31}), given the national network, the one that constitutes the core; i.e., starts agglomerating. The results show that, in an autarkic context, peripheral regions never agglomerate, regardless of transport cost level (i.e., for $\lambda_{1i1} = 1$, i=2, 3, the curves are always above zero). At the other extreme, $\lambda_{111} = 1$, with the most central region agglomerating the entire labor force of sector 1 for a wider range of intermediate transport costs; the range being much larger than for the case of a region in a closed economy with a triangle topology.

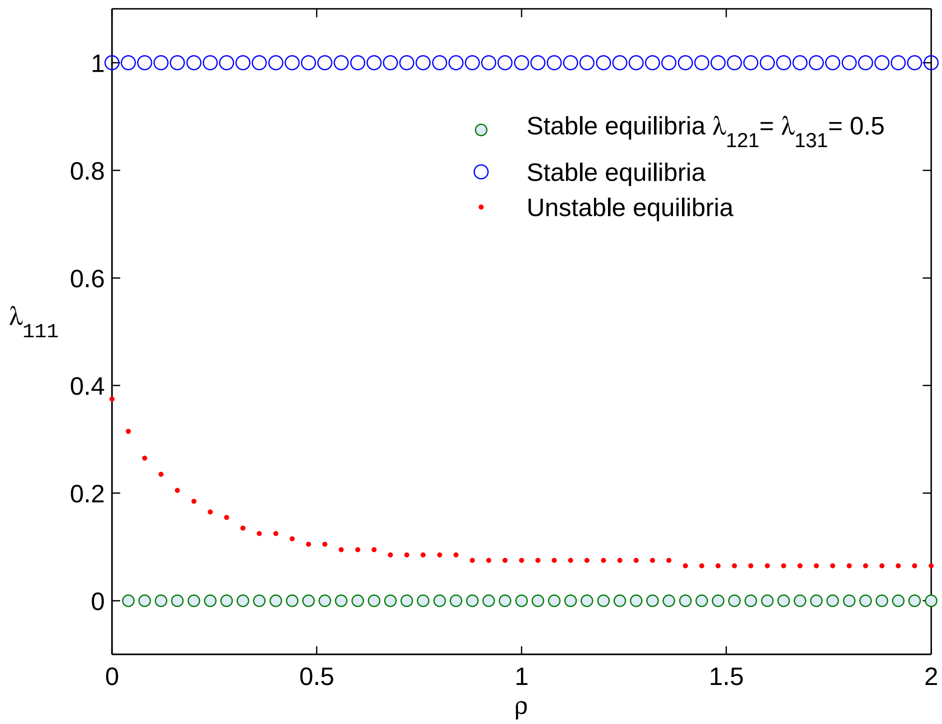
Figure 5-13. Sustain point in region 1 and region 2 (or 3) in country 1 before and after the openness of the economy, $t_2 = 1.275$. **Star and triangle topologies, respectively, where** $\lambda_{1j2} = 1/3$, **j=1, 2, 3.**



With full trade liberalization, the results indicate that the initial central region in an autarkic economy still enjoys a privileged position compared to the other regions of the country, even if for a shorter range of transport costs for which agglomeration in this region is stable. A significant change compared to autarkic situation appears in the results under the range of the lower transport costs, the inner region (r_{11}) will start to agglomerate at higher transport costs after full openness. In this range of lower transport costs, the regions closely located to the foreign market are the ones that begin to agglomerate before. In short, trade liberalization allows agglomeration in border regions, mainly for relatively lower transport costs, but when transport costs are relatively high, the central region of the domestic network is the one maintaining its hegemony.

In the homogeneous space, trade liberalization gave a clear advantage to the border regions. With the introduction of a heterogeneous topology, where the network favors the furthest region to the foreign market, the centripetal forces gain relevance without a clear result at first sight; i.e., regarding accessibility the domestic network favors to the central region, while liberalization favors the border regions. In terms of transport costs ranges for which agglomeration is feasible, results show that the inner topology prevails, especially for relatively high transport costs, and not for relatively low transport costs. Even in a context of full opening: $\rho=0$, where other regions are involved, the importance of the relatively high transportation costs, which intensify the cost of trade between the regions, make the domestic network to prevail favoring the central region r_{11}, over the positive effect of openness in favor of the best internationally located regions, r_{21} or r_{31}.

Figure 5-14. Bifurcation in region 1 of country 1 respect to the degree of openness of the economy, $t_1 = 1.4$ and $t_2 = 1.275$. Star and triangle topologies, respectively, where $\lambda_{1j2} = 1/3$, j=1, 2, 3.



We now summarize the results for different degrees of trade openness in the form of alternative values of the non-transport frictions—ad valorem tariffs ρ. **Figure 5-14** shows the shares of the mobile sector in region 1 that are equilibria for different degrees of trade openness (ρ), comprised between $\rho=0$ (full trade liberalization) and $\rho=2$ (closed economy). As already mentioned, these equilibria may be stable (symbolized with hollows); i.e., robust to small changes in population, or unstable (symbolized by dots); i.e., sensitive to small changes in the population, which would lead to one of the stable equilibria. The results show that, given transportation costs $t_1 = 1.4$ and $t_2 = 1.275$, the core-periphery structure $\lambda_{111}=1$ or $\lambda_{1i1}=1/2$, i=2, 3, is a stable equilibrium for any degree of trade openness, regardless of whether the region that agglomerates is a bordering region or the most inner region. When the economy is an autarky; i.e., rho tends to infinity, we find the same unstable equilibria than in the single country scenario, where the inner location holds a 10% on the industry activity in sector 1 and the remaining 80\% is perfectly distributed among the border regions. However, when a process of opening starts (ρ tends to zero), only those combinations in which the farthest region to the external market (r_{11}) progressively increases its population are equilibria; otherwise a process of relocation will begin toward the other regions. Therefore we note then that the increase in the share of population in region 1 allows offsetting the locational disadvantages emerging from the new network, through the home market effect and the productive advantage of the economies of scale. It is remarkable that, in comparison with the homogeneous topology, the levels of the population required to be in the further region, is much lower, being under the 1/3 of the population, which represents the flat-earth situations—except for very small values of ρ.

The set of graphs in **Figure 5-15** records the real wages in each region for the conventionally analyzed distributions: symmetric dispersion of the mobile industry [a], the agglomeration of this sector in the inner region 1 [b], and its concentration in one of border regions [c]. As in **Figure 5-7**, real wages are observed for each value of ρ (tariff costs) comprised between 0 and 2, but here the country of interest is characterized by the star topology.

Panel [a] depicts the scenario where the mobile activity is evenly distributed across the three regions ($\lambda_{1i1} = 1/3$, i=1, 2, 3). Note that given the model parameters, when the tariff cost is $\rho = 2$ the results correspond to the situation in autarky where the star topology entails that real wages in the inner region r_{11} are much higher than in the peripheries r_{21} and r_{31}. The trade liberalization hardly brings a change in the evolution of these series. It is only when the tariff costs go below 0.5 when we find a process of convergence among the real wages. This convergence basically comes from the increase of real wages in the border regions. However, only when ρ is practically 0 (as in a single market area such as EU or NAFTA) wages in peripheral regions exceed those in the central region, and they would start agglomerating.

Panel [b] shows the case where sector 1 is concentrated in the central region of the country of interest. Under this scenario the differences of the real wages between the inner region r_{11} and the peripheries r_{21} and r_{31} are more intense than in the previous case with the homogeneous distribution. In fact the real wages in the center region are always higher than wages in the border regions, and no opening process can reverse that initial situation. It is for very low values of ρ when we observe a smooth reduction in the real wages of region 1 and a slight increase of them in the border regions. In short, the impact of the home network effect, which favors region 1, dominates over the effect of trade liberalization, which favors frontier regions when the economic activity.

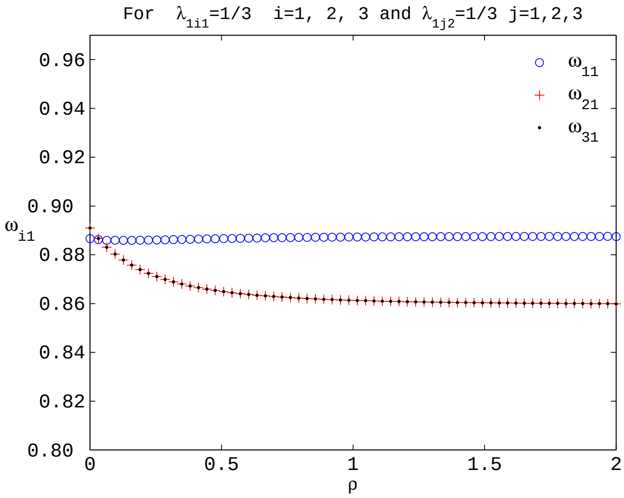
Finally, panel [c] reflects the scenario where the two border regions agglomerate the activity of sector 1 symmetrically ($\lambda_{111}=0$, $\lambda_{1i1}=0.5$, i=2, 3). This graph shows the expected results. As trade openness takes place, it is observed that wages in regions 2 and 3 (larger than in the first region r_{11} in autarky: ($\rho=2$)) increase at the same rate, and therefore agglomeration in both regions is sustained. Therefore, as previously presented in the tomahawk diagram in **section 5.4.3**, this is a stable situation. In sum, for $t_1=1.4$ the openness process brings higher real wages when the economic activity of sector 1 is concentrated in both border regions for all possible values of non-transport related trade barriers[70].

If we now compare these graphs with those obtained in the case of the triangle topology (**Figure 5-7**), where the trade liberalization results in the increase of real wages for the border region, we find different results. Though the trade openness (ρ tends to zero) affects positively the border regions via higher nominal wages and lowering price indices, this fact only offsets part of the negative effect that comes from the remote location of these locations in the domestic network. In fact, just the full liberalization would suppose that these border regions pass to have 2 direct neighbors, as was the case of the central region in the domestic network, but also they become nearer to other foreign region than the central domestic region.

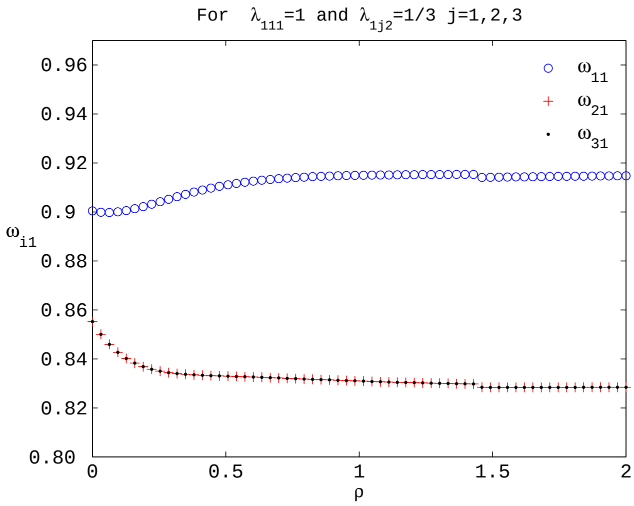
[70] Again, as shown in **Appendix 5.7.4** these results are robust to alternative distributions of the economic activity of sector 1 in the second country, one we change the default distribution: $\lambda_{1j2}=1/3$, j=1, 2, 3. Despite the alternative distributions agglomerating economic activity either in the farthest region: $\lambda_{112}=1$, or symmetrically in the border regions: $\lambda_{1j2}=0.5$, j=2, 3, real wage trends and differences are the same.

Figure 5-15. Real wage in each domestic region for different degrees of openness ($\rho \in [0,2]$), $t_1 = 1.4$ and $t_2 = 1.275$. Star and triangle topologies, respectively.

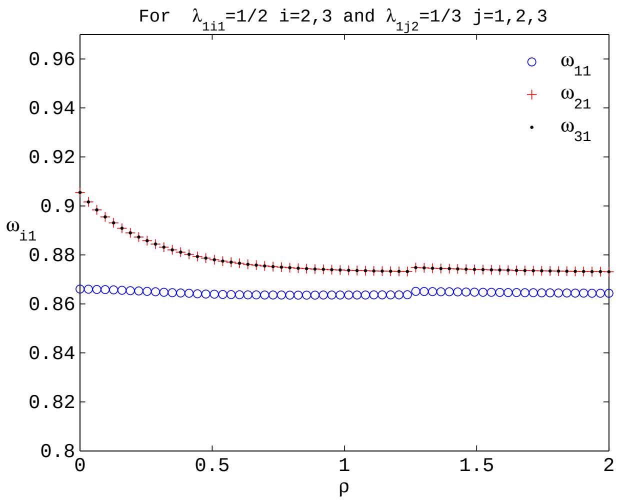
[a]



[b]



[c]



5.5 Conclusions

We model the effect of trade openness on the location of economic activity of the mobile industry within a country, paying special attention to different results depending on its internal topology; i.e., triangle (homogenous space) or star network (heterogeneous space), and its connection with that of the world economy. To do this analysis we adapt and extend the model by Krugman and Livas-Elizondo (1996) and Alonso-Villar (1999) and provide a theoretical answer to the questions posed by Brülhart (2011) regarding the effect that trade liberalization have on regional (within-country) spatial inequality, depending on their specific geographical location and transportation networks (i.e., accessibility). So that, considering a comprehensive NEG/NTT model and alternative network topologies, we can establish how the centrifugal and centripetal forces shape the long-term distribution of the mobile (manufacturing) industry.

Based on standard assumptions, we analyze the stability of the symmetric (flat-earth) and the agglomerated (core-periphery) distributions before and after full trade openness. We rely on the systematic study of the break-point (transport cost at which symmetric equilibrium is broken) and sustain-point (transport costs at which the core-periphery structure is no longer stable) and characterize short and long-run equilibria. Other authors (Barbero et al, 2015) studied the effect of the network centrality in a closed economy, being their main results that, departing from the flat-earth situation, the higher centrality the less likely is the dispersed outcome (and vice versa).

Here, given the chosen (and opposite) network configurations that we adopt as starting points, we observe that trade opening processes always favor border regions, and the dispersed equilibrium becomes more likely in relative terms, and regardless the initial inner spatial topology, either neutral (triangle) or in favour of a central region (star). Therefore, we observe that with trade liberalization border regions result favored as a result of their improved accessibility in the world transport and trade economic network, which can offset an initial privileged position of inner regions in the domestic economy if they were to agglomerate economic activity in the first place (vice versa, if economic activity were already located in border regions). As a result, and keeping in mind this result, the redistributive effects of trade liberalization will be therefore subject to the topology of the home and international networks as well as to the initial distribution of the industry in the mobile.

From our main results we may summarize the distributive effects of trade openness by adopting a narrative that, departing from an autarky scenario where transport costs of the mobile sector bear intermediate values, ends up in a fully integrated "free trade" area:

i. if the departing point is flat-earth (a stable equilibrium that occurs only in the context of a homogeneous topology), trade liberalization involves the break up of this structure in favor of agglomeration in border regions;

ii. if the mobile industry is completely located in the farthest region with respect to the foreign market (which is the most likely long-run outcome under the described heterogeneous star topology), trade liberalization implies that real wages fall slightly in this region, and may trigger the dispersion of economic activity towards border regions for a wider range of transport costs t_1 and trade openness ρ. Under the triangle topology, trade openness makes the dispersive effect more intense as a result of the lower centrality (in the case of this topology real wage differences are lower than for the star network). However, long-run agglomeration in the inner region remains feasible.

iii. Finally, if the region that agglomerates the production of the mobile sector is at the border, the effect of trade liberalization depends on the inner topology. In the case of the triangle topology, where the border regions are well connected with each other, trade liberalization does not break this equilibrium, and makes real wages in both regions higher. It would be also stable equilibrium if the economic activity were equally distributed between border regions.

In the case of the star topology, which is what emerges historically in economies with a hub-and-spoke transport network as a result of strong central states as would be France or Spain (in the latter case in the periphery of the European continent), and where inner locations such as Paris or Madrid enjoy better domestic accessibility, trade liberalization along with improved cross-border transport infrastructure results in a weakening of the agglomerating forces in favor of border regions. Therefore, a reduction in spatial inequality is expected as economic activity shifts to border locations, and whose connections to foreign markets in the new world trading network are developed; i.e., a dispersed equilibrium or even full agglomeration on the border regions may emerge when liberalization processes are high enough. Otherwise, economic activity remains in the most inner region or, at most, divided between border regions, depending on the degree of openness; i.e., the inner network prevails until non-transport related trade barriers (tariffs) reduce to an almost free trade area.

Indeed, as we observe in the autarky scenario, the agglomeration in one extreme (border) location is not a stable equilibrium as a consequence of the high transport costs borne by this region in the consumption of the products from the mobile industry, which increase the price index reducing the real wage in that location (the centrifugal force), more than the increase of nominal wages as a result of its larger income and scale economies (the centripetal forces).

However, trade liberalization, when paired up with better connections (e.g., the triangle topology), can relieve the pressure of prices through the reduction of relative transport costs and the increase the nominal wages.

In conclusion, while in autarky the flat-earth equilibrium can emerge within a homogeneous space, in a context of trade liberalization, the final long-run equilibrium will depend on the particular topology of the case at hand. More abstractly, if we think about more complex trading networks than those described here, as may be the Spanish case where just some regions are in the border (i.e., the País Vasco and Cataluña) and there is a strong central hub (Madrid), we can expect that trade liberalization will favor the border regions by increasing their accessibility to new markets, but also the consolidation of the hub status of the Madrid region at the expense of southern peripheral regions such as Andalusia, Extremadura, Castile-La Mancha,... which certainly helps to explain their lagging position in terms of manufactured and other tradable goods production, as their situation both in the domestic and international networks worsens with the liberalization process.

These results have important implications in terms of trade and infrastructure policies, which are related in a way that cannot be overlooked as the existing literature suggests; i.e., as a country decides to reduce protectionism, local, regional and central administrations should bear in mind the long term effects of this liberalization on firms and workers location decisions. Particularly, the attractiveness of locations with better accessibility in terms of the transportation network. We have shown that trade liberalization may result in larger or smaller spatial inequalities depending on the *initial* and *final* locational patterns of the economic activity and the configuration of the domestic and international networks. As the behavior of economic agents can be anticipated, if larger regional inequalities are expected, this undesirable effect could be compensated by appropriate infrastructure investments that may counter-balance centripetal forces. Indeed, while geographical features are given by nature, "second nature" transport and non-transport related trade barriers are within the realm of human action that our model seeks to explain, and that policymakers and government officials could incorporate in their decision making processes.

5.6 References

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5.7 Appendix

5.7.1 Derivation of the Demand Function and the Price Index.

The individual demand ($d_{sjl}(\phi)$) in region *j* in country *l* for a given variety *(ϕ)* of the industry *s*{1,2} emerges from the maximization of the individual utility function subject to the individual budget constraint.

Demonstration in two steps:

In the first step, we minimize the total consumption expenditure of a general industry *s* associated to the total amount of products that any individual wants to consume in region *j* in country *l* in the sector *s*.

$$Min \sum_k \sum_i \int_{\Omega_{si}} p_{s(ik,jl)}(\phi) d_{s(ik,jl)}(\phi) d\phi \tag{5.17}$$

$$s.t. \quad D_{s(jl)} = \left[\sum_k \sum_i \int_{\Omega_{si}} d_{s(ik,jl)}(\phi)^{\left(\frac{\sigma_s - 1}{\sigma_s}\right)} d\phi \right]^{\left(\frac{\sigma_s}{\sigma_s - 1}\right)} \tag{5.18}$$

where D_{sjl} represents the total amount of product demanded in region *j* in country *l* of sector *s*.

The Lagrangean is:

$$L = \left[\sum_k \sum_i \int_{\Omega_{si}} p_{s(ik,jl)}(\phi) d_{s(ik,jl)}(\phi) d\phi \right] + \lambda \left[D_{s(jl)} - \left[\sum_k \sum_i \int_{\Omega_{si}} d_{s(ik,jl)}(\phi)^{\left(\frac{\sigma_s - 1}{\sigma_s}\right)} d\phi \right]^{\left(\frac{\sigma_s}{\sigma_s - 1}\right)} \right] \tag{5.19}$$

This expression is differentiated with respect to the individual demand of two different varieties of the industry *s* and with respect to the Lagrangean multiplier term. The results are: equation (5.20), for the derivative with respect to the variety produced in location *i* of the country *k*;

equation (5.21), for the derivative with respect to the variety produced in location *n* of the country *m*; and equation (5.22) for the derivative with respect to Lagrangean multiplier term.

$$\frac{\partial L}{\partial d_{s(ik,jl)}} = \frac{\sigma_s}{\sigma_s - 1}\left[\sum_k \sum_i \int_{\Omega_{si}} d_{s(ik,jl)}(\phi)^{(\sigma_s-1)/\sigma_s} d\phi\right]^{\frac{1}{\sigma_s-1}} \frac{\sigma_s - 1}{\sigma_s} d_{s(ik,jl)}(\phi)^{-1/\sigma_s} + \lambda\left[-p_{s(ik,jl)}(\phi)\right] = 0 \quad (5.20)$$

$$\frac{\partial L}{\partial d_{s(nm,jl)}} = \frac{\sigma_s}{\sigma_s - 1}\left[\sum_m \sum_n \int_{\Omega_{sn}} d_{s(nm,jl)}(\phi)^{(\sigma_s-1)/\sigma_s} d\phi\right]^{\frac{1}{\sigma_s-1}} \frac{\sigma_s - 1}{\sigma_s} d_{s(nm,jl)}(\phi)^{-1/\sigma_s} + \lambda\left[-p_{s(nm,jl)}(\phi)\right] = 0 \quad (5.21)$$

$$\frac{\partial L}{\partial \lambda} = \lambda\left[D_{s(jl)} - \left[\sum_k \sum_i \int_{\Omega_{si}} d_{s(ik,jl)}(\phi)^{\frac{\sigma_s-1}{\sigma_s}} d\phi\right]^{\frac{\sigma_s}{\sigma_s-1}}\right] = 0 \quad (5.22)$$

If we divide expression (5.20) by the expression (5.21) we obtain:

$$\frac{\frac{\sigma_s}{\sigma_s - 1}\left[\sum_k \sum_i \int_{\Omega_{si}} d_{s(ik,jl)}(\phi)^{(\sigma_s-1)/\sigma_s} d\phi\right]^{\frac{1}{\sigma_s-1}} \frac{\sigma_s - 1}{\sigma_s} d_{s(ik,jl)}(\phi)^{-1/\sigma_s} - \lambda p_{s(ik,jl)}(\phi)}{\frac{\sigma_s}{\sigma_s - 1}\left[\sum_m \sum_n \int_{\Omega_{sn}} d_{s(nm,jl)}(\phi)^{(\sigma_s-1)/\sigma_s} d\phi\right]^{\frac{1}{\sigma_s-1}} \frac{\sigma_s - 1}{\sigma_s} d_{s(nm,jl)}(\phi)^{-1/\sigma_s} - \lambda p_{s(nm,jl)}(\phi)} = 0 \quad (5.23)$$

$$\frac{d_{s(ik,jl)}(\phi)^{-1/\sigma_s}}{d_{s(nm,jl)}(\phi)^{-1/\sigma_s}} = \frac{p_{s(ik,jl)}(\phi)}{p_{s(nm,jl)}(\phi)} \quad (5.24)$$

$$d_{s(ik,jl)}(\phi) = \left(\frac{p_{s(nm,jl)}(\phi)}{p_{s(ik,jl)}(\phi)}\right)^{\sigma_s} d_{s(nm,jl)}(\phi) \quad (5.25)$$

Substituting this expression into $\frac{\partial L}{\partial \lambda} = 0$ yields the following result:

$$D_{s(jl)} = \left[\sum_k \sum_i \int_{\Omega_{si}} \left[\left(\frac{p_{s(nm,jl)}(\phi)}{p_{s(ik,jl)}(\phi)} \right)^{\sigma_s} d_{s(nm,jl)}(\phi) \right]^{\frac{\sigma_s - 1}{\sigma_s}} d\phi \right]^{\frac{\sigma_s}{\sigma_s - 1}} \quad (5.26)$$

$$D_{s(jl)} = d_{s(nm,jl)}(\phi)\, p_{s(nm,jl)}(\phi)^{\sigma_s} \left[\sum_k \sum_i \int_{\Omega_{si}} (p_{s(ik,jl)}(\phi))^{1-\sigma_s} d\phi \right]^{\frac{\sigma_s}{\sigma_s - 1}} \quad (5.27)$$

After some operations, we get the following individual demand, which still depends on the total amount of consumption in the differentiated sector *s* (D_{sj}).

$$d_{s(nm,jl)}(\phi) = D_{s(jl)} \frac{p_{s(nm,jl)}(\phi)^{-\sigma_s}}{\left[\sum_k \sum_i \int_{\Omega_{si}} p_{s(ik,jl)}(\phi)^{1-\sigma_s} d\phi \right]^{\frac{\sigma_s}{\sigma_s - 1}}} \quad (5.28)$$

Price index expression:

Before that, by inserting this equation into the total expenditure equation, we can obtain the price index for the sector *s* in region *j*, country *l*, as follows:

$$\sum_k \sum_i \int_{\Omega_{si}} p_{s(ik,jl)}(\phi)\, d_{s(ik,jl)}(\phi) d\phi = \sum_k \sum_i \int_{\Omega_{si}} p_{s(ik,jl)}(\phi) D_{s(jl)} \frac{\left(p_{s(ik,jl)}(\phi) \right)^{-\sigma_s}}{\left[\sum_m \sum_n \int_{\Omega_{si}} \left(p_{s(nm,jl)}(\phi) \right)^{1-\sigma_s} d\phi \right]^{\frac{\sigma_s}{\sigma_s - 1}}} d\phi \quad (5.29)$$

$$g_{s(jl)} D_{s(jl)} = D_{s(jl)} \frac{\sum_k \sum_i \int_{\Omega_{si}} \left(p_{s(ik,jl)}(\phi) \right)^{1-\sigma_s} d\phi}{\left[\sum_m \sum_n \int_{\Omega_{si}} \left(p_{s(nm,jl)}(\phi) \right)^{1-\sigma_s} d\phi \right]^{\frac{\sigma_s}{\sigma_s - 1}}} \quad (5.30)$$

From the previous expression we can conclude that the price index for location *j* in country *l* for sector *s* is as follow:

$$g_{s(jl)} = \left[\sum_m \sum_n \int_{\Omega_{si}} \left(p_{s(nm,jl)}(\phi) \right)^{1-\sigma_s} d\phi \right]^{\frac{1}{1-\sigma_s}} \tag{5.31}$$

Which also can be expressed as in Eq. (5.5), which is:

$$g_{s(jl)} = \left(\sum_k \sum_i \int_{\Omega_{si}} p_{s(ik,jl)}(\phi)^{1-\sigma_s} d\phi \right)^{\frac{1}{1-\sigma_s}} \tag{5.32}$$

<u>In the second step</u>, we solve for the term (D_{sj}). To do this, we maximize the consumer utility function subject to the individual budget constraint, and then we obtain the optimal quantities of demand for both differentiated sectors s = {1,2}:

$$Max.U_{jl} = D_{1jl}^{\mu_1} D_{2jl}^{\mu_2}, \tag{5.33}$$

$$s.t.\ \ g_{1jl} D_{1jl} + g_{2jl} D_{2jl} = w_{1jl} \tag{5.34}$$

where μ_2 can be expressed as well as (1-μ_1) and both terms represent the share of expenditure addressed for each sector s ={1,2}. The term w_j is the nominal wage of each inhabitant of region j country l that works in sector 1.

The Lagrangean is as follows:

$$L = D_{1(jl)}^{\mu_1} D_{2(jl)}^{\mu_2} - \lambda \left[w_j - \left(g_{1(jl)} D_{1(jl)} + g_{2(jl)} D_{2(jl)} \right) \right] \tag{5.35}$$

Differentiating this expression respect to the total demand of the two different kinds of products, depending on the industry that they belong s={1,2}, and respect to Lagrangean multiplier term, we get:

$$\frac{\partial L}{\partial D_{1(jl)}} = \mu_1 D_{1(jl)}^{\mu_1 - 1} D_{2(jl)}^{\mu_2} + \lambda g_{1(jl)} = 0 \tag{5.36}$$

$$\frac{\partial L}{\partial D_{2(jl)}} = (1-\mu_1) D_{1(jl)}^{\mu_1} D_{2(jl)}^{-\mu_1} + \lambda g_{2(jl)} = 0 \tag{5.37}$$

$$\frac{\partial L}{\partial \lambda} = \left(g_{1(jl)} D_{1(jl)} + g_{2(jl)} D_{2(jl)} \right) - w_j = 0 \tag{5.38}$$

Dividing the two first equations of the optimization problem $\left(\frac{\partial L}{\partial D_{1(jl)}} \bigg/ \frac{\partial L}{\partial D_{2(jl)}} \right)$ we get:

$$\frac{\mu_1 D_{1(jl)}^{\mu_1 - 1} D_{2(jl)}^{\mu_2}}{(1-\mu_1) D_{1(jl)}^{\mu_1} D_{2(jl)}^{-\mu_1}} = \frac{-\lambda g_{1(jl)}}{-\lambda g_{2(jl)}} \tag{5.39}$$

$$\frac{\mu_1}{(1-\mu_1)} g_{2(jl)} D_{2(jl)} = g_{1(jl)} D_{1(jl)} \tag{5.40}$$

Now we can introduce this equation into the budget constrain, and solve as follows:

$$\left(\frac{\mu_1}{(1-\mu_1)} g_{2(jl)} D_{2(jl)} + g_{2(jl)} D_{2(jl)} \right) = w_{1(jl)} \tag{5.41}$$

Isolating the term D_{2jl}, one can get the next expression:

$$D_{2(jl)} = \frac{w_{1(jl)}}{g_{2(jl)}} (1-\mu_1) \tag{5.42}$$

Coming back to the latter expression of the individual demand, we can substitute the term D_{2jl} for the previous expression and simplify part of the equation introducing the equivalent price index function.

Therefore, given the individual demand of equation (5.28), combined by the price index expression, Eq. (5.32), we obtain the next equation:

$$d_{s(nm,jl)}(\phi)=\frac{w_j}{g_{s(jl)}}(\mu_s)\frac{\left(p_{s(nm,jl)}(\phi)\right)^{-\sigma_s}}{g_{s(jl)}^{-\sigma_s}} \tag{5.43}$$

After some simplification it becomes the same as expressed in the Eq.(5.4)

$$d_{s(ik,jl)}(\phi)=\frac{p_{s(ik,jl)}(\phi)^{-\sigma_s}}{g_{sjl}^{1-\sigma_s}}\mu_s w_{jl} \tag{5.44}$$

Note that $p_{s(ik,jl)}$ may be expressed as $p_{si}\tau^{dij}(1+\rho_s)$.

5.7.2 Producer behavior: profit maximization

Labor required in the production of $x_{s(ik)}$ [71]units is:

$$l_{sik}=F+cx_{sik} \tag{5.45}$$

where *F* represents the fixed labor requirement, and *c* a constant marginal labor requirement.

Therefore, for sector 1the cost function is:

$$w_{sik}l_{sik}=w_{sik}F+w_{sik}cx_{sik} \tag{5.46}$$

where the total production dispatched to satisfy the aggregate demand ($L_{jl}d_{s(ik,jl)}$) is:

$$x_{sik}=\sum_l\sum_j x_{s(ik,jl)}=\sum_l\sum_j L_{jl}d_{s(ik,jl)}(1+\rho_{s(ik,jl)})\delta_{s(ik,jl)},\quad or\quad x_{s(ik,jl)}=d_{s(ik,jl)}\tau_{s(ik,jl)} \tag{5.47}$$

From this equation one can obtain the elasticity of substitution as:

$$\frac{\partial x_{s(ik,jl)}}{\partial p_{s(ik,jl)}}\frac{p_{s(ik,jl)}}{x_{s(ik,jl)}}=-\sigma_s\frac{p_{s(ik,jl)}^{-\sigma_s-1}}{g_{sjl}^{1-\sigma_s}}\mu_s w_{jl}(1+\rho_{s(ik,jl)})\delta_{s(ik,jl)}\frac{p_{s(ik,jl)}}{x_{s(ik,jl)}}=-\sigma_s \tag{5.48}$$

The profit equation of a given sector is:

[71] Note that, in the case of sector 2 the fixed labor required is zero, therefore the sector 2 produces under constant returns to scale.

$$\pi_{sik} = \sum_{l}\sum_{j} p_{s(ik,jl)} L_{jl} d_{s(ik,jl)} - w_{si} \sum_{l}\sum_{j} (F_s + c x_{s(ik,jl)}) \tag{5.49}$$

$$\pi_{sik} = \sum_{l}\sum_{j} (p_{s(ik,jl)} - w_{sik} c \tau_{s(ik,jl)}) L_{jl} d_{s(ik,jl)} - w_{sik} F_s \tag{5.50}$$

Profit maximization implies the followed pricing rule:

$$\frac{\partial \pi_{sik}}{\partial x_{sik}} = 0 \tag{5.51}$$

$$\pi_{sik} = \sum_{l}\sum_{j} \left(\frac{p_{s(ik,jl)}}{\tau_{s(ik,jl)}} - w_{sik} c \right) x_{s(ik,jl)} L_j - w_{sik} F_s$$

where:

$$\pi_{sik} = \sum_{l}\sum_{j} \left(\frac{p_{s(ik,jl)}}{\tau_{s(ik,jl)}} x_{s(ik,jl)} - w_{sik} c x_{s(ik,jl)} \right) L_{jl} - w_{sik} F_s \tag{5.52}$$

$$\frac{\partial \pi_{sik}}{\partial x_{s(ik,jl)}} = \frac{1}{\tau_{s(ik,jl)}} \left(\frac{\partial p_{s(ik,jl)}}{\partial x_{s(ik,jl)}} x_{s(ik,jl)} + p_{s(ik,jl)} \right) L_{jl} - w_{sik} c L_{jl} \tag{5.53}$$

$$\frac{\partial \pi_{sik}}{\partial x_{s(ik,jl)}} = \frac{1}{\tau_{s(ik,jl)}} \left(\frac{1}{-\sigma_s} + 1 \right) p_{s(ik,jl)} L_{jl} - w_{sik} c L_{jl} \tag{5.54}$$

$$\frac{\partial \pi_{sik}}{\partial x_{s(ik,jl)}} = \frac{1}{\tau_{s(ik,jl)}} \left(\frac{\sigma_s - 1}{\sigma_s} \right) p_{s(ik,jl)} L_{jl} - w_{sik} c L_{jl} = 0 \tag{5.55}$$

$$\frac{1}{\tau_{s(ik,jl)}} \left(\frac{\sigma_s - 1}{\sigma_s} \right) p_{s(ik,jl)} = w_{sik} c \tag{5.56}$$

$$p_{s(ik,jl)} = \tau_{s(ik,jl)} w_{sik} c \frac{\sigma_s}{\sigma_s - 1} \tag{5.57}$$

If we introduce the pricing rule in the profit function, we get that the optimal production in region *i* in country *k* is as follows:

$$\pi_{sik} = \sum_{l}\sum_{j} w_{sik} c \tau_{s(ik,jl)} \left(\frac{\sigma_s}{\sigma_s - 1} \right) L_{jl} d_{s(ik,jl)} - w_{sik} \sum_{l}\sum_{j} \left(F + c x_{s(ik,jl)} \right) \tag{5.58}$$

We know that each producer acts as a profit-maximizing monopolist, but free entry drives profits to zero. This condition, with the given pricing rule, implies that the output is:

$$\sum_l \sum_j w_{sik} c \tau_{s(ik,jl)} \left(\frac{\sigma_s}{\sigma_s - 1} \right) L_{jl} d_{s(ik,jl)} = w_{sik} \sum_l \sum_j \left(F + c x_{s(ik,jl)} \right) \tag{5.59}$$

$$\sum_l \sum_j x_{s(ik,jl)} \left(\frac{\sigma_s}{\sigma_s - 1} \right) c = F + c \sum_l \sum_j x_{s(ik,jl)} \tag{5.60}$$

$$\sum_l \sum_j x^*_{s(ik,jl)} = \frac{F(\sigma_s - 1)}{c} \tag{5.61}$$

Consequently, the associated labor input is

$$l^*_{s(ik)} = F + c \frac{F(\sigma_s - 1)}{c} \tag{5.62}$$

$$l^*_{s(ik)} = F \sigma_s \tag{5.63}$$

Nominal wage equation

Given the pricing rule and the quantity produced by a firm in a context of monopolistic competition, we can write:

$$x^*_{sik} = \sum_l \sum_j L_{jl} \frac{p_{s(ik,jl)}^{-\sigma_s}}{g_{sjl}^{1-\sigma_s}} \mu_s w_{jl} \tau_{s(ik,jl)} \tag{5.64}$$

and solve by origin-destination price of region *i* in country *k* to region *j* in country *l* for sector *s* as:

$$p_{s(ik,jl)} = \left[\frac{\mu_s}{x^*_{sik}} \sum_l \sum_j L_{jl} \frac{1}{g_{sjl}^{1-\sigma_s}} w_{jl} \tau_{s(ik,jl)} \right]^{\frac{1}{\sigma_s}} \tag{5.65}$$

Substitution the origin-destination price by the pricing rule, Eq.(5.57), we get

$$\tau_{s(ik,jl)} w_{sik} c \frac{\sigma_s}{\sigma_s - 1} = \left[\frac{\mu_s}{x^*_{sik}} \sum_l \sum_j L_{jl} \frac{1}{g_{sjl}^{1-\sigma_s}} w_j \tau_{s(ik,jl)} \right]^{\frac{1}{\sigma_s}} \tag{5.66}$$

$$w_{sik} = \frac{c}{\tau_{s(ik,jl)}} \frac{\sigma_s - 1}{\sigma_s} \left[\frac{\mu_s}{x^*_{sik}} \sum_l \sum_j L_{jl} \frac{1}{g_{sjl}^{1-\sigma_s}} w_j \tau_{s(ik,jl)} \right]^{\frac{1}{\sigma_s}} \tag{5.67}$$

Real wage equation

Deflating the nominal wage of worker of the sector *s* in region *i* country *k* by the cost of living index $\left(g_{1ik}^{\mu_1} g_{2ik}^{\mu_2}\right)$ we get the following real wage equation:

$$\omega_{sik} = \frac{w_{sik}}{\prod_s g_{s(ik)}^{\mu_s}} \tag{5.68}$$

5.7.3 Normalizations

Some of the equations formulated in the previous sub-sections of the Appendix can be simplified by choosing units of measurement adequate.

Total production for a firm that satisfies the total demand and the transport costs of iceberg form:

$$\sum_l \sum_j x_{s(ik,jl)} = \frac{F_s}{\left(c\left(\frac{\sigma_s}{\sigma_s - 1}\right) - c \right)} \tag{5.69}$$

After some normalizations $\left(c = \frac{(\sigma_s - 1)}{\sigma_s} \; and \; F_1 = \frac{1}{\sigma_1} \; and \; F_2 = 0 \right)$,we get:

$$\sum_l \sum_j x_{s(ik,jl)} = x^*_{sik} = 1 \tag{5.70}$$

The labor input employed:

$$l^*_{s(ik)} = F + c x^*_{s(ik)} \tag{5.71}$$

Considering the total production, the labor required is:

$$l^*_{s(ik)} = F + c \frac{F}{\left(c\left(\frac{\sigma_s}{\sigma_s - 1} \right) - c \right)} \tag{5.72}$$

After some operations we get:

$$l^*_{s(ik)} = F\sigma_s \tag{5.73}$$

After the normalization whereby the fixed labor input requirement satisfies the equation $\left(F = \frac{1}{\sigma_s} \right)$, the labor required for each firm is:

$$l^*_{s(ik)} = x^*_{s(ik)} = 1 \tag{5.74}$$

Market output: pricing rule

Initially the pricing rule had the following form:

$$p_{s(ik,jl)} = \tau_{s(ik,jl)} w_{sik} c \frac{\sigma_s}{\sigma_s - 1}, \tag{5.75}$$

but, once choosing units such that the marginal labor requirement is $c = \frac{(\sigma_s - 1)}{\sigma_s}$, this normalization means that the pricing rule equation becomes:

$$p_{s(ik,jl)} = w_{sik} \tau_{s(ik,jl)} \tag{5.76}$$

Price Index

The inclusion of the normalized pricing rule in the price index implies the transformation of the price index:

$$g_{s(jl)} = \left[\sum_k \sum_i \int_{\Omega_{si}} \left(p_{s(ik,jl)}(\phi) \right)^{1-\sigma_s} d\phi \right]^{\frac{1}{1-\sigma_s}}, \tag{5.77}$$

into the following price index:

$$g_{s(jl)} = \left[\sum_k \sum_i \int_{\Omega_{si}} \left(w_{sik} \tau_{s(ik,jl)} \right)^{1-\sigma_s} d\phi \right]^{\frac{1}{1-\sigma_s}} . \tag{5.78}$$

We also know that in each location the amount of varieties is equal to the total production, since, after some normalizations, each firm just produces one unit $\left(x^*_{sik} = 1\right)$. Due to the fact that the total amount of labor input required for any firm is also equal to one, the total production will be equal to the total number of worker in the sector. Therefore, we can substitute the integral term of the foregoing expression by the share of worker in the sector:

$$g_{s(jl)} = \left[\sum_k \sum_i \lambda_{sik} \left(w_{sik} \tau_{s(ik,jl)} \right)^{1-\sigma_s} \right]^{\frac{1}{1-\sigma_s}} . \tag{5.79}$$

Nominal wage equation:

After the normalization $c = \frac{(\sigma_s - 1)}{\sigma_s}$ the wage equation becomes:

$$\tau_{s(ik,jl)} w_{sik} = \left[\frac{\mu_s}{x^*_{sik}} \sum_l \sum_j L_{jl} \frac{1}{g_{sjl}^{1-\sigma_s}} w_{jl} \tau_{s(ik,jl)} \right]^{\frac{1}{\sigma_s}} \tag{5.80}$$

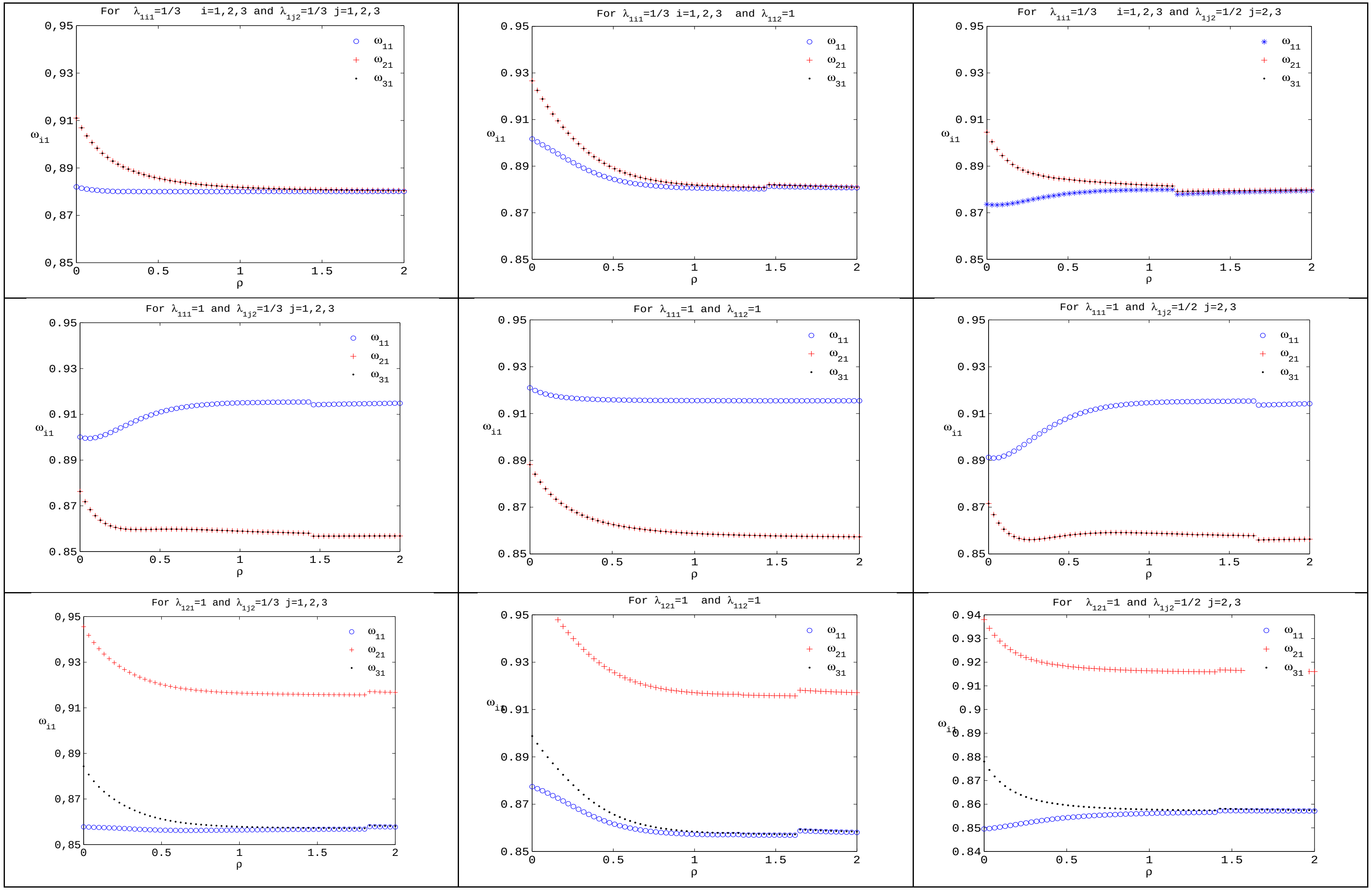
$$w_{sik} = \left[\frac{\mu_s}{x^*_{sik}} \sum_l \sum_j L_{jl} \frac{\tau^{-\sigma_s}_{s(ik,jl)}}{g_{sjl}^{1-\sigma_s}} w_{jl} \tau_{s(ik,jl)} \right]^{\frac{1}{\sigma_s}} \tag{5.81}$$

And substituting x_{sik} by its value after the normalization, the previous equation is:

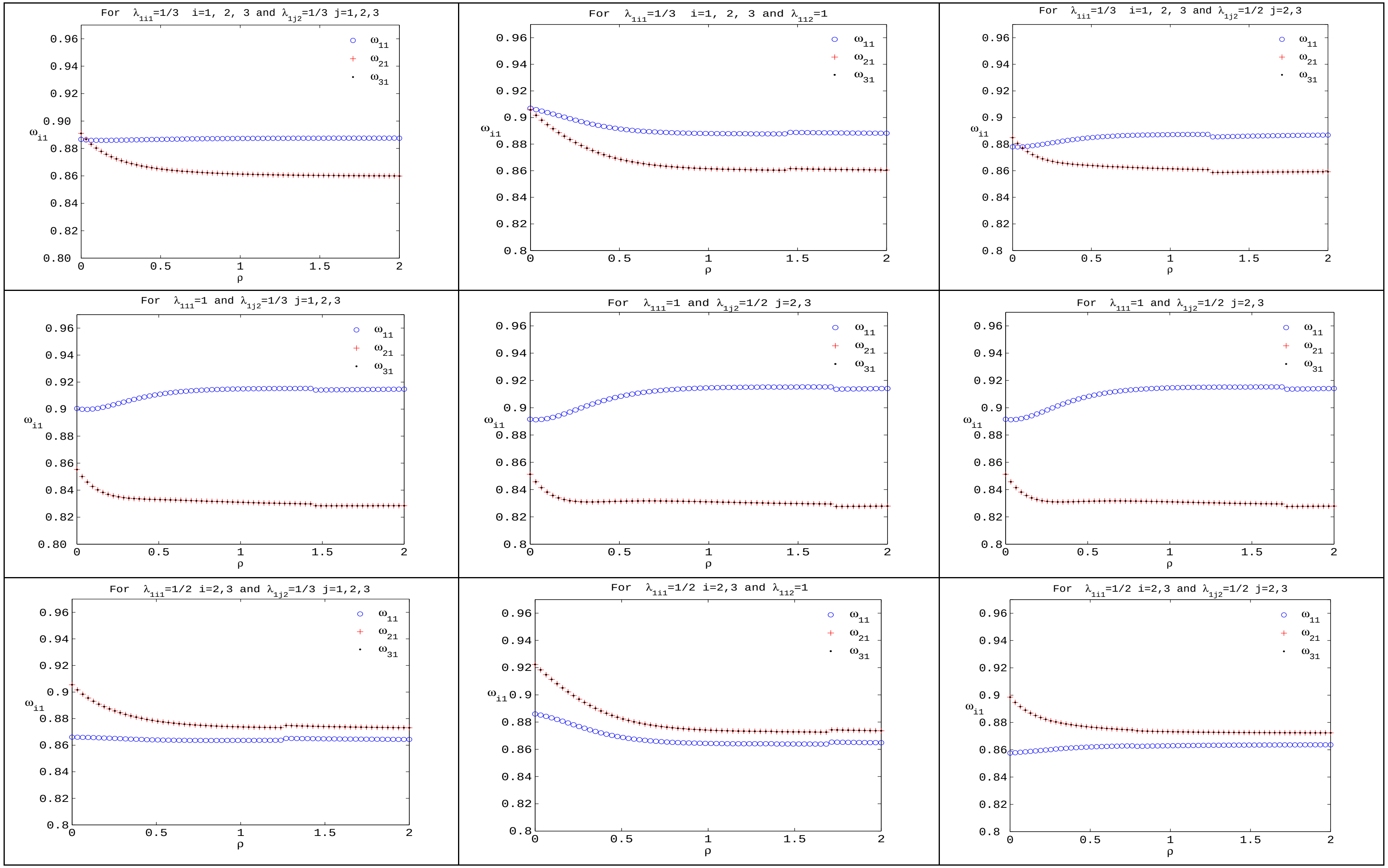
$$w_{sik} = \left[\mu_s \sum_l \sum_j L_{jl} w_{jl} \frac{\tau^{1-\sigma_s}_{s(ik,jl)}}{g_{sjl}^{1-\sigma_s}} \right]^{\frac{1}{\sigma_s}} \tag{5.82}$$

5.7.4 Analysis of the real wage in each region, given the spatial distribution of the foreign economy

Appendix Table 5.1 Real wage in each domestic region for different degrees of openness $\rho \in [0,2]$. Triangle topology in both countries.



Appendix Table 5.2Real wage in each domestic region for different degrees of openness $\rho \in [0,2]$. $t_2 = 1.275$. Triangle and star topologies, respectively.



SECTION III: FINAL REMARKS, POLICE IMPLICATIONS AND FUTURE EXTENTIONS

6 Final remarks, policy implications and future extentions

6.1 Final remarks, policy implications and future research agenda

6.1.1 Final remarks: contributions and limitations.

The aim of this Thesis Dissertation is to shed new light on the role played by borders on trade, as well as the internal effects of sharp increases in the openness ratio with respect to large markets. More specifically, the Thesis includes a set of empirical articles where, by means of the gravity equation, and a new dataset including region-to-region trade flows between the 17 Spanish regions (Nuts 2) and their counterparts in seven European countries, we obtain new estimates for the level of internal (between Spanish regions), and external (with the seven European countries) trade integration. The other objective of this Thesis is to provide a model that describes the impact of trade openness on the locational pattern of the industry within countries, taking into account the initial spatial configuration of the economies, and the network both within and between them.

From a methodological point of view the main contributions are:

i. The elaboration of a methodology to estimate trade flows at region-to-region spatial disaggregation, both within and beyond national borders in Spain. This methodology can be easily extended to other EU countries, with similar statistics on trade and freight flows;

ii. The study of various specifications and econometric techniques to find a better treatment of the non-linear effect of distance on trade, whereby we could assess the effect of the procedures applied in the estimation of the border effect, and achieve a better estimation of their values;

iii. The proposal of a theoretical model to predict the relocation of economic activity within a country, after it starts a trade opening process, given the internal and external transport network topologies. Linked to the study of the liberalization effect, we propose a model with less restrictive features, through the introduction of two sectors (one mobile and one fixed, the latter linked to land resources) that produce differentiated goods, and whose shipments incur in transport costs.

Regarding the main findings, from the descriptive and econometric perspectives, we can conclude that:

a. The existence of an undue intensity of intra-regional trade within the national boundaries of Spain (up to a factor of 4) is confirmed. However, we must be cautious in not attributing uniquely this discontinuity to pure external constrains to trade, or what has been labeled as the "home-bias" effect, with such differences being simply explained by differences in preferences. As other authors suggest, there is also room for frictions coming from information barriers and other transaction costs, but also by potential discontinuities and protectionist-type measures adopted by certain regional governments[72], something that has not been addressed in this manuscript. In our case, as far as the empirical evidence has shown, this internal border effect could be associated to some extent with the predominance of trade in short distance of homogeneous products characterized by relative high transport costs and low prices, i.e., products that are good substitutes among themselves, but with poor transportability;

b. Regarding the international trade flows, for the first time, thanks to our novel dataset, it is observed that the highest intensity of international trade agglomerates around national borders (e.g. between País Vasco or Cataluña with the border French regions). However, when computing the external effect, the largest external border effects are associated with the nearby French regions. Behind this apparent contradiction, we find that although the intensity of trade with the closest French region is large, it is far below the one that would be expected at similar distances within the country. Departing from this result, it is important to emphasize that the main markets for these two important border regions is the rest of Spain.

c. At different spatial disaggregation (either regions or countries) the results for the border effect show the persistence of national borders hampering international trade, what can be explained to a large extent by the presence of multiple geographical-historical features and political factors, which are very difficult to quantify;

d. Related to the extrapolation exercise, which estimates the number of years required by each Spanish region to achieve the same external integration than that observed within national boundaries, the results show that, according to recent Spanish growth rates in international exports with destination to the seven countries here considered, the scenario of full international integration is far from reality. These results highlight the importance

[72] In Spain, for example, there is an intense debate around the potential restrictions to the free movement of goods and services derived from specific decisions taken at the regional level (Nuts II), something that has even been commented by the OCDE and other national and international organizations, and has been object of a recent state law issued in 2012 on “The Unity of the Internal Market” (Ley de Unidad de Mercado).

of 'natural markets', and show how difficult it is that some regions could rely on international markets to drive economic activity and growth.

e. The results of our theoretical model grounded on the NEG and NTT literature, in a context of trade openness to international markets, show that trade liberalization pushes the mobile industry to border regions. As happened in Mexico when the country signed the North American Free Trade Agreement (NAFTA), where its industry came to settle in the north. However, we also observe that when the domestic network clearly favors one of the inner regions (as in the case of Madrid in Spain, which enjoys a privileged location in the home-star-network) and the economic activity is mainly concentrated in it, trade liberalization may not be enough to break up the agglomeration in the central region, no matter the spatial distribution of economic activity in the foreign country. Therefore, while a systematic analysis of sensitiveness to the value of the preference and technological parameters has not been undertaken, the uneven distribution of economic activity may persist for reasonable values of them.

However, beyond the main **contributions** of this Thesis Dissertation, the following **limitations** can be also described:

i. First, keeping in mind the novelty and interest of the data base developed and used in this study on Spanish region-to-region trade flows, a number of improvements are desirable:
   a. Our dataset includes the national and international exports/imports with origin or destination in the Spanish regions. An extension of this dataset to a larger set of regions and countries would enrich its geographical base, which would enable to address a wider variety of phenomena;
   b. Our data includes shipments by road transport mode. Although this primal mode is very representative for Spanish shipments to the considered seven EU countries, the inclusion of alternative transport modes would allow a full coverage of trade relationships. To this regard, the inclusion of air or maritime modes can be of interest for special sectors (high value/volume ratio) and regions (coastal or rich landlocked regions such as Madrid).
   c. Our initial dataset only collects information on shipments served by Spanish truckers. Though article one offers enough support for the significance of Spanish trucks when exporting to these European countries by road, the extension of these dataset to all potential truckers will be a clear improvements (e.g., Portuguese

transportation firms). Having said that, we believe that our decision of re-scaling the original dataset to match the official trade data at the region-to-country level is consistent enough to overcome the most striking source of bias when computing the external border effect.

ii. Moreover, although our empirical analyses include a large set of specifications and effects, it could also be extended to new dimensions also covered by the dataset generated in the first paper; e.g., different units of measurement (price, tons, or number of shipments), the sectoral trade, or the import side of the flows. Some of these ideas will be briefly described in the next subsection commenting future research extensions.

iii. Finally, the theoretical part could also be improved by introducing a welfare analysis so as to evaluate the effect of trade openness depending on whether the internal topology is homogeneous or heterogeneous. Also, given the obvious limitations of time and space, we were not able to undertake an empirical testing or calibration of the theoretical model with historical data on the evolution of the allocation of the Spanish exporting firms, as well as the pattern of specialization with respect of the types of products and final markets of destination. Although some speculative explorations have been done in collaboration with some colleagues, it should be extended in my future research agenda.

6.1.2 Policy implications:

- **Regarding the empirical analysis of the border effect**

Lack of information

As commented in previous sections, European researchers face strong limitations with regards to the statistical information available for analyzing the level of internal and external economic integration in any European country. For Spain, as for any other country, there is no official information on region-to-region flows taking place within the country, or between Spanish regions and the ones of our main partners in Europe. Therefore, the measurement of the evolution of the European Single Market at the regional level is a hard task, and justifies the statistical efforts of this Thesis.

In conclusion, we dare to denounce the need to improve the official statistics on trade and freight flows, with the aim of facilitating the empirical analysis of flows crossing national and international borders using alternative transport modes. In addition, we call regional, national and supra-national statistical agencies, to undertake additional efforts to produce data on shipments collected not just from transportation agents, but also from the exporter side (as the *Commodity Flow Survey* in the US). Such novel statistics should take into account the required variables and standards so as to be able to trace products from the producer to their final destination, considering intermediaries, such as wholesalers, warehouses, as well as multi-modal transport mode connections. Taking into account that such information is available in the US, Europe lags behind (and fails) in measuring and analyzing the interconnection of regional economies within Europe because of the lack of equivalent type of data. Only such information will allow assessing and monitoring the degree of trade integration both within countries and between countries, which is one of the main concerns of the European Commission.

The non-linear effect of distance and the size of partners

Based on the results obtained in Chapter 3 and 4, where the internal and external border effects were quantified, a number of recommendations can be suggested:

Firstly, regarding the use of alternative specifications of the gravity equation to tackle the non-linear relationship between trade and distance, we conclude that the fragmentation of distance is an easy and effective alternative (because it is more flexible than the usual ways) to provide an additional point of reference, while the most sophisticated procedures do not add significant changes in the results, and may be even less appropriate if the number of zeros in trade flows is relevant.

Secondly, our results suggest that distance plays a clear role against trade; however this effect is not equal for each segment of distance. In fact, once a relevant threshold is reached the negative effect of distance remains constant around a more moderate coefficient. This suggests that once the first kilometers are reached, the nature of trade flows enjoy economies of scale in transport costs, partly neutralizing the hampering effect of distance. So that, for sufficiently long distances, other factors comprised in the gravity equation play a more relevant role in explaining the intensity of trade. The smaller effect of distance is clear when analyzing the decreasing coefficients of the segmented distance variable, where the first intervals show the highest negative effects.

Thirdly, from the analysis of the border effect between the Spanish and European regions we get a better perspective of the actual trade integration both within and outside domestic markets. The analysis points out a further integration (in relative terms) of the Spanish regions with the richest and more distant European regions located in the "blue banana" (the "core" of Europe linked to the axis Milan-Paris-London), than with the nearest French regions. These results confirm that for long distance shipments, the drivers of the trade flows are more related to the size of the partners than the distance between them. These results allow us to say that although the improvement of transport infrastructure is a necessary element to foster trade relations, it is not enough. In fact, once the infrastructure is done, the drivers of trade are the capacity of production and/or consumption of the partners. By contrast, the results for Portuguese regions tell us that their integration with Spanish regions is the highest. This is because partners on both sides of the border are of a similar size, and given the short distance between them, their trade intensity is similar to the one between Spanish regions of equal size and proximity.

In conclusion, the size of the origin and the destination economies, together, is a crucial factor in international trade relationships. So that if one of the beliefs of national and supranational authorities (e.g., the EU) is that trade integration reduces inter-regional disparities, it turns out that the economic development of the regions should be promoted before undertaking trade openness. Other alternative that gives a larger degree of attractiveness to a region are its transport connections. As we observe from the theoretical model, locations with better accessibility (either inner or border regions) are able to bring higher real wages at the expense of the most remote, and consequently, lagging regions.

Achieving an international trade integration without barriers

Additionally, with the information on the actual international exports of the Spanish regions to their European counterparts, and with the estimation of these flows, taking as reference the parameters of the gravity equation estimated for the domestic economy, we performed a naïve exercise that quantifies the number of years that would take each Spanish region to get the same level of international integration with their main European partner as that existing with the other domestic regions. The exercise considers two alternative scenarios according to different trends of growth of Spanish exports to the seven European countries considered. The first scenario regards the evolution of the Spanish exports before the 2008 crisis; i.e., it includes the growth rates observed in the exports of each region from 2001 to 2008. The second scenario is based on the evolution of Spanish exports after the peak of the crisis, from 2011 until 2013. The main results of this analysis were:

a. To get a similar level of trade integration between Spanish and European regions to the existing levels between Spanish regions, international exports should increase more than can be reasonably expected, so the completion of a fully integrated single market as in national economies should not be expected.

b. Indeed, considering the growth rates of regional exports to the countries concerned, and according to the two scenarios described, we observe a wide range of years that, on average, each Spanish region would take to match the same level of integration with the EU than within Spain. These range from a minimum of 30 years for Galicia and a maximum of 1,337 years for Asturias.
c. In all cases, these numbers are relevant in highlighting that: i) the presence of significant differences in the ability to penetrate (and stay) in foreign markets, despite being very close; ii) any additional points and how trade integration in different national markets may require a major effort. In some cases such as Asturias, this figure could be between 400 and the aforementioned 1,337 years.

In our opinion, these dramatic figures, obtained under conservative assumptions, illustrate the role of the internal and external borders, and provide an important reference to the debate on what should be regarded as the natural market for most of the regions, even after years of active policies designed to smooth the effects of external barriers to trade between countries. Although it is not explicitly measured, one of our tables also shows the number of zero flows that each Spanish region has registered when trading with regions in other countries. This fact, being a proxy for the extensive margin of trade, suggests that if the European countries and the European Commission want to achieve a rapid expansion of the European Single Market, a first goal would be to extend the number of regions trading in Europe (rising connectivity), as well as the promotion of the number and value of shipments between them. The large number of trade zeros observed with regions of the nearest countries speaks out about the lack of historical interaction between a large set of sub-national units in regions. This result also suggests that the deepening of the European market integration is, for some sectors, a matter concerning and restricted to the leading regions, rather than a generalized process that reaches all regions and industries.

- **Policy implications: Modelling the effect of trade liberalization in the distribution of economic activity of a country**

The results from this chapter show that, in general, trade openness tends to bring higher growth rates in the real wages in the locations closer to the foreign markets. However, if the initial topology endows one of the inner regions with a privileged position in the domestic network (e.g., a star configuration), the openness process does not have to break up this configuration and we could observe two kinds of core locations (border regions or well-connected regions in the domestic country) against the periphery locations (neither at the border nor well connected).

Trade openness trade and the external border effect

Given these findings, we might ask to what extent this phenomenon can be happening within the EU; i.e., how some border or inner hub-spoke location have consolidated their economic growth at the expense of lagging or peripheral regions, and how this process can be linked to our estimations of the external border effect by region of destination. Undoubtedly, to study these relations we should control many other factors, but here we just want to remark that one could expect a parallelism between the results of both analyses. Therefore, we might formulate the following question:

To what extent could we believe that the external border effect estimates respond to the relocation of part of the industry in Europe as consequence of the European integration process?

From the conclusions of the theoretical model, one would expect that for the case of the European Union, the largest shares of economic activity concentrate in the initial hub locations and in the borders close to the richest countries. In the case of Spain, in fact the wealthiest regions are nearby the French border or in costal locations; but also Madrid, in the center of the country, is one of the richest regions as a result of being the administrative capital of the country. In general terms, within Europe this pattern is repeated in many of the countries considered in the analysis (Italy, France, UK, Germany, etc.). As previously mentioned, a good example of this phenomenon is the group of regions in Europe constituting the "blue banana".

Turning to the results of the border effect, they show that the negative effect of distance vanishes once it exceeds a threshold of approximately 1,000 kilometers; gaining importance then the effect of size of the emitting and receiving regions. Specifically, we found lower border effect estimates when the destination of the shipment is in the European "core". According to the results of our model, among other factors; e.g., those related to "first nature" geographical locations, natural resource endowments, and historical facts, we can believe that the cluster location of the richer regions can be the results of the trade integration process combined with first nature elements, that are later reinforced by agglomerating (centripetal) forces; e.g., increasing returns in production. Therefore, to get a more integrated commercial area, policy makers should have in mind the effect of trade openness, and its relation with a suitable transport infrastructure policy; i.e., the design of an appropriate network in terms of regional accessibility, so as to try to compensate the expected agglomeration effects over the border regions.

6.1.3 Future research agenda

In this section we summarize the main lines for future research. Some of them have a direct relation with the work done along this Thesis, others, though also related to trade, have emerged in parallel to the present work, and are more related to the logistic complexity, and the effect of re-exporting flows in the estimation of the border effect. This last branch of research has taken place through the collaboration with other colleagues.

i. Modeling the region-to-region international trade flows using an extended gravity equation that embeds the endowment variables suggested by Heckscher Ohlin (1933).

As a natural extension of chapter one, our novel dataset with international trade flows at the region-to-region level will be modeled with an extended gravity model, which allows controlling for the endowment of (first nature) production factors, and a number of geographical variables available for all the European regions.

ii. Sectoral analysis of the distance effect, and the internal and external border effect.

The aim of this extension is twofold: On one hand, we attempt to identify irregularities in the estimation of the border effects depending on the specific sector considered; and, on the other hand, we want to control for differences in the effect of distance subjected to the physical nature of the products of each sector. This analysis will also allow identifying different effects that may explain the border effect, such as the elasticity of distance (transportability of the products) and the home bias (differences in preferences).

iii. Analysis of intensive and extensive margin within and across national borders by sector, and its evolution before and after the current economic crisis.

This study will go a step forward to the one described above, since it aims at identifying the type of commercial relations of the Spanish regions (i.e., intensive versus extensive), depending on the destination market (intra-regional, national or international) and the particular sector. This line of research attempts to test two hypothesis: i) whether short shipments characterized by a high frequency in repetition and/or low economic value that are concentrated within national boundaries are particularly important, while in the case of international trade, shipments are less frequent, but contain a higher economic value (i.e., the predominance of the intensive margin over the extended one in this latter case); ii) whether domestic shipments are more related to more homogeneous and heavier products (low value/weight ratio), while international shipments concern differentiated and lighter products (high value/weight ratio)

iv. Empirical development of the theoretical model developed in this Thesis, building on the New Trade Theory and New Economic Geography frameworks.

Before analyzing the case of Spain empirically, in the theoretical paper we want to introduce a welfare indicator, so that we could evaluate more precisely the welfare effects of the reallocation of economic activity as a consequence of trade openness, given the national and international network topologies, and the initial distribution of the industry. In a second stage, we will study to what extent the spatial economic configuration of the Spanish economy can be explained by the long and consolidated trade agreements within the EU. For this last phase, we will use a more detailed dataset, recently completed, that encompasses a higher level of spatial disaggregation of intra-national trade flows (municipal data), and also higher disaggregated international trade flows (municipality-to-province).

v. Intermodal competition in the domestic market.

As previously mentioned, in parallel to this Thesis and in collaboration with other colleagues, a number of works were started with the aim of disentangling the logistical complexity of trade, which requires our detailed micro-data.

On one side, we study the limitation of the transport statistics when this information is used as a proxy of trade given the existence and importance of re-exportation flows, what implies that an actual trade flow can be registered twice. To study this issue, we propose a more complex specification that controls for hub-spoke structures inside of the country, the presence of international transit flows, and the existence of logistics and freight centers, such as wholesalers or warehouses.

On the other side, we are currently analyzing how the different transport modes can compete or complement to each other in domestic shipments. Thanks to this analysis we are to understand the role of each transport mode, depending on the distance developed.

Methodologically, we analyze how the different transport modes (road, rail, ship and airplane) compete with, or a complements to each other, for different thresholds of the distance variable. With this analysis we want to shed more light on this research field and provide strategies for policy making. This novel line of research has already produced a number of papers, linking the literature of spatial econometrics and the gravity equation. Some of them are close to publication (Gallego et al. 2015; Llano et al., 2015; Díaz-Lanchas et al. 2015).

6.2 Conclusiones y principales contribuciones (in Spanish)

La principal motivación de esta Tesis es la de arrojar luz sobre el papel que juegan las fronteras administrativas como restricciones al comercio de bienes dentro y fuera de un país. Así mismo, se quiere analizar, desde un punto de vista más teórico, la influencia que tiene la apertura comercial de un país, respecto a un mercado exterior influyente, en la distribución interna de la actividad económica. De forma más particular, esta Tesis introduce un conjunto de trabajos empíricos que, a través del uso de la ecuación gravitatoria y gracias a la estimación de una novedosa base de datos que incluye información del comercio interregional entre la 17 regiones españolas (Nuts 2) y entre éstas y sus homólogas europeas de los siete principales socios Europeos del país, nos permite obtener estimaciones inéditas del nivel de integración interno (entre las regiones españolas) y externo (con los siete países Europeos) del país. El otro objetivo de esta Tesis es proporcionar un modelo teórico capaz de describir el impacto de la apertura comercial en el patrón de localización de la industria dentro de los países. Con este modelo hemos demostrado como resultan ser factores clave: por un lado, la distribución de la actividad económica previa a la apertura, y por otro, la configuración de la red de transporte de los países en cuestión.

De forma breve, desde el ámbito metodológico, se puede decir que las principales aportaciones de esta Tesis Doctoral son:

i) La propuesta de una metodología dirigida a la estimación de los flujos de comerciales a nivel región-región, tanto dentro como fuera de las fronteras españolas. Dicha metodología, cuenta con la ventaja de que puede ser fácilmente replicable por otros países miembros de la UE con similares estadísticas de transporte y de comercio;

ii) El estudio de varias especificaciones y técnicas econométricas encaminadas a encontrar un mejor tratamiento del efecto no-lineal de la distancia sobre el comercio de bienes, y así lograr una estimación más precisa del resto de parámetros de interés, como son los efectos fronteras;

iii) La formulación de un modelo teórico capaz de predecir los efectos en términos de relocalización de la actividad económica dentro de un país, como consecuencia del inicio de un proceso de apertura comercial. Para ello se estudian distintas topologías internas completamente opuestas (la homogénea y la centralizada). Dicho modelo teórico cuenta con la ventaja de incluir ciertas características que lo hacen menos restrictivo que otros, como son la consideración de dos sectores (uno móvil y otro fijo, este último ligado a los recursos de la tierra) donde ambos producen bienes diferenciados e incurren en costes de transporte en sus envíos a otras regiones.

En relación a los principales resultados obtenidos, respecto al análisis descriptivo de los datos y al análisis econométrico, podemos concluir que:

a. El comercio intra-regional es muy superior al interregional dentro de las fronteras nacionales (alcanza un factor de 4). Sin embargo, debemos ser precavidos en atribuir de forma univoca este valor al efecto "home-bias" (sesgo hacia los productos intra-regionales), según el cual dicha discontinuidad en los niveles de comercio sólo responde a las preferencias de los individuos hacia productos locales. Tal y como otros autores han sugerido, detrás del efecto frontera interno (dentro de un país), pueden haber otros elementos, tales como: asimetrías en la información, lo que incrementa los costes de transacción, o incluso el propio sesgo que podría estar introduciendo, por ejemplo en España, determinadas políticas regionales que podrían estar estableciendo trabas sutiles al intercambio de bienes o servicios dentro del mercado interior, algo que ha dado lugar a un intenso debate y a una reciente ley sobre la unidad de mercado.. Según nuestros resultados, este efecto frontera podría estar asociado con la predominancia de flujos comerciales que recorren cortas distancias, y que habitualmente se caracterizan por transportar productos poco diferenciados y con un elevado ratio volumen/precio.
b. Respecto al comercio internacional, por primera vez, gracias a la nueva base de datos desarrollada en esta Tesis, se ha podido comprobar como la mayor intensidad de comercio internacional se concentra en las regiones vecinas, (por ejemplo, entre País Vasco o Cataluña y la frontera con Francia). Sin embargo, en la estimación del efecto frontera exterior desglosado por país y/o región de destino, los mayores valores del efecto frontera han sido encontrados en las regiones francesas más próximas. Detrás de esta aparentemente contradicción, los resultados de la estimación de la ecuación de gravedad nos han mostrado que este hecho se debe a que, pese a que el comercio con las regiones francesas es muy elevado, éste está muy por debajo de lo que cabría esperar, dada la cercanía de estas regiones y el tamaño similar que éstas tienen en comparación con otras regiones españolas, las cuales perciben un mayor volumen de exportaciones desde las dos principales regiones exportadoras próximas a la frontera Francesa (Cataluña y País Vasco).
c. Ante diferentes niveles de desagregación (regiones o países) los resultados para la estimación del efecto frontera exterior muestran de forma persistente el impacto negativo de las fronteras internacionales, que constituyen un freno al comercio incluso dentro de una misma área comercial, como es la UE, y que posiblemente también sean fruto de múltiples factores geográficos, históricos y políticos, de muy difícil cuantificación;
d. En relación al ejercicio de extrapolación, el cual estima el periodo que necesitarían las

regiones españolas para alcanzar un nivel de integración con las extranjeras similar al intra-nacional, hemos constatado que al ritmo de crecimiento de las exportaciones españolas en los últimos años, el escenario de plena integración está muy lejos de ser una realidad. Estos resultados remarcan la importancia de los “mercados naturales”, y lo difícil que podría resultar para las regiones españolas apoyar su crecimiento únicamente en el mercado exterior.

e. Los resultados de nuestro modelo teórico, que combina la literatura NTT y NEG en un contexto de apertura comercial, muestran que el efecto de la liberalización comercial empuja al sector móvil hacia las fronteras del país. Tal y como pasó en la economía de México cuando el país firmó el Tratado de Libre Comercio de América del Norte (NAFTA, según sus siglas en inglés), donde su industria pasó a ubicarse en el norte del país. Sin embargo, hemos observado que cuando la red favorece a una de las regiones centrales (como sería el caso de Madrid en España, que goza de una situación privilegiada en la red doméstica), la apertura comercial no tiene por qué significar la ruptura de la aglomeración en dicha región central. Por lo tanto, ante este tipo de red centralizada, y aunque no hemos llevado a cabo un análisis sistemático de la sensibilidad de los resultados ante cambios en los parámetros que definen las preferencias de los individuos o la estructura de costes de los sectores, podemos creer que la distribución desigual de la actividad económica puede persistir para un rango razonable de estos parámetros.

Sin embargo, más allá de las importantes contribuciones de esta Tesis, somos conscientes de la persistencia de algunas limitaciones, las cuales se pueden resumir de la siguiente manera:

i. En primer lugar, pese a la gran novedad que supone la nueva base de datos aquí descrita, para el estudio de las relaciones comerciales españolas a nivel región-región, una serie de mejoras serían deseables:
   a. Nuestra base de datos incluye las exportaciones/importaciones nacionales e internacionales con origen o destino español y las regiones de los 7 países europeos más relevantes para el comercio de España. Una extensión de esta base de datos sería la consideración de los flujos regionales entre otros orígenes y destinos europeos, lo que enriquecería la dimensión geográfica de dicha base de datos, y permitiría abordar un mayor rango de análisis;
   b. Nuestra base de datos únicamente incluye los envíos transportados por carretera. Aunque este es el principal modo de transporte para el caso de la economía española en relación con los destinos aquí considerados, la incorporación de alternativos modos de transporte proporcionaría una mayor cobertura de las

relaciones comerciales. En este sentido, el transporte marítimo, por tren y aéreo serían de especial interés para el análisis de algunos sectores especiales (elevado ratio valor/volumen) y para aquellas regiones costeras o interiores bien conectadas por avión o tren, como Madrid.

c. Nuestra base de datos, inicialmente sólo contaba con los envíos realizados por camiones españoles. En el capítulo relativo a la elaboración de la base de datos, se mostró que el porcentaje de envíos realizados por transportistas nacionales era suficientemente importante. Sin embargo, la incorporación de otros transportistas (por ejemplo, portugueses, franceses, etc.) supondría una clara mejora en la representatividad de nuestra base de datos, particularmente para el caso del comercio internacional. En consecuencia, creemos que la propuesta de realizar un re-escalamiento de los flujos internacionales conforme al dato oficial (a nivel región-país) fue una decisión adecuada para reducir, el la medida de lo posible, sesgos en la estimación del efecto frontera con el exterior.

ii. Adicionalmente, aunque nuestro trabajo empírico incluye un amplio rango de especificaciones, el análisis se podría haber ampliado a través de varias dimensiones, dada la riqueza de la base de datos; por ejemplo, a través del estudio de las distintas unidades de medida (precios, toneladas o número de envíos), o el análisis pormenorizado según los distintos sectores económicos, o también mediante la cuantificación del efecto frontera para el caso de las importaciones españolas. Sin lugar a dudas, estos asuntos pendientes forman parte de lo que será la futura agenda de trabajo que se desarrollada en la fase postdoctoral.

iii. Finalmente, en cuanto al apartado teórico de esta Tesis, creemos que el trabajo realizado debería ir acompañado con la incorporación de un indicador capaz de evaluar el nivel de bienestar, asociado al nivel de apertura comercial. Adicionalmente, se llevará a cabo una aplicación empírica del modelo, con la que se pretende calibrarlo según los datos de la economía española. Para ello, se tendrán en cuenta datos históricos que permitan mostrar la evolución de la localización de las empresas exportadoras, al igual que se identificarán los sectores típicamente exportadores, y los principales destinos europeos a nivel regional.

6.3 References

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