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Economic Geography, Network Infrastructure and Institutions: Implications for Agglomeration and Trade

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Chapter 1

Introduction

Economic geography is the study of where economic activity takes place and what are the underlying forces explaining it. To the traditional questions that economics aims to answer — *what* to produce, *how* to produce, and *for whom* to produce — economic geography adds a new important one: *where* to produce.

The roots of economic geography have to be found in location theory – also known as spatial economics. The origins of location theory are found in the 1826 Johann Heinrich von Thünen's book, "The Isolated State", in which there is a central large isolated town and, based on a land-rent gradient, he studies how different crops are grown and commercialized across the rural landscape surrounding the town.

Among the foundations that conform the huge body of spatial economics literature we must highlight: urban economics (Alonso, 1964), as a generalization of the Thünen (1826) ideas to an urban context; spatial price policy (Launhardt, 1885; Hotelling, 1929); agglomeration of the economic activity (Marshall, 1890); industrial location (Weber, 1909), market areas (Lösch, 1940), and central place theory (Christaller, 1933).[1]

The so called New Economic Geography begins with the pioneering works of Krugman (1991a,b) and Krugman (1995), and since them it has attracted great attention from many researchers, especially since the publication of the book "The Spatial Economy: Cities, Regions, and International Trade" by Masahisa Fujita, Paul Krugman and Anthony J. Venables in 1999. The importance of new economic geography has been remarked by the concession of the Nobel Prize in economics to Paul Krugman in 2008 "for his analysis of trade patterns and location of economic activity" and by the publication of the 2009 World Development Report by the World Bank focusing on "reshaping economic geography".[2] [3]

Following Dixit and Stiglitz (1977), the main modelling architecture of new trade theory and new economic geography is the combination of "love for variety" preferences on the demand side, and increasing returns within a monopolistic competition market structure on the supply side, along with iceberg transportation costs, and factor mobility, which leads to non-linear models (that are not

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[1] For a detailed historical development of spatial economics see Fujita (2010).

[2] `http://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/2008/press.html`

[3] `https://openknowledge.worldbank.org/handle/10986/5991`

analytically tractable) and adopts an evolutionary approach towards the equilibrium. This leads to the well-known motto of "Dixit-Stiglitz, Icebergs, Evolution, and the Computer".[4]

New economic geography models have its roots on new trade theory. In contrast to the neoclassical trade theory, where trade flows are analyzed on the roots of comparative advantage given from technological differences (Ricardo) or factor endowment (Heckscher-Ohlin), the new trade theory analyze trade flows in a setting with increasing returns to scale, love for variety and monopolistic competition (Krugman 1979, Krugman 1980, Krugman and Venables 1990). That is, a Dixit and Stiglitz (1977) modelling framework. This new framework is compatible with the empirical evidence that intra-industry trade – trading different varieties of the same good – are increasing in importance with respect to inter-industry trade – trading different kinds of goods. From these model, a gravity equation can be obtained and estimated in order to assess empirically the determinants of the trade flows and how trade barriers restraint international trade (Anderson and van Wincoop, 2003).

Although a good geographic location gives a competitive advantage favoring the location and agglomeration of economic activity, countries, regions and cities have found ways to overcome and reshape it. There are three mains ways of doing that. First, is via transportation infrastructure as a way to change geography. The second one is by technological progress, since innovations that rise labor productivity foster the agglomeration of economic activity (Tabuchi, Thisse and Zhu, 2014). Third is by developing well-functioning institutions that favors the attraction of economic activity by securing property rights and investments, and ensuring government effectiveness, control of corruption, law enforcement, and political stability.

This is precisely what this dissertation aims to address focusing on transportation infrastructure and on institutions. Resorting to network theory we are able to model the transportation infrastructure of a country and, depending on the network topology, determine how economic activity is (un)evenly distributed across the space. This allows us to draw policy implications on how infrastructure policies should be targeted to increase cohesion between regions. By considering institutional quality as a trade barrier, we address how national institutions affect the magnitude and content of sectoral production and its associated bilateral trade flows. The insight that institutions are important in determining trade flows is fundamental since trade is one of the main roots of agglomeration economies, and knowing the effect of institutions on trade will allow us to understand how institutions are important in determining the location of the economic activity.

The dissertation consists of three chapters, each of them written following the style of an academic paper, with their introduction, literature review, methodology, results and conclusions. In the last chapter, we present general conclusions of the whole dissertation. Now we present a brief resume of each of the three main chapters.

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[4] See Fujita and Krugman (2004) for an extensive discussion about the roots, the state of the art and the future of the new economic geography.

Chapter 2: “The Multiregional Core-Periphery Model: The Role of the Spatial Topology”

The real world shows that economic activity is distributed unevenly across locations, both at the national, regional and urban levels. One of the most important explanations for that uneven distribution is geography, Krugman et al. (2011). Economic forces are influenced by the economy’s spatial characteristics, as both “first nature” geographical determinants and “second nature‘” economic factors (consumer and firm behavior, market structure, pricing rules, etc.) shape the particular distribution of economic activity in a given space. The aim of the present study is to generalize the well-known canonical model of the new economic geography by analyzing systematically the effect of different geographic configurations on the location patterns of economic activity.

We use the multiregional core-periphery model to analyze and compare the agglomeration and dispersion forces shaping the location of economic activity for a continuum of network topologies – spatial or geographic configuration – characterized by their degree of centrality, and comprised between two extremes represented by the homogenous (ring) and the heterogeneous (star) configurations. Resorting to graph theory, we systematically extend the analytical tools and graphical representations of the core-periphery model for alternative spatial configurations, and study the sustain and break points. We unveil new phenomena such as the infeasibility of the dispersed equilibrium in the heterogeneous space, resulting in the introduction of the concept “pseudo flat-earth” as a long-run equilibrium corresponding to an uneven distribution of economic activity between regions.

Using the analytical tools and graphical representations of the traditional framework of the new economic geography, and considering both the homogeneous and the heterogeneous spaces topologies for the case of four regions, we analyze the range of transportation costs up to which agglomeration is sustainable, the sustain point, and the level of transportation costs under which the dispersion of the economic activity is broken, i.e., the break points.

As expected, computing simulations show that agglomeration of the economic activity in a region with a locational advantage, the central region in the space topology, is sustainable over higher transportation costs that when the economic activity is concentrated on a periphery region or in a region of a homogeneous space.

A flat-earth equilibrium, in which all regions have the same share of economic activity, is only possible in a homogeneous space, whereas in a heterogeneous space topology the full dispersed long-run stable equilibrium for high values of transportation costs will correspond to a “pseudo flat-earth” where the regions with a locational advantage having a slightly more economic activity than the periphery regions. The difference in share of manufacture between the central regions and the periphery regions will depend on the level of transportation costs. We then show that the full dispersed equilibrium is broken earlier in a heterogeneous space topology precisely due to the existence of regions with locational advantages.

The results obtained have important implications for transportation and infrastructure policies intended to promote territorial cohesion across regions in terms of a more egalitarian income distribution. Full cohesion is not possible unless transport costs are equalized across all regions (e.g., by way of infrastructure investment), and therefore transportation and infrastructure policies should take this into account. Furthermore, we can assess these policies aimed at equalizing the relative position of all the regions by transforming a heterogeneous network into a less heterogeneous one; i.e., determine how successful they are in reducing the economy's centrality and the location patterns of economic activity.

Chapter 3: "Industry Location and Wages: The Role of Market Size and Accessibility in Trading Networks"

We investigate the geographical distribution of economic activity and wages in a general equilibrium model with many asymmetric regions and costly trade. As shown by extensive simulations on random networks, local market size better explains a region's industry share, whereas accessibility better explains a region's wage. The correlation between equilibrium wages and industry shares is low, thus suggesting that the two variables operate largely independently. The model replicates well the spatial distribution of industry using Spanish data, yet overpredict changes in that distribution due to changes in 'generalized transport costs'. The latter had only small impacts on changes in the geographical distribution of economic activity in Spain from 1980 to 2007.

Since general analytical results as those presented in Behrens and Ottaviano (2011) cannot be derived when trade costs are asymmetric across a large number of regions, we simulate the model for a large number of random trading networks and explore its numerical properties. We pay particular attention to the case where factor prices are not equalized, and to the network properties of the trading system—including both transport related and non-transport related costs (e.g., tariffs).

Our key findings are that local market size is crucial in explaining a region's industry share, whereas accessibility is crucial in explaining a region's wage. The correlation between equilibrium wages and industry shares is rather low, thus suggesting that the two adjustment channels work largely independently. A model with two differentiated sectors is also computed and we find that in this case localization of the economic activity for each sector is driven mainly by the share of expenditure in that sector whereas wage levels are more dependent on the network topology. We also apply the model without factor price equalization to the case of Spain – using Generalized Transport Costs between regions as a measure of trade frictions – and perform some counterfactual analysis for changes in the trading network.

In the analysis, growing random tree networks are generated using two alternative algorithms: equal probability attachment, and the Barabasi-Albert (1999) method with preferential attachment. Correlation results are different between networks generated using these two algorithms, being network characteristics -— represented by the centrality measures of node degree and node closeness — more important in determining the equilibrium of firms in the case of networks generated with preferential attachment.

Specifically, two trade models are considered. The first model assumes one homogeneous sector and one differentiated CES sector without factor price equalization (FPE). The second model allows for two differentiated sectors with CES preferences. In this latter case, industry shares for each sector are determined mainly by the share of expenditure in both sectors in each region, whereas wages are determined mainly by network characteristics and by population shares.

We solve the model without factor price equalization to the case of Spain and compute alternative spatial equilibria using Generalized Transport Costs and population data corresponding to 1980 and 2007 for the 47 NUTS-3 peninsular provinces. We decompose the change in the spatial location of economic activity between the base-starting period (1980) and the final period (2007) into two mutually exclusive components corresponding to a) changes due to the improvements of the transportation infrastructure (resulting in an uneven reductions of transportation costs between regions), and b) the change in population shares. Proceeding this way we obtain a measure of the individual impacts that the transportation infrastructure policy and demographic trends have had in the spatial distribution of economic activity in the last three decades. When applying the two models to Spanish data – using Generalized Transport Costs between regions as a measure of trade frictions – we find that the models generally predict well the distribution of industries, yet predict less well the spatial patterns in wages. The latter may be due to the fact that GDP per capita – though often used in the literature – is a rather crude proxy for wages. It may, however, also be linked to the fact that regional differences in accessibility are generally less pronounced than regional differences in population shares. Thus the second effect may dwarf the former in the applications.

Chapter 4: "Does Institutional Quality Matter for Trade? Institutional Conditions in a Sectoral Trade Framework"

The role of institutions as a driver of economic development has been attracting considerable attention in the literature on long-run economic growth (Acemoglu et al., 2005; Rodríguez-Pose and Storper, 2006; Rodriguez-Pose, 2013). There is, however, much less on the link between institutions and trade and our knowledge about how the local quality of institutions impinges on trade trends remains rather limited. This paper aims to address this gap in the literature from a theoretical and empirical perspective in order to assess a) whether local institutional quality affects the dimension of trade by any given country; and b) whether the impact of institutions has been waxing or waning with time. To provide a theoretical foundation to the gravity equation, we propose a model that considers Anderson and van Wincoop's (2003) multilateral resistance framework within a new trade theory model that includes as determinants of trade a labour competitiveness measure in origin (in terms of productivity and wages) and sectoral income shares at destination, as well as the institutional conditions in the countries of origin and destination. From an applied perspective we compile the most comprehensive and representative database of sectoral trade flows. It contains data on trade on tangible goods as well as services, covering 186 countries over the period between 1986 and 2012.

We hypothesise that better quality institutions reduce transaction costs and contribute to increase the volume of international trade. Institutions are introduced in two different ways: 1) as a barrier at destination, and 2) as the difference between the institutional indicators in origin and destination, which constitutes a measure of institutional distance. Geographical distances, common border, and language are also accounted for, so as to control for additional transport costs and trade barriers.

The results of the analysis confirm the hypothesis that the quality of institutions at destination matter for trade. With the exception of political stability and voice and accountability, all institutional variables considered in the analysis are closely connected to trade trends. The better the institutional quality in the country of destination, the greater the bilateral trade. This effect is particularly strong for control of corruption, government effectiveness, rule of law, and regulatory quality. Hence, improvements in institutional quality have a positive impact on trade.

Results also indicate that countries with a similar institutional quality trade more, meaning that smaller gaps in institutional distance lead to a reduction in transaction costs. These results are robust to analyzing the role of institutions by trade sectors separately – agriculture, industry and services, with the latter being more sensitive to institutions. Our results also show that the role of institutions for trade has changed over time. Contrary to expectations, the role of institutions seems to have diminished over the time, possibly as a consequence of the rise in commodity trade over the period of analysis.

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Chapter 1

Introducción (in Spanish)

La economía geográfica es el estudio de dónde tiene lugar la actividad económica y cuáles son las fuerzas subyacentes que lo explican. A las cuestiones tradicionales que la economía intenta resolver — *qué* producir, *cómo* producir, y *para quién* producir — la economía geográfica añade una nueva e importante: *dónde* producir.

Las raíces de la economía geográfica se encuentran en la teoría de la localización — también conocida como economía espacial. Los orígenes de la teoría de la localización se ecuentran en el libro de 1826 de Johann Heinrich von Thünen, "The Isolated State", en el que hay un largo y aislado pueblo central y, basándose en el gradiente de renta de la tierra, estudia cómo diferentes cultivos crecen y se comercializan a lo largo del paisaje rural que rodea al pueblo.

Entre los fundadores que conforman la basta literatura de la economía espacial se deben destacar: la economía urbana (Alonso, 1964), como una generalización de las ideas de Thünen (1826) a un contexto urbano; la política de precios espacial (Launhardt, 1885; Hotelling, 1929); la aglomeración de la actividad económica (Marshall, 1890), localización industrial (Weber, 1990), áreas de mercado (Lösch, 1940), y la teoría de los lugares centrales (Christaller, 1933).[1]

La llamada Nueva Economía Geográfica empieza con los trabajos pioneros de Krugman (1991a,b) y Krugman (1995), y desde entonces ha atraído una enorme atención por parte de multitud de investigadores, especialmente desde la publicación del libro "The Spatial Economy: Cities, Regions, and International Trade" de Masahisa Fujita, Paul Krugman y Anthony J. Venables en 1999. La importancia de la nueva economía geográfica ha sido reconocida por la concesión del Premio Nobel en economía a Paul Krugman en el año 2008 "por sus análisis de los patrones de comercio y la localización de la actividad económica" y por la publicación en el 2009 del Informe sobre el Desarrollo Mundial por el Banco Mundial centrándose en "Una nueva geografía económica".[2] [3]

Siguiendo a Dixit y Stiglitz (1997), la principal arquitectura de modelado de la nueva teoría del comercio internacional y la nueva economía geográfica es la combinación de "preferencia por la variedad" en el lado de la demanda, y rendimientos crecientes con una estructura de mercado de competencia monopolística en el lado de la oferta, junto con costes de transporte *iceberg*, y mobilidad

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[1] Para una historia detallada sobre el desarrollo de la economía espacial ver Fujita (2010).

[2] `http://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/2008/press.html`

[3] `https://openknowledge.worldbank.org/handle/10986/5991`

de factores, que dan lugar a modelos no lineales (que no son tratables analíticamente) y adoptan una aproximación evolutiva hacia el equilibrio. Esto da lugar al famoso lema de “Dixit-Stiglitz, Iceberg, Evolución, y la Computadora”.[4].

Los modelos de la nueva economía geográfica tienen sus raíces en la nueva teoría del comercio. En contraste con la teoría neoclásica del comercio, en la que los flujos del comercio son analizados en base a la ventaja comparativa dada por diferencias tecnológicas (Ricardo) o por la dotación de factores (Heckscher-Ohlin), la nueva teoría del comercio analiza los flujos comerciales en un contexto de rendimientos creciente a escala, preferencia por la variedad y competencia monopolística (Krugman 1979, Kugman 1980, Krugman y Venables 1990). Esto es, un marco de modelado basado en Dixit y Stiglitz (1977). Esto nuevo marco es compatible con la evidencia empírica de que el comercio intra-industrial — comerciar diferentes variedades del mismo bien — está creciendo en importancia con respecto al comercio inter-industrial — comercial diferentes tipos de bienes. De estos modelos, se puede obtener y estimar una ecuación gravitatoria a fin de evaluar empíricamente los determinantes de los flujos comerciales y cómo las barreras comerciales frenan el comercio internacional (Anderson y van Wincoop, 2003).

Aunque una buena localización geográfica proporciona una ventaja competitiva favoreciendo la localización y aglomeración de la actividad económica, países, regiones y ciudades han encontrado formas de superarla y remodelarla. Existen principalmente tres formas de llevarlo a cabo. La primera es mediante infraestructuras de transporte como forma de cambiar la geografía. La segunda es por el progreso tecnológico, dado que las innovaciones aumentan la productividad del trabajo e incentivan la aglomeración de la actividad económica (Tabuchi, Thisse y Zhu, 2014). Tercero es mediante el desarrollo de instituciones que funcionen bien y favorezcan la atracción de la actividad económica garantizando los derechos de propiedad e inversiones, asegurando la efectividad del gobierno, control de la corrupción, el cumplimiento de la ley, y la estabilidad política.

Esto es precisamente lo que ésta tesis pretende abordar centrándose en las infraestructuras de transporte y en las instituciones. Recurriendo a la teoría de redes somos capaces de modelar las infraestructuras de transporte de un país y, dependiendo de la topología de la red, determinar cómo la actividad económica se distribuye (des)igualmente a lo largo del espacio. Esto nos permite extraer conclusiones de política económica sobre cómo la política de infraestructuras debe dirigirse para incrementar la cohesión entre las regiones. Considerando la calidad institucional como una barrera comercial, abordamos cómo las instituciones nacionales afectan a la magnitud y la composición de la producción sectorial y sus flujos comerciales asociados. La idea de que las instituciones son importantes para determinar los flujos comerciales es fundamental dado que el comercio es una de las raíces de la aglomeración de la actividad económica, y conociendo el efecto de las instituciones sobre el comercio nos va a permitir entender cómo las instituciones importan para determinar la localización de la actividad económica.

Ésta tesis consiste en tres capítulos, cada uno de ellos escrito siguiente el estilo de un artículo

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[4] Ver Fujita y Krugman (1994) para una extensa discusión sobre las raíces, el estado del arte y el futuro de la nueva economía geográfica

académico, con su introducción, revisión de la literatura, metodología, resultados y conclusiones. En el último capítulo, se presentan las conclusiones generales de toda la tesis. Ahora se presenta un breve resumen de cada uno de los tres capítulos principales.

Capítulo 2: "El Modelo Centro-Periferia Multiregional: El Papel de la Topología Espacial"

El mundo real muestra que la actividad económica está distribuida de forma desigual entre las localidades, tanto a nivel nacional, regional y urbano. Una de las más importantes explicaciones para esta distribución desigual es la geografía, Krugman et al. (2011). Las fuerzas económicas están influenciadas por las características espaciales de la economía, ya que tanto los determinantes geográficos de "primera naturaleza" como por los factores económicos de "segunda naturaleza" (comportamiento de los consumidores y de las empresas, estructura de mercado, reglas de pecios, etc.) dan forma a la particular distribución de la actividad económica en un espacio dado. El objetivo del presente estudio es generalizar el conocido modelo canónico de la nueva economía geográfica analizando sistemáticamente el efecto que diferentes configuraciones geográficas tienen en los patrones de la localización de la actividad económica.

Utilizamos el modelo multiregional centro-periferia para analizar y comparar las fuerzas de aglomeración y dispersión que dan forma a la localización de la actividad económico para un continuo de topologías de red — configuración geográfica o espacial — caracterizadas por su grado de centralidad y comprendidas entre dos topologías extremas representadas por la configuración homogénea (anillo) y heterogénea (estrella). Recurriendo a la teoría de grafos, extendemos sistemáticamente las herramientas analíticas y las representaciones gráficas del modelo centro-periferia para configuraciones espaciales alternativas, estudiando el punto de sostenimiento y de ruptura. Desvelamos nuevos fenómenos como la imposibilidad del equilibrio disperso en el espacio heterogéneo, resultando en la introducción del concepto de "pseudo tierra plana" como un equilibrio a largo plazo correspondiente a una distribución de la actividad económica desigual entre las regiones.

Usando las herramientas analíticas y las representaciones gráficas del marco tradicional de la nueva economía geográfica, y considerando tanto las topologías del espacio homogéneo y el espacio heterogéneo para el caso de cuatro regiones, analizamos el rango de costes de transporte para el que la aglomeración es sostenible, el punto de sostenimiento, y el nivel de costes de transportes por debajo del cual la dispersión de la actividad económica se rompe, es decir, el punto de ruptura.

Como es de esperar, las simulaciones por ordenador muestran que la aglomeración de la actividad económica en una región con una ventaja locacional, la región central en el espacio topológico, es sostenible para mayores costes de transporte que cuando la actividad se concentra en una región en la periférica o en una región en el espacio homogéneo.

Un equilibrio de tierra plana, en el que todas las regiones tienen la misma proporción de actividad económica, es sólo posible en un espacio homogéneo, mientras que en un espacio heterogéneo el equilibrio estable a largo plazo de dispersión total para altos valores de costes de transporte corresponderá con la "pesudo tierra plana" donde las regiones con una ventaja locaciones tienen una ligeramente mayor proporción de actividad económica que las regiones periféricas. La diferencia en la proporción de actividad manufacturera entre la región central y las periférica dependerá del nivel de costes de transporte. Mostramos que el equilibrio de dispersión total se rompe antes en un espacio heterogéneo precisamente debido a la existencia de regiones con ventajas locacionales.

Los resultados obtenidos tienen importantes implicaciones para el transporte y la política de infraestructuras destinada a promover la cohesión territorial entre las regiones en términos de una más igualitaria distribución de la renta. La cohesión plena no es posible mientras que los costes de transporte no se igualen entre las regiones (p.j., por medio de inversión en infraestructuras) y por lo tanto las políticas de transportes e infraestructuras tienen que tener esto en cuenta. Asimismo, podemos evaluar éstas políticas dirigidas a igualar la posición relativa de todas las regiones mediante la transformación de un espacio heterogéneo en uno menos heterogéneo; es decir, determinar cómo de exitosas son en reducir la centralidad de la economía y en los patrones de localización de la actividad económica.

Capítulo 3: "Localización Industrial y Salarios: El Papel del Tamaño del Mercado y la Accesibilidad en Redes Comerciales"

Investigamos la distribución geográfica de la actividad económica y los salarios en un modelo de equilibrio general con multitud de regiones asimétricas y comercio costoso. Como muestran las extensas simulaciones en redes aleatorias, el tamaño del mercado local explica mejor la proporción industrial de la región, mientras que la accesibilidad explica mejor el salario de la región. La correlación entre los salarios y la proporción industrial de equilibrio es baja, sugiriendo que las dos variables operan en gran medida de forma independiente. El modelo replica bien la distribución espacial de la industria usando datos de España, aunque sobreestima los cambios en dicha distribución debido a cambios en los 'costes generalizados del transporte'. Éste último sólo tiene un pequeño impacto en la distribución geográfica de la actividad económica en España entre 1980 y 2007.

Dado que resultados generales analíticos como los presentados en Behrens y Ottaviano (2011) no se pueden derivar cuando los costes de transporte son asimétricos entre un gran número de regiones, simulamos el modelo para un gran número de redes de comercio aleatorias y exploramos sus propiedades numéricas. Prestamos una particular atención al caso en el que los precios de los factores no están igualados, y a propiedades de las redes en el sistema comercial – incluyendo costes de transporte y costes no relacionados con el transporte (p.ej., tarifas).

Nuestros principales hallazgos son que el tamaño del mercado local es crucial en explicar la proporción industrial de la región, mientras que la accesibilidad es crucial en explicar el salario de la región. La correlación entre los salarios y las proporciones industriales es baja, sugeriendo que los dos canales de ajuste trabajan de manera independiente. También se computa un modelo con dos sectores diferenciados y encontramos que en este caso la localización de la actividad económica para cada sector está impulsada principalmente por la proporción de gasto en cada sector mientras que los niveles salariales son más dependientes de la topología de la red. También aplicamos el modelo sin igualdad en el precio de los factores al caso de España — utilizando Costes Generalizados del Transporte entre regiones como medida de fricción al comercio — y realizamos análisis contrafactual para cambios en la red comercial.

En el análisis, se generan redes aleatorias crecientes en árbol usando dos algoritmos alternativos: igual probabilidad de adhesión, y el método de Barabasi-Albert (1999) de adhesión preferencial. Análisis de correlaciones muestran que los resultados difieren entre redes generadas utilizando estos dos algoritmos, siendo las características de las redes — representadas por las medidas de centralidad del grado de un nodo y la cercanía — más importantes para determinar el equilibrio de empresas en el caso de redes generadas con adhesión preferencial.

Específicamente, dos modelos de comercio son considerados. El primer modelo asume un sector homogéneo y un sector diferenciado CES sin igualdad en el precio de los factores (FPE). El segundo modelo permite dos sectores diferenciados con preferencias CES. En este último caso, las proporciones industriales para cada sector vienen determinadas principalmente por la proporción de gasto en ambos sectores en cada región, mientras que los salarios son determinados principalmente por características de las redes y sus proporciones de población.

Resolvemos el modelo sin igualdad en el precio de los factores para el caso de España y computamos equilibrios espaciales alternativos utilizando Costes Generalizados de Transporte y datos de población correspondientes a 1980 y a 2007 para las 47 regiones peninsulares NUTS-3. Descomponemos los cambios en la localización espacial de la actividad económica entre el periodo base de partida (1980) y el periodo final (2007) entre dos componentes mutuamente excluyentes correspondientes a: a) cambios debidos a las mejoras en las infraestructuras de transporte (resultantes de una reducción desigual de los costes de transporte entre las regiones), y b) cambios en las proporciones de población. Procediendo de ésta forma obtenemos una medida del impacto individual que la política de infraestructura de transporte y las tendencias demográficas han tenido en la distribución espacial de la actividad económica en las últimas tres décadas. Cuando aplicamos ambos modelos a datos de España — usando Costes Generalizados del Transporte entre regiones como una medida de fricción al comercio — encontramos que ambos modelos predicen bien la distribución de las industrias, aunque predicen peor los patrones espaciales de los salarios. Esto último puede deberse al hecho de que el PIB per cápita — aunque usado habitualmente en la literatura — es una aproximación bastante burda de los salarios. También puede deberse, sin embargo, al hecho de que las diferencias regionales en accesibilidad son generalmente menos pronunciadas que las diferencias regionales en las proporciones poblacionales. Por lo que el segundo efecto puede eclipsar al primero en las aplicaciones.

Capítulo 4: "¿Importa la Calidad Institucional en el Comercio? Condiciones Institucionales en un Marco de Comercio Sectorial

El papel de las instituciones como motor del desarrollo económico ha atraído una atención considerable en la literatura sobre el crecimiento económico a largo plazo (Acemoglu et al., 2005, Rodriguez-Pose and Storper, 2006; Rodríguez-Pose, 2013). Sin embargo, la literatura es mas escasa en torno a la relación entre las instituciones y el comercio y nuestro conocimiento sobre cómo la calidad de las instituciones locales incide sobre las tendencias comerciales aún es bastante limitada. Éste artículo pretende abordar ésta brecha en la literatura desde una perspectiva teórica y empírica a fin de evaluar: a) si la calidad de las instituciones locales afecta a la dimensión del comercio de un país; y b) si el impacto de las instituciones ha sido creciente o menguante con el tiempo. Para proporcionar una base teórica a la ecuación gravitatoria, se propone un modelo que considera los términos de resistencia multilateral de Anderson y van Wincoop's (2003) en un modelo de la nueva teoría del comercio que incluye como determinantes del comercio la competitividad laboral medida en origen (en términos de productividad y salarios) y las proporciones de renta sectorial en destino, así como las condiciones instituciones de los países de origen y destino. Desde una perspectiva aplicada compilamos la mas comprehensiva y representativa base de datos de flujos comerciales sectoriales. Contiene datos sobre comercio de bienes tangibles así como servicios, cubriendo 186 países a lo largo del periodo comprendido entre 1986 y 2012.

Nuestra hipótesis es que una mayor calidad institucional reduce los costes de transacción y contribuye al incremento del volumen de comercio internacional. Las instituciones se introducen de dos formas diferentes: 1) como barrera en destino, y 2) como la diferencia en los indicadores institucionales entre el origen y el destino, lo que constituye una medida de distancia institucional. La distancia geográfica, el borde común, y el lenguale común también son tenidos en cuenta, para controlar por costes de transporte y barreras al comercio adicionales.

Los resultados del análisis confirman la hipótesis de que la calidad de las instituciones en destino importa para el comercio. Con la excepción de la estabilidad política y la voz y la rendición de cuentas, todas las variables institucionales consideradas en el análisis están estrechamente conectadas con las tendencias comerciales. A mayor calidad institucional en el país de destino, mayor el comercio bilateral. Este efecto es particularmente fuerte en el control de la corrupción, efectividad del gobierno, estado de derecho, y calidad reguladora. Por lo tanto, mejoras en la calidad institucional tienen un impacto positivo sobre el comercio.

Los resultados también indican que los países con similar calidad institucional comercian más, lo que significa que una menor brecha en la distancia institucional lleva a una reducción de los costes de transacción. Estos resultados son robustos a analizar el papel de las instituciones por sectores comerciales por separado — agricultura, industria y servicios, siendo este último más sensible a las instituciones. Nuestros resultados también muestran que el papel de las instituciones en el comercio ha cambiado con el tiempo. En contra de lo esperado, el papel de las instituciones parece haber descendido con el tiempo, posiblemente debido al incremento del comercio de *commodities* durante el periodo de análisis.

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Chapter 2

The Multiregional Core-Periphery Model: The Role of the Spatial Topology

2.1 Introduction

The real world shows that economic activity is distributed unevenly across locations, both at the national, regional and urban levels. One of the most important explanations for that uneven distribution is geography, Krugman et al. (2011). Indeed, the configuration of economic activity at any of the above mentioned territorial scales cannot be dissociated from the particular geography where market processes take place. That is, economic forces are influenced by the economy's spatial characteristics, as both "first nature" geographical determinants and "second nature" economic factors (market structure, pricing rules, etc...) shape the particular distribution of economic activity in a given space.[1] For example, if we take regions as the territorial benchmark, the distribution of economic activity and transport networks in France has given rise to a topology resembling a star network, where the central Île-de-France region presents a prominent situation, characterized by its high degree of centrality. Meanwhile, Germany presents a more even geographical distribution of economic activity, with a tightly woven transport grid that results in a more balanced, less centralized economy. It is clear, then, that geography, understood as a specific spatial configuration, determines the final distribution of economic activity along with economic forces. Levinson (2009) and Blumenfeld-Lieberthal (2009) discuss the fundamentals and empirical analyses on the topology and evolution of transportation network infrastructures at country level.

Graph theory makes it possible to introduce a spatial dimension into new economic geography models based on increasing returns and imperfect competition, by way of a network topology that includes transport costs—as the opposing centrifugal force, normally associated to the concept of distance between locations, and shaping a specific spatial configuration. In this study we explore the behavior of the canonical core-periphery model on different network topologies, which represent

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[1] Cronon (1991) defines "first nature" as the local natural advantages that firms seek when settling on their location, and "second nature" as the forces arising from the presence of other firms. The first is related to geographical features and results in diverse market potential, while the second corresponds to economic interactions; i.e., Marshallian externalities.

specific configurations of locations in an abstract space, and that would need to be qualified with real geographic variables in empirical applications of the model (e.g., specific transport costs between locations). Therefore, by network topology we understand a specific spatial configuration of locations, corresponding in the real world to the geographical features of economic activity.[2] In this context, the question naturally arises on how a particular topology influences the centripetal and centrifugal forces that drive agglomeration or dispersion.

In recent years several contributions have appeared that qualify the initial setting of the seminal core-periphery model introduced by Krugman (1991); e.g., allowing for different definitions of the utility function as in Ottaviano et al. (2002), the existence of vertical linkages as in Puga and Venables (1995), etc. But it is fair to say that the behavior of these models under alternative spatial configurations of the economy has not been systematically discussed. In its original version, there are two regions with the long-run distribution of economic activity either fully agglomerated in one or equally divided between the two.

Nevertheless, a few ways to generalize the model to a multiregional setting have been proposed in the literature. The core-periphery model has been extended to a greater number of regions with the assumption that they are evenly located along the rim of a circumference, in the so-called “racetrack economy”, e.g., Krugman (1993), Fujita et al. (1999), Brakman et al. (2009). Whereas these authors obtain results through numerical simulation, Castro et al. (2012) obtain analytical results for the case of three regions equally spaced along a circle, while Akamatsu et al. (2012), using bifurcation theory, generalize these results to a larger number of locations. Closed form analytical solutions are also obtained by Picard and Tabuchi (2010) adopting the simpler version of the NEG model proposed by Ottaviano et al. (2002) and allowing for different transport cost functions. Alternatively, adopting the opposite spatial configuration, Ago et al. (2006) analytically study a situation in which three regions are located on a line—a star network topology. The former authors conclude that the central region has locational advantages and that economic activity will concentrate there as transport costs fall. However, using also the alternative model of Ottaviano et al. (2002) they also show that the central region can present locational disadvantages and that price competition can make economic activity move to two or just one of the peripheral regions. Castro et al. (2012) qualify the results obtained for two regions regarding long-run equilibria, generalizing some of them to a larger number of regions. In graph theory, the previous racetrack (or ring) economy and the line (star) economy represent two simple and extreme topologies of a spatial network; the former characterizing a neutral or homogeneous topology where no region has a (first nature) geographical advantage, and the latter the most uneven heterogeneous space where central regions enjoy privileged locations.[3]

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[2] See Ducruet and Beauguitte (2014) for a review of how network research has been integrated into regional science.

[3] The study of multi-country models based on networks has been also undertaken in the New trade Theory (NTT) literature as in Behrens et al. (2009). The main difference between NTT models and new economic geography (NEG) models is the assumption about workers mobility. Indeed both sets of models assume that there is an upper tier CD utility function with a homogenous and differentiated products, with the latter corresponding to a CES specification which yields the desirable price index. Also, the technology in both models is characterized by increasing returns, and the market equilibrium is solved within a monopolistic competition market structure. Considering that transport costs are

The aim of the present study is to generalize the well-known canonical model of the new economic geography by analyzing systematically the effect of different geographic configurations on the locational patterns of economic activity. To accomplish this goal we use the customary analytical and simulation tools to study how alternative network topologies determine the long-run equilibria of the multiregional model. In particular we calculate the sustain and break points: i.e., the transport cost levels at which full agglomeration cannot be sustained and the symmetric dispersion is broken, and determine the existence (or absence) of alternative equilibria. Instead of studying the sustain and break points for one specific topology, as it is usually done in the literature, we do so for a continuum of network topologies between the already mentioned extreme cases: the racetrack-ring economy and the star economy. In fact, a racetrack-ring economy with three locations corresponds geometrically to the triangle studied by Castro et al. (2012), while the star economy corresponds to the line economy of Ago et al. (2006). Because our methodology can be extended to a larger number of regions, we can with no loss of generality study all possible network topologies (spatial or geographical configurations) that we particularize for simplicity to the case of four locations, yielding new results and properties never studied in the literature.[4]

By exploring the effect of different spatial or geographical configurations on the locational patterns of economic activity our study determines the relationship between "first" nature network characteristics and "second" nature economic forces. On one hand, first nature characteristics correspond to the existing transport costs between regions, and more particularly the bilateral transport costs, while network geography is summarized by a centrality index . On the other, second nature economic forces relate to the consumers and firms behavior. For consumers, preferences are defined in terms of an upper tier CD utility function with a homogenous and differentiated products, with the latter corresponding to a CES specification. For firms, it is assumed that the technology is characterized by increasing returns, and the market equilibrium is solved within a monopolistic competition market structure. In the model, second nature parameters correspond to the shares of income spent in the homogenous and differentiated goods, the price-elasticity and elasticity of substitution, marginal and fixed costs, and so no. It is the trade-off between these economic forces resulting as in the price index and home market effects, and first nature characteristics represented by transportation costs, what determine the final equilibrium outcome in terms of agglomeration or dispersion of economic activity.

In this sense we contribute to the literature studying the combination—harmonization—of both

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also of the iceberg form, the only 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, RMP, in NEG models the equilibrium is defined under the same conditions but it is workers mobility what clears the market so as to equalize real wages across locations, (i.e., the instantaneous equilibrium). Both types of models can be solved in a particular network as in Behrens et al. (2009)—who exemplify their model with a line and triangle topologies, or our four region model. Therefore, market equilibrium through RMP equalization in NTT models and real wage equalization in NEG models summarize the main difference between both types of models.

[4] The methodology can be also interpreted in terms of urban systems where the different locations within the network are cities or metropoleis characterized by densely populated areas, and whose growth and evolution respond to economic forces, Barthélemy and Flammini (2009).

first and second nature determinants, with a particular focus on the former, which is characterized by relative transport costs; and see how localization patterns change as some locations benefit from first-nature advantages, yielding endogenous asymmetries associated with short-run and long-run equilibria, as well as the dynamics associated with continuous or catastrophic changes (see the recent discussion on this matter by Picard and Zeng (2010)).

The paper is structured as follows. The multiregional core-periphery model and the characterization of the network topologies by their centrality index, including the extreme racetrack-ring and star space topologies, are presented in Section 2.2. In this section we also generalize the model's dynamics relative to workers moving between existing locations. In Section 2.3, without loss of generality, we perform the four-region analysis for the well-known racetrack economy and for its opposite spatial configuration in network topology, the star. We determine the transport cost value up to which the agglomeration of the economic activity is sustainable, the sustain point. We introduce the infeasibility of the symmetric flat-earth equilibrium in heterogeneous space. In Section 2.4, we analyze the continuum of intermediate topologies using the network centrality index, determine the corresponding sustain and break points, and generalize the previous results for any degree of centrality. Section 2.5 concludes.

2.2 The multiregional core-periphery model and the network topology

In the multiregional core-periphery model, there are N regions with two sectors of production: the numéraire agricultural sector, perfectly competitive, and the manufacturing sector, with increasing returns to scale. The agricultural workers are immobile and equally distributed across regions.[5] Manufacturing workers can move between regions, and λ_i is the share of manufacturing workers and manufacturing activity in region i, as labor is the only production factor and technology is symmetric across regions. Iceberg transport costs are assumed for the manufacturing sector. Transport costs between region i and region j, τ_{ij} , depend on the unit-distance transport cost T and on the distance between the regions d^h_{ij} in the network h. The transport cost function defines as:

$$\tau_{ij} = T^{d^h_{ij}} \tag{2.1}$$

The system of non-linear equations that determine the multiregional instantaneous equilibrium are

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[5] Although different asymmetries can be incorporated into the model (e.g., uneven distribution of the population working in the agricultural sector, varying productivity among firms, etc.), we follow the seminal core-periphery model where all locations are symmetric, as we are interested in isolating the effects of changing unitary transport costs and network topology on the reallocation of economic activity across regions, and therefore they constitute the only sources of variation of the sustain and break points defining the long-run equilibria. The study of these changes that are related to transport policy can be complemented with other governmental policies such as trade, tax and regional subsidies as discussed in Baldwin et al. (2005).

well known:

$$y_i = \mu w_i \lambda_i + \left(\frac{1-\mu}{N}\right), \quad i = 1,\ldots,N \tag{2.2}$$

$$g_i = \left(\lambda_i w_i^{1-\sigma} + \sum_{j=1\neq i}^{N} \lambda_j \left(w_j \tau_{ji}\right)^{1-\sigma}\right)^{1/(1-\sigma)}, \quad i = 1,\ldots,N \tag{2.3}$$

$$w_i = \left(y_i g_i^{\sigma-1} + \sum_{j=1\neq i}^{N} y_j g_j^{\sigma-1} \tau_{ij}^{1-\sigma}\right)^{1/\sigma}, \quad i = 1,\ldots,N \tag{2.4}$$

$$\omega_i = w_i g_i^{-\mu}, \quad i = 1,\ldots,N, \tag{2.5}$$

where y_i, g_i and w_i represent the income, price index and nominal wage of region i, λ_i is the share of manufacturing activity, and ω_i is the real wage, which defines as the nominal wage deflated by the price index. The parameter σ represents the elasticity of substitution between varieties of the manufacturing sector, $\sigma > 1$, whereas μ is the share of income expended in the manufacturing sector, $0 < \mu < 1$. As for the income (2.2), it is the sum of manufacturing and agricultural workers' incomes (whose wages are w_i and one by choice of numéraire, respectively). As for the price index (2.3), representing a weighted average of delivered prices, it is lower the larger the share of the manufacturing industry in region i (which is domestically produced), and the larger the imports from nearby regions rather than distant regions as transports costs will be lower for the former than the latter. Finally, the wage equation (2.4) shows that it will be higher if incomes in other regions with low transport costs from i are high, as firms pay higher wages if they have inexpensive access to large markets. [6]

The previous system of non-linear equations embeds both first nature advantages corresponding to the network topology in terms of the relative transport costs, τ_{ij}, as well as economic parameters representing second nature economic factors that condition the location of the (mobile) manufacturing production and its associated labor force. Particularly, preference parameters as the shares of income spent in the homogeneous or differentiated good, μ, and the elasticity of substitution σ, along with the technological parameters characterizing the strength of increasing returns in manufacturing in terms of fixed costs F and marginal costs c.

The homogeneous space is defined as a topology in which all regions have the same relative position, whereas in the heterogeneous space certain regions are better positioned in the network; i.e., first nature locational advantages. The simplest and most extensively studied case of a homogeneous topology corresponds to the afore-mentioned racetrack-ring economy, where all regions are evenly situated along the rim of a circumference, Krugman (1993).[7] The extreme heterogeneous topology is the star, where one region, the center, has the best relative position, while all the other regions, the periphery, also situated along the rim of the circumference, have the least advantageous relative

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[6] Step by step solution of the model obtaining the equilibrium conditions for consumers and producers, market clearing and trade balance for multiple regions can be found in Fujita et al. (1999, chs 4 and 5) or Robert-Nicoud (2005, 8-10), including the normalizations yielding the specific system of equations above.

[7] Another example of the use of a racetrack-ring economy is Kuroda (2014), who study a dispersed supply chain network with intermediate and final goods sectors, and the changes that take place in their spatial distribution as a result of location-specific risky hazards (shocks).

positions and are connected to the center only through the spokes of the star. Figure 2.1 represents the four-location case for both the homogeneous ring and heterogeneous star network topologies.

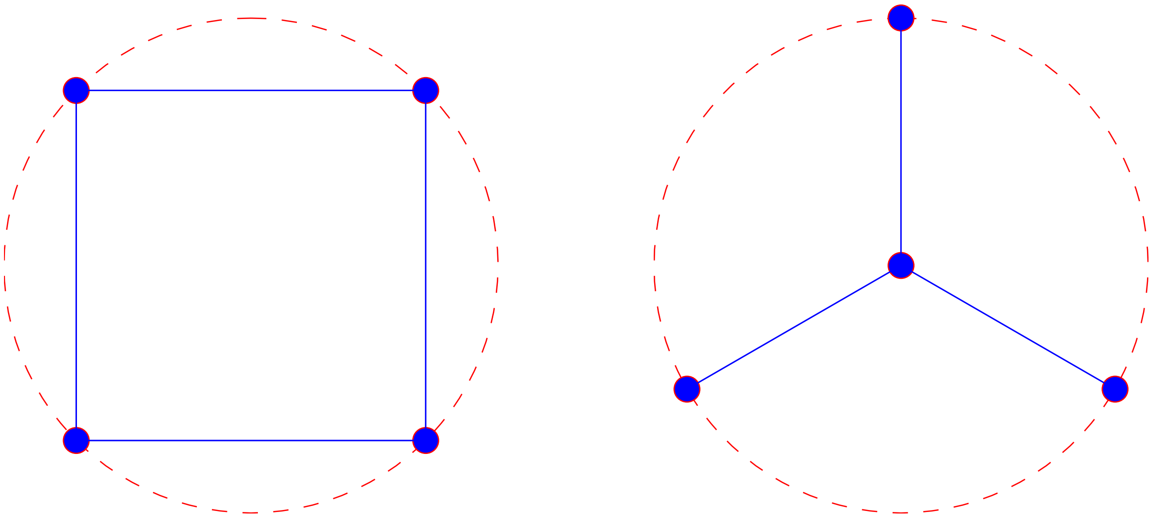

Figure 2.1: The extreme homogeneous ring and heterogeneous star network topologies.

The network topology enters the model as the distance between regions, which determines the transport costs between them. Since we are interested in how changes to the topology affect the agglomeration and dispersion of economic activity, we normalize the absolute measures of distance and transport cost, so as to render all topologies comparable. We do so by circumscribing both the homogeneous ring and heterogeneous star network topologies in a circle of radius 1. For the ring economy, the length of the n sides of a regular polygon—square in our case—is given by the formula: $d_{ij}^{HM} = 2r\sin(\pi/n), n = 4$. As for the star, all it is required is that length of the spokes is 1. To illustrate, Figure 2.1 shows the circumference enclosing the networks; the dotted circle denotes that regions are not connected through the circumference but through the distances within the network h, represented in these cases by straight, solid lines: i.e., the ring or star topologies.

With regard to the shares of workers and manufacturing activity, the dynamics are as follows: (i) workers will leave region i if there is a region j with a higher real wage, (2.5), or, equivalently, higher indirect utility, Castro et al. (2012); (ii) if several regions have higher real wages, workers are assumed to move to the one offering the highest value; (iii) when the highest wage is observed in several regions, workers emigrate evenly towards those regions. Therefore, from region i's perspective, workers will move according to these rules:

$$\dot{\lambda}_i \quad \begin{cases} \dot{\lambda}_i < 0 & \text{if} \quad \omega_i < \max(\omega_j), \forall j \neq i \\ \dot{\lambda}_i = 0 & \text{if} \quad \omega_i = \max(\omega_j), \forall j \quad \wedge \quad \nexists \omega_j < \omega_i, \ \forall j \neq i \\ \dot{\lambda}_i > 0 & \text{if} \quad \omega_i = \max(\omega_j), \forall j \quad \wedge \quad \exists \omega_j < \omega_i, \forall j \neq i \end{cases} \tag{2.6}$$

where the second line summarizes the instantaneous equilibrium: i.e., equal real wages across regions.[8] A distribution of lambdas for which the system of equations (2.2) through (2.5) holds there-

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[8] It is possible to include moving costs that must be compensated by wage differentials before workers actually change

fore represents an instantaneous equilibrium, while a long-run equilibrium—steady state—is one in which workers do not have an incentive to move according to (2.6) if there is a shock marginally increasing the share of manufactures in any region, and it is denoted by $\lambda^* = (\lambda_1^*, \ldots, \lambda_N^*)$.

In a multiregional economy we can characterize the spatial or network topology with graph theory, which proposes several indicators that summarize the pattern of interconnections between various locations; e.g., Harary (1969). Centrality measures are particularly useful for the study of the multiregional network, as they are good indicators of the relative position of the regions within the network.

With $\sum_{j=1}^{N} d_{ij}^h$ being the sum of the distances from location i to all other j locations within the network h, the centrality of location i corresponds to the following expression:

$$c_i^h = \frac{\min\left(\sum_{j=1}^{N} d_{ij}^h\right)}{\sum_{j=1}^{N} d_{ij}^h} \tag{2.7}$$

where $\min\left(\sum_{j=1}^{N} d_{ij}^h\right)$ corresponds to the value of the location(s) best positioned within the economy, denoted by i^*, with $c_{i^*}^h = 1$. In a homogeneous space such as that represented by the ring topology all locations have a centrality of 1, whereas in the heterogeneous star topology the central node has a centrality of 1 and all peripheral nodes have equal centrality values lower than 1: $c_i^h < c_{i^*}^h = 1$.

The centrality of the economy — network centrality — defines as:

$$C(h) = \frac{\sum_{i=1}^{N}\left[c_{i^*}^h - c_i^h\right]}{\max\left[\sum_{i=1}^{N}\left[c_{i^*}^h - c_i^h\right]\right]} = \frac{\sum_{i=1}^{N}\left[c_{i^*}^h - c_i^h\right]}{\frac{(N-1)(N-2)}{(2N-3)}} \tag{2.8}$$

where $\sum_{i=1}^{N}\left[c_{i^*}^h - c_i^h\right]$ is the sum of the centrality differences between the location with the highest centrality and all remaining locations, and $\max\left[\sum_{i=1}^{N}\left[c_{i^*}^h - c_i^h\right]\right]$ is the maximum sum of the differences that can exist in a network with the same number of nodes. This maximum corresponds to a heterogeneous star network with a central node and $N-1$ periphery nodes. The network centrality for the homogeneous ring space is $C(h^{HM}) = 0$ and for the heterogeneous star space $C(h^{HT}) = 1$. The two extreme topologies have the extreme network centralities.

2.3 Analysis of the extreme topologies: the ring and star economies

Without loss of generality, we can study a four-region economy by comparing the two opposite cases of spatial topology in terms of network centrality: the ring and the star (Figure 2.1). In the homogeneous space the four regions are the four vertices of a square. In the heterogeneous three-pointed star topology there is a central location, 1, and three peripheral locations connected to the center. Both spaces are circumscribed in a circle of radius 1. The distance matrices of the four-region ring and star

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location, Tabuchi et al. (2014). Studying workers flows between locations as discussed by Patuelli et al. (2007), which would require relaxing the assumption that wage earners work where they live and incur in commuting costs, also represents an interesting extension.

networks are the following:

$$D^{HM} = \begin{pmatrix} 0 & 1.4142 & 2.8284 & 1.4142 \\ 1.4142 & 0 & 1.4142 & 2.8284 \\ 2.8284 & 1.4142 & 0 & 1.4142 \\ 1.4142 & 2.8284 & 1.4142 & 0 \end{pmatrix}, \quad D^{HT} = \begin{pmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 2 & 2 \\ 1 & 2 & 0 & 2 \\ 1 & 2 & 2 & 0 \end{pmatrix}$$

The sustain point is the level of transport cost at which the agglomeration of economic activity is no longer sustainable and economic activity disperses across regions. To compute the value of the sustain point we must select the reference region, or regions, where the economic activity is initially agglomerated and check whether it is a feasible solution for the instantaneous equilibrium defined in eqs. (2.2) through (2.5). Next, given a particular network h, we use the dynamic rules set in (2.6) to compute the value of T for which $\dot{\lambda}_i > 0$ in each region.

For example, assuming that a single location agglomerates (e.g., region 1: $\omega_1 = 1$ in (2.5)) and given the generalized definition of the real wages for the remaining regions ($i \neq 1$),[9] we compute the level of the transport cost corresponding to the sustain point $T_{1i}(S)$ for which $\omega_i > \omega_1, i \neq 1$, and determine the subsequent final instantaneous equilibrium compatible with $T > T_{1i}(S)$: i.e., a comparative statics analysis. In this section we explore the sustain point for the two extreme ring and star topologies when the region in the center starts agglomerating. In the first case all the regions in the homogeneous space are equivalent, and we need to explore only the case of one of the regions, as the long-run equilibria are symmetric: i.e., any permutation of the agglomerating location yields identical results.

2.3.1 Homogeneous-ring topology: from full agglomeration to flat-earth dispersion

In simulations for the ring network with region 1 agglomerating ($\lambda_1^* = 1$), as shown in Figure 2.2, the sustain point for region 3 (the farthest region from 1, as $d_{13}^{HM} = 2.83$) is $T_{13}^{HM}(S) = 1.39$, which is lower than the value for neighbor regions 2 and 4 (separated by $d_{ij}^{HM} = 1.41, j = 2,4$): $T_{1j}^{HM}(S) = 1.52, j = 2,4$. [10] That is, when the transport cost rises above 1.39 economic activity spreads to region 3, since $\omega_3 > \omega_1$, and regions 1 and 3 both produce manufactures. The sustain point, defined as $\min\left(T_{1j}^{HM}(S)\right) = 1.39, j = 2,3,4$, suggests a partial agglomeration in two regions separated by the maximum distance $d_{13}^{HM} = 2.83$. As a result, the configuration $\lambda = (\lambda_1 = 0.5, \lambda_2 = 0, \lambda_3 = 0.5, \lambda_4 = 0)$ is a candidate for a stable equilibrium, since real salaries in the agglomerating regions are equal: $\omega_i = 0.9353, i = 1,3$, while those of the empty regions are $\omega_i = 0.8611, i = 2,4$. Because the minimum sustain value corresponds to the farthest regions, the balance between competition and transport costs makes it more profitable for firms and workers leaving the agglomerating region to relocate as far as

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[9] See Appendix 2.A for the expression of real wages when one region is agglomerating.

[10] To ease comparability with Fujita et al. (1999), all simulations in these sections use the parameter values $\sigma = 5$ and $\mu = 0.4$. Expressions for real wages when only one region is agglomerating and the agglomeration depends only on transport costs are presented in Appendix 2.A for N regions and in Appendix 2.B for $N = 4$ regions.

possible and thereby equally serve the markets of the regions with no manufacturing activity, regions 2 and 4.

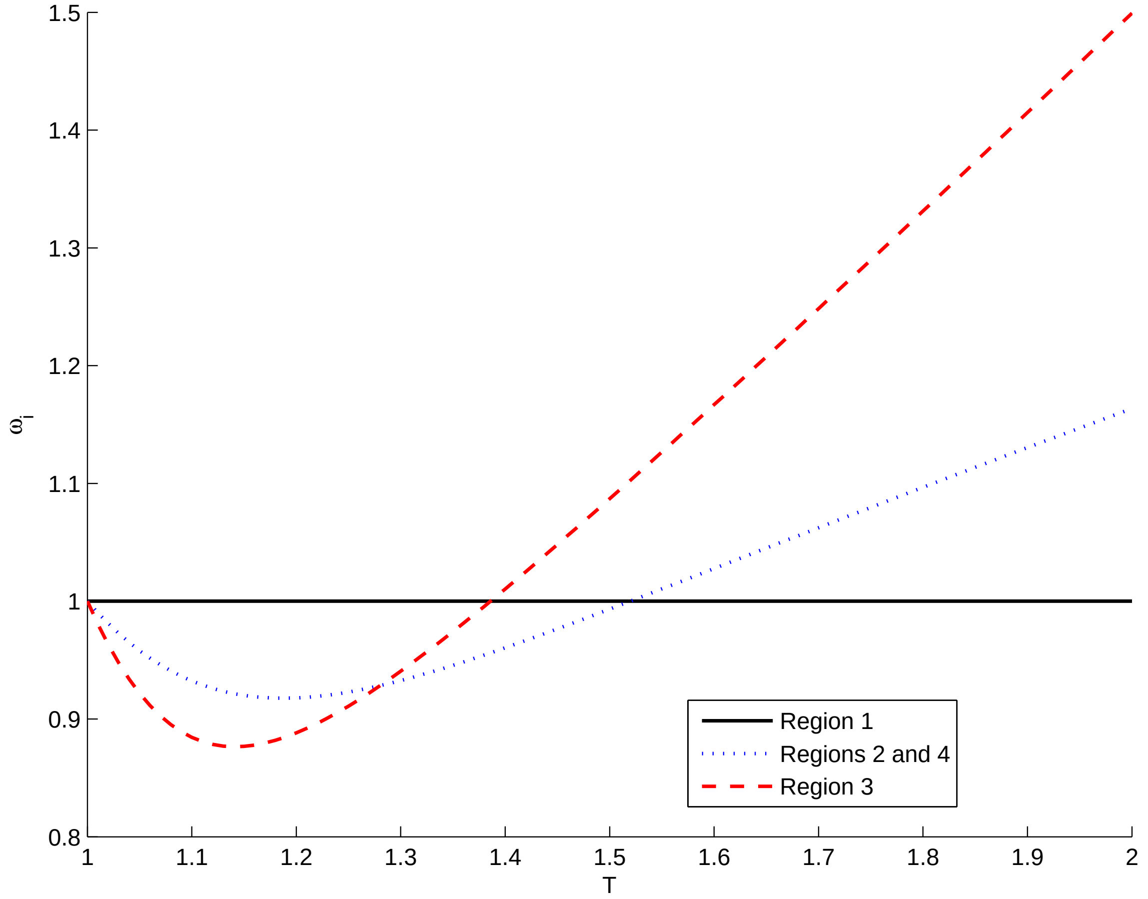

Figure 2.2: Real wages for the ring topology when one region agglomerates.

Whether the partial agglomeration (or partial dispersion) given by $\lambda = (\lambda_1 = 0.5, \lambda_2 = 0, \lambda_3 = 0.5, \lambda_4 = 0)$ is a long-run equilibrium depends on the corresponding stability analysis for a shock that marginally increases the share of manufactures in one or more agglomerating regions, and its effect on the real wages: i.e.,$\partial\omega_i/\partial\lambda_i, i = 1,3$. Nevertheless, if we assume that such a shock does not take place, and since the previous distribution may represent a subsequent instantaneous equilibrium, we can further study its sustainability as transport costs keep rising. Figure 2.3 shows real wages for different transport-cost values when the instantaneous equilibrium corresponds to agglomeration in regions 1 and 3. The sustain point in this case is $T_{1j}^{HM}(S) = T_{3j}^{HM}(S) = 1.72, j = 2,4$. When transport cost increases beyond 1.72 manufacturing activity disperses across all regions — flat-earth. That is, a situation where all regions have the same share of manufacturing activity, $\lambda_i = 0.25$, emerges as a possible long-run equilibrium, as regions end up having the same real wage $\omega_i = 0.878, \forall i$. Once again, however, its steady-state assessment depends on the necessary stability analysis for long-run equilibrium.

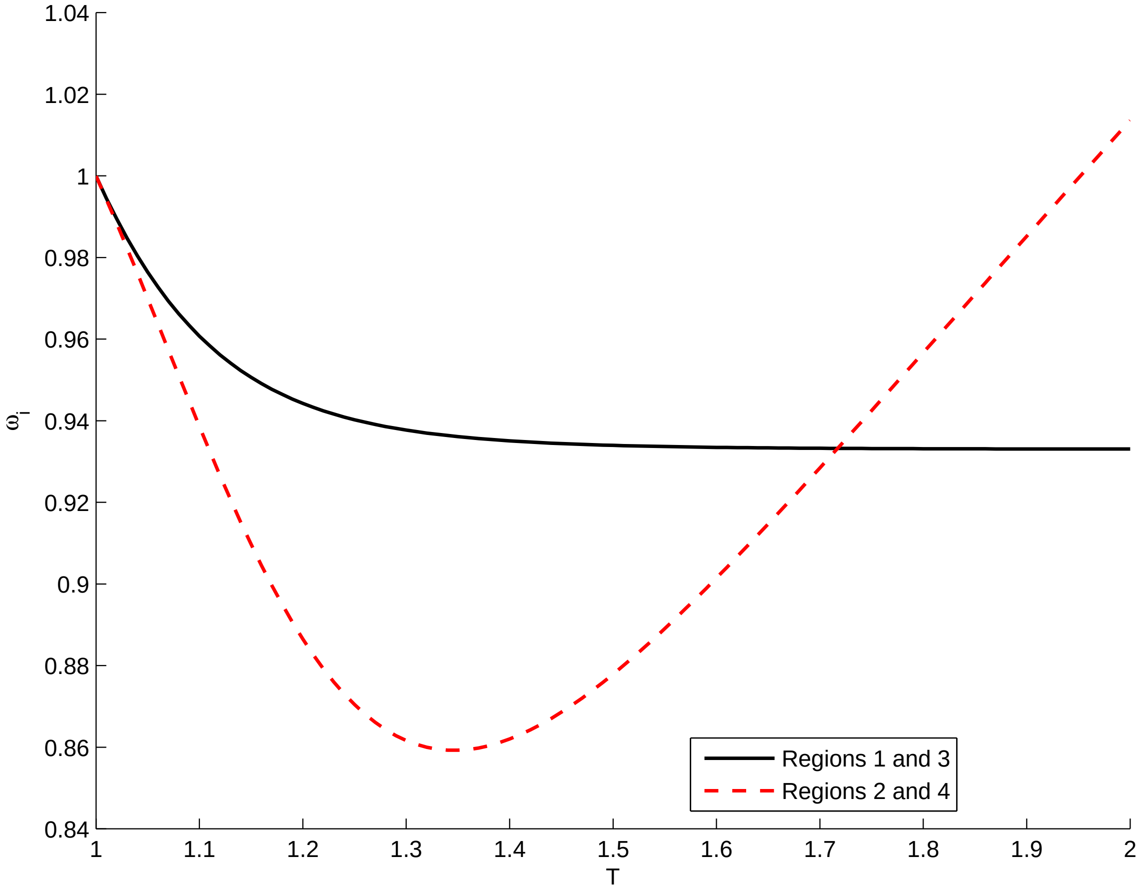

Figure 2.3: Real wages for the ring topology when opposite regions agglomerate.

2.3.2 Heterogeneous-star topology: from full agglomeration to ‘pseudo’ flat-earth

We now examine the star topology when the location with the highest centrality – the center of the star: $\max c_i^{HT} = c_{i^*}^{HT} = c_1^{HT} = 1$ —begins agglomerating: $\lambda_1^* = 1$. As shown in the following Section 2.4, this extreme heterogeneous network topology defines an upper bound (highest value) for the sustain point of all possible spatial configurations, with $T_{C_i^* j}^{HT}(S) = 2.58, j = 2,3,4$ (Figure 2.4). Above this value of transport cost, agglomeration is no longer sustainable and manufacturing activity disperses to the three peripheral regions. Once again, the question is whether the dispersion of economic activity can result in an equal distribution of the manufacturing industry: i.e., whether $\lambda_i = 0.25 \forall i$ corresponds to a long-run equilibrium.

Once again, we must resort to stability analysis, but it turns out that we can immediately prove that this spatial configuration does not represent a stable equilibrium, because it simply cannot exist. That is, the flat-earth long-run equilibrium is infeasible in any heterogeneous space with the system of equations (2.2) through (2.5) characterizing it, because it requires transport costs to be equal for all regions (i.e., a homogeneous space topology is a necessary condition). Indeed, symmetric equilibrium is possible only if all regions have the same real wage: $\omega_i = w_i g_i^{-\mu}$. If all regions have the same share

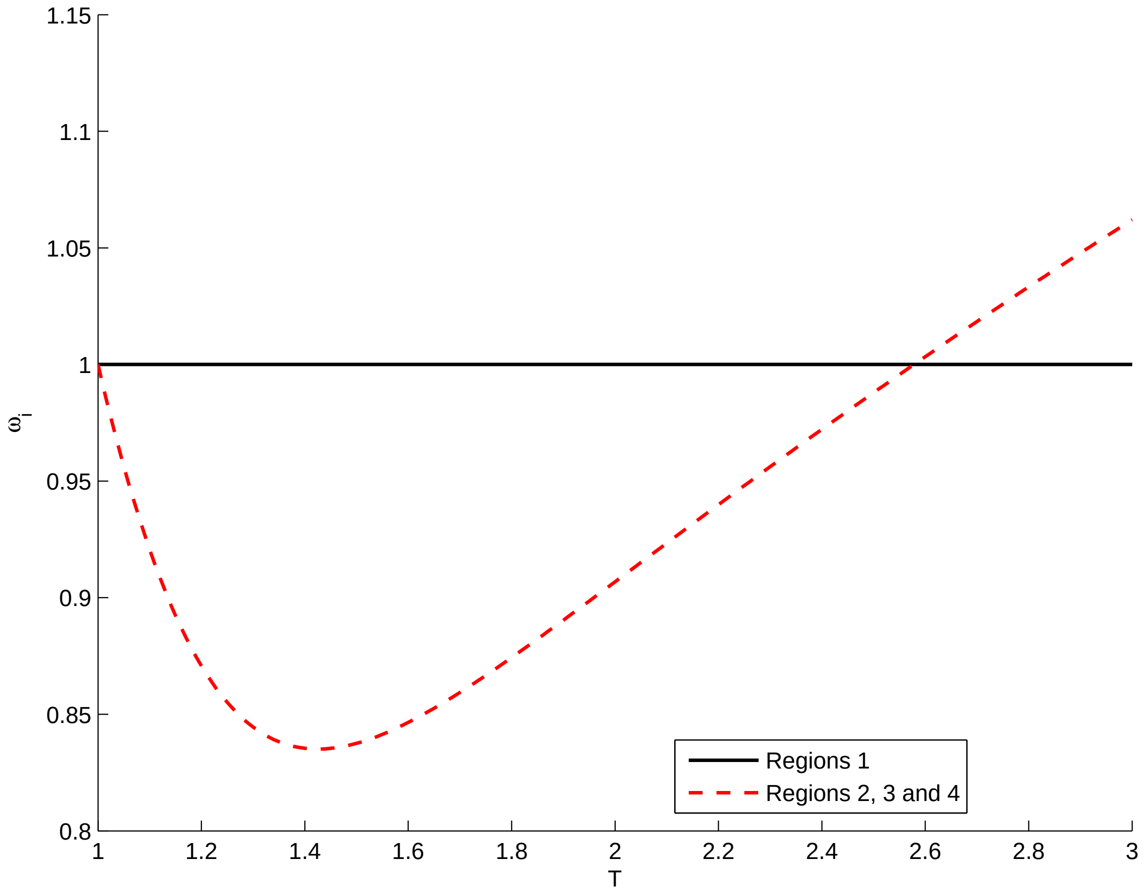

Figure 2.4: Real wages for the star topology when the central region agglomerates.

of manufacturing, $\lambda_i = 1/N$, the nominal wage in all agglomerating regions is $w_i = 1$, as the following condition holds (Robert-Nicoud (2005) for $N = 2$, as well as Ago et al. (2006) and Castro et al. (2012) for $N = 3$):

$$\sum_{i=1}^{N} \lambda_i w_i = 1 \tag{2.9}$$

Therefore, real wages are equal in all regions only if price indices are equal in all regions. Since the price index of a region i depends on the transport cost between all agglomerating regions and region i, the price index will be equal across regions if and only if all the regions have the same relative position in the network economy.

Proposition 1 (Non-existence of the flat-earth equilibrium in a heterogeneous space)**.** *Symmetric equilibrium, flat-earth, is feasible only if all locations have the same relative position in the network. Therefore, symmetric equilibrium is feasible only in a homogeneous space.*

Proof. Equality of real wages across regions: $\omega_i = \omega_j, \forall i, j$, agglomerating an even share of manufacturing activity $\lambda_i = 1/N$, requires that price indices be equal: $g_i = g_j, \forall i, j$. Substituting this even share of manufacturing and $w_i = 1$ – from (2.9) — in (2.3), real wages are (not) equal if bilateral transport costs—centralities—are the same (different); this is (not) verified in the homogeneous (heterogeneous) space. □

Proposition 1 can be easily illustrated. Real wages when the four regions of the star hypothetically have the same share of manufacturing activity: $\lambda_i = 0.25$, are represented in Figure 2.5. For all levels of transport cost, the real wage of the central region 1 is higher than the real wages of the remaining regions except in the unreal case when transport is costless: $T = 1$. This illustrates that economic activity moves from the periphery to the center and that the flat-earth equilibrium is not feasible in the heterogeneous space.

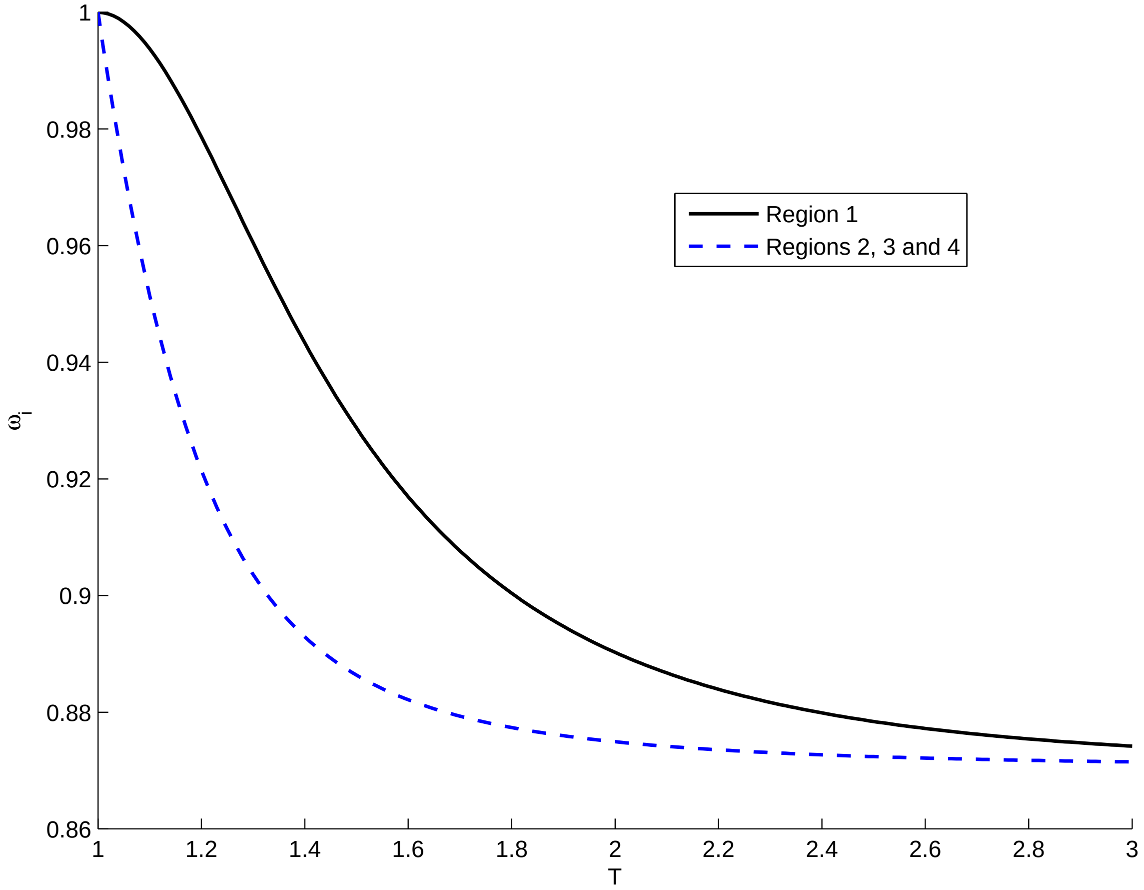

Figure 2.5: Real wages for the star topology when all regions have an equal share of economic activity.

Therefore, with region 1 agglomerating, once transport costs overcome the (single) sustain point $T^{HT}_{c^*_i}(S) = 2.58. j = 2,3,4$, manufacturing activity will disperse across regions and reach a configuration that we define and characterize in the following section and name pseudo flat-earth, i.e., a long run equilibrium where all regions produce the manufacturing good with unequal distribution As we show, for a pseudo flat-earth the central region's share of manufacturing is above 0.25, while peripheral regions' shares are below 0.25. Figure 2.5 illustrates that the hypothetical flat-earth situation is not a stable equilibrium for all transport costs, including the sustain point, as the real wage is higher in the central region than in any other: $\omega_1 = 0.8774 > \omega_i = 0.8772, i = 2,3,4$.

2.3.3 Comparing sustain points in ring and star network topologies

The differences in the sustain points between the homogeneous and the heterogeneous space lead to the following result:

Result 1 (The sustain point in a heterogeneous space is higher (lower) than in the homogeneous space for central (peripheral) regions)**.** *There is a transport-cost level in the homogeneous ring topology and the heterogeneous star topology at which agglomeration forces are outweighed by the dispersion forces. Regarding this level of the transport cost, the sustain point for the central region (peripheral region) is higher (lower) in a heterogeneous space than in a homogeneous space, because agglomeration forces are higher (lower) in regions that have a locational advantage (disadvantage), i.e., that exhibit a better (worse) relative position:* [11]

$$T^{HT}_{c_{i^*}j}(S) > T^{HM}_{ij}(S) > T^{HT}_{jc_{i^*}}(S) \tag{2.10}$$

The values of the sustain point for the different situations already examined are presented in Table 2.1. Beginning with the homogeneous space we have the initial equilibrium, $E^{HM} = 1$, in which only one region is agglomerating. When transport cost reaches $T^{HM}_{13}(S) = 1.39$, half of the economic activity moves to the farthest region, thereby reaching a second-unstable-equilibrium, $E^{HM} = 2$. If transport cost continues to increase beyond $T^{HM}_{1j}(S) = T^{HM}_{3j}(S) = 1.72, j = 2,4$ economic activity disperses across all regions, attaining a final long-run equilibrium, $E^{HM} = 3$. In a heterogeneous star topology, starting at an equilibrium in which the center is agglomerating economic activity, $E^{HT} = 1$, when transport cost rises above $T^{HT}_{1j}(S) = 2.58, j = 2,3,4$, economic activity disperses across all regions, attaining a pseudo flat-earth long-run situation, $E^{HT} = 2$.

Table 2.1: Sustain-point values for different network topologies: from agglomeration to dispersion

	Homogeneous ring topology			Heterogeneous star topology	
Region	$E^{HM} = 1$	$E^{HM} = 2$	$E^{HM} = 3$	$E^{HT} = 1$	$E^{HT} = 2$
1	$\lambda_1 = 1$	$\lambda_1 = 0.5$	$\lambda_1 = 0.25$	$\lambda_1 = 1$	$\lambda_1 > 0.25$
2	1.52	1.72	$\lambda_2 = 0.25$	2.58	$\lambda_2 < 0.25$
3	1.39	$\lambda_2 = 0.5$	$\lambda_3 = 0.25$	2.58	$\lambda_3 < 0.25$
4	1.52	1.72	$\lambda_4 = 0.25$	2.58	$\lambda_4 < 0.25$

2.3.4 Break points

Studying the break point involves determining when a symmetric equilibrium is unstable. To obtain the break point analytically we generalize the procedure set out in Fujita et al. (2009), which

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[11] We have also studied the sustain point for one of the peripheral regions with lowest centrality: $\lambda_2 = 1$ with $c^{HT}_i = 0.6, i = 2,3,4$ (top region in Figure 2.1). In this case, the central region defines the lowest value for the sustain point: $\min T_{2c^{HT}_{i^*}} = 1.44$. Complete results for the full range of alternative simulations are available upon request.

requires defining an initial distribution for the stability analysis. We start with a symmetric equilibrium—either flat-earth in the homogeneous ring topology or pseudo flat-earth in the heterogeneous star topology—in which all regions have the same share of manufacturing activity ($\lambda_i = 1/N$), and evaluate the derivative of the real wage with respect to the change in a region's share of manufacturing activity i: $\partial \omega_i / \partial \lambda_i$. A break point is the transport cost at which the derivative of the real wage equals zero and the symmetric equilibrium is unstable, because the derivative to its right is positive and the derivative to its left is negative. If the equilibrium is unstable, a small shock increasing a region's share of manufacturing activity triggers agglomeration in that region.[12]

Stability of the equilibrium and breakpoints for the ring topology has been widely studied analytically in the literature: Fujita et al. (2009) for the two regions economy, Castro et al. (2009) for three regions, and Ikeda et al. (2012) for four regions, by inspecting the sign of the eigenvalues of the Jacobian matrix of the dynamic equation. For non symmetric distributions of λ, however, it is not possible to obtain analytical expressions of those eigenvalues and numerical techniques must be used (Akamatsu and Takayama, 2009). Thus, analytical expressions cannot be obtained for our heterogeneous-star topology. Nevertheless, instead of dealing with numerical techniques based on the Jacobian, we introduce a new method to analyze when a long-run equilibrium in the heterogeneous star space in broken, for a given shock, using the derivatives of the functions defining the spatial equilibrium.

The system of nonlinear equation derivatives of (2.2) through (2.5) that allows us to determine the value of $\partial \omega_i / \partial \lambda_i$ is the following:[13]

$$dy_i = \mu dw_i \lambda + \mu w_i d\lambda_i, \tag{2.11}$$

$$\begin{aligned} (1-\sigma)\frac{dg_i}{g_i^{\sigma}} =& w_i^{1-\sigma} d\lambda_i + (1-\sigma)\lambda_i w_i^{-\sigma} dw_i + \\ &+ \sum_{j=1 \neq i}^{N} \left((w_j \tau_{ji})^{1-\sigma} d\lambda_j + (1-\sigma)\lambda_j \tau_{ji}^{1-\sigma} w_j^{-\sigma} dw_j \right), \end{aligned} \tag{2.12}$$

$$\begin{aligned} \sigma \frac{dw_i}{w_i^{1-\sigma}} =& g_i^{\sigma-1} dy_i + (\sigma-1) y_i \sigma_i^{\sigma-2} dg_i + \\ &+ \sum_{j=1 \neq i}^{N} \left(g_j^{\sigma-1} \tau_{ij}^{1-\sigma} dy_j + (\sigma-1) y_j \tau_{ij}^{1-\sigma} g_j^{\sigma-2} dg_j \right), \end{aligned} \tag{2.13}$$

$$g_i^{\mu} d\omega_i = dw_i - \mu w_i \frac{dg_i}{g_i}. \tag{2.14}$$

In any heterogeneous network topology like the star the flat-earth equilibrium, with all regions having the same share of manufacturing activity is infeasible (Proposition 1). Therefore, to analyze

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[12] This is normally illustrated in the literature with the so-called "wiggle" diagram, which presents the value of the derivative $\partial \omega_i / \partial \lambda_i$ for the full range on lambda values: $\lambda \in [0, 1]$. In this diagram, instantaneous equilibria are characterized by equality of real wages. The instability (stability) of these interior equilibria depends on whether the derivatives to the right of and to the left of the break point are positive (negative) and negative (positive), respectively.

[13] Equation (2.11) is obtained directly by totally differentiating the income equation (2.2). The differentiation process yielding (2.12) through (2.14) is presented in Appendices (2.C) through (2.E), respectively.

the break point we must first characterize the stable long-run equilibrium that best captures the idea of symmetric dispersion: i.e., a spatial configuration where no region lacks manufacturing production: $\lambda^* = (\lambda_1^*, \ldots, \lambda_N^*)$, $\lambda_i^* > 0$. In general, then, what we call pseudo flat-earth is a situation in which all locations have some level of manufacturing but some (central) regions have a greater share. Given this criterion we can introduce a further qualification that allows us to determine the bounds for the set of lambdas λ^* for which long-run equilibria exist. The lowest bound can be defined according to the principle of least difference, by which the sum of the differences in manufacturing shares is the lowest: $\min \sum_i^N (\max(\lambda_i) - \lambda_i)$ —denoted by $\lambda^{*L} = (\lambda_1^{*L}, \ldots, \lambda_N^{*L}), \lambda_i^{*L} > 0$ and named minimum pseudo flat-earth. Opposite to this, the upper bound corresponds to that distribution for which the sum of differences is the highest: $\lambda^{*H} = (\lambda_1^{*H}, \ldots, \lambda_N^{*H}), \lambda_i^{*H} > 0$, termed maximum pseudo flat-earth: $\max \sum_i^N (\max(\lambda_i) - \lambda_i)$. The introduction of pseudo flat-earth (including its maximum and minimum qualifications) is a novel outcome of the present multiregional core-periphery model, which, unlike the two- and three-region models, allows us to characterize a steady state where all regions produce manufacturing but have different shares depending their relative position in the network. Formally, in a multiregional heterogeneous network topology, pseudo flat-earth is a stable long-run equilibrium characterized by:

1. $\lambda_i^* > 0, \quad \forall i$
2. $\omega_i = \omega_j, \quad \forall i, j$
3. $\partial \omega_i / \partial \lambda_i \leq 0, \quad \forall i$
4. $\exists(\lambda_i^*, \lambda_j^*) |\ \lambda_i^* \neq \lambda_j^*$

In the particular case of the heterogeneous star network topology, the derivative of the real wage should be zero for the central region and negative for peripheral regions. Pseudo flat-earth is therefore given by the set of lambdas $\lambda^* = (\lambda_1^*, \ldots, \lambda_N^*), \lambda_i^* > 0$, with the upper and lower bounds being values that solve the following optimization programs for all transport-cost levels, corresponding to the maximum and minimum pseudo-flat-earth distributions of manufacturing production, respectively. Considering the system of equations (2.2) through (2.5) and its associated system of derivatives (2.11) through (2.14), we determine the upper bound associated with the maximum lambda of the region of highest centrality (maximum pseudo flat-earth distribution) by solving the following program:

$$\max \lambda_{c_i^*}^H$$
$$\text{s.t.} \begin{cases} \lambda_i > 0, \forall i \\ \omega_i = \omega_j, \forall i, j \\ \frac{\partial \omega_1}{\partial \lambda_1} = 0, \\ \frac{\partial \omega_j}{\partial \lambda_j} < 0, \forall j \neq 1 \end{cases} \tag{2.15}$$

where the first set of restrictions characterizes the new pseudo-flat-earth definition (no emptiness), the second set ensures that an instantaneous equilibrium exists, and the third and fourth sets determine its stability. Precisely, the upper bound corresponds to the third restriction, which determines the largest value of lambda λ_1^{*H} for which the pseudo flat-earth still holds, thereby signaling the associated transport cost corresponding to the break-point value.

The minimum value of lambda for which the dispersed equilibrium holds – i.e., characterizing the minimum pseudo flat-earth distribution — is:

$$\max \lambda_{c_i^*}^{L}$$
$$\text{s.t.} \begin{cases} \lambda_i > 0, \forall i \\ \omega_i = \omega_j, \forall i, j \\ \frac{\partial \omega_1}{\partial \lambda_1} = 0, \end{cases} \tag{2.16}$$

We let δ denote the difference between the maximum and minimum shares of manufacturing that the central region can have for pseudo flat-earth equilibria to be stable; i.e., intervals of stable equilibria:

$$\delta = \max \lambda_{c_i^*}^{*H} - \min \lambda_{c_i^*}^{*L} \tag{2.17}$$

Consequently uneven distributions of manufacturing activity may exhibit long run stability for *any* transport cost value, a property unknown in the literature. As for the stability analysis, since the central region tends to attract and agglomerate economic activity as a result of its privileged "first nature" situation—see proposition 1 in Ago et al. (2006)—we consider the shock: $d\lambda = (d\lambda_1 = 0.001, d\lambda_2 = -d\lambda_1/3, d\lambda_3 = -d\lambda_1/3, d\lambda_4 = -d\lambda_4/3)$, when evaluating $\partial\omega_i/\partial\lambda_i$. In this analysis, maximum pseudo flat-earth corresponds to the transport cost and its associated distribution of manufacturing shares for which $\partial\omega_i/\partial\lambda_i = 0$ constitutes a break point $T^{HT}(B)|_{d\lambda}$, for the given shock $d\lambda$. Conversely, minimum pseudo flat-earth is asymptotic to the traditional flat-earth definition, with manufacturing production approaching equal distribution as transport cost tends to infinity.

For our particular four-region star network topology, the combination of shares that solves the maximization problem given by (2.15) is $\lambda_1^{*H} = 0.3376, \lambda_j = 0.2208, j = 2,3,4$, yielding a break point value of $T^{HT}(B)|_{d\lambda} = 2.14$, at which real wages across regions are equal $\omega_i = \omega_j \forall i, j$ and $\partial\omega_1/\partial\lambda_1 = 0$, with the right derivative being positive and the left derivative negative. The combination of shares of manufacturing that solves the minimization problem given by (2.16) is $\lambda_1^{*L} \approx 0.25$, slightly over 0.25 for the central region, and $\lambda_j^{*L} = 0.25, j = 2,3,4$, slightly under 0.25 for the peripheral regions. The distance between the maximum and the minimum is $\delta = 0.0875$. Consequently, pseudo flat-earth exists for $\lambda_1^* \in \left(\lambda_1^{*L}; \lambda_1^{*H}\right] = (0.25; 0.3376], \lambda_j^* \in [0.2208; 0.25), j = 2,3,4$ and for this range of transport costs $T \in [2.139; +\infty)$. For each level of transport cost we find a unique combination of shares of manufacturing that produces stable long-run pseudo-flat-earth equilibrium.

2.4 Intermediate topologies: centrality and critical points

In this section we explore the sustain and break points for a continuum of topologies between the already studied extremes: the homogeneous ring configuration, exhibiting a centrality measure $C(h^{HM}) =$

0, and the heterogeneous star configuration, with $C(h^{HT}) = 1$. First, we determine the number of intermediate topologies, or steps, that we want to study between these two cases. If we recall the distance matrices in section 2.3, the differences between these extreme topologies are given by a linear transition matrix:

$$D_{dif} = \frac{D^{HM} - D^{HT}}{s}, \tag{2.18}$$

where D^{HM} is the distance matrix of the ring topology, D^{HT} the distance matrix of the star topology and s stands for the total number of steps.

For our four-region case, the difference matrix is:

$$D_{dif} = \begin{pmatrix} 0 & 0.4142/s & 1.8284/s & 0.4142/s \\ 0.4142/s & 0 & -0.5858/s & 0.8284/s \\ 1.8284/s & -0.5858/s & 0 & -0.5858/s \\ 0.4142/s & 0.8284/s & -0.5858/s & 0 \end{pmatrix} \tag{2.19}$$

In our simulation we determine the sustain and break points for a hundred network topologies: $s = 100$, each corresponding to the following matrices: $D^{HT(h)} = D^{HT} + hD_{dif}, h = 0, \ldots, s$ were $D^{HT(h)}$ varies as the matrix of the star topology gets successively one step closer to that of the ring topology: i.e., for $h = 100$, $D^{HT(100)} = D^{HM}$.

Given the linear transition schedule represented by the difference matrix (2.19), we determine the extension of the economy represented by the circle of radius 1 circumscribing each topology as discussed in section 2.2. This ensures that transportation costs are normalized and we can disentangle the effect on changes in the unit transport cost and each network's centrality.

2.4.1 Sustain points for the continuum of network topologies

Figure 2.6 shows the sustain point for intermediate space topologies from $C(h^{HM}) = 0$ to $C(h^{HT}) = 1$. Generalizing the first result, we see that the underlying function that defines the sustain point, $T_{13}^{C(h)}(S)$, increases as the network centrality increases. Moreover, it is convex, implying that as the uneven spatial configuration associated with first-nature characteristics reduces (increases), the reduction (increment) in the sustain point is smaller (larger). Assuming that the "no-black-hole" condition holds, we can summarize this finding as follows:

Result 2 (The higher (lower) the centrality of the network, the higher (lower) the sustain point)**.** *There exists a transport-cost level at which the forces agglomerating economic activity are outweighed by the opposite dispersion forces. This transport-cost level—the sustain point—rises (falls) as the centrality of the network, $C(h)$, rises (falls).*

This result, which can be summarized in the following inequality:

$$\min\left(T_{1j}^{C(h)}(S)\right) > \min\left(T_{1j}^{C(h')}(S)\right), C(h) > C(h)' \tag{2.20}$$

implies that as centrality increases the agglomerating forces associated to the price index and home market effect are reinforced given the existing transport costs. That is, these elements of cumulative causation tend to increase agglomeration because: i) locations with larger manufacturing sectors enjoy lower price indices (and therefore higher real wages) as transports costs are nonexistent for local production and lower for imports (price index effect); that is, increasing the centrality reduces the price index in the agglomerating region; and ii) locations with a higher demand for manufacturers attract a lñarger proportion of employment (and therefore higher nominal and real wages), reinforcing the attractiveness of this location for manufacturing workers.

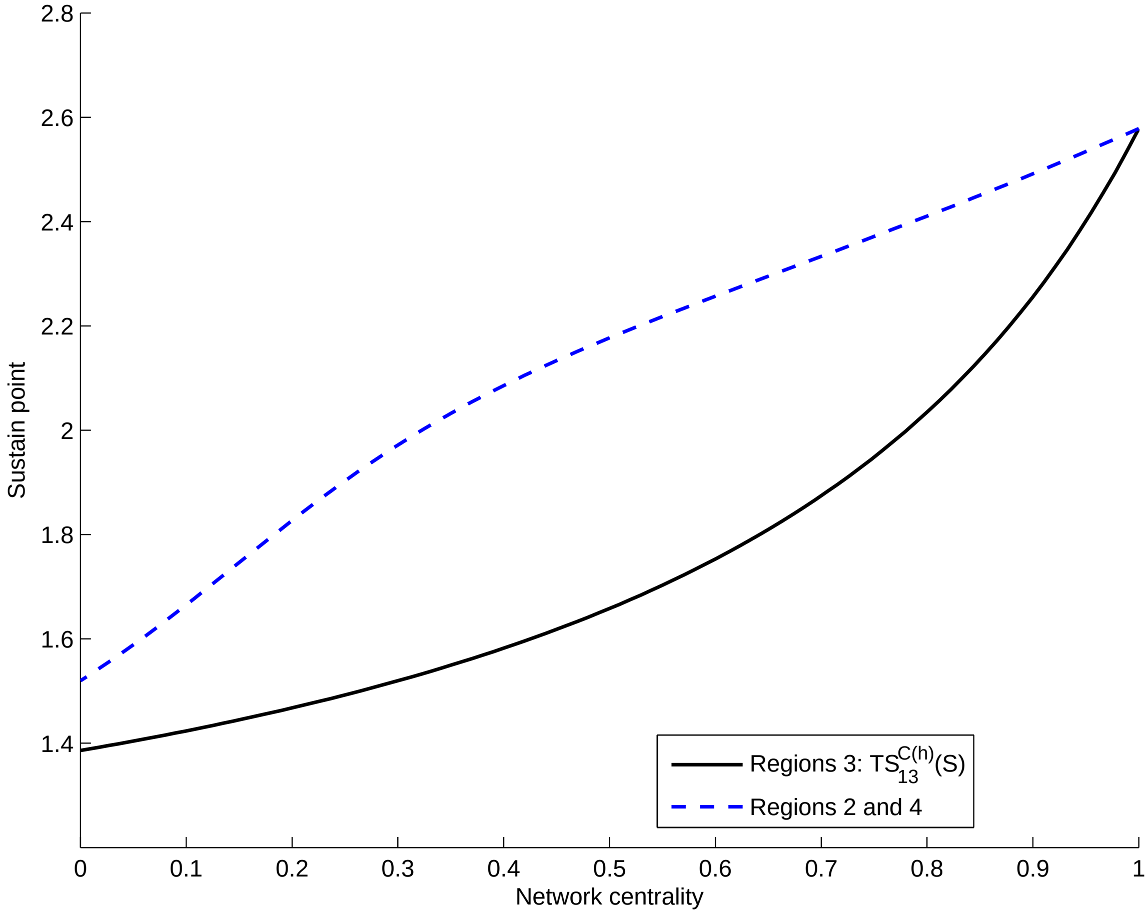

Figure 2.6: Sustain points for the continuum of network topologies.

2.4.2 Break point values for the continuum of network topologies

To compute the break point for each intermediate topology and its associated maximum pseudo-flat-earth distribution: $\lambda_{c_i^*}^{*H}$, we once again evaluate the system of equations (2.2) through (2.5) along with its associated system of derivatives (2.11) through (2.14), for the following vectors of differentials, which correspond to the previous analyses of ring and star topologies.

$$d\lambda^{HM} = \begin{pmatrix} d\lambda_1 \\ d\lambda_2 \\ d\lambda_3 \\ d\lambda_4 \end{pmatrix} = \begin{pmatrix} 0.005 \\ -0.005 \\ 0.005 \\ -0.005 \end{pmatrix}; \quad d\lambda^{HT} = \begin{pmatrix} d\lambda_1 \\ d\lambda_2 \\ d\lambda_3 \\ d\lambda_4 \end{pmatrix} = \begin{pmatrix} 0.001 \\ -0.001/3 \\ -0.001/3 \\ -0.001/3 \end{pmatrix}. \tag{2.21}$$

The difference vector of the shock from one topology to the next is given by:

$$d\lambda_{dif} = \frac{d\lambda^{HM} - d\lambda^{HT}}{s}. \tag{2.22}$$

As for the distance matrices, the vector of differentials for each simulation is $d\lambda^{HT(h)} = d\lambda^{HT} + hd\lambda_{dif}, h = 0, \ldots, 100$, where $d\lambda^{HT(h)}$ varies as the star's matrix gets one step closer to that of the ring topology, and $d\lambda^{HT(h)} = d\lambda^{HM}$ for $h = 100$.

The break point values for intermediate topologies are shown at the top of Figure 2.7 and their associated shares of manufactures at the bottom. As with the sustain points, the function underlying the break point shows increasing network centrality and it is convex. This implies that decreasing (increasing) network centrality makes the full dispersed equilibrium stable over a larger (smaller) range of transport costs. Once again, if the "no-black-hole" condition holds, we get the following result.

Result 3 (The higher (lower) the centrality of the network, the higher (lower) the break point)**.** *There exists a transport-cost level at which long-run dispersed equilibrium becomes unstable. This level rises (falls) as the centrality of the network rises (falls).*

Again, this result can be summarized in the following inequality:

$$\min\left(T^{C(h)}(B)|_{d\lambda^{HT(h)}}\right) > \min\left(T^{C(h')}(B)|_{d\lambda^{HT(h')}}\right), C(h) > C(h)' \tag{2.23}$$

Figures 2.7 allows us to disentangle the effects of changes in network topology, $C(h)$, and the unit-distance transport cost T. Regarding the parameters' space, any centrality and transport cost combination above the dotted line represents a dispersed equilibrium. On the other hand, a combination below the solid line, implies full agglomeration. Alternatively, the area "A" represents a situation where there are multiple equilibria. For a given value of transport cost between the minimum (ring) and maximum (star) sustain points, and with a departure from a fully agglomerated equilibrium (below the sustain point line), reducing the centrality of the network will eventually result in a dispersed spatial configuration as the sustain point is reached. Alternatively, for a given value of transport cost between the minimum (ring) and maximum (star) break points, and with a departure from a dispersed pseudo-flat-earth equilibrium (above the break point line), increasing the centrality of the network will break the equilibrium eventually and shift the economy toward a more agglomerated outcome. Regarding the convexity of the sustain and break points, this non-linearity implies that increases in the centrality of the network result in ranges of transport costs for which agglomeration is sustainablñe that increase at a higher rate (the area below the sustain point line), but also results into a lower range of transports costs for which the dispersed equilibrium exists, which in turn diminishes also to a higher rate (the area above the break point points). Altogether, this implies that the agglomerated equilibrium is sustainable for an increasingly larger range of transports cost, while the dispersed equilibrium exists for a decreasingly lower range of transport costs. Finally, Figure 2.7 also illustrates the gap between the maximum and minimum pseudo flat-earth for a given network centrality (2.17). The largest and smallest gaps are observed for the extreme star and ring topologies, respectively.[14]

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[14] Given the transition matrix (2.19), regions 2 and 4 present the same centrality index (2.7) for all network topologies.

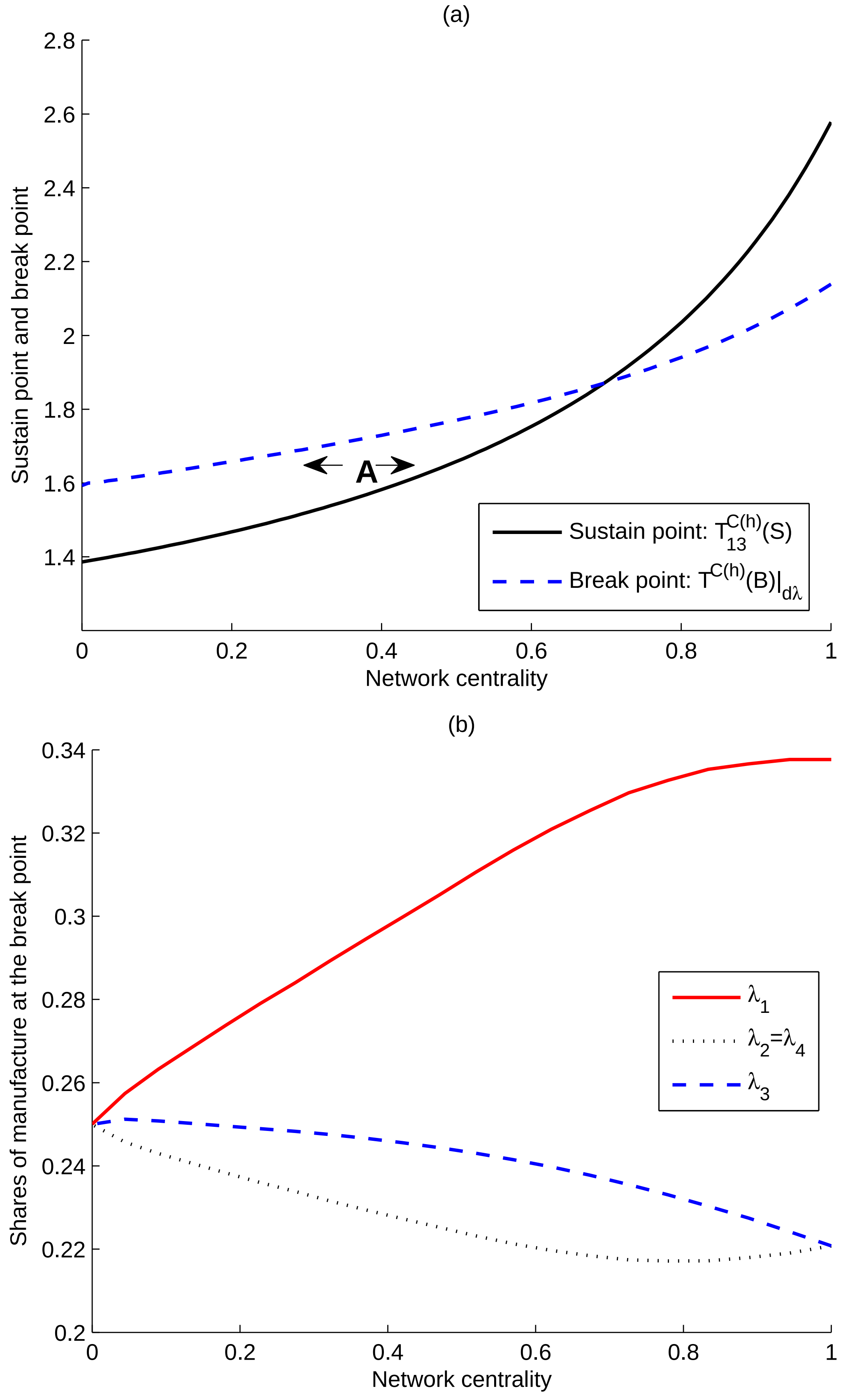

Figure 2.7: (a) Sustain points, and break points for intermediate network topologies and a given shock $d\lambda$; (b) share of manufacturing activity at the break point for intermediate network topologies and a given shock $d\lambda$.

2.5 Conclusions

The relative position of locations —nation, region or city —in space plays a critical role in the agglomeration and dispersion of economic activity. Whereas transport cost is one of the elements that shapes the current distribution of economic activity, geographical topology must also be taken into account, since the effects of a change in transport costs on the distribution of economic activity (e.g., the triggering of alternative processes of agglomeration or dispersion) differ depending on the economy's spatial configuration. Thus the relative position of a region in space determines the final result of these processes.

Our results show that alternative network topologies present different behaviors for agglomerating and dispersing forces and thus for alternative spatial configurations of economic activity. Indeed, result 1 shows that for the two polar cases—homogeneous ring topology and heterogeneous star topology—the sustain point is higher in the latter. The existence of a "first nature" advantage in favor of the central region makes agglomeration in that region more sustainable (and therefore less sustainable in peripheral regions). We generalize the result for these extreme topologies to any pair of network configurations, showing in results 2 and 3 that both the sustain and break points are higher in networks presenting higher centralities. If we were to depart from a symmetric equilibrium, regions with higher centralities would start drawing economic activity at a higher transport-cost level than if the network were neutral, with no region presenting a locational advantage.

The systematic study of sustain and break points yields several interesting results never studied in the literature. For heterogeneous networks exhibiting a positive degree of centrality, we stress that the dispersed flat-earth equilibrium, which is the initial configuration of manufacturing activity when studying break points, is infeasible (proposition 1). Therefore, we introduce the concept of pseudo flat-earth that defines as a steady-state equilibrium in which all regions produce manufacturing in unequal shares. As there are various values of manufacturing shares that satisfy this stability criterion, we further qualify this concept in terms of inequality between shares. Thereby we introduce maximum pseudo flat-earth as that economy where the share difference between the central region and the peripheral regions is at its largest, and the minimum pseudo flat-earth as that economy where the difference is at its smallest. Additionally, we find that both the sustain and break points are convex on the degree of centrality. Consequently, as the centrality of the network increases the transport-cost thresholds for which full agglomeration and symmetric dispersion are no longer stable increase to a higher rate, showing that the higher first-nature advantages, the stronger the agglomeration forces in favor of central locations.

The definition of the spatial equilibrium and its changes in terms of the network centrality is one of the main contributions of this study, with the previous results having important implications for policies aiming to increase territorial cohesion between regions by way of infrastructure investment; e.g., in terms of accessibility, which in our network framework corresponds to a reduction of network centrality. This situation is illustrated in Figure 2.7, where the spatial equilibrium of an economy in terms of its centrality and transport cost corresponds to $A = (C(h), T)$. In this situation neither fully agglomerated nor fully dispersed equilibria are steady states, and reducing network centrality favors the dispersed outcome, whereas if network centrality were increased the agglomerated outcome would emerge. In general, with a departure from a heterogeneous space, full cohesion between regions can be achieved only if all regions have the same relative position in terms of transport costs. Because in real geographical patterns some locations are better situated than others as a result of first-nature advantages, full cohesion is not possible unless transport costs are equalized across all regions (e.g., with infrastructure investments). An objective beyond reach of transportation planners. Indeed, because in the real world it is impossible with infrastructure policies to transform a heterogeneous space into a homogeneous space like the "racetrack economy", policymakers should bear in mind that there might be situations where the first-nature advantages of some locations are so large that any feasible reduction in the centrality of network topology may not be enough to trigger a dispersion of economic activity. In other words, at existing levels of unit-transport costs, using infrastructure policy to reshape the economy's spatial configuration in terms of network centrality may not be enough to substantially change the distribution of economic activity. In the same vein, given a network centrality, a reduction in unitary transport cost driven by lower market prices (e.g., as expected from a liberalization of labor and capital markets) or by technological improvements (e.g., vehicle fuel efficiency) may not be enough to overcome the privileged position of some locations[15]

For our model, we normalize the size of the different topologies so as to render them comparable; i.e., networks are defined in the two-dimensional Euclidean plane confined within a circle of radius 1. This can be understood as a units-invariant framework. As distances can be measure in any unit of measurement and the sustain and break points are not units invariant, this is a simple way to obtain results based on relative transport-cost differences, regardless of their absolute values. This allows us to disentangle the effects of changes in transport cost and in the degree of centrality in the network topology. Nevertheless, it is clear that both elements end up configuring total transport costs. In fact, distance as cost in economics, and even in geography, is not represented solely by the obvious geographical distance between two locations. There are other measures besides it: for instance, distance as travel time, generalized transport costs. All of these can be expressed in unit-distance terms (e.g., per kilometer, minute, dollars), and thus our distinction between these two elements can be maintained in empirical applications. Still other clear alternatives for the introduction of transport costs would be weighted networks, where distance matrices capture more sophisticated definitions of the cost function. This opens the possibility of using weighted links—e.g., distances weighted by generalized transport costs—within network theory (e.g., Opsahl et al. (2010)). In any case, it would be possible to simulate the effect on particular economies of transport policies aimed at reducing network centrality, thereby predicting whether such investments would in fact increase territorial

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[15] Note that we do not favor a particular locational pattern, since the superiority of dispersion or agglomeration as a social outcome depends on transport costs and the alternative social functions defined, see Charlot et al. (2006). Nevertheless, it is widely accepted that transport-infrastructure policies aim to increase territorial cohesion in terms of per-capita income. Therefore, when promoting infrastructure improvements public officials take for granted that a reduction in network centrality favors less-developed (peripheral) regions: i.e., their expected long-run outcome is territorial cohesion through reduction of income differentials.

cohesion. For example, as previously suggested, a country's network topology could be such that no investment whatsoever would change the existing geographical distribution of economic activity, due to a network so central that no sustain point could ever be reached; i.e., the existence of a "black hole" location in terms of network centrality, complementing that associated to other parameters of the model.

Finally, for the multiregional model in this study we have considered only the canonical core-periphery model of Krugman (1991), but we could extend the analysis and introduce network theory in other simple models of the new economic geography, like the linear version by Ottaviano et al. (2002), or more elaborated models as the one with vertical linkages by Puga and Venables (1995).

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Appendices

2.A Real wages in a multiregional economy when one region is agglomerating

When only one region — say, region 1 — is agglomerating we set $\lambda_1 = 1$ and $\lambda_i = 0 \quad \forall i \neq 1$ in equation (2.2), thereby obtaining:

$$y_1 = \frac{1+(N-1)\mu}{N}; \quad y_i = \frac{1-\mu}{N}, \quad i = 2, \dots, N.$$

Since by equation (2.9) the nominal wage of region 1 is equal to 1, we can substitute and get price indices (2.3):

$$g_1 = 1; \quad g_i = \tau_{1i}, \quad i = 2, \dots, N.$$

Inserting the price indices and income we obtain nominal wages (2.4):

$$w_1 = 1$$

$$w_i = \left(\frac{1-\mu}{N} \tau_{1i}^{\sigma-1} + \frac{1+(N-1)\mu}{N} \tau_{i1}^{1-\sigma} + \sum_{j=2\neq i}^{N} \frac{1-\mu}{N} \tau_{1j}^{\sigma-1} \tau_{ij}^{1-\sigma} \right)^{1/\sigma}.$$

as well as the real wage (2.5):

$$\omega_1^\sigma = 1$$

$$\omega_i^\sigma = \frac{1-\mu}{N} \tau_{1i}^{\sigma-1-\mu\sigma} + \frac{1+(N-1)\mu}{N} \tau_{i1}^{1-\sigma} \tau_{1i}^{-\mu\sigma} + \frac{1-\mu}{N} \tau_{1i}^{-\mu\sigma} \sum_{j=2\neq i}^{N} \tau_{1j}^{\sigma-1} \tau_{ij}^{1-\sigma}$$

2.B Real wages in a multiregional economy with N = 4

Following the same procedure as in Appendix 2.A and setting $N = 4$, we obtain the following expressions of real wages:

$$\begin{aligned}
\omega_1^\sigma &= 1\\
\omega_2^\sigma &= \frac{1-\mu}{4}\tau_{12}^{\sigma-1-\mu\sigma} + \frac{1+3\mu}{4}\tau_{21}^{1-\sigma}\tau_{12}^{-\mu\sigma} + \frac{1-\mu}{4}\tau_{12}^{-\mu\sigma}\left(\tau_{13}^{\sigma-1}\tau_{23}^{1-\sigma} + \tau_{14}^{\sigma-1}\tau_{24}^{1-\sigma}\right)\\
\omega_3^\sigma &= \frac{1-\mu}{4}\tau_{13}^{\sigma-1-\mu\sigma} + \frac{1+3\mu}{4}\tau_{31}^{1-\sigma}\tau_{13}^{-\mu\sigma} + \frac{1-\mu}{4}\tau_{13}^{-\mu\sigma}\left(\tau_{12}^{\sigma-1}\tau_{32}^{1-\sigma} + \tau_{14}^{\sigma-1}\tau_{34}^{1-\sigma}\right)\\
\omega_4^\sigma &= \frac{1-\mu}{4}\tau_{14}^{\sigma-1-\mu\sigma} + \frac{1+3\mu}{4}\tau_{41}^{1-\sigma}\tau_{14}^{-\mu\sigma} + \frac{1-\mu}{4}\tau_{14}^{-\mu\sigma}\left(\tau_{12}^{\sigma-1}\tau_{42}^{1-\sigma} + \tau_{13}^{\sigma-1}\tau_{43}^{1-\sigma}\right)
\end{aligned}$$

2.C Price index derivative

Raising the price index equation (2.3) to $1-\sigma$ yields:

$$g_i^{1-\sigma} = \lambda_i w_i^{1-\sigma} + \sum_{j=1\neq i}^{N} \lambda_j (w_j \tau_{ji})^{1-\sigma},$$

Taking logs:

$$(1-\sigma)\ln g_i = \ln\left(\lambda_i w_i^{1-\sigma} + \sum_{j=1\neq i}^{N} \lambda_j (w_j \tau_{ji})^{1-\sigma}\right)$$

and taking the derivative:

$$(1-\sigma)\frac{dg_i}{g_i} = \frac{d\left(\lambda_i w_i^{1-\sigma} + \sum_{j=1\neq i}^{N} \lambda_j (w_j \tau_{ji})^{1-\sigma}\right)}{\lambda_i w_i^{1-\sigma} + \sum_{j=1\neq i}^{N} \lambda_j (w_j \tau_{ji})^{1-\sigma}}$$

The denominator of the right-hand side is $g_i^{1-\sigma}$, which can be brought to the left side:

$$(1-\sigma)\frac{dg_i}{g_i^\sigma} = d\left(\lambda_i w_i^{1-\sigma} + \sum_{j=1\neq i}^{N} \lambda_j (w_j \tau_{ji})^{1-\sigma}\right).$$

Totally differentiating the right-hand side, we arrive at (2.12):

$$\begin{aligned}
(1-\sigma)\frac{dg_i}{g_i^\sigma} =& w_i^{1-\sigma} d\lambda_i + (1-\sigma)\lambda_i w_i^{-\sigma} dw_i +\\
&+ \sum_{j=1\neq i}^{N} \left((w_j\tau_{ji})^{1-\sigma} d\lambda_j + (1-\sigma)\lambda_j \tau_{ji}^{1-\sigma} w_j^{-\sigma} dw_j\right),
\end{aligned}$$

2.D Wage derivative

Raising wage equation (2.4) to σ yields:

$$w_i^\sigma = y_i g_i^{\sigma-1} + \sum_{j=1\neq i}^{N} y_j g_j^{\sigma-1} \tau_{ij}^{1-\sigma},$$

Taking logs:

$$\sigma \ln w_i = \ln\left(y_i g_i^{\sigma-1} + \sum_{j=1\neq i}^{N} y_j g_j^{\sigma-1} \tau_{ij}^{1-\sigma} \right),$$

and taking derivatives:

$$\sigma \frac{dw_i}{w_i} = \frac{d\left(y_i g_i^{\sigma-1} + \sum_{j=1\neq i}^{N} y_j g_j^{\sigma-1} \tau_{ij}^{1-\sigma} \right)}{y_i g_i^{\sigma-1} + \sum_{j=1\neq i}^{N} y_j g_j^{\sigma-1} \tau_{ij}^{1-\sigma}}.$$

The denominator of the right-hand side is w_i^{σ}, so it can be brought to the left side:

$$\sigma \frac{dw_i}{w_i^{1-\sigma}} = d\left(y_i g_i^{\sigma-1} + \sum_{j=1\neq i}^{N} y_j g_j^{\sigma-1} \tau_{ij}^{1-\sigma} \right)$$

Totally differentiating the right-hand side, we get equation (2.13):

$$\begin{aligned} \sigma \frac{dw_i}{w_i^{1-\sigma}} =& g_i^{\sigma-1} dy_i + (\sigma-1) y_i \sigma_i^{\sigma-2} dg_i + \\ &+ \sum_{j=1\neq i}^{N} \left(g_j^{\sigma-1} \tau_{ij}^{1-\sigma} dy_j + (\sigma-1) y_j \tau_{ij}^{1-\sigma} g_j^{\sigma-2} dg_j \right), \end{aligned}$$

2.E Real wage derivative

Totally differentiating equation (2.5) yields:

$$d\omega_i = g_i^{-\mu} dw_i - \mu w_i g_i^{-\mu-1} dg_i.$$

Multiplying both sides by g_i^{μ}:

$$g_i^{\mu} d\omega_i = dw_i - \mu w_i g_i^{-1} dg_i,$$

results in equation (2.14)

$$g_i^{\mu} d\omega_i = dw_i - \mu w_i \frac{dg_i}{g_i}.$$

Chapter 3

Industry Location and Wages: The Role of Market Size and Accessibility in Trading Networks

3.1 Introduction

Do market size and accessibility matter for industry location and wages? This question has attracted substantial attention in the literature ever since Krugman's (1980) and Helpman and Krugman's (1985) seminal contributions to new trade theory. The answer is 'yes', at least in simple models. It has indeed been shown that, in a world with increasing returns and costly trade, market size and 'accessibility' are locational advantages that significantly influence the geographical distribution of industry and regional factor prices.[1]

Despite those fundamental insights of 'new trade theory' and 'new economic geography', it is fair to say that the models in which the results have been derived rely on a number of highly restrictive assumptions. Those assumptions include, among others: (i) the existence of a costlessly tradable good; (ii) a single production factor; (iii) constant elasticity of substitution (CES) preferences; (iv) two industries only, with one producing a homogeneous good; and (v) two locations only. Though necessary to derive clear-cut results, those assumptions imply that little is know about the robustness of the results and on how they can guide empirical analysis.

Conscious of those limitations, and of the fact that a better understanding is required to push further empirical work on that topic, much subsequent work has started to relax some of those assumptions. First, Ottaviano and Thisse (2004), Picard and Zeng (2005), Zeng and Kikuchi (2009), Baldwin, Martin, Forslid, Ottaviano, and Robert-Nicoud (2003), Head, Mayer, and Ries (2002), and Yu (2005), among others, have shown that the basic insights of 'home market effects' (HME) gener-

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[1] The so-called 'home market effect' (HME) quickly became a key building block of New Trade Theory (NTT) first, and New Economic Geography (NEG) later (Krugman, 1991; Ottaviano, Tabuchi, and Thisse, 2002). It also attracted much attention in the empirical trade literature (e.g., Davis and Weinstein, 2003; Hanson and Xiang, 2004), because it potentially allowed to investigate the role of market size in shaping industry structure and trade.

alize to other preference structures – such as quadratic-linear preferences – or other market structures – such as oligopolistic competition. Second, Davis (1998) and Picard and Zeng (2005) have shown that the effect of market size on industry location is strongly dampenend (or even disappears) when the homogeneous good is not costlessly tradable. Davis (1998), in particular, shows that when trading the homogeneous good is as costly as trading the differentiated good, market size has no longer any bearing on regional specialization. This is also one basic message of Hanson and Xiang (2004), who argue that – in the absence of a costlessly tradable good – not all increasing returns sectors can be disproportionately present in one region, i.e., display 'home market effects'. Zeng and Kikuchi (2009), and Takahashi, Takatsuka, and Zeng (2013) derive analytical results in the case without factor price equalization (FPE), but only with two regions.[2] Behrens, Lamorgese, Ottaviano, and Tabuchi (2009) use a 'hybrid' approach, where trading the homogenenous good is costless, but where exogenous Ricardian differences in labor productivity in the homogeneous sector across countries create exogenous wage differences. Though conceptually simple and applicable to multiple countries, that approach does not allow for endogeneous wage changes in response to changes in economic fundamentals. Last, turning to multi-country extensions of those models, Behrens, Lamorgese, Ottaviano, and Tabuchi (2007, 2009) derive results for models with more than two countries. They show that the topology of the trading network matters for several of the results, and that the impact of market size on industry location arises only when differences in factor costs and in accessibility to markets are adequately controlled for. While being empirically very important, multi-location extensions of new trade models to arbitrary geographical structures have been very rare in the literature until now.[3]

While all of the foregoing contributions shed some light on the role of market size and accessibility on industry location and wages, what is missing to date is more systematic evidence for what happens in more 'realistic settings' where several of the basic assumptions are relaxed simultaneously. To the best of our knowledge, there has been no systematic investigation when there are multiple locations, several industries, and costly trade for all goods. This paper addresses precisely these issues. As there is no hope to obtain clear-cut analytical results in the general case, we instead resort to systematic numerical simulations. More precisely, we simulate the equilibria of two different models using a large number of randomly generated networks with a large number of regions. We then run simple regressions to extract the essence of the 'comparative static' results that are out of reach of pencil-and-paper analysis. In a nutshell, our research strategy is to combine theory and numerical analysis to: (i) first prove some theorems in 'toy models'; (ii) then solve large-scale models by numerical

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[2] See also Takatsuka and Zeng (2012) for another model with trade costs and two countries. As in Picard and Zeng (2005), all those models build on quadratic quasi-linear preferences following Ottaviano, Tabuchi, and Thisse (2002). These authors show that trade costs in the homogeneous good do not 'obscure' the HME, but the results are difficult to compare with those of the literature since there are no income effects in those models.

[3] There are many other dimensions along which the basic models have been extended. Without being exhaustive, we can mention Zeng and Kikuchi (2009), who provide an alternative model based on a footloose-capital specification with two production factors: labor, for the variable cost, and capital for the fixed cost. Behrens and Picard (2007, 2011) show that 'home market effects' get weaker or can even be reversed in the presence of multi-plant firms, or when trade imbalances translate into higher freight rates.

analysis; (iii) then run a detailed statistical analysis of the numerical results, very much like engineers or physicists do; and (iv) finally confront the models with real data to use if for simulation purposes.

Our key findings can be summarized as follows. First, absolute local market size – as measured by population – and accessibility – as measured by centrality in the trading network – are crucial in explaining a region's wage. This result is due to the fact that absolute size and accessibility affect all industries in similar ways, i.e., constitute a region's *absolute advantage*. The effect is stronger and more systematic in models where all sectors are subject to transport costs and exhibit increasing returns to scale. Second the relative local market size of industries (as measured by their consumer expenditure shares) is crucial in explaining a region's industrial composition. This result is due to the fact that relative spending patterns do not affect all industries in similar ways, i.e., constitute a region's *comparative advantage*. In a nutshell – and in line with Ricardian trade theory – absolute advantage translates into wages, whereas comparative advantage maps into specialization patterns. Third, the correlation between equilibrium wages and equilibrium industry shares is rather low, thus suggesting that both variables operate largely independently.

We then apply the models to Spanish data. Using 'Generalized Transport Costs' between regions as a measure of trade frictions, we find that the models generally predict well the distribution of industries, yet predict less well wages. A formal test does not allow to reject the null hypothesis that the industry distribution predicted by the models is the same than that observed in the data. We then use the calibrated model for Spain to run two counterfactual exercises, the aim of which is to disentangle the impact of changes in accessibility and changes in market size on regional industry shares and wages. Holding population fixed at 1980 levels, we find that changes in transport costs between 1980 and 2007 do not explain much of the increase in regional inequalities observed in Spain during that period. The change in inequality is much better captured when we hold transport costs fixed at 1980 levels and consider changes in population shares between 1980 and 2007. Although the simulated models capture the qualitative trend towards more regional inequality in Spain, they also tend to significantly overpredict the increase in polarization observed between 1980 and 2007.

The remainder of the paper is organized as follows. Section 3.2 develops two different new trade 'toy models': one with a single differentiated industry and a homogeneous good industry; and one with two differentiated industries. In both models, trade is costly and factor prices are endogenous. In Section 3.3, we extent the models to a larger scale and discuss a set of numerical results obtained from simulating those two models for a large number of random networks. We then present, in Section 3.4, an application to the case of Spanish regional data, as well as results from two counterfactuals. Finally, Section 3.5 concludes. Technical details are relegated to an extensive set of appendices.

3.2 Models

We develop two models within which we analyze the geographical distribution of economic activity and wages. In both models, there are $M \geq 2$ regions subscripted by $i = 1, 2, \ldots, M$. Each region is endowed with L_i immobile workers-consumers. The total population in the economy is fixed at

$L \equiv \sum_i L_i$. Labor is the only production factor, i.e., we abstract from comparative advantage across regions.

3.2.1 Model 1: One differentiated sector and one homogeneous sector

Our first model builds on Helpman and Krugman (1985) and its multi-location extensions by Behrens *et al.* (2007, 2009). There is one increasing returns to scale (IRS) sector with monopolistic competition that produces a continuum of varieties of a horizontally differentiated good; and one constant returns to scale (CRS) sector with perfect competition that produces a homogeneous good. In the differentiated sector, the combination of IRS, costless product differentiation, and the absence of scope economies yields a one-to-one equilibrium relationship between firms and varieties.

Preferences and demands

Preferences of a representative consumer in region j are given by:

$$U_j = H_j^{1-\mu} D_j^{\mu}, \tag{3.1}$$

where H_j stands for the consumption of the homogeneous good; where D_j is an aggregate of the varieties of the differentiated good; and where $0 < \mu < 1$ is the income share spent on the differentiated good. We assume that D_j is given by a CES subutility function

$$D_j = \left[\sum_i \int_{\Omega_i} d_{ij}(\omega)^{(\sigma-1)/\sigma} \mathrm{d}\omega \right]^{\frac{\sigma}{\sigma-1}},$$

where $d_{ij}(\omega)$ is the individual consumption in region j of variety ω produced in region i; and where Ω_i is the set of varieties produced in i. The parameter $\sigma > 1$ measures the elasticity of substitution between any two varieties. Let p_j^H denote the price of the homogeneous good in region j and $p_{ij}(\omega)$ the price of variety ω produced in region i and consumed in region j. Let w_j denote the wage in region j. Maximizing (3.1) subject to the budget constraint $p_j^H H_j + \sum_i \int_{\Omega_i} p_{ij}(\omega) d_{ij}(\omega) \mathrm{d}\omega = w_j$ yields the following individual demands:

$$d_{ij}(\omega) = \frac{p_{ij}(\omega)^{-\sigma}}{\mathbb{P}_j^{1-\sigma}} \mu w_j \quad \text{and} \quad H_j = \frac{(1-\mu) w_j}{p_j^H}, \tag{3.2}$$

where $\mathbb{P}_j$ is the CES price index in region j, given by

$$\mathbb{P}_j = \left[\sum_i \int_{\Omega_i} p_{ij}(\omega)^{1-\sigma} \mathrm{d}\omega \right]^{\frac{1}{1-\sigma}}. \tag{3.3}$$

Differentiated good

We first explain the workings of the IRS industry. Technology is assumed to be identical across firms and regions, therefore implying that firms differ only by the variety they produce and the region they are located in. Since varieties enter preferences in a symmetric way, we henceforth suppress the variety index ω to alleviate notation. Production of any variety involves a fixed labor requirement, F, and a constant marginal labor requirement, c. Denote by x_{ij} the amount of a variety produced in i and shipped to j. The total labor requirement for producing output $x_i \equiv \sum_j x_{ij}$ is given by $l_i = F + cx_i$.

Trade in the differentiated good is costly. Following standard practice we assume that trade cost are of the *iceberg* form: $\tau_{ij} \geq 1$ units must be dispatched from region i in order for one unit to arrive in region j. We further assume that trade costs are symmetric, i.e., $\tau_{ij} = \tau_{ji}$.[4] Using the demands (3.2), each firm in i maximizes its profit

$$\pi_i = \sum_j \left(p_{ij} - cw_i\tau_{ij}\right) L_j \frac{p_{ij}^{-\sigma}}{\mathbb{P}_j^{1-\sigma}} \mu w_j - Fw_i \tag{3.4}$$

with respect to all its prices p_{ij}, taking the price indices $\mathbb{P}_j$ and the wages w_j as given. Because of CES preferences, profit-maximizing prices have constant markups

$$p_{ij} = \frac{\sigma}{\sigma - 1} cw_i\tau_{ij}. \tag{3.5}$$

We denote by n_i the endogenously determined mass of firms located in i, and by $N \equiv \sum_i n_i$ the total mass of firms in the economy. We also denote by $\lambda_i \equiv n_i/N$ the share of firms in region i.

Because of iceberg trade costs, a firm in region i has to produce $x_{ij} \equiv L_j d_{ij}\tau_{ij}$ units to satisfy aggregate demand in region j. Free entry and exit imply that profits are non-positive in equilibrium which, using (3.4) and the pricing rule (3.5), yields the standard condition

$$x_i \equiv \sum_j L_j d_{ij}\tau_{ij} \leq \frac{F(\sigma - 1)}{c}. \tag{3.6}$$

Let $\phi_{ij} \equiv \tau_{ij}^{1-\sigma} \in [0,1]$ denote the 'freeness of trade' in the differentiated good between regions i and j. Inserting the demand (3.2) and the price index (3.3) into (3.6), multiplying both sides by p_{ij}, and using the prices (3.5), we get the wage equations

$$\sum_j \frac{w_i^{-\sigma} w_j \phi_{ij} L_j}{\sum_k w_k^{1-\sigma}\phi_{kj} n_k} \leq \frac{\sigma F}{\mu}. \tag{3.7}$$

Dividing both sides by the total population, L, letting $\theta_j \equiv L_j/L$, and choosing – without loss of generality – units for F such that $F \equiv \mu L/\sigma$, we can rewrite (3.7) as follows:

$$\mathrm{RMP}_i \equiv \sum_j \frac{w_i^{-\sigma} w_j \phi_{ij}\theta_j}{\sum_k w_k^{1-\sigma}\phi_{kj} n_k} \leq 1, \tag{3.8}$$

where RMP_i stands for the *real market potential* of region i (Head and Mayer, 2004). The number of workers employed in the differentiated industry of region i, when it has n_i firms, is

$$L_i^D \equiv n_i l_i = n_i(F + cx_i) = n_i\mu L, \tag{3.9}$$

where we have made use of our normalization of F.

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[4] This assumption is not crucial but makes our life easier in terms of modeling. We relax it later in Section 3.4 when appying our model to Spanish regions.

Homogeneous good

We next explain the workings of the perfectly competitive CRS industry. We assume that technology is the same in all regions. Without loss of generality, we normalize the unit labor requirement to one. Perfect competition implies marginal cost pricing. Given L_i^D workers employed in the differentiated good industry, the number of workers employed in the homogeneous sector equals $L_i^H \equiv L_i - L_i^D$. Inserting (3.9) into that expression, we can rewrite the number of workers in the homogeneous sector as follows:

$$L_i^H = L_i - n_i \mu L. \tag{3.10}$$

Note that (3.10) need not be positive, i.e., some regions may specialize in the production of the differentiated good only.

We assume that trading the homogeneous good is costly.[5] Hence, factor price equalization (FPE) does not hold in general and the world mass of firms in the differentiated industry is no longer constant.[6] The price of the homogeneous good produced in i and delivered to j equals its marginal cost of production, the wage w_i, times the trade cost τ_{ij}^H between regions i and j: $p_{ij}^H = w_i \tau_{ij}^H \equiv w_i \xi \tau_{ij}$, where $\xi > 0$ is a parameter that captures the *relative cost of trading the homogeneous good compared to the differentiated good*. If $\xi = 1$, there are no cost differences. When $\xi > 1$, trading the homogeneous good is more costly than trading the differentiated good, and vice versa when $\xi < 1$. In what follows, we set $\xi < 1$ because in the opposite case there is no trade in the homogeneous good so that the only equilibrium is one where industry shares are proportional to the size of the local market (Davis, 1998).[7]

Because good H is homogeneous and can be produced in, and imported from, any region, its price in region i must be the lowest one that can be secured from any source:

$$p_i^H = \min_k \{w_k \xi \tau_{ki}\}. \tag{3.11}$$

Demand for the homogeneous good is given by (3.2), while supply is determined by the domestic production for the local market, X_{ii}, and the sum of imports. Let X_{ji} denote the imports of the homogeneous good from region j. Market clearing for the homogeneous good in region i requires that:

$$\frac{(1-\mu) w_i L_i}{p_i^H} = X_{ii} + \sum_{j \neq i} X_{ji}. \tag{3.12}$$

Dividing the foregoing expression by the total population, L, and using the price (3.11), we can write

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[5] See Appendix A for a discussion of the case with costless trade of the homogeneous good. In that Appendix, we also explain why we disregard this case in what follows.

[6] The total mass of firms, N, varies with the spatial structure of the economy when there is costly trade in the homogeneous good (see, e.g., Takatsuka and Zeng, 2012). Hence, (3.8) cannot be generally expressed in the usual share notation λ_i with respect to firms, which explains the presence of n_k in that expression.

[7] There is of course still two-way trade in the differentiated good and the wages adjust to balance that trade. However, our focus is on industry structure and wages. The former cannot be meaningfully analyzed when we assume that $\xi \geq 1$, whereas the latter cannot be meaningfully analyzed if we assume that there is free trade in the homogeneous good.

(3.12) in terms of population shares, production, and imports:

$$\frac{(1-\mu)\,w_i\theta_i}{\min_k\{w_k\xi\,\tau_{ki}\}} = \widetilde{X}_{ii} + \sum_{j\neq i}\widetilde{X}_{ji}, \tag{3.13}$$

where $\widetilde{X}_{ii} \equiv X_{ii}/L$, and $\widetilde{X}_{ji} \equiv X_{ji}/L$ denote per capita variables. Labor market clearing in region i then requires that $L_i^H = L_i - n_i\mu L = \xi\left(\tau_{ii}X_{ii} + \sum_{j\neq i}\tau_{ij}X_{ij}\right)$. Since $L_i = \theta_i L$, we can rewrite the foregoing condition in per capita terms as follows:

$$\theta_i - n_i\mu = \xi\left(\tau_{ii}\widetilde{X}_{ii} + \sum_{j\neq i}\tau_{ij}\widetilde{X}_{ij}\right). \tag{3.14}$$

Because of perfect competition, the homogeneous good will not be simultaneously imported and exported by the same region. Hence, it must be that

$$\widetilde{X}_{ij} = \begin{cases} > 0 & \text{if} \quad w_i\tau_{ij} \leq \min_k\{w_k\tau_{kj}\} \\ = 0 & \qquad \text{otherwise.} \end{cases}$$

This latter condition can be rewritten equivalently in complementaty slackness terms as

$$\widetilde{X}_{ij}\cdot\left[w_i\tau_{ij} - \min_k\{w_k\tau_{kj}\}\right] = 0 \quad \text{and} \quad \widetilde{X}_{ij} \geq 0, \quad \forall j = 1,2,\ldots,M. \tag{3.15}$$

Equilibirum

An equilibrium in the IRS sector is such that the real market potential (3.8) is equal to one in all regions with a positive measure of firms, and less than one for regions devoid of firms. If all regions have a positive measure of firms, we obtain an *interior equilibrium*, whereas if there are some regions without firms we get a *corner equilibrium*. Formally, an equilibrium is defined as:

$$\begin{aligned} \text{RMP}_i = 1 \quad &\text{if} \quad n_i^* > 0 \\ \text{RMP}_i \leq 1 \quad &\text{if} \quad n_i^* = 0. \end{aligned} \tag{3.16}$$

Using notation in terms of complementary slackness, this implies that $n_i^*\cdot(\text{RMP}_i - 1) = 0$ and $n_i^* \geq 0$ for all regions. In addition to the zero profit free entry condition (3.16), the market clearing conditions (3.14) for the homogeneous good must hold for all regions at the equilibrium wages w_i. Conditions (3.13), (3.14), (3.15), and (3.16) define a system of $3M + M(M-1)$ equations in as many unknowns – the firm masses n_i, the wages w_i, the per capita domestic supplies $\widetilde{X}_{ii}$, and the per capita imports $\widetilde{X}_{ij}$.

3.2.2 Model 2: Two differentiated sectors

Our second model builds on Krugman (1980) and Behrens and Ottaviano (2011). There are two IRS sectors with CES monopolistic competition.[8] Regional market sizes differ both because of the

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[8] Hanson and Xiang (2004) develop a model with a continuum of sectors, but their focus is on two regions only. In this section, we take a complementary approach: we focus on two sectors only, but consider a large number of regions to look at industry location and wages.

numbers of consumers and because consumers have different spending patterns for the two goods. In such a setting, we can look at how differences in *absolute market sizes* – the population shares θ_i – and differences in *relative market sizes* – the expenditure shares μ_i – affect wages and the location patterns of industries.

Preferences and demands

The basic setup is the same as in Section 3.2.1, except that there are now two CES sectors and no homogeneous sector. Preferences of a representative consumer in region j are given by:

$$U_j = D_{1j}^{\mu_{1j}} D_{2j}^{\mu_{2j}}, \tag{3.17}$$

where D_{sj} stands for the CES consumption aggregate in sector s in region j; and $0 < \mu_{sj} < 1$ is the *region-specific* income shares for sector s. With two sectors, μ_{sj} is equal to μ_j in sector 1 and to $1-\mu_j$ in sector 2. Since expenditure shares are region specific, the relative consumption patterns differ across regions. Hence, market sizes differ due to spending patters on top of differences in regional population sizes.

The aggregator for consumption of the differentiated good, D_{sj}, is as follows:

$$D_{sj} = \left[\sum_i \int_{\Omega_{si}} d_{sij}(\omega)^{(\sigma-1)/\sigma} \mathrm{d}\omega\right]^{\frac{\sigma}{\sigma-1}},$$

where $d_{sij}(\omega)$ is the individual consumption in region j of sector-s variety ω produced in region i; and where Ω_{si} is the set of sector-s varieties produced in i. For simplicity, we assume that the elasticity of substitution between any two varieties, σ, is the same in both sectors.[9] Let $p_{sij}(\omega)$ denote the price of sector-s variety ω produced in i and consumed in j; and let w_j denote the wage in region j. Maximizing (3.17) subject to the budget constraint $\sum_i \left[\int_{\Omega_{1i}} p_{1ij}(\omega) d_{1ij}(\omega)\mathrm{d}\omega + \int_{\Omega_{2i}} p_{2ij}(\omega) d_{2ij}(\omega)\mathrm{d}\omega\right] = w_j$ yields the following individual demands:

$$d_{sij}(\omega) = \frac{p_{sij}(\omega)^{-\sigma}}{\mathbb{P}_{sj}^{1-\sigma}} \mu_{sj} w_j, \quad \text{where} \quad \mathbb{P}_{sj} = \left[\sum_i \int_{\Omega_{si}} p_{sij}(\omega)^{1-\sigma} \mathrm{d}\omega\right]^{\frac{1}{1-\sigma}} \tag{3.18}$$

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

Technology and trade

For simplicity, we assume that technology is the same in both sectors. As in Section 3.2.1, the total labor requirement for producing the output $x_{si} \equiv \sum_j x_{sij}$ is given by $l_{si} = F + c x_{si}$. Trade in both differentiated goods is costly and trade cost are symmetric and of the iceberg form: $\tau_{sij} = \tau_{sji} \geq 1$

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[9] We could relax that assumption, but there is not much to be learned from that exercise. The same holds true for relaxing the assumption of identical technologies in the two sectors. Nevertheless, as explained in footnote 17 below, we have also studied the effects of alternative values of σ and expenditure patterns μ_{sj} on industry shares, λ_{si}, and wages, w_i.

units must be dispatched from region i in order for one unit of a sector-s variety to arrive in region j. Using (3.18), a sector-s firm in i maximizes profit

$$\pi_{si} = \sum_j \left(p_{sij} - cw_i\tau_{sij}\right) L_j \frac{p_{sij}^{-\sigma}}{\mathbb{P}_{sj}^{1-\sigma}} \mu_{sj} w_j - Fw_i \tag{3.19}$$

with respect to all its prices p_{sij}, taking the price indices $\mathbb{P}_{sj}$ and the wages w_j as given. As before, profit-maximizing prices have constant markups:

$$p_{sij} = \frac{\sigma}{\sigma - 1} cw_i\tau_{sij}. \tag{3.20}$$

We denote by n_{si} the endogenously determined mass of sector-s firms located in i, and by $N_s \equiv \sum_i n_{si}$ the total mass of sector-s firms in the economy. Last, $\lambda_{si} \equiv n_{si}/N_s$ denotes the share of sector-s firms in region i.

A firm in region i and sector s has to produce $x_{sij} \equiv L_j d_{sij}\tau_{sij}$ units to satisfy aggregate demand in region j. Free entry and exit imply that profits are non-positive in equilibrium which, using the prices (3.20), yields again the standard free entry zero profit condition (3.6). Inserting the demands and the price index (3.18) into that expression, using the prices (3.20), and letting $\phi_{sij} \equiv \tau_{sij}^{1-\sigma} \in [0,1]$ denote the 'freeness of trade' in sector s, we get the wage equations:

$$\sum_j \frac{w_i^{-\sigma} w_j \phi_{sij} L_j \mu_{sj}}{\sum_k w_k^{1-\sigma} \phi_{skj} n_{sk}} \leq \sigma F. \tag{3.21}$$

Dividing both sides by world population, L, letting $\theta_j \equiv L_j/L$ as before, and choosing without loss of generality units of F such that $F = L/\sigma$, we obtain the real market potential for sector-s firms in region i as follows:

$$\mathrm{RMP}_{si} \equiv \sum_j \frac{w_i^{-\sigma} w_j \phi_{sij} \theta_j \mu_{sj}}{\sum_k w_k^{1-\sigma} \phi_{skj} n_{sk}} \leq 1. \tag{3.22}$$

Equilibrium

Expressions (3.22) define $2M$ conditions in the $3M$ unknowns $\{n_{1i}, n_{2i}, w_i\}$, for $i = 1, 2, \ldots, M$. To pin down the wages, we can impose either the labor market clearing conditions or the trade balance conditions. In what follows, we use the former as they are easier to handle given our choices of normalization. Labor market clearing in i requires that $L_i = n_{1i}(F + cx_{1i}) + n_{2i}(F + cx_{2i}) = L(n_{1i} + n_{2i})$, where we have used the normalization of F. Hence,

$$\theta_i = n_{1i} + n_{2i}. \tag{3.23}$$

Conditions (3.22) and (3.23) can be solved for the equilibrium wages and industry shares. The total masses of firms in the two sectors in the economy, $N_1 = \sum_i n_{1i}$ and $N_2 = \sum_i n_{2i}$ are not constant and vary with the spatial distribution of demand and with the structure of the trading network. Note, of course, that the total mass of firms in both sectors in the world economy is equal to one: $\sum_i (n_{1i} + n_{2i}) = \sum_i \theta_i = 1$ from (3.23).

To solve the model, we set $w_1 \equiv 1$ by choice of numeraire. Focusing on two regions with symmetric trade costs and free intra-regional trade ($\phi_{sii} = 1$ and $\phi_{sij} = \phi$ for all $i \neq j$), Behrens and Ottaviano (2011) have proven the following analytical results for two special cases: *absolute advantage*, i.e., when the spending patterns of the two regions are the same but when the regions differ by population size ($\mu_{11} = \mu_{12}$ and $\mu_{21} = \mu_{22}$, but $\theta_1 > \theta_2$); and *comparative advantage*, i.e., when spending patterns are anti-symmetric but when the regions have the same population size ($\mu_{11} = \mu_{22}$ and $\mu_{21} = \mu_{12}$, but $\theta_1 = \theta_2$). In those two polar cases, it can be shown that (see Behrens and Ottaviano, 2011, for the proofs):

Proposition 2 (Pure 'Comparative Advantage')**.** *Assume that preferences are anti-symmetric across regions ($\mu_{11} = \mu_{22}$ and $\mu_{21} = \mu_{12}$), and that both regions are of the same size ($\theta_1 = \theta_2$). The equilibrium is such that*

$$n_{11}^* = n_{22}^* = \frac{\mu(1+\phi)-\phi}{2(1-\phi)} \quad \text{and} \quad n_{21}^* = n_{12}^* = \frac{1-\mu(1+\phi)}{2(1-\phi)}$$

The equilibrium relative wage satisfies $w_2^* = 1$.

Proposition 3 (Pure 'Absolute Advantage')**.** *Assume that preferences are symmetric across regions ($\mu_{11} = \mu_{12}$ and $\mu_{21} = \mu_{22}$), and that region 1 has the larger market ($\theta_1 > \theta_2$). The equilibrium is such that*

$$n_{1i}^* = \mu\theta_i \quad \text{and} \quad n_{2i}^* = (1-\mu)\theta_i \tag{3.24}$$

for $i = 1,2$. The equilibrium relative wage satisfies $0 < w_2^* < 1$.

In Proposition 2, each region is the larger market for one of the two goods. Hence, each region specializes in the production of the good for which it has a relatively larger local demand. In other words, relative differences in market sizes lead to different specialization patters but do not affect factor prices. In the case of Proposition 3, one region is the larger market for both goods. In that case, the wage in the larger region must be higher because it offers a locational advantage for *both* industries. Clearly, this is akin to absolute advantage in a Ricardian sense and it is, therefore, capitalized into factor prices.

Of course, the two cases in Propositions 2 and 3 are extreme ones, and intermediate cases where both absolute and comparative advantage play a role should be considered. Furthermore, it is of interest to relax the assumption of just two regions and of symmetric trade costs to investigate also the interactions with 'geography'. This is what we do using numerical simulations in the next section and Spanish data in Section 3.4.

3.3 Size and accessibility in random tree networks

It is virtually impossible to derive general analytical results in an arbitrary multi-region setting without FPE, because the equilibrium allocations of firms and wages are determined by a complex trade-off between a region's market size and its accessibility in the trading network.[10] To nevertheless gain insights into how size and accessibility – as well as the whole structure of the trading network – influence the equilibrium, we resort to systematic numerical simulation. To this end, we proceed as follows.

First, we generate a random tree network with a random number of nodes (see Appendix B for details). The nodes are the regions, and the links between nodes represent the connections for shipping goods. Networks are generated incrementally either by having equal attachment probabilities for new nodes, or by using the Barabási and Albert (1999; henceforth BA) preferential attachment algorithm that generates networks which exhibit a 'hub-and-spoke' structure. Second, we assign a random population share, θ_i, to each node i of the network.[11] In the case with two differentiated industries, we also randomly assign a region-specific expenditure share for each industry. Third, we solve the two models for their equilibria. We repeat this three-step process for a large number of randomly generated networks and then relate selected characteristics of the equilibria thus obtained to underlying networks characteristics. Doing so will allow us to gain more systematic insights into how size and accessibility interact to determine the regional allocation of firms and wages, and how those allocations depend on the econonic model we have choosen.

We describe the numerical implementation in detail in Appendix C. In the following sections, we explore the results obtained for the two models.

3.3.1 Model 1: One differentiated sector and one homogeneous sector

We first compute simple correlations between the equilibrium masses of firms in the different regions (n_i^*), their population shares (θ_i), and their centrality (C_i). The latter is measured either by the *closeness centrality* (henceforth 'closeness', for short) or by the node's degree. Following standard practice in the network literature (see, e.g., Freeman, 1979), closeness is defined as

$$C_i = \left[\frac{\sum_j d_{ij}}{\min_k \{\sum_j d_{kj}\}} \right]^{-1}, \tag{3.25}$$

where d_{ij} denotes the length of the link – the distance – between nodes i and j. By definition, closeness varies between 0 and 1. 'Degree' is simply measured by the number of links of the node. Centrally located nodes have both a high value for closeness and for degree. This can be seen from

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[10] One can derive analytical results by having multiple regions and a symmetric trading network, but this is in the end isomorphic to using just two regions and thus of no particular interest.

[11] Choosing 'totally random' networks – though providing an interesting benchmark case – is not fully satisfying because transportation networks are endogenous and obey certain rules. This is why we also derive results using networks that display a 'hub-and-spoke' structure to capture the empirical fact that some places are very well connected while others are very poorly connected (see, e.g., Xie and Levinsohn, 2008, for the case of the road network in Indiana). Observe that we assign θ_i randomly, i.e., there is no systematic correlation between size and accessibility. The reason for that choice is that we want to study the distribution of industry as a function of size and accessibility separately. Introducing a systematic correlation between the two (though empirically relevant since larger places are better connected and since places that are better connected tend to grow larger; see Duranton and Turner, 2012) is not required for our analysis.

the correlations in the top panel of Table 3.1. That panel shows that, as expected, size (θ_i) and accessibility (closeness$_i$ and degree$_i$) are positively linked to a region's equilibrium industry share (λ_i^* or, alternatively, n_i^*) and to a region's wage (w_i^*). The correlation is particularly strong for the degree measure of centrality. Observe also that size is more strongly linked to industry location, whereas accessibility is more strongly linked to wages. Put differently, size differences map into differences in industry structures, whereas accessibility differences translate into factor price difference. In general, however, the correlations with factor prices are weaker than the correlations with industry location.

Table 3.1: Simple correlations (Model 1).

	λ_i^*	n_i^*	w_i^*	θ_i	closeness$_i$	degree$_i$
λ_i^*	1					
n_i^*	0.9987	1				
w_i^*	0.0849	0.0806	1			
θ_i	0.8119	0.8065	0.0899	1		
closeness$_i$	0.2680	0.2693	0.1316	0.0134	1	
degree$_i$	0.3972	0.4023	0.1799	0.0135	0.7075	1
	CV(Λ^*)	CV($\mathbf{n}^*$)	CV($\mathbf{w}^*$)	CV(θ)	CV(closeness)	CV(degree)
CV(Λ^*)	1					
CV($\mathbf{n}^*$)	1	1				
CV($\mathbf{w}^*$)	-0.0082	-0.0082				
CV(θ)	0.3005	0.3005	0.1581	1		
CV(closeness)	0.0113	0.0113	0.2475	0.2156	1	
CV(degree)	0.3255	0.3255	-0.0728	-0.2254	-0.2215	1

Notes: Simple correlations for 100 random tree networks with a random number of 20 to 30 nodes. The top panel of the table gives correlations at the level of individual nodes (pooled across all 100 networks), whereas the bottom panel of the table gives correlations at the level of the whole network. The shares λ_i^* are given by $\lambda_i^* = n_i^*/(\sum_j n_j^*)$. CV denotes the coefficient of variation, whereas Λ^*, $\mathbf{n}^*$, $\mathbf{w}^*$, and θ denote the equilibrium vectors of industry shares, masses of firms, wages, and market size, respectively.

The bottom panel of Table 3.1 displays the same correlations as in the top panel, but now between aggregate network statistics and the vectors of equilibrium outcomes. More precisely, it displays the correlations between the coefficients of variation (CV) of industry shares and wages (computed for each network at the node level), and the coefficients of variation of size and accessibility. As can be seen, dispersion in market sizes – as captured by a larger CV – is positively associated with dispersion of industry shares and wages. The same holds true for dispersion in the accessibility measures, with again a much stronger effect of degree as compared to closeness. It is finally of interest to note that the correlations between the equilibrium industry shares, λ_i^* (or the equilibrium masses of firms, n_i^*) and the equilibrium wages – though positive – are fairly small (0.080 and 0.085, respectively). This result suggest that the two variables operate largely independently to determine the equilibrium.

To go beyond simple univariate correlations, we now run several ordinary least squares (OLS) regressions to estimate the partial effect of increasing market size or centrality of nodes on the equilibrium shares of manufacturing activity and the equilibrium wages, controlling for accessibility and for size. In Model 1, there are two endogeneous variables that can be analyzed in the regressions: the equilibrium allocation of firms, λ_i^*, and the equilibrium wages, w_i^*.[12] Mirroring the two panels of Table 3.1, we start with an analysis at the level of the individual nodes, and turn then to an analysis at the level of the whole network.

Results for individual nodes

We regress the equilibrium shares of firms, λ_i^*, or the equilibrium wages, w_i^*, on measures of: (i) the node's centrality, as given by either closeness or degree; and (ii) the node's market size.[13] We perform a pooled analysis with both types of networks (based on preferential attachment, BA, or equal probabilities) – in which case we include a network dummy indicating the network type – and separate regressions for each type of network. Formally, we estimate

$$\begin{aligned} \lambda_i^* &= \beta_0 + \beta_1 \text{centrality}_i + \beta_2 \theta_i + \text{network\_dummy}_i + \varepsilon_i && (3.26) \\ w_i^* &= \gamma_0 + \gamma_1 \text{centrality}_i + \gamma_2 \theta_i + \text{network\_dummy}_i + \varepsilon_i, && (3.27) \end{aligned}$$

for all the nodes of the networks we have generated.

Table 3.2 summarizes our estimation results of (3.26) and (3.27). As can be seen from that table, both centrality and market size positively influence a node's equilibrium share of firms and its equilibrium wage. It is worth pointing out that the so-called 'Home Market Effect' (HME) – defined as a more than proportional increase in industry shares in response to an increase in local market size – always arises in both types of networks: ($\partial \lambda_i^* / \partial \theta_i > 1$). This effect seems to generally hold in models without FPE (see, e.g., Takahashi, Takatsuka, and Zeng, 2013, for a discussion of the two-region case).

Note further that both measures of centrality – closeness and degree – have a statistically strongly significant impact on the equilibrium allocation of firms across regions.[14] We also ran the regressions by quintiles in terms of the degree or the closeness distributions of the nodes. In both cases, the estimated coefficients for θ_i increase monotonically with the quintiles. Thus, there is some complementarity between market size and accessibility: more accessible regions benefit more strongly from an increase in market size than more peripheral regions. In other words, increasing the size of the market in peripheral regions is unlikely to have strong impacts on the equilibrium allocation of industry.

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[12] Due to the high correlation between λ_i^* and n_i^* (see Table 3.1), there is no reason to look at the latter separately.

[13] We do not include both measures of centrality simultaneously, because of their high correlation (see Table 3.1).

[14] The results are identical when using the mass of firms, n_i^*, instead of the share of firms, λ_i^*. This finding suggests that the total mass of firms has no specific additional effect on the equilibrium allocation across regions. Since our regressions are not in logarithmic form, scaling by the total number of firms is *not* neutral. One might have expected that the total number of firms has a significant dispersive impact. Indeed, as the total number of firms rises, 'competition' gets tougher, and thus firms tend to disperse more.

Table 3.2: OLS regression results for individual nodes (Model 1).

	Dependent variable: λ_i^*					
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Closeness$_i$	0.0671^a		0.1019^a		0.0347^a	
	(24.637)		(23.110)		(11.821)	
Degree$_i$		0.0090^a		0.0097^a		0.0074^a
		(44.085)		(34.725)		(24.247)
θ_i	1.2201^a	1.2175^a	1.2095^a	1.2094^a	1.2340^a	1.2277^a
	(77.116)	(92.053)	(47.772)	(55.957)	(71.466)	(81.959)
Constant	-0.0528^a	-0.0260^a	-0.0725^a	-0.0270^a	-0.0321^a	-0.0233^a
	(-26.905)	(-32.700)	(-24.090)	(-23.765)	(-15.490)	(-25.825)
Network type	Both	Both	BA	BA	Equal	Equal
Network dummy	Yes	Yes	No	No	No	No
Observations	2,498	2,498	1,274	1,274	1,224	1,224
Adjusted R^2	0.726	0.808	0.689	0.773	0.812	0.859

	Dependent variable: w_i^*					
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Closeness$_i$	0.0420^a		0.0361^a		0.0465^a	
	(6.130)		(4.366)		(4.350)	
Degree$_i$		0.0056^a		0.0049^a		0.0071^a
		(9.164)		(8.165)		(5.553)
θ_i	0.1788^a	0.1772^a	-0.1424^a	-0.1428^a	0.4906^a	0.4863^a
	(4.487)	(4.488)	(-2.999)	(-3.062)	(7.804)	(7.772)
Constant	0.9646^a	0.9815^a	0.9717^a	0.9850^a	0.9492^a	0.9663^a
	(195.120)	(412.934)	(172.098)	(401.503)	(125.631)	(256.572)
Network type	Both	Both	BA	BA	Equal	Equal
Network dummy	Yes	Yes	No	No	No	No
Observations	2,498	2,498	1,274	1,274	1,224	1,224
Adjusted R^2	0.0333	0.0507	0.0200	0.0549	0.0610	0.0699

Notes: We set $\sigma = 5$, $\mu = 0.4$, and $\xi = 0.7$. See Appendix D for a discussion of those choices. Simple OLS regressions. BA denotes networks generated using the Barabási and Albert (1999) algorithm. T-stats in parentheses. ^{a}, ^{b}, and ^{c} denote coefficients significant at 1%, 5%, and 10%, respectively.

The results pertaining to wages in the bottom panel of Table 3.2 deserve some comments. First, as can be seen, the two measures of centrality are always positively linked to a region's equilibrium wage. In other words, more centrally located regions or regions with better market access command higher wages, which is in line with predictions of new economic geography models and with empirical evidence (see, e.g., Mion, 2004, for Italy; and Hanson, 2005, for the US). The average equilibrium wage for 'peripheral' regions – in the first quintile of the degree distribution – is $\overline{w}_{Q1} = 0.9854$;

whereas that for more 'central' regions – in the fifth quintile of the degree distribution – is $\overline{w}_{Q5} = 1.0074$. Consequently, peripheral regions tend to specialize in the homogeneous good, paying lower wages and exporting to more central locations characterized by a high degree. The latter enjoy lower transportation costs over the network, and hence specialize in the differentiated good paying higher wages.

Second, observe that the correlation between θ_i and w_i^* is quite low – though still positive. The intuition underlying this surprising result is as follows. Consider two regions i and j, where $\theta_i > \theta_j$. Assume that region i is *not fully specialized* in the production of the differentiated good, i.e., there is still some local production of the homogeneous good. If region i imports some of the homogeneous good from region j, by (3.11) the following condition must hold: $p_{ji}^H = w_j \xi \tau_{ji} = p_{ii}^H = w_i \xi \tau_{ii}$. Hence, the relative wage w_i/w_j in the two regions just depends on the relative trade costs τ_{ji}/τ_{ii}, but it is independent of market sizes θ_i and θ_j. In other words, it is just the structure of the trading network that matters, but not the distribution of market sizes. Of course, this result only holds true when a region is not fully specialized in the production of differentiated goods. Should no production of the homogeneous good take place in a region, its wage will increase with its market size – and so will the wages of the regions that export the homogeneous good to that region. We can easily confirm this conjecture by computing the correlation between θ_i and w_i^* for the regions that do not produce any of the homogeneous good. In that case the correlation is about 0.4, instead of 0.09 when considering all regions. In other words, costly trade in the homogeneous good imposes strong conditions on wages, and those conditions partly destroy the positive link between market size and wages.

Table 3.3: Link between market size and equilibrium wages by node type (Model 1).

Node type	# nodes	$\overline{\theta}_i$	$\overline{w}_i^*$
		Barabási and Albert	
Nodes specialized in the homogeneous good	225	0.0124	0.9974
Nodes specialized in the differentiated good	122	0.0310	1.0000
Nodes not specialized in either good	927	0.0470	0.9852
		Equal probability	
Nodes specialized in the homogeneous good	205	0.0090	0.9982
Nodes specialized in the differentiated good	41	0.0240	1.0011
Nodes not specialized in either good	978	0.0460	0.9990

Notes: Breakdown of individual nodes by specialization type. The sample is the same than that used for the regression analysis. $\overline{\theta}_i$ and $\overline{w}_i^*$ denote the average market size and the average equilibrium wages of the types of nodes.

Third, centrality – both in terms of closeness *and* in terms of degree – generally has a strong impact on industry location and, to a lesser extent, on wages as explained above. A larger local market is weakly associated with higher wages, except in hub-and-spoke type BA networks (see columns (iii) and (iv) of Table 3.2). This latter result is surprising and requires some further explanation. As can be seen from Table 3.3, the largest regions are not fully specialized in the production of either type of good: their large size prevents them from being fully specialized since they cannot source all the homogeneous good that they need. Consequently, these regions have lower wages than smaller regions specialized in the differentiated good. The reason is that, as stated before, their wage is linked to the wage of the regions that supply them with the homogeneous good since they are unspecialized. In BA type networks, the largest regions have relatively low wages compared to the equal random network case, as there are on average less links with other regions in those networks. This strong non-linear effect between equilibrium wages and market size drives the negative coefficients in the lower panel of Table 3.2 for BA networks. Note also that the constant term in the wage regressions is close to unity, which is the theoretical value of relative wages in the absence of any differences in size and accessibility.

Our findings suggest that any analysis focusing on two regions only or disregarding the spatial structure of the trading network is likely to miss an important part of the story. It also shows that more careful theoretical analysis of multi-region trading systems is necessary, though it is well known that such an analysis is difficult to carry out in the general case when factor prices are not equalized.[15]

Results for the whole network

We next run regressions at the level of the network. The underlying idea is to link a measure of inequality in either the equilibrium allocation of industry or wages to measures of inequality in the distribution of market sizes and centrality in the network. We use as our inequality measure the CV of the different variables. As in the case of individual nodes, we first compute the correlations – this time across networks – for our measures of inequality. The results are reported in the bottom half of Table 3.4.

We then run OLS regressions to estimate the effect of the dispersion in the population shares and in centrality on the inequality in the distribution of manufacturing shares and wages. Formally, we estimate:

$$\begin{aligned} \mathrm{CV}(\lambda_l^*) &= \beta_0 + \beta_1 \mathrm{CV\_centrality}_l + \beta_2 \mathrm{CV}(\theta_l) + \mathrm{network\_dummy}_l + \varepsilon_l && (3.28) \\ \mathrm{CV}(\mathbf{w}_l^*) &= \gamma_0 + \gamma_1 \mathrm{CV\_centrality}_l + \gamma_2 \mathrm{CV}(\theta_l) + \mathrm{network\_dummy}_l + \varepsilon_l, && (3.29) \end{aligned}$$

where the subscript l now denotes the network and not the individual nodes.

As can be seen from Table 3.4, the dispersion in market sizes, θ_i, has a significant impact on the dispersion in the equilibrium allocation of firms, whereas the geographical structure of the trading network seems to be of lesser importance. Inequality in market size is more important for explaining inequality in the allocation of firms than the network structure. Quite surprisingly, wage inequality is not strongly linked to either inequality in the distribution of market sizes or to inequality in accessibility in the trading network. Closeness has a positive impact on wage inequality, but only in networks that have a sufficiently strong topological structure (i.e., in BA-type networks). Observe

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[15] Behrens *et al.* (2009) take an intermediate route where factor prices differ because of *exogenous* Ricardian differences. Though conceptually simpler than the case with endogeneous factor prices, this approach does not allow to analyze how wages change with market size and accessibility.

that in totally random tree networks, neither dispersion in market sizes nor in accessibility correlate significantly with dispersion in wages. One might suspect that some non-linear relationship is at work, especially since many regions can become deindustrialized, i.e., have a zero industry share (see Table 3.3). When a large number of regions have zero industry shares, the CV may decrease since there is no more variation coming from the deindustrialized regions. We checked formally the impact of deindustrialized regions on equilibrium inequality. Controlling for the number of regions without industry (about 430 out of 2498, or 17.25%), we find that this variable is significant in all regressions, but that it does not change in any way the qualitative results. Thus, deindustrialized regions do not drive our key findings. They are also not driven by units of measurement issues, since we use the CV which is unit free. Last, observe that the model fit is generally much better for the dispersion of industry (top half of the table) than for the dispersion in wages (bottom half of the table). It seems thus much harder to link wage inequality to inequality in the model's fundamentals than spatial inequality in industry shares.

Table 3.4: OLS regression results for the whole network (Model 1).

	Dependent variable: CV(Λ_l)					
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
CV(Closeness$_l$)	0.1530		-0.2892		0.5292	
	(0.110)		(-0.133)		(0.299)	
CV(Degree$_l$)		0.2614^b		0.1597		0.6380^b
		(2.106)		(1.027)		(2.639)
CV(θ_l)	0.6269^a	0.7112^a	0.7167^a	0.7325^a	0.5185^b	0.8577^a
	(3.688)	(4.250)	(2.871)	(3.041)	(2.225)	(3.454)
Constant	0.4326	0.2515^c	0.5920	0.3678^c	0.4145	-0.0727
	(1.430)	(1.780)	(1.295)	(1.720)	(1.056)	(-0.279)
Network type	Both	Both	BA	BA	Equal	Equal
Network dummy	Yes	Yes	No	No	No	No
Observations	100	100	51	51	49	49
Adjusted R^2	0.198	0.233	0.116	0.135	0.0655	0.187

	Dependent variable: CV($\mathbf{w}_l$)					
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
CV(Closeness$_l$)	0.4631^b		0.6153^c		0.3053	
	(2.082)		(1.708)		(1.157)	
CV(Degree$_l$)		0.0154		0.0264		-0.0413
		(0.745)		(0.997)		(-1.066)
CV(θ_l)	0.0284	0.0443	0.0481	0.0688^c	0.0005	-0.0146
	(1.043)	(1.588)	(1.165)	(1.677)	(0.016)	(-0.367)
Constant	-0.0835^c	-0.0011	-0.1305^c	-0.0352	-0.0323	0.0697
	(-1.725)	(-0.046)	(-1.726)	(-0.967)	(-0.552)	(1.670)
Network type	Both	Both	BA	BA	Equal	Equal
Network dummy	Yes	Yes	No	No	No	No
Observations	100	100	51	51	49	49
Adjusted R^2	0.0476	0.0103	0.0661	0.0295	-0.0132	-0.0175

Notes: CV stands for 'coefficient of variation'. We set $\sigma = 5$, $\mu = 0.4$, and $\xi = 0.7$. See Appendix D for a discussion of those choices of parameter values. Simple OLS regressions. BA denotes networks generated using the Barabási and Albert (1999) algorithm. T-stats in parentheses. ^{a}, ^{b}, and ^{c} denote coefficients significant at 1%, 5%, and 10%, respectively.

3.3.2 Model 2: Two differentiated sectors

We now look at the multi-region case with two differentiated CES industries. To the best of our knowledge, this has not been done until now. With two differentiated sectors, we have to examine the spatial distribution of firms in both sectors, $\lambda_{1i}^* \equiv n_{1i}^*/(\sum_j n_{1j}^*)$ and $\lambda_{2i}^* \equiv n_{2i}^*/(\sum_j n_{2j}^*)$, as well as the equilibrium wages w_i^*. Simple correlations among the equilibrium values are presented in Table 3.5.

Table 3.5: Simple correlations (Model 2).

	λ_{1i}^*	λ_{2i}^*	w_i^*	θ_i	closeness$_i$	degree$_i$	μ_{1i}	μ_{2i}
λ_{1i}^*	1							
λ_{2i}^*	-0.2194	1						
w_i^*	0.3202	0.3397	1					
θ_i	0.6134	0.6261	0.5314	1				
closeness$_i$	0.0008	0.0199	0.2916	0.0134	1			
degree$_i$	0.0004	0.0182	0.3295	0.0135	0.7075	1		
μ_{1i}	0.6470	-0.6587	-0.0183	-0.0157	0.0072	0.0004	1	
μ_{2i}	-0.6470	0.6587	0.0183	0.0157	-0.0072	-0.0004	-1.0000	1
	CV(Λ_{1l}^*)	CV(Λ_{2l}^*)	CV($\mathbf{w}_l^*$)	CV(θ_l)	CV(closeness$_l$)	CV(degree$_l$)	CV(μ_{1l})	CV(μ_{2l})
CV(Λ_{1l}^*)	1							
CV(Λ_{2l}^*)	0.2574	1						
CV($\mathbf{w}_l^*$)	0.2597	0.3537	1					
CV(θ_l)	0.4656	0.6389	0.5578	1				
CV(closeness$_l$)	0.1260	0.0786	0.0642	0.2156	1			
CV(degree$_l$)	-0.0563	-0.1678	0.0451	-0.2254	-0.2215	1		
CV(μ_{1l})	0.4842	-0.0632	-0.2405	-0.1219	-0.0439	-0.0404	1	
CV(μ_{2l})	0.0456	0.5774	-0.0615	0.1009	-0.0848	-0.1315	0.0289	1

Notes: Simple correlations for 100 random tree networks with 20–30 nodes. The top panel of the table gives correlations at the level of individual nodes, whereas the bottom panel of the table gives correlations at the level of the whole network. The shares λ_{si}^* are computed as $\lambda_{si}^* = n_{si}^*/(\sum_j n_{sj}^*)$, for $s = 1, 2$. CV denotes the coefficient of variation, whereas Λ_1^*, Λ_2^*, $\mathbf{w}^*$, and θ denote the equilibrium vectors of industry shares in sectors 1 and 2, masses of firms, wages, and market size, respectively.

As can be seen from the top panel of Table 3.5, size and accessibility are strongly positively linked to the equilibrium industry shares and to the equilibrium wages, respectively. Although market size still positively influences wages, there is almost no correlation between our measures of centrality and the shares of firms in the two industries. As can further be seen, there is regional specialization, as shown by the negative correlation between the equilibrium shares in both industries, as well as the positive correlation with the own expenditure share, and the negative correlation with the other industry's expenditure share. In words, this specialization is strongly driven by differences in local spending patterns, as can be seen from the last two lines of Table 3.5. Our finding thus extends the result on 'comparative advantage' from Proposition 2 to a multi-region setting. Note, finally, that market size has roughly the same positive impact on industry location in both industries *conditional* on expenditure shares. This is the manifestation of market size as 'absolute advantage', as subsumed by Proposition 3, which states that more centrally located regions should have, ceteris paribus, higher wages.

As for Model 1, we run the same regressions (3.26), (3.27), (3.28) and (3.29). The first two regressions are now run separately for the equilibrium shares of firms in each of the two sectors, λ_{1i}^* and λ_{2i}^*. In all regressions, we control for the region-specific share of expenditure on the two differentiated sectors, μ_{1i} and μ_{2i}.

Results for individual nodes

Table 3.6 shows that market size, θ_i, and the expenditure share for the two differentiated sectors, μ_{1i} and μ_{2i}, are the key variables that explain the spatial distribution λ_{1i}^* and λ_{2i}^* of firms in the two sectors. The positive sign for market size is expected as labor market clearing (3.23) requires that the number of firms in the two sectors must sum to the population share. Once we control for local market size and the spending patterns, the centrality of a region is no longer associated with its industry share. The reason is that centrality affects both industries in the *same way*, which suggests that accessibility is akin to an absolute Ricardian advantage and should, therefore, be capitalized into factor prices.[16] This effect can precisely be seen from the bottom panel of Table 3.6. Clearly, both market size, θ_i, and centrality are positively linked to wages, w_i^*. Regions with better access to markets and/or more trading links tend to have higher wages. Last, note that the expenditure shares μ_{si} are nowhere near statistical significance in our wage regressions. In words, different expenditure shares affect industries differentially and, therefore, have no strong effect on regional wages. This is in line with our previous results on comparative and absolute advantage.[17]

To summarize, regional size and expenditure patterns determine the structure of regional specialization in the two industries in Model 2, whereas accessibility has a strong impact on wages. Observe that a home market effect – defined as a more than proportional increase in industry shares in response to an increase in local market size, i.e., $\partial\lambda_i^*/\partial\theta_i > 1$ – generally does not arise, as shown in Table 3.6. The reason is that when all sectors are operating under increasing returns and face trade costs, not all of them can – by definition – exhibit home market effects (see Hanson and Xiang, 2004). In that case, an alternative definition of the HME, involving both the size θ_i and the expenditure share μ_{si}, would be required. To the best of our knowledge, such a definition has not been used to date in the literature.

Results for the whole network

As shown in Table 3.7, inequality in the distribution of market sizes and in the distribution of expenditure shares in the two differentiated sectors are the key variables that drive the inequality in the spatial distribution of firms and wages. Inequality in the network characteristics are only weakly associated with inequality in the equilibrium distributions of firms and wages. It is worth emphasizing that, as can be seen from columns (iii) and (iv) in the bottom panel of Table 3.7, more dispersion in the expenditure shares is negatively associated with wage inequality in the case of BA-type networks. This

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[16] This result would be weakened if accessibility affected industries in different ways (as in, e.g., Hanson and Xiang, 2004). In that case, accessibility would also be in part a ‘comparative advantage’ and would, therefore, have a much stronger impact on industry location and not only wages.

[17] We performed extensive sensitivity analyses with respect to σ and μ_{1i} and μ_{2i} in Model 2. Holding the network structure constant, we study the behavior of industry location (λ_{1i} and λ_{2i}) and regional wages, w_i, when these basic parameters change. The results consistently show that increasing σ in the range $(1, 10]$ leads to higher nominal wages, while industry shares remain largely unaffected. In accord with the regression results that we report in the main text, the income shares map into the specialization. Solving a hundred times the model for each specific network and assigning random values of μ_{1i} and μ_{2i}, we find that industry shares present a strong correlation with income shares ($\rho = 0.7$). Income shares, however, are basically uncorrelated with nominal wages.

result is similar to the one linking the dispersion of population shares θ_i to wage inequality in the case of BA networks in Model 1 (see the bottom panel of Table 3.4). In the case of equal random networks, there is no significant link between the dispersion in expenditure shares and wage dispersion.

3.3.3 Summary of results

A number of findings emerge from the foregoing analyses of the two models. Let us briefly summarize the key insights.

Starting from Model 1 with a single CES sector, we have firstly seen that accessibility has a strong impact on industry location and, to a lesser extent, on wages. This suggests that any analysis involving trade in homogeneous goods and focusing on two regions only – or disregarding the spatial structure of the trading network entirely – is likely to miss an important part of the story. Secondly, we have shown that the correlations between w_i^* and either λ_i^* or θ_i are quite low, i.e., there is no strong correlation between either market size or the equilibrium industry shares and the equilibrium wages. As we have explained, this unexpected result is due to the fact that incomplete specialization in the production of the homogeneous good imposes strong restrictions on the relative wages of the trading regions, which break the link between market size and wages over the range of incomplete specialization. In that case, relative wages across regions depend on relative trade costs only but are independent of the regions' market sizes. Last, the home market effect generally holds even when trading the homogeneous good is costly, provided that it is less costly than trading the differentiated good.

Turning next to Model 2 with two CES sectors, both absolute market size – as captured by θ_i – and centrality – as measured by either closeness or the degree distribution – are capitalized into factor prices, thus showing that they constitute absolute advantage affecting all industries in the same way. Differences in spending patterns – as captured by the μ_{si} – are however capitalized into industry structure, thus showing that they constitute comparative advantage affecting industries differently. Our findings, therefore, extend the theoretical results of Behrens and Ottaviano (2011), which have been derived with two regions only, to a multi-region setting.

Last, it is worth pointing out that the effects of accessibility and market size on wages are an order of magnitude larger in Model 2 than in Model 1 (compare Tables 3.6 and 3.2). As we have explained, the reason is that the equalization of prices in the traded homogeneous sector imposes strong restrictions on the determination of wages among trading partners when specialization is incomplete (a very frequent case). This in turn breaks the link between accessibility and market size in the wage determination. In a nutshell, market size and centrality matter all the more the more industries are subject to trade costs and increasing returns to scale.

Table 3.6: OLS regression results for individual nodes (Model 2).

	Dependent variable: λ^*_{1i}					
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Closeness$_i$	-0.0034		-0.0048		-0.0021	
	(-1.425)		(-1.430)		(-0.605)	
Degree$_i$		-0.0002		-0.0002		-0.0002
		(-0.935)		(-0.854)		(-0.434)
θ_i	0.9885^a	0.9884^a	1.0037^a	1.0037^a	0.9741^a	0.9741^a
	(71.008)	(70.985)	(51.605)	(51.575)	(48.881)	(48.867)
μ_{1i}	0.1068^a	0.1068^a	0.1090^a	0.1090^a	0.1046^a	0.1046^a
	(74.763)	(74.737)	(55.252)	(55.219)	(50.567)	(50.548)
Constant	-0.0510^a	-0.0528^a	-0.0520^a	-0.0547^a	-0.0502^a	-0.0512^a
	(-27.273)	(-47.617)	(-20.666)	(-37.983)	(-19.246)	(-32.047)
Network type	Both	Both	BA	BA	Equal	Equal
Network dummy	Yes	Yes	No	No	No	No
Observations	2,498	2,498	1,274	1,274	1,224	1,224
Adjusted R^2	0.807	0.807	0.814	0.813	0.801	0.801

	Dependent variable: λ^*_{2i}					
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Closeness$_i$	0.0046^c		0.0060^c		0.0032	
	(1.904)		(1.779)		(0.941)	
Degree$_i$		0.0003		0.0003		0.0002
		(1.176)		(1.083)		(0.527)
θ_i	0.9921^a	0.9922^a	0.9756^a	0.9757^a	1.0079^a	1.0080^a
	(71.139)	(71.117)	(50.663)	(50.627)	(49.907)	(49.890)
μ_{2i}	0.1074^a	0.1073^a	0.1088^a	0.1087^a	0.1060^a	0.1059^a
	(75.016)	(74.970)	(55.664)	(55.615)	(50.564)	(50.533)
Constant	-0.0561^a	-0.0536^a	-0.0568^a	-0.0535^a	-0.0552^a	-0.0534^a
	(-29.964)	(-48.900)	(-22.845)	(-38.461)	(-20.843)	(-33.548)
Network type	Both	Both	BA	BA	Equal	Equal
Network dummy	Yes	Yes	No	No	No	No
Observations	2,498	2,498	1,274	1,274	1,224	1,224
Adjusted R^2	0.813	0.813	0.821	0.820	0.805	0.805

	Dependent variable: w^*_i					
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Closeness$_i$	0.1828^a		0.2202^a		0.1475^a	
	(17.456)		(13.412)		(11.378)	
Degree$_i$		0.0190^a		0.0172^a		0.0233^a
		(20.650)		(14.251)		(15.669)
θ_i	2.0129^a	2.0107^a	1.8348^a	1.8355^a	2.1892^a	2.1743^a
	(33.071)	(33.747)	(19.452)	(19.614)	(28.726)	(29.726)
μ_{1i}	-0.0047	-0.0039	-0.0072	-0.0074	-0.0026	-0.0003
	(-0.746)	(-0.638)	(-0.749)	(-0.783)	(-0.334)	(-0.038)
Constant	0.7609^a	0.8440^a	0.7363^a	0.8419^a	0.7760^a	0.8275^a
	(93.127)	(177.839)	(60.309)	(121.672)	(77.848)	(141.247)
Network type	Both	Both	BA	BA	Equal	Equal
Network dummy	Yes	Yes	No	No	No	No
Observations	2,498	2,498	1,274	1,274	1,224	1,224
Adjusted R^2	0.365	0.392	0.305	0.316	0.442	0.486

Notes: We set $\sigma = 5$. Simple OLS regressions. BA denotes networks generated using the Barabási and Albert (1999) algorithm. T-stats in parentheses. ^{a}, ^{b}, and ^{c} denote coefficients significant at 1%, 5%, and 10%, respectively.

Table 3.7: OLS regression results for the whole network (Model 2).

	Dependent variable: CV(Λ_1)					
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
CV(Closeness)	0.5556		-0.3225		1.5801	
	(0.711)		(-0.301)		(1.356)	
CV(Degree)		0.0471		0.0830		-0.0734
		(0.660)		(1.090)		(-0.422)
CV(θ)	0.6972^a	0.7249^a	0.7276^a	0.7300^a	0.6774^a	0.6642^a
	(7.248)	(7.475)	(5.906)	(6.161)	(4.439)	(3.679)
CV(μ_1)	1.0501^a	1.0482^a	0.9557^a	0.9418^a	1.2256^a	1.1589^a
	(7.761)	(7.748)	(5.610)	(5.604)	(5.518)	(5.112)
Constant	-0.0827	-0.0060	0.1517	0.0078	-0.3783	0.0541
	(-0.444)	(-0.055)	(0.648)	(0.059)	(-1.261)	(0.227)
Network type	Both	Both	BA	BA	Equal	Equal
Network dummy	Yes	Yes	No	No	No	No
Observations	100	100	51	51	49	49
Adjusted R^2	0.502	0.502	0.537	0.547	0.470	0.451

	Dependent variable: CV(Λ_2)					
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
CV(Closeness)	0.4631^b		0.6153^c		0.3053	
	(2.082)		(1.708)		(1.157)	
CV(Degree)		0.0303		-0.0135		0.1105
		(0.390)		(-0.183)		(0.552)
CV(θ)	1.0065^a	1.0153^a	0.9901^a	0.9865^a	0.9289^a	0.9954^a
	(9.735)	(9.816)	(8.663)	(8.792)	(4.660)	(4.459)
CV(μ_2)	1.1911^a	1.2004^a	1.0333^a	1.0267^a	1.4361^a	1.4178^a
	(8.757)	(8.750)	(6.932)	(6.694)	(5.437)	(5.443)
Constant	-0.1996	-0.2268^b	-0.0998	-0.0889	-0.3113	-0.3683
	(-1.005)	(-2.027)	(-0.440)	(-0.634)	(-0.949)	(-1.649)
Network type	Both	Both	BA	BA	Equal	Equal
Network dummy	Yes	Yes	No	No	No	No
Observations	100	100	51	51	49	49
Adjusted R^2	0.661	0.661	0.686	0.686	0.643	0.646

	Dependent variable: CV($\mathbf{w}$)					
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
CV(Closeness)	-0.0826		-0.1392		0.0639	
	(-0.414)		(-0.409)		(0.303)	
CV(Degree)		0.0154		0.0107		0.0527^c
		(0.845)		(0.437)		(1.757)
CV(θ)	0.1633^a	0.1661^a	0.1599^a	0.1574^a	0.1697^a	0.1993^a
	(6.650)	(6.730)	(4.076)	(4.126)	(6.143)	(6.409)
CV(μ_1)	-0.0688^b	-0.0680^c	-0.1209^b	-0.1240^b	0.0078	0.0180
	(-1.992)	(-1.974)	(-2.230)	(-2.292)	(0.195)	(0.462)
Constant	0.0270	-0.0028	0.0726	0.0352	-0.0449	-0.0864^b
	(0.569)	(-0.102)	(0.974)	(0.826)	(-0.827)	(-2.110)
Network type	Both	Both	BA	BA	Equal	Equal
Network dummy	Yes	Yes	No	No	No	No
Observations	100	100	51	51	49	49
Adjusted R^2	0.339	0.342	0.301	0.301	0.433	0.468

Notes: CV stands for 'coefficient of variation'. We set $\sigma = 5$. Simple OLS regressions. BA denotes networks generated using the Barabási and Albert (1999) algorithm. T-stats in parentheses. ^{a}, ^{b}, and ^{c} denote coefficients significant at 1%, 5%, and 10%, respectively.

3.4 Numerical application to Spanish regions

While the foregoing numerical simulations highlight regularities of our multi-region trade models without FPE, they provide no sense of how well those models perform when confronted with data. The aim of this section is hence to use calibrated versions of the models to check their fit with the data and to run a series of counterfactuals. To this end, we compute the equilibria of the two models using Spanish provincial data in two years: 1980 and 2007 (see Appendix D for a description of the data). This is an interesting period because it coincides with significant changes in demographic trends, and with important infrastructure improvements. Paluzie *et al.* (2007) discuss the migration trends in Spain from rural to urban areas that, starting in the sixties, still characterized demographic trends in the eighties. The fundamental tendency was the agglomeration of population in ever larger urban areas. Zofío *et al.* (2014) show that the decentralization of public administration – as Spain joined the European Community – accompanied by substantial funding from the European Regional Development Plan (ERDP) helped to finance remarkable improvements in the road network. Along with price changes in the transportation sector, mainly driven by salaries and fuel, generalized transport costs fell by about 15% over the period we consider. In a nutshell, our study period was one of important changes in the population distribution and in transport costs, both of which should have a strong influence on the spatial equilibrium structure of the economy.

Our aim in the remainder of this section is twofold. First, we compare the equilibrium distribution of economic activity predicted by our models with the data. Doing so will allow us to assess to what extent the models can ‘replicate’ the observed distributions. Second, we use the model to run some simple counterfactuals with respect to changes in demographic trends and transportation costs. We disentangle the role of market size from the role of transportation costs by shutting down one of the two channels when running our counterfactuals. More precisely, we first look at the equilibria of the models in the absence of any changes in the labor force between 1980 and 2007, i.e., when changes are ‘solely’ driven by changes in transportation costs. Second, we repeat the exercise by assuming that there are no changes in transportation costs between 1980 and 2007, so that changes are ‘solely’ driven by changes in the spatial distribution and in the size of the labor force.

3.4.1 Equilibrium distributions vs. observed distributions

The equilibrium distributions of firms in 1980 and 2007, as well as the equilibrium wages, are summarized in Table 3.8. Our results show large disparities in the distribution of firms across provinces, and those disparities increased between 1980 and 2007. In each year, the distribution of firms varies from almost 0% to about 16%–25%. Not surprisingly, the provinces of Madrid and Barcelona have the highest shares of firms in both models. These provinces are the largest – in terms of population shares – which, as reported in the previous sections, is the main determinant of firm shares (followed, to a lesser extent, by centrality that benefits Madrid as the geographical center of the Spanish infrastructure network). On the contrary, very small provinces situated in the Iberian Peninsula plateau (plain or meseta) are almost devoid of production (e.g., the provinces surrounding Madrid such as

Toledo, Cuenca, Guadalajara, Segovia, or Ávila have a really negligible share of firms).

To tentatively gauge the predictive power of the models, we check the statistical significance of the differences between the observed distributions of production in 'differentiated products' and those associated with the equilibria of the models: λ_i^* (Model 1) and λ_{1i}^* and λ_{2i}^* (Model 2). Besides Pearson's r and Spearman's ρ coefficients of correlation, we also test the equality of distributions by way of a Kolmogorov-Smirnoff test. Table 3.9 reports large and significant correlations, both for linear (Pearson) and rank (Spearman) dependencies. The Pearson standard correlation ranges from 0.8638 in Model 1 for 2007 to a remarkable 0.9910 for Model 2 in the same year. The maximum values for the Spearman correlations correspond to the same models and year. Additionally, the hypothesis of equality of distributions cannot be generally rejected, except for the 2007 distribution in Model 1. Our results show that solving the models using real data yields model equilibrium distributions of economic activity that are in many cases statistically hard to distinguish from those observed in the real economy.

Turning to wages, we however do not find large correlations between those proxied by GDP per employee (our empirical counterpart for 'wages' at the aggregate level) and the solutions to the two models. Hence, while the models perform well in terms of their spatial predictions of economic activity, they perform much worse in terms of their predictions for prices. There are two possible reasons for this. First, GDP per capita – though widely used in the literature (see Head and Mayer, 2004) – is only a crude proxy for wages. Second, as shown in the previous section, the multi-region simulated models do not deliver clear results as to the roles of market size and centrality on wages. It is thus not surprising that their empirical fit to wage data in also fairly weak.

Table 3.8: Simulation results for Model 1 and Model 2.

	Model 1				Model 2					
	λ_i^*		w_i^*		λ_{1i}^*		λ_{2i}^*		w_i^*	
Region	1980	2007	1980	2007	1980	2007	1980	2007	1980	2007
Almeria	0.012	0.020	1	1	0.010	0.015	0.012	0.016	1	1
Cadiz	0.02	0.009	1.046	1.027	0.021	0.022	0.024	0.025	1.122	1.051
Cordoba	0.015	0.004	1.073	1.049	0.017	0.014	0.019	0.015	1.089	1.031
Granada	0.010	0	1.052	1.033	0.017	0.015	0.019	0.017	0.937	0.964
Huelva	0.005	0.001	1.061	1.043	0.009	0.009	0.010	0.010	1.074	1.002
Jaen	0.014	0.002	1.067	1.045	0.014	0.010	0.016	0.012	0.988	0.957
Malaga	0.024	0.028	1.040	1.033	0.023	0.029	0.025	0.032	1.051	1.042
Sevilla	0.058	0.096	1.077	1.067	0.033	0.036	0.037	0.040	1.260	1.169
Huesca	0.001	0	1.073	1.047	0.007	0.006	0.006	0.005	0.931	0.892
Teruel	0	0	1.089	1.059	0.005	0.004	0.004	0.003	0.953	0.933
Zaragoza	0.027	0.015	1.067	1.034	0.026	0.027	0.023	0.023	1.012	0.954
Asturias	0.031	0.012	1.020	1.008	0.035	0.023	0.034	0.022	0.878	0.812
Cantabria	0.011	0.012	1.049	1.046	0.016	0.013	0.016	0.014	0.919	0.934
Avila	0	0	1.102	1.076	0.005	0.004	0.005	0.004	1.034	1.089
Burgos	0.004	0.003	1.077	1.048	0.011	0.009	0.011	0.010	1.003	1.016
Leon	0.015	0	1.062	1.047	0.017	0.010	0.018	0.010	0.98	0.946
Palencia	0.005	0.001	1.106	1.087	0.005	0.004	0.006	0.004	1.071	1.045
Salamanca	0.012	0	1.087	1.052	0.010	0.007	0.010	0.007	1.101	1.020
Segovia	0	0	1.109	1.097	0.004	0.004	0.005	0.005	1.097	1.159
Soria	0.002	0.003	1.117	1.098	0.003	0.002	0.003	0.003	1.080	1.089
Valladolid	0.023	0.033	1.116	1.08	0.013	0.013	0.013	0.013	1.175	1.145
Zamora	0.002	0	1.082	1.061	0.007	0.004	0.007	0.004	1.002	0.981
Albacete	0.004	0	1.092	1.062	0.010	0.009	0.009	0.008	1.047	1.048
Ciudad Real	0.008	0.001	1.085	1.050	0.013	0.011	0.012	0.010	1.020	1.045
Cuenca	0	0	1.100	1.073	0.006	0.005	0.006	0.004	1.007	1.066
Guadalajara	0	0	1.102	1.079	0.004	0.005	0.004	0.005	1.059	1.109
Toledo	0	0	1.081	1.066	0.014	0.014	0.013	0.014	1.090	1.147
Barcelona	0.171	0.190	1.047	0.991	0.14	0.145	0.133	0.138	1.271	1.095
Girona	0	0	1.035	1.009	0.018	0.02	0.017	0.019	0.884	0.789
Lleida	0	0	1.053	1.035	0.012	0.012	0.012	0.012	0.882	0.888
Tarragona	0.014	0.005	1.088	1.061	0.017	0.019	0.016	0.018	1.153	1.062
Alicante	0.045	0.057	1.092	1.065	0.032	0.038	0.033	0.039	1.282	1.178
Castellon	0.016	0.014	1.093	1.068	0.014	0.013	0.014	0.015	1.213	1.105
Valencia	0.064	0.067	1.034	1.011	0.058	0.057	0.060	0.061	1.16	1.103
Badajoz	0.014	0.007	1.061	1.038	0.014	0.012	0.017	0.015	0.997	0.99
Caceres	0.006	0	1.066	1.041	0.010	0.006	0.012	0.009	0.931	0.945
A coruna	0.036	0.021	1.036	1.02	0.033	0.024	0.034	0.025	1.112	0.984
Lugo	0.012	0	1.047	1.036	0.016	0.007	0.017	0.008	0.989	0.916
Orense	0.016	0.003	1.054	1.052	0.016	0.006	0.017	0.007	1.072	1.010
Pontevedra	0.035	0.038	1.051	1.046	0.030	0.021	0.031	0.022	1.184	1.081
Madrid	0.157	0.256	1.142	1.095	0.123	0.181	0.113	0.165	1.505	1.475
Murcia	0.017	0.02	1.055	1.065	0.022	0.028	0.025	0.033	1.086	1.117
Navarra	0.006	0.004	1.056	1.033	0.016	0.017	0.015	0.018	0.978	0.959
Alava	0.012	0.022	1.123	1.090	0.009	0.009	0.008	0.008	1.302	1.156
Guipuzcoa	0.025	0.031	1.053	1.102	0.022	0.021	0.019	0.018	1.28	1.204
Vizcaya	0.031	0.01	1.041	1.003	0.033	0.031	0.029	0.026	1.074	0.936
La Rioja	0.02	0.016	1.139	1.028	0.008	0.008	0.007	0.008	1.283	1.026
Mean	0.021	0.021	1.072	1.05	0.021	0.021	0.021	0.021	1.077	1.035
Std. Dev	0.039	0.054	0.030	0.029	0.030	0.038	0.028	0.035	0.133	0.117
Max.	0.171	0.256	1.142	1.102	0.140	0.181	0.133	0.165	1.505	1.475
Min.	0	0	1	0.991	0.003	0.002	0.003	0.003	0.878	0.789

Notes: Simulations use the following values. For Model 1, we let $\sigma = 5$, $\mu = 0.4$, and $\xi = 0.7$. For Model 2, we let $\sigma = 5$. See Appendix D for a discussion of these choices.

Table 3.9: Differences between observed and model distributions.

Test		Pearson's[1] r		Spearman's[2] ρ		Kolmogorov-Smirnov[3]	
Model	Share	1980	2007	1980	2007	1980	2007
1	$\lambda_i^\star$	0.9386	0.8638	0.7222	0.7261	0.1915	0.4043
		(0.000)	(0.000)	(0.000)	(0.000)	(0.3207)	(0.0006)
2	$\lambda_{1i}^\star$	0.9627	0.9334	0.8321	0.8582	0.1702	0.2128
		(0.000)	(0.000)	(0.000)	(0.000)	(0.4662)	(0.2096)
	$\lambda_{2i}^\star$	0.9401	0.991	0.9339	0.9886	0.2128	0.1277
		(0.000)	(0.000)	(0.000)	(0.000)	(0.2096)	(0.8117)

Notes: [1,2]The null hypothesis is that both variables are independent; [3]The null hypothesis is that both variables come from the same continuous distribution. p-values for all tests in parenthesis.

3.4.2 Population, transport costs, and trends in inequality

The equilibria computed in the foregoing section can be used to analyze to what extent the models capture the process of agglomeration that has taken place in Spain between 1980 and 2007, and which resulted in a more unequal distribution of manufacturing activity.

Figure 3.1: Manufacturing distributions for Model 1.

Figure 3.1 depicts the changes in the equilibrium manufacturing shares for Model 1. The equilibrium distributions in 1980 and 2007 are displayed as solid and as dashed lines, respectively. As can be seen from Figure 3.1, although the distributions are fairly similar (because there is a lot of inertia in spatial structures), the one in 2007 exhibits a higher density for low values of the manufacturing shares in the area identified by A (just below the mean value of 0.021, depicted by the vertical line).

Another difference pointing towards an increase in inequality is the agglomeration of manufacturing activity that can be seen in 2007, with the equilibrium shares of Madrid and Barcelona driving this process. Indeed, both provinces increased their values from 0.167 to 0.196 and from 0.157 to 0.254, respectively. This evolution is visible from the dilation of the right tail of the distribution in the area identified by C. For values in the range between 0.05 and 0.15, both distributions display similar densities (area B) between the two years.[18]

To provide a quantitative sense of the increase in inequality, we have computed the Gini indices G for the distribution of observed manufacturing shares and for the equilibria of the two models in both years. Both models capture the increase in inequality, even if *both clearly overstate it*. Observed inequality in the distribution of the manufacturing sector increases by 0.60% (from $G^{80} = 0.7700$ to $G^{07} = 0.7816$), while Model 1 yields an increase in inequality of 12.84% (from $G^{80}_{M1} = 0.7805$ to $G^{07}_{M1} = 0.8808$). Using the equilibria from Model 2, the observed increase in inequality is 2.12% for the manufacturing sector (from $G^{80}_1 = 0.7609$ to $G^{07}_1 = 0.7770$), and 2.41% (from $G^{80}_2 = 0.7762$ to $G^{07}_2 = 0.7950$) for the service sector, respectively.[19] The model again overpredicts these values at 11.69% ($G^{80}_{M2,1} = 0.6841$ to $G^{07}_{M2,1} = 0.7641$), and 11.90% ($G^{80}_{M2,2} = 0.6683$ to $G^{07}_{M2,2} = 0.7479$), respectively.

We may thus conclude that while the model reasonably well predicts the spatial distribution of manufacturing in Spain for a given year, it overpredicts the impacts of changes in population or changes in transportation costs on that spatial distribution.

3.4.3 Counterfactuals

Keeping in mind the caveat from the previous section, we finally run two counterfactuals, the aim of which is to simulate the spatial equilibrium that would prevail if only population changes to its 2007 values, but not the transportation costs which are kept fixed at their 1980 values, and vice versa. Put differently, in the first counterfactual we fix the transport costs to their 1980 values and use observed population changes; whereas in the second counterfactual, we fix population to their 1980 values and use observed changes in transportation costs. In so doing, we can compare the ‘pure’ effect of population changes conditional on transport costs, and the ‘pure’ effect of changes in transport costs conditional on population. We compare the equilibria of the model in 1980 and 2007 to those derived in the counterfactuals to determine how each change contributes to the overall shift in the manufacturing shares.[20]

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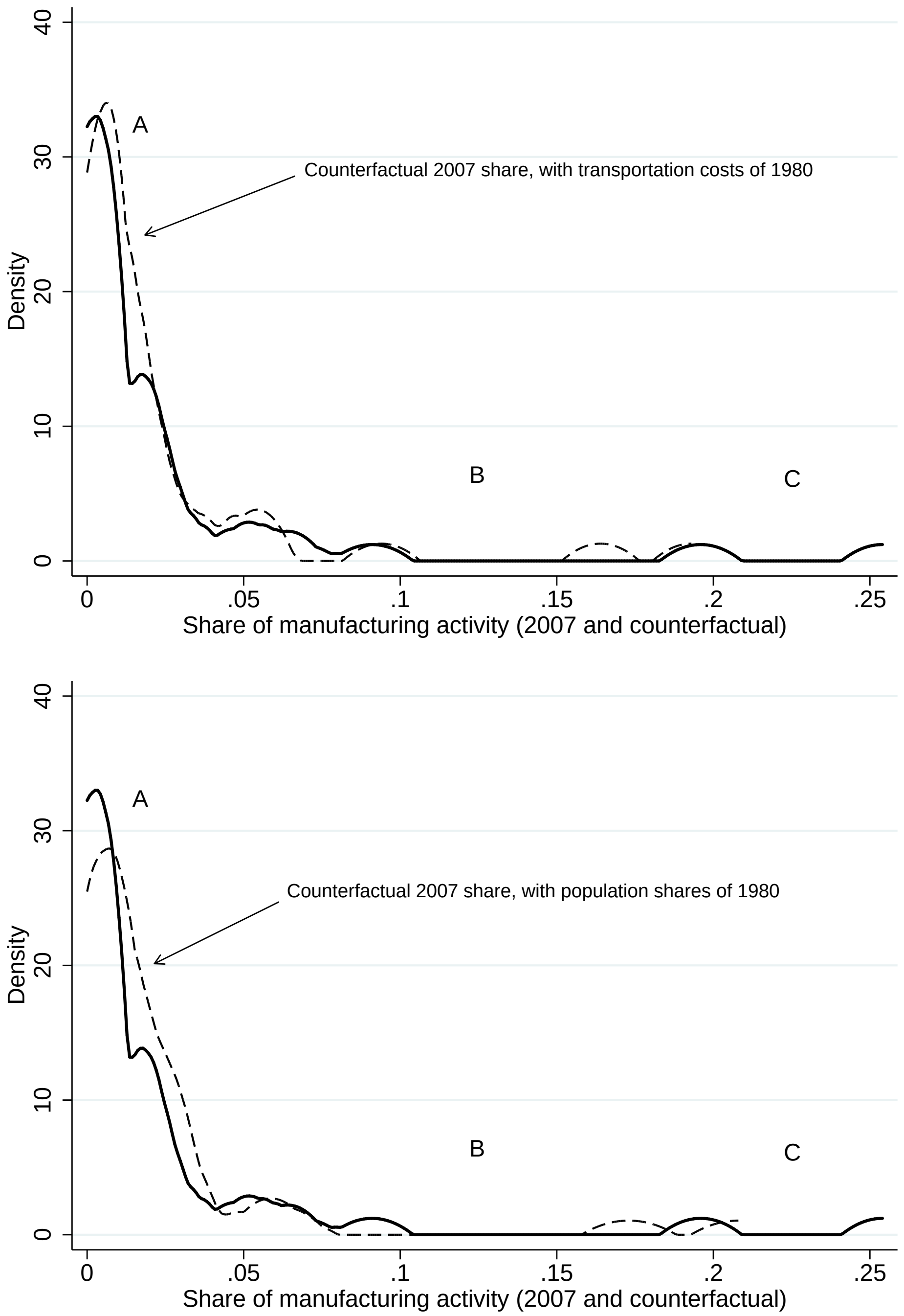
[18] Similar results are observed for the two distributions of shares in Model 2. The results are available from the authors upon request.

[19] In Appendix D, we explain that the sectors are not defined in the same way in the two models. Hence the difference in the changes in observed inequality in the data.

[20] Note that this is of course not an exact decomposition since the observed changes are not the sum of the changes in the two alternative scenarios.

Figure 3.2: Manufacturing distributions for Model 1 (with counterfactual distribution).



The top panel of Figure 3.2 depicts the distributions of the counterfactual industry shares (in red) for the case where only population changes; whereas the bottom panel of the figure depicts the same change for the case where only transport costs change. Table 3.10 summarizes the detailed results, with the first superscript referring to the reference year for the population share, θ_i, and the second one referring to the bilateral transportation costs, ϕ_{ij}.

As can be seen from the top panel of Figure 3.2, the increase in the density of the left tail of the distribution of manufacturing shares is mainly driven by the change in the geographical distribution of the labor force rather than the reduction in transportation costs. As can be seen from the bottom panel of Figure 3.2, the effect of the latter is rather small, despite the fact that over the 1980–2007 period the fall in the average value of the Generalized Transport Costs was large.[21] As this change was similar across provinces, their relative position in the network remained basically unchanged. Observe that the fall in transport costs has slowed down the process of agglomeration, as can be seen from the bottom panel of Figure 3.2.

Generally, when comparing the counterfactual distributions with the observed ones in 1980 and 2007, Figure 3.2 reveals that changes in the spatial distribution of regional market shares have a stronger predictive power of changes in industrial specialization than changes in transportation costs. Our results thus suggest that the reallocation of the labor force was the main driver of agglomeration and larger inequalities as reflected by the change in the Gini indices. Note that these results are compatible with those obtained in the simulations presented in Section 3.3, and particularly with those in Table 3.2 for Model 1. In that case, the equilibrium shares λ_i^* depend mainly on the θ_i rather than on network features as captured by transportation costs (i.e., closeness or degree). As the relative position of the provinces in the trading network did not change much between 1980 and 2007, this explains the stability in the distributions of the spatial equilibria when considering changes in this variable only.

To conclude on a policy note, observe that after three decades of significant investments in the road network, the distribution of industry shares had not changed much in Spain. Thus, these investments do not seem to have contributed much to territorial cohesion – though the main goal of infrastructure investment in the eyes of policy makers is often to ‘reduce regional inequality’. In fact, the opposite occured: Madrid and Barcelona had larger shares of economic activity in 2007 than in 1980. These changes in industry shares were mostly driven by population reshuffling, and little by decreasing transportation costs. The financial efforts of transport improvements did apparently not translate into higher cohesion and lower inequality.[22]

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[21] The fall in GTC_{ij} amounted to 14.14%. This fall corresponds to an increase of 109.65% in the average ϕ_{ij}, thus implying that the freeness of trade more than doubled.

[22] One word of caution is in order. Our approach does not capture the fact that the population change between 1980 and 2007 would possibly have been different in the absence of changes in transportation costs. Conversely, the changes in transportation costs would possibly have been different between 1980 and 2007 in the absence of population movements. Hence, changing one parameter while holding fixed the other is only a partial exercise (though, we believe, a suggestive one).

Table 3.10: Counterfactual results for Models 1 and 2.

	Model 1				Model 2					
Region	$\lambda_i^{\star 80,07}$	$\lambda_i^{\star 07,80}$	$w_i^{\star 80,07}$	$w_i^{\star 07,80}$	$\lambda_{1i}^{\star 80,07}$	$\lambda_{1i}^{\star 07,80}$	$\lambda_{2i}^{\star 80,07}$	$\lambda_{2i}^{\star 07,80}$	$w_i^{\star 80,07}$	$w_i^{\star 07,80}$
Almeria	0.007	0.018	1	1	0.010	0.015	0.012	0.016	1	1
Cadiz	0.008	0.021	1.005	1.061	0.021	0.022	0.024	0.025	1.080	1.088
Cordoba	0.014	0.008	1.007	1.114	0.017	0.014	0.019	0.015	1.082	1.029
Granada	0.009	0.007	1.006	1.086	0.017	0.015	0.019	0.017	0.997	0.898
Huelva	0	0.005	1.006	1.077	0.009	0.009	0.010	0.010	1.037	1.032
Jaen	0.008	0.009	1.007	1.095	0.014	0.010	0.017	0.012	1.011	0.924
Malaga	0.021	0.035	1.005	1.049	0.023	0.029	0.025	0.032	1.056	1.037
Sevilla	0.094	0.06	1.007	1.112	0.033	0.036	0.037	0.040	1.203	1.223
Huesca	0	0	1.007	1.104	0.007	0.006	0.006	0.005	0.927	0.881
Teruel	0	0	1.009	1.116	0.005	0.004	0.004	0.003	0.975	0.897
Zaragoza	0.014	0.028	1.007	1.101	0.026	0.026	0.023	0.023	0.986	0.973
Asturias	0.017	0.021	1.004	1.032	0.035	0.023	0.033	0.022	0.878	0.807
Cantabria	0.01	0.01	1.006	1.062	0.016	0.014	0.016	0.013	0.980	0.868
Avila	0	0	1.011	1.110	0.005	0.004	0.005	0.004	1.136	0.969
Burgos	0.008	0.003	1.009	1.104	0.011	0.009	0.011	0.009	1.064	0.947
Leon	0	0.007	1.007	1.083	0.017	0.010	0.018	0.010	1.026	0.893
Palencia	0.023	0.003	1.011	1.150	0.005	0.004	0.006	0.004	1.103	1.003
Salamanca	0.001	0.008	1.009	1.095	0.010	0.007	0.010	0.007	1.088	1.02
Segovia	0.001	0	1.012	1.097	0.004	0.004	0.005	0.004	1.187	1.054
Soria	0.004	0.002	1.012	1.143	0.003	0.002	0.003	0.002	1.131	1.021
Valladolid	0.036	0.022	1.011	1.150	0.013	0.013	0.013	0.013	1.193	1.125
Zamora	0.004	0	1.009	1.101	0.007	0.004	0.007	0.004	1.057	0.914
Albacete	0	0.002	1.009	1.122	0.010	0.009	0.009	0.008	1.089	0.996
Ciudad Real	0.004	0.007	1.009	1.114	0.013	0.011	0.012	0.010	1.089	0.969
Cuenca	0	0	1.011	1.113	0.006	0.005	0.006	0.004	1.106	0.951
Guadalajara	0	0	1.011	1.079	0.004	0.005	0.005	0.005	1.124	1.032
Toledo	0	0	1.010	1.059	0.013	0.014	0.014	0.014	1.168	1.059
Barcelona	0.164	0.173	1.002	1.134	0.140	0.145	0.133	0.138	1.125	1.227
Girona	0.001	0	1.004	1.024	0.018	0.020	0.017	0.019	0.806	0.859
Lleida	0	0	1.006	1.061	0.012	0.012	0.012	0.012	0.916	0.847
Tarragona	0.013	0.019	1.007	1.110	0.017	0.019	0.016	0.018	1.087	1.120
Alicante	0.056	0.051	1.008	1.133	0.033	0.038	0.033	0.039	1.196	1.256
Castellon	0.019	0.015	1.008	1.126	0.013	0.014	0.014	0.014	1.139	1.168
Valencia	0.053	0.065	1.006	1.053	0.057	0.058	0.060	0.060	1.137	1.118
Badajoz	0.016	0.012	1.007	1.08	0.014	0.012	0.017	0.015	1.038	0.945
Caceres	0	0.004	1.008	1.076	0.009	0.007	0.012	0.009	1.001	0.869
A coruna	0.018	0.027	1.004	1.044	0.033	0.024	0.034	0.025	1.056	1.033
Lugo	0.011	0.003	1.006	1.066	0.016	0.007	0.017	0.007	1.019	0.875
Orense	0.017	0.006	1.007	1.076	0.016	0.006	0.017	0.007	1.126	0.939
Pontevedra	0.054	0.026	1.006	1.052	0.030	0.021	0.031	0.022	1.157	1.098
Madrid	0.193	0.208	1.009	1.253	0.124	0.18	0.113	0.166	1.464	1.509
Murcia	0.015	0.024	1.007	1.084	0.021	0.028	0.025	0.032	1.126	1.075
Navarra	0.004	0.006	1.007	1.089	0.015	0.018	0.016	0.018	0.983	0.950
Alava	0.03	0.011	1.011	1.200	0.009	0.009	0.008	0.008	1.193	1.251
Guipuzcoa	0.038	0.026	1.008	1.033	0.022	0.021	0.019	0.019	1.249	1.225
Vizcaya	0.003	0.028	1.005	1.069	0.034	0.031	0.029	0.027	0.974	1.023
La Rioja	0.009	0.02	1.009	1.193	0.008	0.008	0.007	0.008	1.059	1.233
Mean	0.021	0.021	1.008	1.095	0.021	0.021	0.021	0.021	1.077	1.026
Std. Dev	0.043	0.045	0.003	0.049	0.03	0.037	0.028	0.035	0.108	0.144
Max.	0.193	0.208	1.012	1.253	0.140	0.180	0.133	0.166	1.464	1.509
Min.	0	0	1	1	0.003	0.002	0.003	0.002	0.806	0.807

Notes: The simulations use the following values. For Model 1, we set $\sigma = 5$, $\mu = 0.4$, and $\xi = 0.7$. For Model 2, we let $\sigma = 5$. See Appendix D for a discussion of those choices.

3.5 Conclusions

We have investigated the geographical distribution of industries and wages in a asymmetric multi-region models without factor price equalization. Using systematic numerical simulations for two different trade models – one with a homogeneous and a differentiated sector, and another with two differentiated sectors – we have studied whether and how size and accessibility are linked to the equilibrium industry shares and to wages.

Our key findings can be summarized as follows. First, absolute local market size and accessibility are crucial in explaining a region's wage. This is due to the fact that absolute market size – as measured by the population size of a region – and accessibility – as measured by network centrality or the degree distribution of a region – affect all industries in similar ways, i.e., constitute a region's *absolute advantage*. This effect is stronger and more systematic in models where all sectors are subject to transport costs and exhibit increasing returns to scale.

Second the relative local market size of industries – as captured by their expenditure shares – is crucial in explaining a region's industrial composition. This is due to the fact that relative spending patterns do not affect all industries in the same way, i.e., constitute a region-specific *comparative advantage*. In a nutshell – and very much in line with Ricardian trade theory – absolute advantage translates into higher wages, whereas comparative advantage maps into specialization patterns.

Third, the correlation between equilibrium wages and equilibrium industry shares is rather low in both models, thus suggesting that the two adjustment channels work largely independently. Empirical tests and formal definitions of the home market effect should take into account both dimensions – industry location and wages – in order to be relevant. To the best of our knowledge, tests looking simulataneously at industry location and factor prices have not yet been devised.

Finally, when applying the two models to Spanish data – using Generalized Transport Costs between regions as a measure of trade frictions – we find that the models generally predict well the distribution of industries, yet predict less well the spatial patterns in wages. The latter may be due to the fact that GDP per capita – though often used in the literature – is a rather crude proxy for wages. It may, however, also be linked to the fact that regional differences in accessibility are generally less pronounced than regional differences in population shares. Thus the second effect may dwarve the former in the applications.

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Appendices

3.A Factor price equalization

Assume that the homogeneous good can be costlessly traded across all regions. This is the case usually considered in the literature (e.g., Helpman and Krugman, 1985). Marginal cost pricing then implies that the price of the homogeneous good is equal to the wage, which must be the same everywhere. In other words, factor price equalization (FPE) holds.

In a multi-region world, the assumption of FPE has a major technical drawback. To see this, ask under what conditions FPE will hold? Clearly, FPE will hold if and only if some homogeneous good is produced in every region. Following Behrens, Lamorgese, Ottaviano, and Tabuchi (2007), a *sufficient condition* is that

$$\theta_i > \mu, \quad \forall i = 1, 2, \ldots, M. \tag{A-1}$$

When (A-1) holds for all regions, and when trade in the homogeneous good is free, we have $w_i = 1$ for all $i = 1, 2, \ldots, M$. Observe that condition (A-1) is extremely restrictive. Consider, e.g., a world with 30 regions. If market sizes θ_i were identical across regions, we must have $\mu < 1/30$. This is already very restrictive. But in our case, since we randomly assign the shares θ_i to regions, we may have very small shares in some cases. In those cases, the foregoing restriction can never be met for 'reasonable values' of μ.

Although condition (A-1) is technically speaking only a *sufficient* condition – i.e., we may still have FPE even when it is violated – it seems still very unlikely to be met in general. Another potential problem in the FPE version of the model is that it displays a much larger share of 'corner equilibria', i.e., equilibria in which some regions are deindustrialized and do not host any of the differentiated sector. We have simulated the model with FPE and find that the number of nodes with a zero industry share is 920 out of 2498, i.e. 36.82%. This is a large number, so that regression methods dealing with zeros may be required to analyze the general properties of these equilibria.

In a nutshell, the FPE model does not make much sense in a world with many regions, neither theoretically nor empirically, and it is difficult to implement consistently for reasonable values of μ. We thus disregard it in the remainder of this paper.

3.B Generating random tree networks

We use two different algorithms for generating random tree networks. The first one is based on Barabási and Albert (1999). This algorithm starts with a network having M_0 linked nodes. Then, it adds new nodes one by one, up to M_T nodes in total, where M_T is the number of nodes of the network (i.e., the number of regions in the model). Each time a new node is added to the network at iteration t, it is connected to M_{t-1} pre-existing nodes. The probability of being linked to an existing node during iteration t depends on the degree of that node in the following way: $p_{it} = \deg(i_{t-1})/[\sum_j \deg(j_{t-1})]$, where p_{it} is the probability of being linked to node i at iteration t, and where $\deg(i_{t-1})$ is the degree of node i at iteration $t-1$. The Barabási and Albert (1999) preferential attachment algorithm tends to create networks with some nodes that have a high degree, who are very well connected, and other nodes with a very low degree, who are badly connected. Put differently, the resulting network tends to have hub-and-spoke characteristics. By setting the initial number of nodes to $M_0 = 2$, and by setting the number of links for new nodes to $m = 1$, we ensure that the resulting network is a connected tree with $M_T - 1$ links.

In the second algorithm we use, new nodes are added to preexisting nodes with equal attachment probability, which means that the probability of being linked to node i at iteration t does not depend on the degree of node i. Formally, we have $p_{it} = 1/M_{t-1}$, where M_{t-1} is the number of nodes in the network when adding the new node at iteration t.

Observe that the average degree of the tree network is equal to $2(M_T-1)/M_T$, independently of the algorithm used to generate it. The reason is that in an undirected graph, the degree sum formula is $\sum_j \deg(j) = 2|E|$, where $|E|$ is the number of links in the network. Since in the generated tree networks there are $M_T - 1$ links, the degree sum formula becomes $2(M_T-1)$. Then, the average degree of the network, defined as the degree sum over the number of nodes in the network, is equal to $2(M_T-1)/M_T$.

Observe further that the standard deviation of the degree of the nodes in the network will usually be higher in networks using the Barabási and Albert (1999) algorithm than in totally random tree networks. The reason is that this algorithm tends to generate a few nodes with a high degree, and a lot of nodes with a very low degree.

Last, when generating random links in the networks, we assume that the freeness of trade, ϕ_{ij}, between adjacent nodes i and j is given by $1/5$. Hence, the freeness of trade between two nodes i and k, linked by a path $\mathscr{P} = \{i, j_1, j_2, \dots, j_{n-1}, k\}$ of length n, is given by

$$\phi_{ik} = \prod_{(j,l)\in\mathscr{P}} \phi_{jl}. \tag{B-1}$$

We use only shortest paths in the network, which are computed using the Floyd-Warshall algorithm. Because we work with trees, the shortest path is uniquely determined.

3.C Details on the numerical implementation

We first use the algorithms described in Appendix B to generate random networks. In all cases, we compute the equilibria of the two models for the *same* set of networks. Hence, the results are directly comparable across models. For computational reasons, we generate random networks with between 20 and 30 nodes, the number of nodes being itself random (and drawn from a uniform distribution). Larger networks require too long to solve in the case with a homogeneous good.

To solve the model, we transform the spatial equilibrium conditions (3.16) into complementary slackness conditions as follows:

$$[\mathrm{RMP}_i(\mathbf{n}) - 1]\, n_i = 0, \quad i = 1, 2, \dots, M, \tag{C-1}$$

where we make explicit the dependence of the real market potential on the whole distribution of firms $\mathbf{n} = (n_1, n_2, \ldots, n_M)$.

Model 1: One differentiated sector and one homogeneous sector. We add as nonlinear inequality constraints the equilibrium conditions (3.13) in the homogeneous good market, the labor market clearing conditions (3.14), and the complementary slackness conditions (3.15) for exports of the homogeneous good:

$$\begin{array}{rcl} \dfrac{(1-\mu)\,w_i\theta_i}{\min_k\{w_k\xi\tau_{ki}\}} - (\widetilde{X}_{ii} + \sum\limits_{j\neq i}\widetilde{X}_{ji}) & = & 0, \quad \forall i \\ \theta - n_i\mu - (\tau_{ii}\widetilde{X}_{ii} + \sum\limits_{j\neq i}\xi\tau_{ij}\widetilde{X}_{ij}) & = & 0, \quad \forall i \\ \widetilde{X}_{ij}\left[w_i\xi\tau_{ij} - \min\limits_{k}\{w_k\xi\tau_{kj}\}\right] & = & 0, \quad \forall i \end{array}$$

Furthermore, the following bounds for the variables are imposed: $w_i > 0$ for all i and $\widetilde{X}_{ji} \geq 0$ for all i and j. We also have the constraints that $n_i \geq 0$ for all i. Note that the presence of the min function, which is not differentiable, makes it more difficult to solve the problem. To overcome this problem, we replace all occurrences of the min function with a new variable, z_i. To make sure that this new variable z_i will be equal to the minimum, we substract it from the objective function (i.e., it works as a penalty). Thus, the solver will maximize it. We add the constraint that it should not exceed the delivered price of the homogeneous good: $z_i \leq w_j\xi\tau_{ji}$, $\forall i, j$. In doing so, we make sure that – in the final iteration – z_i is equal to the minimum delivered price of the good.

We transform (C-1) into an equivalent problem that consists in minimizing the sum of squared residuals subject to the set of equilibrium constraints. The numerical implementation of the minimization problem – when substituting out the min operator – is as follows:

$$(\mathscr{P}_1)\left\{\begin{array}{lcl} \min\limits_{\mathbf{n}} \; \sum\limits_{i=1}^{M}\{[\mathrm{RMP}_i(\mathbf{n}) - 1]\,n_i\}^2 - \sum\limits_{i=1}^{M} z_i & & \\ \mathrm{RMP}_i(\mathbf{n}) \leq 1, \quad i = 1, 2, \ldots, M & & \\ \dfrac{(1-\mu)\,w_i\theta_i}{z_i} - (\widetilde{X}_{ii} + \sum\limits_{j\neq i}\widetilde{X}_{ji}) & = & 0, \quad \forall i \\ \theta_i - n_i\mu - (\tau_{ii}\widetilde{X}_{ii} + \sum_{j\neq i}\xi\tau_{ij}\widetilde{X}_{ij}) & = & 0, \quad \forall i \\ z_i \leq w_j\xi\tau_{ji}, \quad \forall i, j & & \\ \theta_i - n_i\mu \geq 0, \quad \forall i & & \\ \widetilde{X}_{ij}\left[w_i\xi\tau_{ij} - z_j\right] & = & 0, \quad \forall i \\ n_i \geq 0, \quad \forall i, \quad w_i > 0, \quad \forall i & & \\ \widetilde{X}_{ji} \geq 0, \quad \forall i, j & & \end{array}\right. \tag{C-2}$$

As starting values for the solver, we use the population share, θ_i, for the mass of firms, i.e., $n_i^0 = \theta_i$. For the wages, we use $w_i^0 = 1$ for all i. Last, we start with zeros for trade in the homogeneous good, $\widetilde{X}_{ki}^0 = 0$, and $\widetilde{X}_{ii}^0 = (1-\mu)\theta_i$ for the domestic supply of the homogeneous good to the local market.

Model 2: Two differentiated sectors. For the model with two differentiated sectors, we minimize the sum of the squared residuals of the two complementary slackness conditions of the real market potential for each sector:

$$[\mathrm{RMP}_{si}(\mathbf{n_s},\mathbf{w})-1]\,n_{si}=0,\quad i=1,2,\ldots,M,\quad s=1,2.$$

The minimization problem is similar to the one in the case with a homogeneous good, but with two real market potential functions with the number of firms, n_{si}, in each sector, the inclusion of the wages, and the constraint on the number of firms and the population shares:

$$(\mathscr{P}_2)\begin{cases}\min\limits_{\mathbf{n_1},\mathbf{n_2},\mathbf{w}} \sum\limits_{i=1}^{M}\{[\mathrm{RMP}_{1i}(\mathbf{n_1},\mathbf{w})-1]\,n_{1i}\}^2+\sum\limits_{i=1}^{M}\{[\mathrm{RMP}_{2i}(\mathbf{n_2},\mathbf{w})-1]\,n_{2i}\}^2\\ \mathrm{RMP}_{1i}(\mathbf{n_1},\mathbf{w})\le 1,\quad \forall i\\ \mathrm{RMP}_{2i}(\mathbf{n_2},\mathbf{w})\le 1,\quad \forall i\\ \theta_i=n_{1i}+n_{2i},\quad \forall i\\ n_{1i}>0,\quad \forall i,\quad n_{2i}>0,\quad \forall i,\quad w_i>0,\quad \forall i,\end{cases}\tag{C-3}$$

We solve the problems $(\mathscr{P}_1)$ and $(\mathscr{P}_2)$ for their equilibria $\{n_i^*,w_i^*\}$, and $\{n_{1i}^*,n_{2i}^*,w_i^*\}$, respectively. We use the MATLAB function `fmincon` with the *interior-point* algorithm. The code is available upon request.

3.D Data and calibration

We work with Spanish provincial data at the NUTS-3 level, totaling 47 observations.[23] Table 3.11 provides details on the variables needed to solve the different models. For Model 1, these include the labor force shares (θ_i), the gross value added shares in the differentiated sector (the observed n_i or λ_i), and the mean of the bilateral transportation costs (τ_{ij}). Population and industrial gross value added – our proxy for the differentiated production in the economy – for 1980 are obtained from the 'Spanish Domestic Income and its Distribution by Provinces' (FBBVA) publication. The 2007 data come from the Spanish National Statistics Institute (Instituto Nacional de Estadística, INE). The FBBVA data on private gross value added at the provincial level is disaggregated into Agriculture, Energy, Industry, Construction, and Services. Bilateral shipping costs are measured as the monetary value of the generalized transportation cost (GTC_{ij}) of delivering one ton of cargo between origin i and destination j. Zofío *et al.* (2014) describe the model assuming a cost minimizing behavior on the part of transportation firms, and determine the least cost optimal itineraries using geographical information systems that account for the actual road network in those years. In Table 3.11, we provide the mean value of all bilateral transportation costs for each province, i.e., $\overline{GTC_{ij}^t}=\frac{1}{47}\sum_{i=1}^{47}GTC_{ij}^t$.

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[23] We use all Spanish provinces of the Iberian Peninsula (i.e., we exclude the Balearic islands and the Canary islands) because our measures of transport costs are derived from road freight transportation.

Following the definition of the freeness of trade, ϕ_{ij}, transport costs are computed as follows:

$$\phi_{ij} = \tau_{ij}^{1-\sigma} = \left(\frac{GTC_{ij}}{\min\{GTC_{ij}\}}\right)^{1-\sigma} \in [0,1]. \tag{D-1}$$

As for the structural parameters μ and σ of the model, few studies have attempted to test the main propositions of new trade theory and new economic geography using Spanish data. Pons *et al.* (2007) estimate a migration equation based on an NEG model, and obtain a value for σ between 2.8 and 4.2, conditional on the values of the other parameters. Gómez-Antonio and Fingleton (2012) adopt a value of $\sigma = 6.25$ when analyzing the impact of the public capital stock on Spanish productivity. Their choice is justified on the grounds that it coincides with the key estimates in the literature (e.g., Table 5 in Head and Mayer, 2004). More recently, Broda and Weinstein (2006) estimate the elasticities of substitution for traded goods imports to the US using SITC rev2 for 1972–1988, and SITC rev3 for 1990–2001 at the 3-, 4-, and 5-digit levels, respectively. At the 3-digit level and across all goods, they find a mean elasticity of 6.8 from 1972–1988 and of 4.0 from 1990–2001, respectively. Looking only at differentiated goods – as defined using the Rauch (1999) classification – at the 4-digit level, they find a mean elasticity of 5.2 from 1972–1988 and of 4.7 from 1990–2001, respectively. Since the estimates obtained by these authors are probably the best currently available, and since they are roughly in line with the estimates obtained for Spain, we take the midpoint value of $\sigma = 5$ (as we also assumed in the numerical simulations performed in the previous sections). Turning to the expenditure share on the differentiated product, μ, we use the expenditure shares for manufacturing goods in total domestic demand coming from the household budget survey published by INE, which in 2007 was 41.92% (data for 1980 is unfortunately unavailable, but this share exhibits remarkable stability both in time and across developed countries, fluctuating around this value depending on the economic cycle). For simplicity, we round the value to $\mu = 0.4$ (as we also assumed in the numerical simulations).

Since wages are endogenous, we require additional data to test whether the results of the calibrated model match the observed values. In particular, we need information on wages. The latter are obtained, as in many previous studies, by dividing aggregate GDP by the labor force (see the literature review in Head and Mayer, 2004). For Model 1, we associate the homogeneous sector with agriculture, while the differentiated sector corresponds to the manufacturing industry. As for the parameter ξ capturing the relative level of trade cost of the homogeneous good compared to the differentiated good, we adopt a value 0.7. Based on data from the 'Ongoing Survey on Freight Road Transportation', carried out by the Ministry of Transport (see Ministerio de Fomento, MFOM, 2007a), we can calculate a comparative range of relative freight costs in terms of tons-kilometer.[24] The difference in the cost of shipping homogeneous and differentiated products ranges from 0.7 to 1, with an average around 0.8. To keep consistency with the values adopted in the previous section, we take the lower bound for ξ .

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[24] The 'Ongoing Survey on Freight Road Transportation' classifies shipments of manufactured goods according to Council Regulation (EC) No 1172/98, and the prevalent type of vehicle used to transport each type of good, along with the information provided by the Observatory of Road Freight Transport Costs on each type of vehicle (MFOM, 2007b).

Finally, besides regional labor shares and bilateral trade costs, we need to identify two differentiated sectors for Model 2. We associate the first differentiated sector with manufacturing plus energy, whereas services are associated with the second sector. We leave out agriculture – which is more homogeneous – and construction – which is essentially non-tradable – from the analysis. We determine expenditure shares to match the production side from the expenditure household survey, with the first share corresponding to manufacturing and utilities (processed food, clothing, water, electricity,…) and the second one to services (health, communication, leisure, education, accomodation,…). These shares are, unfortunately, only available at the NUTS-2 regional level (States or Comunidades Autónomas), and they are an average of all NUTS-3 provinces included in each region. As a result we apply the regional values to all provinces of a region. Although this reduces the regional variation, it is the only way we can use that required piece of information. Table 3.11 below summarizes the data that we use.

Table 3.11: Data for the 47 peninsular Spanish provinces (NUTS-3 level).

	Data 1980					**Data 2007**					
Model	All	All	Model 1	Model 2	Model 2	All	All	Model 1	Model 2	Model 2	Model 2
Region	Labor %	Mean GTC €	G.V.A. Industry %	G.V.A. Ind+Ene %	G.V.A. Services %	Labor %	Mean GTC €	G.V.A. Industry %	G.V.A. Ind+Ene %	G.V.A. Services %	μ_1 Ind+Ene
Almeria	0.011	902.224	0.004	0.004	0.008	0.016	754.879	0.004	0.004	0.013	0.435
Cadiz	0.023	958.657	0.019	0.020	0.023	0.024	829.657	0.015	0.018	0.023	0.435
Cordoba	0.019	731.552	0.011	0.011	0.014	0.015	637.700	0.010	0.010	0.013	0.435
Granada	0.018	837.438	0.007	0.007	0.017	0.017	705.907	0.007	0.006	0.016	0.435
Huelva	0.010	889.677	0.012	0.013	0.008	0.009	751.991	0.007	0.009	0.009	0.435
Jaen	0.016	691.018	0.010	0.010	0.012	0.011	575.984	0.008	0.007	0.010	0.435
Malaga	0.024	959.042	0.010	0.010	0.028	0.031	821.833	0.008	0.008	0.032	0.435
Sevilla	0.036	799.573	0.023	0.022	0.036	0.038	685.078	0.026	0.031	0.035	0.435
Huesca	0.007	665.786	0.006	0.007	0.005	0.006	626.479	0.005	0.005	0.005	0.488
Teruel	0.005	562.000	0.005	0.007	0.003	0.004	517.986	0.003	0.005	0.003	0.488
Zaragoza	0.024	582.48	0.022	0.021	0.024	0.025	538.244	0.035	0.033	0.023	0.488
Asturias	0.034	936.268	0.033	0.042	0.018	0.023	810.024	0.027	0.029	0.022	0.471
Cantabria	0.016	778.184	0.017	0.016	0.014	0.014	649.923	0.016	0.015	0.013	0.471
Avila	0.005	457.276	0.002	0.002	0.004	0.004	403.746	0.002	0.003	0.003	0.460
Burgos	0.011	550.503	0.012	0.012	0.009	0.009	468.094	0.017	0.016	0.008	0.460
Leon	0.017	642.546	0.011	0.015	0.009	0.010	544.999	0.007	0.012	0.010	0.460
Palencia	0.006	536.972	0.005	0.006	0.004	0.004	445.716	0.005	0.005	0.003	0.460
Salamanca	0.010	557.103	0.006	0.008	0.007	0.007	472.840	0.005	0.005	0.007	0.460
Segovia	0.005	443.097	0.003	0.003	0.004	0.004	384.724	0.002	0.002	0.004	0.460
Soria	0.003	458.082	0.002	0.002	0.003	0.002	385.037	0.003	0.002	0.002	0.460
Valladolid	0.013	487.398	0.017	0.015	0.011	0.013	412.244	0.015	0.014	0.013	0.460
Zamora	0.007	597.455	0.003	0.004	0.004	0.004	493.528	0.002	0.002	0.004	0.460
Albacete	0.010	560.532	0.006	0.005	0.007	0.008	486.351	0.005	0.005	0.006	0.471
Ciudad Real	0.012	532.628	0.009	0.012	0.008	0.011	450.946	0.008	0.010	0.008	0.471
Cuenca	0.006	466.723	0.003	0.003	0.005	0.005	405.691	0.002	0.002	0.004	0.471
Guadalajara	0.004	451.418	0.005	0.005	0.004	0.005	394.952	0.006	0.006	0.004	0.471
Toledo	0.014	471.100	0.010	0.010	0.009	0.014	410.415	0.015	0.014	0.01	0.471
Barcelona	0.137	940.605	0.200	0.188	0.148	0.142	879.725	0.211	0.197	0.151	0.477
Girona	0.017	1166.402	0.017	0.016	0.018	0.020	1049.276	0.019	0.017	0.020	0.477
Lleida	0.012	797.744	0.011	0.012	0.011	0.012	720.807	0.010	0.009	0.011	0.477
Tarragona	0.017	747.118	0.024	0.030	0.015	0.019	667.449	0.021	0.022	0.019	0.477
Alicante	0.033	689.785	0.036	0.033	0.033	0.039	585.947	0.028	0.027	0.038	0.454
Castellon	0.014	633.634	0.016	0.017	0.012	0.014	562.700	0.024	0.023	0.012	0.454
Valencia	0.059	631.054	0.059	0.055	0.06	0.059	552.074	0.057	0.054	0.056	0.454
Badajoz	0.016	687.265	0.005	0.005	0.011	0.013	564.444	0.005	0.006	0.010	0.419
Caceres	0.011	602.853	0.005	0.007	0.006	0.008	502.318	0.002	0.004	0.007	0.419
A coruna	0.034	1084.937	0.022	0.025	0.025	0.025	861.847	0.018	0.025	0.023	0.452
Lugo	0.017	957.134	0.006	0.007	0.008	0.007	768.696	0.007	0.006	0.006	0.452
Orense	0.016	851.836	0.006	0.007	0.006	0.007	660.066	0.005	0.006	0.005	0.452
Pontevedra	0.031	1084.473	0.017	0.016	0.019	0.022	827.120	0.025	0.022	0.018	0.452
Madrid	0.118	442.748	0.130	0.124	0.217	0.173	387.143	0.128	0.136	0.215	0.483
Murcia	0.024	769.986	0.023	0.026	0.028	0.030	615.794	0.023	0.024	0.026	0.435
Navarra	0.016	625.343	0.025	0.023	0.016	0.018	575.838	0.031	0.029	0.016	0.471
Alava	0.009	639.970	0.02	0.018	0.008	0.009	556.701	0.024	0.021	0.009	0.494
Guipuzcoa	0.020	785.055	0.041	0.037	0.021	0.020	659.040	0.046	0.041	0.019	0.494
Vizcaya	0.031	777.486	0.059	0.057	0.036	0.029	682.024	0.042	0.047	0.032	0.494
La Rioja	0.008	490.447	0.008	0.007	0.006	0.008	513.364	0.012	0.011	0.007	0.482
Mean	0.021	700.268	0.021	0.021	0.021	0.021	601.220	0.021	0.021	0.021	0.461
Std. Dev	0.029	189.805	0.04	0.037	0.043	0.036	156.292	0.041	0.039	0.043	0.018
Max.	0.137	1166.402	0.200	0.188	0.217	0.173	1049.276	0.211	0.197	0.215	0.494
Min.	0.003	442.748	0.002	0.002	0.003	0.002	384.724	0.002	0.002	0.002	0.419

Notes: For Model 2, we have $\mu_2 = 1 - \mu_1$ by definition.

Chapter 4

Does Institutional Quality Matter for Trade? Institutional Conditions in a Sectoral Trade Framework

4.1 Introduction

The role of institutions as a driver of economic development has been attracting considerable attention in the literature on long-run economic growth. It has been widely acknowledged that local institutional conditions shape growth trajectories in different parts of the world (Acemoglu et al., 2005; Rodríguez-Pose and Storper, 2006). Trade is also considered a fundamental driver of economic growth. Yet, our knowledge about how the local quality of institutions impinges on trade trends remains rather limited. It has been claimed that good institutional environments facilitate bilateral trade. High institutional quality reflects pluralistic and inclusive political institutions that facilitate the existence of a level playing field, where individual economic agents cannot abusive market power monopolizing trade in their favour (e.g., tariffs and quotas), thereby restricting flows as a result of rent-seeking activities. Indeed, institutional quality and smaller gaps in governance drive trade flows (De Groot et al., 2004), while weak or inadequate institutions may restrain trade in magnitudes which are not dissimilar to those related to the introduction of tariffs (Anderson and Marcouiller, 2002). Specific institutional dimensions have also been found to affect trade. Low levels of trust, for example, have been associated with lower bilateral trade in the European context (Guiso et al., 2009), whereas both an efficient rule of law and a good endowment of informal institutions can facilitate trade (Yu et al., 2015). Using firm-level data, Söderlun and Tingvall (2014) find that weak institutions in destination countries make exports less likely for Swedish firms.

Beyond these general indicators, the association between institutions and trade is still poorly understood. This modest grasp of the role institutions play in bilateral trade is possibly related to problems in both defining and measuring institutions. It has been argued that "defining institutions is notoriously difficult and the current literature on the topic does not agree on a common definition" (Rodríguez-Pose, 2013: 1037). Measuring institutions across different territorial contexts has also proven difficult. In particular, informal institutions – individual habits, values, group routines and social norms – have proven much more difficult to assess and value than formal ones – laws, rules, and organization (Amin, 1999).

The aim of this paper is precisely to shed greater light on the role of different types of institutions on bilateral trade. The paper focuses on two key issues: a) whether local institutional quality affects the volume of trade by any given country and at sectoral level; and b) whether the impact of institutions has been waxing or waning with time. In trying to answer these two questions, the paper improves our understanding of which institutions matter for international trade both from a theoretical and applied perspectives. To provide a theoretical foundation to the gravity equation, we propose a model that considers Anderson and van Wincoop's (2003) multilateral resistance framework within a new trade theory model that includes as determinants of trade a labour competitiveness measure in origin (in terms of productivity and wages) and sectoral income shares at destination, as well as the institutional conditions in the countries of origin and destination. From an applied perspective we compile the most comprehensive and representative database of sectoral trade flows. It contains data on trade on tangible goods (commodities) as well as services, covering 186 countries over the period between 1986 and 2012. We hypothesise that better institutional quality reduces transaction costs and promotes international trade. Institutions will be introduced in two different ways: a) as a barrier at destination, and b) as the difference between the institutional indicators of the exporting and importing countries, which constitutes a measure of institutional distance. Geographical distance, common border, and language are also accounted for, so as to control for additional transport costs and trade barriers.

To achieve these aims, the paper adopts the following structure. The next section presents the theoretical model on which the analysis is based. Section 4.3 dwells on the data used in the empirical analysis and its sources. The effects of institutional barriers on sectoral countries across the world are estimated in section 4.4, allowing us to address the questions of whether institutions matter for trade and whether, if that is the case, their influence has been waxing or waning over time. The analysis also unveils disparities across sectors in the relationship between institutional quality and trade patterns. Finally, Section 4.5 draws relevant conclusions.

4.2 Model

We estimate the effect of institutional barriers on trade flows between any two economies i and j relaying on a theoretically founded specification of the gravity equation based on the so-called new trade theory, NTT. The model is characterized by the Dixit-Stiglitz-Krugman assumptions regarding "love-for-variety" preferences, increasing returns to scale technologies and iceberg transport costs. Following Barbero et al. (2015) it allows for multiple countries and multiple differentiated sectors regarding the definition of trade flows (exports and imports), thereby extending the different specifications surveyed by Berhens and Ottaviano (2009). These authors summarize the NTT analytical framework including the effect of transport and non-transport related trade costs for the case of two countries. We extend this model and include our independent variable of interest, institutional quality, as yet another barrier to sectoral trade, and empirically test if it affects trade flows in alternative sectors in different ways.

4.2.1 Sectoral trade framework

We derive the sectoral gravity equation allowing for a continuum of varieties within multiple sectors and countries.

Consumer preferences and demands

The preferences of a consumer in economy j are given by:

$$U_j = \prod_s D_{sj}^{\mu_{sj}}, \tag{4.1}$$

where $D_s j$ is the aggregate consumption of the differentiated good in sector s in country j; and $0 < \mu_{sj} < 1$ is the income share spent on each sector s by consumers in j. The aggregate consumption of each differentiated good, D_{sj}, corresponds to the following constant elasticity of substitution (CES) subutility function:

$$D_{sj} = \left[\sum_i \int_{\Omega_{si}} d_{sij}(\omega)^{(\sigma-1)/\sigma} d\omega \right]^{\frac{\sigma}{\sigma-1}}, \tag{4.2}$$

where $d_{sij}(\omega)$ is the individual consumption of sector s variety ω produced in i and consumed in j; and Ω_{si} is the set of varieties of sector s produced in i. The parameter $\sigma > 1$ measures the elasticity of substitution between any two varieties, as well as the price elasticity of demand. Let $p_{sij}(\omega)$ denote the price of sector s variety ω produced in i and consumed in j; and w_j be the wage rate in region j.

Maximizing the utility (1) subject to the budget constraint:

$$\sum_s \sum_i \int_{\Omega_{si}} p_{sij}(\omega) d_{sij}(\omega) d\omega = w_j, \tag{4.3}$$

yields the following individual demand for each variety:

$$d_{sij}(\omega) = \frac{p_{sij}(\omega)^{-\sigma}}{P_{sj}^{1-\sigma}} \mu_{sj} w_j, \tag{4.4}$$

where P_{sj} is the CES price index in sector s and region j, defined as:

$$P_{sj} = \left[\sum_i \int_{\Omega_{si}} p_{sij}(\omega)^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}} \tag{4.5}$$

Firms: technology and trade

Taking labour to be immobile across economies, firms in country i and sector s produce the same variety of goods and services with increasing returns to scale. Trade in the differentiated products between countries is hampered by transport and non-transport related barriers (trade costs) and is of the standard "iceberg" form, which implies that the cost of each variety from sector s and country i is multiplied by $\tau_{sij} \geq 1$, resulting in the delivered price at country j. The labour requirement for producing the output in sector s and country i is given by $l_{si} = F_i + c_i \sum_i \tau_{sij} d_{sij}$, where F_i and c_i represent country specific fixed costs and marginal labour requirements, respectively.

A country i firm producing in sector s maximizes profit:

$$\pi_{si} = \sum_j p_{sij} d_{sij} - (F_i + c_i \sum_j \tau_{sij} d_{sij}) w_i. \tag{4.6}$$

Assuming that markets are characterized by monopolistic competition, with free entry and the absence of strategic interactions, first-order conditions under price competition yield the following equilibrium price (Appendix A.2):

$$p_{sij} = \left(\frac{\sigma}{\sigma - 1}\right) c_i w_i \tau_{sij}, \tag{4.7}$$

so there is a constant mark-up $\left(\frac{\sigma}{\sigma-1}\right)$, decreasing in σ.

Therefore, bilateral trade flows are obtained aggregating the value of exports from country i to country j as follows:

$$x_{sij} = L_j p_{sij} d_{sij} = \left[\left(\frac{\sigma}{\sigma - 1}\right) c_i w_i\right]^{1-\sigma} (\tau_{sij})^{1-\sigma} \left[(P_{sj}^{\sigma-1} \mu_{sj} w_j L_j)\right], \tag{4.8}$$

which represents the specific gravity equation for bilateral trade in the proposed analytical framework. The value of sector s export flows from i to j depends inversely on transport costs τ_{sij} and a measure of labour competitiveness jointly represented by the marginal factor requirements and wages of the exporter region: $c_i w_i$, rendering country i more competitive as the required labour inputs and salaries decrease, thereby reducing mill prices (and vice versa). Conversely, exports are directly related to the price index P_{sj} of the importing country, its share of income spent in sector s, μ_{sj}, as well as its aggregate income $w_j L_j$.

4.2.2 Econometric specification

From the gravity equation in (8) and taking logs, we obtain the following specification:

$$\ln x_{sij} = (1-\sigma)\ln\left(\frac{\sigma}{\sigma - 1}\right) + (1-\sigma)\ln(c_i w_i) + (1-\sigma)\ln\tau_{sij} + (\sigma - 1)\ln P_{sj} + \ln(\mu_{sj}) + \ln(w_j L_j) \tag{4.9}$$

Consequently, considering time period t, the functional form to be estimated corresponds to the following econometric specification:

$$\ln x_{sijt} = \beta_0 + \beta_1 \ln(c_{it} w_{it}) + \beta_2 \ln\tau_{sijt} + \beta_3 \ln P_{sjt} + \beta_4 \ln\mu_{sjt} + \beta_5 \ln(w_{jt} L_{jt}) + \delta_{si} + v_{sijt} \tag{4.10}$$

where $\beta_0 = (1-\sigma)\ln\left(\frac{\sigma}{\sigma-1}\right)$, δ_{si} represents the individual effects in origin, and v_{sijt} is the error term. Equation (10) can be consistently estimated using single equation methods.

Trade barriers τ_{sijt} are further specified to include the institutional factors of interest conditioning trade, and additional variables related to both transport related costs, proxied by physical distance (*dist*) and geographical contiguity (*cont*) to control for border effects, or cultural distance (*lang*, common language). We propose two alternative specifications for the institutional barriers:

$$\ln\tau^{l}_{sijt} = \gamma_k I_{jkt} + \alpha\ln d_{ij} - \varphi cont_{ij} - \rho lang_{ij}, \qquad k = 1\ldots 6, \tag{4.11a}$$

$$\ln\tau^{d}_{sijt} = \gamma_k I_{ijkt} + \alpha\ln d_{ij} - \varphi cont_{ij} - \rho lang_{ij}, \qquad k = 1\ldots 6, \tag{4.11b}$$

whose only difference lies in the definition of the indicators I_{jkt} and I_{ijkt} representing governance in terms of *Control of corruption*, *Government effectiveness*, *Political stability*, *Rule of law*, *Regulatory quality*, and *Voice and accountability*—discussed in the next section. In equation (11a) we consider these indicators in *levels* (l) at the destination country j to determine to what extent weak institutional quality is capable of holding back import flows. Equation (11b), by contrast, focuses on the *difference* (d) in the levels corresponding to the exporting and importing countries: $|I_{ijkt}| = |I_{ikt} - I_{jkt}|$. This represents a measure of institutional distance between i and j that is defined in absolute value. As for the contiguity and common language variables, these dummies take value one when countries i and j have a common border or share the same language, respectively.

4.3 Data and sources

The empirical analysis is performed on a comprehensive data set compiled from several sources. Data on bilateral trade of tangible goods is gathered from the UN Comtrade database, whereas that corresponding to services stems from the UN Service Trade. The data are collected for the periods 1996-2012 and 2000-2012, respectively. This data set is developed by the United Nations Statistics Division (UNSD) and provides bilateral statistics among 186 countries for tangibles and 181 in the case of services. Trade data of tangibles is disaggregated into the primary (agriculture and raw materials) and industry sectors to test for trade differences between them.

Country-specific variables correspond to labour competitiveness, sectoral price indices, sectoral income shares, and Gross Value Added (GVA) in the importing—destination—country j. Data on labour competiveness depending on productivity and wages is proxied by the GVA per worker of the exporting country. The income share represents the participation of sectoral GVA on total GVA. Employment is taken from the World Databank elaborated by The World Bank. GVA in current and 2005 US dollars constant prices by type of economic activity are extracted from UN data.

Geographical distances, adjacency, and common language are idiosyncratic characteristics that are taken into account for each pair of countries, as they may represent relevant enablers/barriers to bilateral trade. Distances between countries, as well as information about contiguity and common official language, are obtained from the GeoDist database elaborated by Mayer and Zignago (2011).

We use geodesic distances, calculated by computing the distance between the most populated cities of each country.

We study the role played by institutions in promoting or hindering trade and contend that better institutions promote bilateral trade, often counterbalancing the potentially negative effects associated to existing trade barriers, such as longer distances, lack of contiguity, and cultural differences. Our measure of institutional quality at country level stems from the World Bank's World Governance Indicators (WGI), elaborated by Kaufmann et al. (2010). While not exempt from controversy, the WGI is the most detailed and geographically comprehensive array of institutional indicators currently available. The WGI provides six governance indicators for 215 economies over the period 1996-2013, capturing different aspects of institutional quality at a national level. We discuss the main elements in the composition of these six indicators in turn:

- *Control of corruptio*n (CC) is a measure of anti-corruption policy; i.e., how a society prevents that public power is used by individuals to obtain private gains. It measures, among other things, the level of irregular payments, the degree of corruption in administrations and companies, and the frequency of corruption in public institutions. It is assumed that corruption increases transaction costs and introduces a component of uncertainty in economic transactions which is likely to hamper bilateral trade.

- *Government effectiveness* (GE) measures the quality and satisfaction of the general public with public services, bureaucracy, infrastructure, as well as the credibility of governments. This measure is a proxy for the ability of a government to deliver efficient and effective policies.

- *Political stability and absence of violence* (PV) is an indicator of politically motivated violence, terrorism, social unrest, armed conflicts. Lower political stability and greater violence are expected to be detrimental to trade.

- *Rule of law* (RL) captures confidence in the judicial system, contract enforcement, property rights, law enforcement against violent and organized crime, and judicial independence. It is a proxy for the overall quality of the legal system.

- *Regulatory quality* (RQ) measures the ability of the government to implement policies to promote private sector development. It considers the capacity to tackle unfair competition practices, the ease of starting a new business, the presence of anti-trust policy, financial freedom and tax effectiveness, as well as the presence or absence of impose price controls, excessive protections,.... It complements the indicators depicting *Control of corruption* and *Rule of law*.

- *Voice and accountability* (VA) captures the extent to which citizens are able to participate in choosing their government representatives, as well as the existence of civil liberties, free press, freedom of speech, freedom of association, and human rights.

Combining all 186 countries for the period 1996-2012, the data set includes a total of 125,703 observations of bilateral trade flows of tangible goods.[1] For bilateral trade in services the sample size is reduced to 23,661 observations for the period 2000-2012. The descriptive statistics for the variables considered in the analysis are presented in Table 1.

Table 4.1: Descriptive statistics

Variables	Mean	Std. Dev.	Min	Max	Change Rate 1996-2012 (%)
Trade of tangible goods (in millions USD)	856.508	7,007.278	0.000	353,782.700	1.296
Distance (in km)	6,801.110	4,601.369	59.617	19,812.040	0.041
Labour competitiveness in origin (exporter) (in thousands USD)	29.617	31.179	0.182	234.475	0.566
Sectoral price at destination (importer)	1.116	0.342	0.177	2.885	0.700
Sectoral income share at destination (importer)	0.421	0.153	0.069	0.977	-0.058
Institutional indicators in the importing country, I_{jkt}					
Control of corruption	0.163	1.085	-1.924	2.586	-0.581
Government effectiveness	0.216	1.035	-2.450	2.430	-0.310
Political stability	-0.016	0.961	-3.324	1.938	-3.946
Rule of law	0.123	1.035	-2.669	2.000	-0.346
Regulatory quality	0.211	1.012	-2.675	2.247	-0.361
Voice and accountability	0.039	1.021	-2.284	1.826	-0.990
Institutional distance as the difference in indicators between exp. and imp. countries, I_{ijkt}					
Control of corruption	1.282	0.942	0.000	4.387	-0.104
Government Effectiveness	1.219	0.858	0.000	4.688	-0.062
Political Stability	1.073	0.797	0.000	4.533	-0.026
Rule of Law	1.221	0.856	0.000	4.498	-0.035
Regulatory Quality	1.156	0.829	0.000	4.644	-0.016
Voice and Accountability	1.135	0.820	0.000	3.986	-0.028
Control of Corruption	1.282	0.942	0.000	4.387	-0.104

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[1] 1999 and 2001 are not considered in the analysis, as the World Governance Indicators were not collected in those years.

4.4 Estimating the effect of institutional barriers on sectoral trade in world countries

As in the recent literature examining the impact of institutions on trade (Anderson and Marcouiller, 2002; De Groot et al., 2004; Linders et al., 2005; Yu et al., 2015), we base our analysis on the gravity equation theoretically obtained in section 2. We analyse the extent to which institutional conditions affect bilateral sectoral trade flows, using what we consider to be the most complete database that has been collected for this purpose. A further novelty is the inclusion of a labour competitiveness measure in origin and sectoral income shares at destination as determinants of sectoral trade flows in line with the literature that analyses the implications of income inequality on trade (Rodriguez-Pose, 2012).

4.4.1 Do institutions matter for trade?

In a first stage we estimate the gravity model (10) for total tangible commodities. All model specifications include year and exporter fixed effects to control for their corresponding specific factors, such as supply and market capacity, as well as to control for trade policy features of exporting countries. The analysis is dually developed in terms of institutional quality levels and differences as presented in equations (11a-b), and controlling for geographical distances, common border and language, as determinants of trade costs. The rationale behind these two measures is that better institutional conditions in the importing country would guarantee legal security and reduce uncertainty, whereas a lower institutional distance between the exporting and the importing country may reduce the risk related to differences and/or lack of familiarity with formal procedures, business practices, norms of behaviour and contract enforcement—e.g., by sanctioning international agreements, De Groot et al., (2004). Traditionally, the majority of bilateral trade has taken place between countries with high levels of institutional quality and, therefore, with small differences in their indicators. We therefore hypothesise that better institutional quality at destination and a lower institutional distance between trading partners lower trade barriers by reducing transactions costs thereby facilitating overall trade. In contrast, large institutional differences between two countries resulting from asymmetric institutional frameworks discourage bilateral trade and prevent its consolidation and growth.

Table 2 presents the estimation results of the analysis for trade in tangible goods according to the gravity equation. As there is a high correlation between the six different institutional indicators we run separate regressions for each one. Results show that labour competitiveness of the exporting country—in origin—resulting from lower factor requirements and wages, as well as the aggregate GVA of the importing country (national income at destination) affect bilateral trade in positive ways. Regarding the GVA at destination it represents market size and contributes to increase economic relations as expected. As for the sectoral price index in the importing country it represents the multilateral resistance term, firstly introduced by Anderson and van Wincoop (2003).[2] It allows taking into ac-

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[2] Anderson and van Wincoop (2003) extend the original specification presented by Anderson (1979), who provides a theoretical foundation for the gravity models in trade, but also introduces a method to deal with cross price index terms,

count the relative position of countries in terms of competitiveness at the destination country. The negative coefficients of this variable indicate that inflationary trends of import prices reduce bilateral trade.[34] These latter results are in line with those observed in the literature analysing trade on the basis of gravity equation models.[5]

The model proposed implies that internal demand drives trade flows. This results in a gravity equation including the share of domestic income that is spent in the sector at destination, and whose empirical approximation is sectoral GVA. Its negative sign in the estimations indicates that increasing sectoral production at destination diminishes trade in goods, a result that corroborates the idea that foreign countries export less when domestic production at destination is enough to meet demand.

Finally, besides institutional quality, trade barriers depend on distance, sharing borders, and common language. Geographical distance is used as an approximation of transport (physical) costs, as studied in Limao and Venables (2001), Combes and Lafourcade (2005), and Zofío et al. (2014). Our results confirm that geographical distance influence trade flows. Our distance elasticities are a tad below -1.3, which is higher than the -0.93 and the -0.91 reported by Disdier and Head (2008) and Head and Mayer (2013), respectively, but this may be a result of using a larger sample, including a larger number of countries over a longer time period, than these authors. Contiguity (border) and cultural linkages (common language) effects display very similar positive values, with coefficients around 0.9.[6]

Focusing now on our variables of interest, we find that most institutional indicators display significant coefficients with the expected sign. The exceptions are *Political stability* and *Voice and accountability*. In particular, the strongest connections with bilateral trade volumes are exhibited by *Control of corruption*, *Government effectiveness*, *Rule of law*, and *Regulatory quality*. This is in line with studies signalling that corruption, legal security, and market competition are some of the most serious concerns in economic relations, conditioning economic growth and hampering trade. Such is the case of Yu at el. (2015), who remark the importance of institutional quality, in general, and rule of law, in particular, or Anderson and Marcouiller (2002) and Jansen and Nordas (2004), who stress the role of corruption as a fundamental impediment to trade. Overall, our results strongly suggest that an improvement in institutional quality in importing countries positively affects trade.

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constituting the multilateral resistance term.

[3] Indeed, the price index (5) is homogenous of degree $(1-\sigma)^2$ in prices; therefore if individual country prices increase proportionally, the aggregate index increases according to that degree.

[4] Several authors propose different estimation methods when multilateral resistance terms are unobserved (e.g., Rose and van Wincoop, 2001; Redding and Venables, 2004; Feenstra, 2004; Baier and Bergstrand, 2009).

[5] Head and Mayer (2013) offer a chronological overview on the most common and/or efficient methods in the empirical estimation of gravity equations.

[6] Tadesse and White (2010) find that cultural distances contribute to reduce trade based on data for US State level exports to 75 countries. Common language can be considered as a proxy of cultural proximity.

Table 4.2: The influence of institutions in the importing country on total trade

	Tangible					
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Labour competitiv. in	0.511***	0.511***	0.511***	0.511***	0.510***	0.511***
origin (exporter) $(\ln(c_i w_i))$	(20.36)	(20.36)	(20.37)	(20.36)	(20.34)	(20.37)
Control of corruption	0.0438***					
(I_jt1)	(7.181)					
Government effectiveness		0.0522***				
(I_jt2)		(7.378)				
Political stability			-0.00321			
(I_jt3)			(-0.589)			
Rule of law				0.0260**		
(I_jt4)				(4.031)		
Regulatory quality					0.0490***	
(I_jt5)					(7.100)	
Voice and accountability						0.00189
(I_jt6)						(0.307)
Distance	-1.297***	-1.296***	-1.297***	-1.296***	-1.295***	-1.297***
$(\ln d_{ij})$	(-204.9)	(-204.6)	(-204.8)	(-204.6)	(-204.4)	(-204.8)
Contiguity	0.953***	0.954***	0.944***	0.951***	0.953***	0.945***
$(cont_{ij})$	(36.27)	(36.30)	(35.94)	(36.15)	(36.24)	(35.97)
Common language	0.989***	0.992***	0.989***	0.991***	0.992***	0.989***
$(lang_i j)$	(72.36)	(72.59)	(72.26)	(72.47)	(72.59)	(72.36)
Sectoral price at destination	-0.197***	-0.197***	-0.220***	-0.207***	-0.203***	-0.218***
(importer) $(\ln P_{jt})$	(-7.978)	(-8.017)	(-8.947)	(-8.399)	(-8.286)	(-8.859)
Sectoral inc. share at destin.	-0.242***	-0.233***	-0.314***	-0.271***	-0.237***	-0.307***
(importer)$(\ln \mu_{sjt})$	(-16.05)	(-14.89)	(-23.65)	(-17.87)	(-15.29)	(-20.26)
GVA at destination	0.797***	0.794***	0.804***	0.800***	0.796***	0.804***
(importer) $(\ln(w_{tj} L_{jt}))$	(339.2)	(311.9)	(372.6)	(338.5)	(326.6)	(363.0)
Constant	-0.731***	-0.657**	-0.963***	-0.833***	-0.704***	-0.951***
	(-2.817)	(-2.517)	(-3.733)	(-3.208)	(-2.707)	(-3.678)
Exporter Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	125,703	125,703	125,703	125,703	125,703	125,703
R-squared	0.717	0.717	0.717	0.717	0.717	0.717

t-statistic in parenthesis. *** $p < 0.01$, **$p < 0.05$, *$p < 0.1$

Using standardized coefficients allows us to compare the different dimensions of the estimated parameters directly.[7] The results of this type of analysis indicate that geographical distance is the most important factor determining bilateral trade (eqs. 11a-b). A significant result is that, in comparison with transport costs, the significant and positive coefficients for *Control of corruption*, *Government effectiveness*, *Rule of law*, and *Regulatory qualit*y play a minor role in trade, to the tune of 3.94%, 4.47%, 2.23% and 4.12% of the effect of geographical distance, respectively. Hence, while institutional factors play a significant role in bilateral trade flows, their magnitude is limited in comparison to that of geographical distance, the most important factor shaping bilateral trade. These results also show that there is no significant difference in the dimension of the association with trade among the different institutional indicators considered in the analysis. The four relevant institutional factors—*Control of corruption*, *Government effectiveness*, *Rule of law*, and *Regulatory quality*—display roughly the same coefficients, strongest in the case of Government effectiveness, and weakest for *Rule of law*. *Voice and accountability* and *Political stability*, by contrast, display insignificant coefficients, meaning that they are disconnected from bilateral trade. The use of standardized coefficients allows us to qualify previous findings as those by De Groot et al. (2004) and Linders et al. (2005)—also using Kaufmann et al.'s (2010) six institutional dimensions—who indicate that institutional quality, regardless of the indicator considered, always mattered for trade, but without exposing its relative importance.

In Table 3 we present the estimation results of looking at the institutional distance between two countries, rather than just at the quality of institutions at destination. All institutional variables are calculated as the absolute value of the difference between the indicators of country of destination and that of origin. The results for the control variables are similar to those reported in Table 2. The variables that represent market size, multilateral resistance term, and sectoral income share at destination all show the expected signs and have similar values to those in the previous specification. Once again, bilateral flows are negatively affected by distance, while contiguity and common language are associated with increases in trade.

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[7] Results are available upon request.

Table 4.3: The influence of institutional distance between exporting and importing countries on total trade

	Tangible					
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Labour competitiv. in	0.509***	0.509***	0.502***	0.501***	0.505***	0.513***
origin (exporter) ($\ln(c_i w_i)$)	(20.29)	(20.29)	(20.02)	(20.02)	(20.16)	(20.49)
Control of corruption	-0.0836***					
(I_{jt1})	(-15.16)					
Government effectiveness		-0.0890***				
(I_{jt2})		(-15.00)				
Political stability			-0.0802***			
($I_j t3$)			(-13.25)			
Rule of law				-0.117***		
($I_j t4$)				(-20.06)		
Regulatory quality					-0.133***	
($I_j t5$)					(-22.06)	
Voice and accountability						-0.115***
($I_j t6$)						(-19.09)
Distance	-1.288***	-1.284***	-1.292***	-1.281***	-1.279***	-1.284***
($\ln d_{ij}$)	(-202.5)	(-201.2)	(-203.8)	(-201.1)	(-200.7)	(-201.8)
Contiguity	0.920***	0.922***	0.930***	0.915***	0.917***	0.919***
($cont_{ij}$)	(35.00)	(35.07)	(35.40)	(34.85)	(34.95)	(34.99)
Common language	0.983***	0.981***	0.988***	0.980***	0.983***	0.966***
($lang_{ij}$)	(71.95)	(71.76)	(72.38)	(71.75)	(72.06)	(70.56)
Sectoral price at destination	-0.227***	-0.230***	-0.222***	-0.236***	-0.233***	-0.229***
(importer) ($\ln P_{sjt}$)	(-9.289)	(-9.421)	(-9.066)	(-9.653)	(-9.525)	(-9.356)
Sectoral inc. share at destin.	-0.314***	-0.298***	-0.297***	-0.298***	-0.285***	-0.274***
(importer)($\ln \mu_{sjt}$)	(-26.84)	(-25.48)	(-25.33)	(-25.48)	(-24.34)	(-23.13)
GVA at destination	0.807***	0.804***	0.804***	0.806***	0.803***	0.807***
(importer) ($\ln(w_{tj} L_{jt})$)	(373.4)	(373.3)	(373.4)	(374.2)	(373.2)	(374.1)
Constant	-0.944***	-0.862***	-0.734***	-0.812***	-0.777***	-0.979***
	(-3.666)	(-3.347)	(-2.845)	(-3.153)	(-3.020)	(-3.803)
Exporter Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	125,703	125,703	125,703	125,703	125,703	125,703
R-squared	0.718	0.718	0.718	0.718	0.718	0.718

t-statistic in parenthesis. *** $p < 0.01$, **$p < 0.05$, *$p < 0.1$

The institutional distance in all six governance indicators are statistically significant and negative. These results suggest that institutional distance between the exporter and importer represent, as expected, an important impairment for trade, irrespective of the institutional conditions at destination. Countries with similar levels of institutional quality (and with better overall institutions) tend, everything else being equal, to trade more. Lower institutional distance and a greater familiarity with the institutional environment at destination reduces transaction costs. Institutional distance remains, however, a minor player in comparison to geographical distance when it comes to bilateral trade. Comparing standardized coefficients, the relative impact (weight) of the different indicators of institutional distance with respect to geographical distance ranges between 5.30% for *Rule of law*, and 9.27%, in the case of *Regulatory quality*. Again these results regarding the relative importance of institutional distance complement recent results by Yu et al. (2015).

4.4.2 Evolution of the impact of geographical distance and institutional barriers on trade

The second research question in this study refers to whether the role of institutional quality for trade has been increasing over time. We address it by studying the stability of the coefficients associated to both geographical and institutional distance by means of interacting the institutional indicators with time dummies. This way we can compute the marginal effects of the institutional variables for every year. This type of analysis can be then transformed into annual figures, facilitating the visual inspection of the association between each variable and trade over time.

Figure 4.1: Evolution of the impact of geographical distance

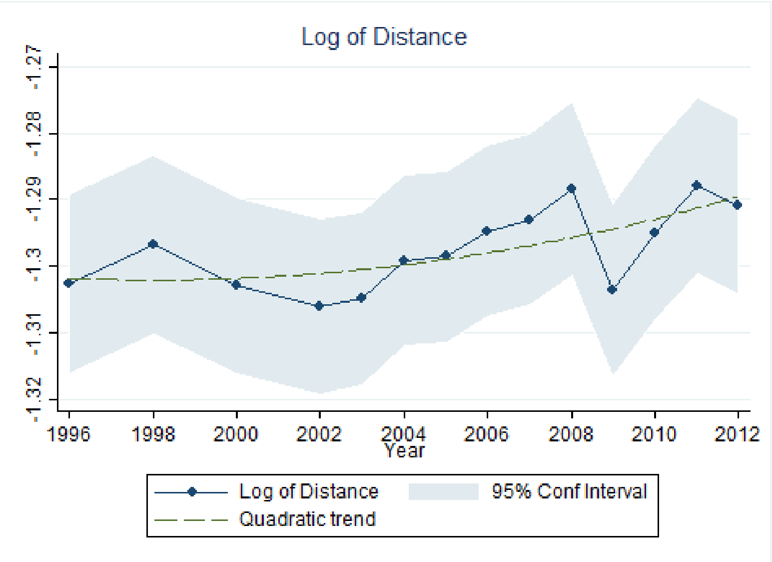


Figure 1 shows the evolution of the coefficients estimating the association of geographical distance with bilateral trade. The persistence of the negative impact of distance on trade, as generally established in the literature for the last half the 20th century, is confirmed by the negligible decline in this coefficient in the first decade of the 21^{st} century; e.g., the above mentioned meta-analysis by Disdier and Head (2008). The explanations for this continuing and undiminishing effect of geographical distance can be found in the composition of trade in a large number of countries that appears to be biased toward industries where distance still heavily determines the propensity to trade. It may also be the case, as hypothesized by Duranton and Storper (2008), that greater trade in sophisticated goods with higher transaction costs may offset the effects of the decline in transport costs.

Figure 2 presents the evolution of the coefficients of institutional quality in the importing country, whereas Figure 3 displays the annual variation of the institutional distance between origin and destination in absolute values. Given increasing globalisation and overall rising trade levels, a rising connection between institutional quality and bilateral trade over time would be expected. However, for virtually all the indicators of institutional quality at destination, a downward sloping trend is observed throughout the period. In spite of some upsurges in the dimension of the coefficients in the last years, the overall trajectory indicates a lower relevance of institutional factors in the importing country until the early 2010s, relative to the late 1990s s and early 2000s. This may be simply a factor of the commodity boom of the 2000s, with raw materials badly needed for industrial production often found in countries with weaker institutions—as confirmed in the following section. The end of the boom is then associated with the revival of the role of institutions observed in the early 2000s. It also seems to reflect the rapid rise of new players in trade presenting relatively lower institutional indicators, such as China, with importing countries adopting a realpolitik attitude based on practical considerations and respecting countries' internal affairs. Finally, it captures the overall decline in institutional quality as presented in the change rates of the governance indicators (Table 1); particularly in regions of the world that were relatively open to trade in previous years and whose trade flows did not wane.

As for the different institutional indicators representing institutional distances, rather than the quality of institutions at destination, there is a consistent behaviour among them as shown in Figure 3. Here more/less intense negative associations imply increasing/declining differences and hence higher/lower barriers to trade in terms of our regression results. Accordingly, institutional distances between countries increase their negative effects as trade barriers. These trends are particularly marked for *Control of corruption*, *Political stability*, and *Regulatory quality*, with reductions in their parameter estimates to the tune of 100% when taking as reference a quadratic tendency. Contrarily, *Government Effectiveness*, *Rule of law* and *Voice and accountability* do not exhibit noticeable changes with practically the same values for the initial and last years. In the case of *Voice and accountability*, a moderately flat U-shaped is observed (using an inverted scale on the y-axis) with the downward trend reverting since 2004.

Figure 4.2: Evolution of the impact of institutions in the importing country.

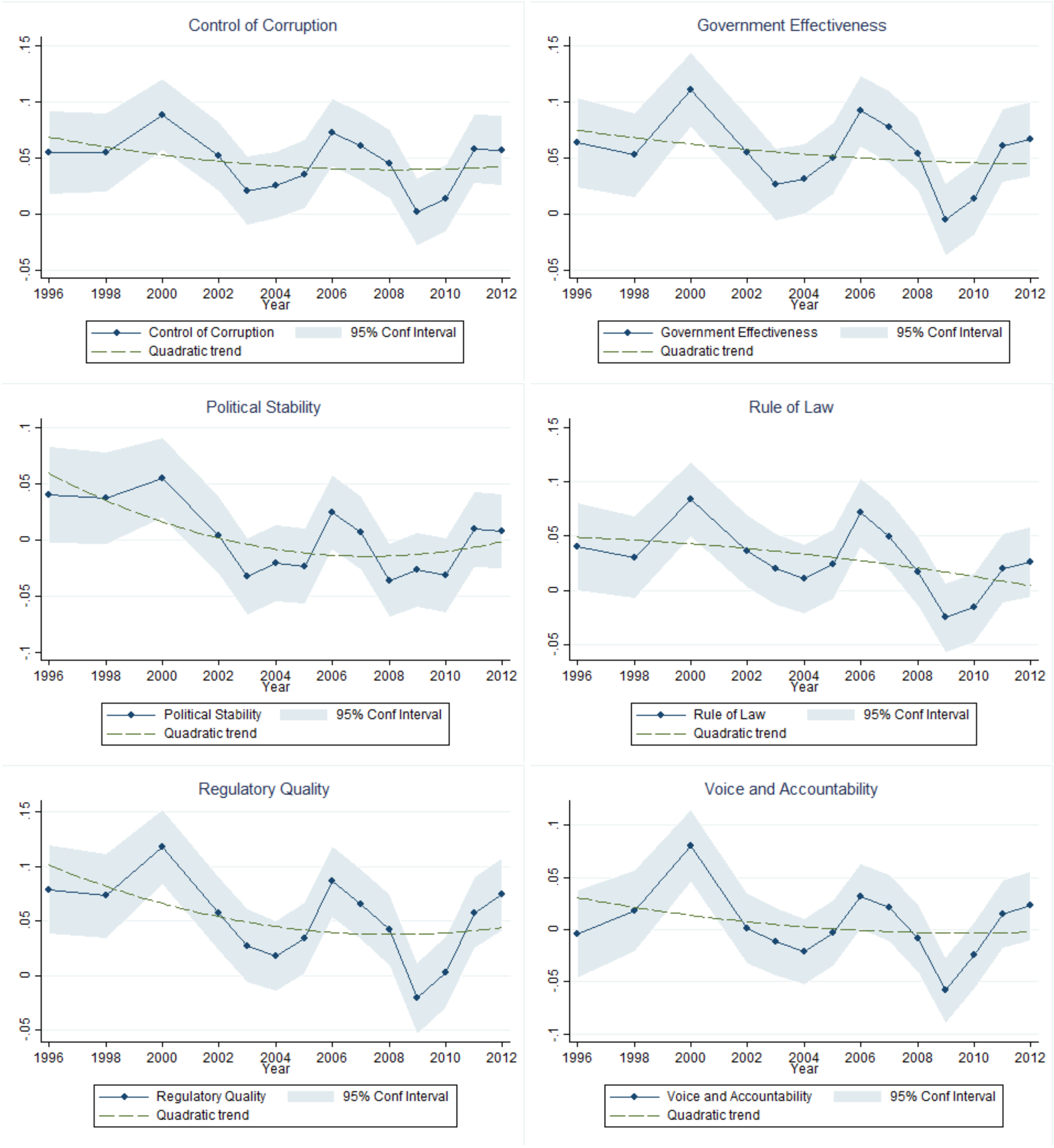
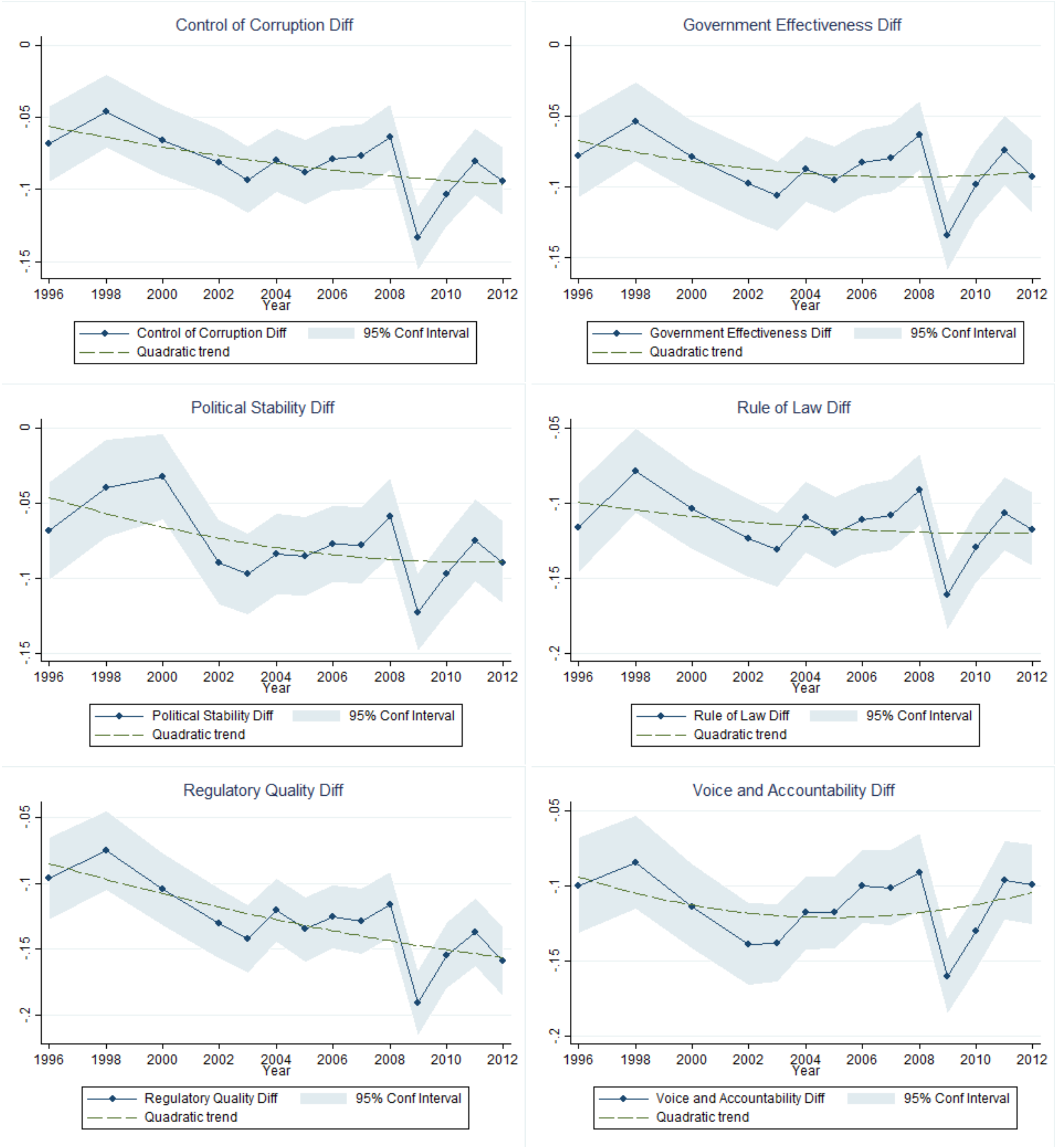


Figure 4.3: Evolution of the impact of institutional distance indicators between exporting and importing countries



4.4.3 What sector is most sensitive to institutions?

In order to assess the robustness of previous results, we further perform a series of equivalent regressions for trade flows in different economic sectors, and compare the obtained results to those obtained in section 4.1. We first analyse the connection between institutions and trade by sectors, with the aim of assessing whether differences exist depending on the nature of the products—goods or services—being traded. Tables 4 and 5 report the results estimating the gravity equation (10) for trade in the primary sector (agriculture and natural resources), industry, and services, including trade barriers with institutional quality indicators in the importing country and institutional distances between exporters and importers, (11a-b) respectively. As the different variables in the gravity equation present the expected signs when statistically significant, we only report the coefficients and t-student significance statistics for the institutional quality variables. Columns (1) and (3) offer the estimated coefficients for tangible goods separated into the primary sector and industry, as well their difference with respect to the previously estimated coefficients for the aggregate trade in tangibles already reported in Tables 2 and 3, which are subtracted from the new estimates—columns (2) and (4). In addition, we report the relationship between institutions and flows of services in column (5), also in terms of institutions at destination and institutional distances. Finally, in the last column (6), we also present the difference with the coefficients of total trade—tangibles and services, restricted to those countries in the sample where services trade data are available.[8]

Table 4 shows that the influence of institutional quality at destination on trade in agricultural goods and natural resources greatly differs from that of industry, columns (1) and (3). Institutions quality lead to improvements in trade to a much lower extent for agriculture and natural resources than for industry. Whereas better institutional quality in the importing country facilitates bilateral trade in industrial products, greater Political stability, Regulatory quality, and Voice and accountability have been associated with lover volumes of trade when it comes to agricultural produce and natural resources. Indeed, the relationship with primary sector production is only positive and significant for Control of corruption and Rule of law. This may simply be, as convincingly argued by Méon and Sekkat (2008), a consequence of the characteristics of natural resources—bulkier to transport, often requiring no transformation at the point of origin. It may also reflect how the greater price volatility of these products affects trade patterns. However, our contention is that this is an indication of how the resource boom has affected the role of institutional factors for trade since the early 2000s. In light of the increasing need to use natural resources and raw materials to feed industrial production as a result of rising demand, bilateral trade involving countries with weaker institutional quality has blossomed in this sector, as the Chinese case previously remarked. This is, however, not the case for the industry sector, where a better quality of government is a fundamental factor facilitating trade.

Restricted data availability for trade in services reduces the sample for this sector to 23,661 observations in the period 2000-2012. Results show that institutional quality is a fundamental factor for bilateral trade, column (5). The standardized value of the coefficient in the case of services is now

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[8] Results of these regressions, including 23.661 observations, are available upon request.

about half in magnitude to that reported for geographical distance—50%, implying that for services having a good institutional setting at destination is an essential element for fostering trade and overcome the negative effect of distance. This is a remarkable result given that the effect of institutional indicators for trade in tangibles—less than 10%—was rather small when compared to distance.

Table 4.4: The influence of institutions in the importing country on trade by sectors

Variables	Primary sector		Industry		Services	
	Value (1)	Difference (2)	Value (3)	Difference (4)	Value (5)	Difference (6)
Control of corruption	0.0284***	-0.0154*	0.0881***	0.0443***	0.413***	0.171***
(I_{jt1})	(3.133)		(15.48)		(36.74)	
Government effectiveness	0.0085	-0.0438***	0.0881***	0.0359***	0.525***	0.212***
(I_{jt2})	(0.838)		(15.48)		(39.17)	
Political stability	-0.0587***	-0.0619***	0.0785***	0.0753***	0.347***	0.117***
(I_{jt3})	(-6.782)		(14.20)		(31.80)	
Rule of law	0.0371***	0.0111	0.0827***	0.0274***	0.452***	0.181***
(I_{jt4})	(3.928)		(13.93)		(36.66)	
Regulatory quality	-0.0181*	-0.0671***	0.114***	0.065***	0.515***	0.193***
(I_{jt5})	(-1.829)		(18.36)		(38.65)	
Voice and accountability	-0.0498***	-0.0480***	0.0655***	0.0636***	0.414***	0.19***
(I_jt6)	(-6.564)		(11.08)		(32.08)	

Note: The difference columns for the Primary Sector and Industry is the difference with respect to the estimated coefficient for Tangibles in Tables 2 and 3. The difference column for Services is the difference with respect the estimated coefficient of an estimation of Total trade (Primary Sector + Industry + Services) restricted to the sample where service trade data is available (only 23,661 observations) T-statistic in parenthesis. *** $p < 0.01$, **$p < 0.05$, *$p < 0.1$

The analysis of the link between institutional quality and trade for different sectors considering institutional distances yields similar results, Table 5. As before, a negative value in the columns (1), (3) and (5) indicates that greater institutional differences between the exporting and importing countries reduce bilateral trade. Institutional differences between origin and destination not only present a higher negative effect in the industry sector than in the primary sector, but also in comparison with the aggregate of tangible goods, columns (2) and (4). Again, the magnitude of the negative coefficients is in general the greatest for trade in services, especially in the cases of large differences in *Political Stability*, *Regulatory Quality*, and *Voice and accountability*. Hence, greater institutional distances between countries affect trade in industrial goods and in services to a greater extent than trade in natural resources and agricultural produce.

Table 4.5: The influence of institutional distance between exporting and importing countries on trade by sectors

Variables	Primary sector		Industry		Services	
	Value (1)	Difference (2)	Value (3)	Difference (4)	Value (5)	Difference (6)
Control of corruption	-0.0232***	-0.0604***	-0.105***	0.0214***	-0.0587***	-0.1383***
(I_{jt1})	(-2.832)		(-16.52)		(-4.776)	
Government effectiveness	0.0103	-0.0993***	-0.127***	0.0380***	-0.170***	-0.1230***
(I_{jt2})	(1.170)		(-18.61)		(-11.96)	
Political stability	-0.0267***	-0.0535***	-0.131***	0.0508***	-0.296***	0.0460***
(I_{jt3})	(-2.976)		(-18.91)		(-24.01)	
Rule of law	-0.0190**	-0.0980***	-0.159***	0.0420***	-0.187***	-0.0970***
(I_{jt4})	(-2.197)		(-23.86)		(-14.32)	
Regulatory quality	-0.0324***	-0.1006***	-0.171***	0.038***	-0.274***	-0.0520***
(I_{jt5})	(-3.624)		(-24.72)		(-19.27)	
Voice and accountability	-0.131***	0.0160***	-0.132***	0.0170***	-0.287***	0.0310**
(I_{jt6})	(-14.81)		(-19.34)		(-21.35)	

T-statistic in parenthesis. *** p¡0.01, **p¡0.05, *p¡0.1

4.5 Conclusions

This paper explores the extent to which institutional quality affects bilateral trade across the majority of countries in the world and whether the role of institutions for trade has been waxing or waning over the last two decades. Based on the extension of the canonical new trade theory model to multiple countries and sectors by Barbero et al. (2015), we derive a novel—sector specific—gravity equation that allows us to consider trade barriers in light of the institutional conditions in levels for the importing country, as well as the institutional difference—distance—between the countries engaged in bilateral trade. In particular, we have been able to assess the role of institutions for trade, controlling for geographical distance, labour cost competitiveness in origin (involving productivity and wages), trade costs, sectoral prices, and incomes shares at destination. All controls display the expected signs and significance.

The results of the analysis confirm the hypothesis that the quality of institutions—both in levels and in differences—matter for trade. With few exceptions, mostly centred on Political stability and Voice and accountability, all institutional variables considered in the analysis are closely connected to trade trends. The better the institutional quality in the importing country and the lower the institutional distance, the greater the bilateral trade. However, our results also show that the influence of institutional quality on bilateral trade is still a fraction of the capacity of other factors to affect exchanges between countries, especially geographical distance. This is particularly the case for trade in agricultural produce and natural resources—primary sector—where institutional quality plays a relatively minor role, if at all, on trade patterns. By contrast, institutions matter much more for trade in manufactured goods and can be considered as one of the most important factors for trade in services, given their intangible, complex, and interactive nature. The analysis also puts in evidence that, contrary to our expectations, the effect of institutional quality on trade has tended to wane rather than to wax with time.

The commodity boom both in trade and prices of the 2000s, goes a long way in explaining these patterns, IMF (2008). When industry and consumers require commodities and energy sources, institutional conditions do not seem to be a hindrance for trade. Trade is established regardless of the quality of institutions and governance at the origin and destination. Institutional distance is also a minor impediment in this respect. This is however not the case for trade in manufacturing goods and, particularly, in services. In these two sectors institutional quality and institutional distance considerably affect with whom one trades. The end of the commodity boom may thus very well signal a new rise in the relationship between trade and institutional quality, not just in services and manufacturing, but also in the primary sector. This is particularly relevant for developing economies whose chances to succeed in integrating into the global economy will require better quality institutions and policies, as compared with geographic location or factor endowments.

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4.6 References

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Chapter 5

Overall Conclusions

From the research undertaken in this dissertation three main and clear conclusions that are relevant for government officials in policy making are drawn, and further research questions are open.

The first message is that the relative position of a location in space matters for the agglomeration of the economic activity. Locations —- cities, regions, or countries — that have a locational advantage—i.e., a first-nature advantage given by geography and measured by the location centrality index—will agglomerate economic activity by drawing firms and workers from peripheral regions. Contrary to the widespread belief that reducing transport costs contributes to regional cohesion and a more equal distribution of income across locations, policymakers should have this in mind when designing the infrastructure policy, since reducing the centrality of a transport network may not be enough to reshape the distribution of the economic activity if the spatial topology configuring relative accessibility between locations remains basically the same. Since full cohesion is not possible in an economy where there are different locations with different accessibility, infrastructure policy should be targeted in reducing the disparities in accessibility by making central regions less central, and periphery regions less peripheral.

The second main finding is that the accessibility—-centrality—of a location constitutes an absolute advantage, as it is the market size of that location. Having a locational advantage translates in agglomeration of the economic activity—-in line with the previous result—and into higher wages for that location. The specialization patterns of the economy is not determined by the accessibility of the location, but by the expenditures shares and other factors. This is important for policymakers since infrastructure policy aimed to reshape the network can change the overall distribution of the economic activity, but it cannot change by itself the industrial composition of the locations.

The last result is that the quality of national institutions affects the volume and composition of international trade. By sector, institutional quality matters more for manufactured goods and services than for the primary sector: agriculture, raw materials and energy. This can be explained because consumers and firms need commodities and energy sources both for basic living and economic activity, and thus institutions became less important when trading these essential primary goods. This institutional inelasticity is due both to the simple nature of these goods that do not require much value added transformations and developed institutional standards. However, developing economies that want to be a player in the global economy, exporting more complex manufactured goods and particularly services, need to improve the quality of their institutions in order to increase their participation in world trade.

These three findings open new future research opportunities. The modeling framework of the analysis of accessibility and agglomeration of the economic activity can be extended in several ways: by considering heterogeneous firms and workers as in Melitz (2003), labor sorting and matching based on their observed and unobserved characteristics, and by the inclusion of congestion costs as a source of diseconomies of scale. A more challenging extension will be the integration of a city modelling framework – from the Urban Economics literature – with the new economic geography analysis of different network topologies undertaken, and considering different types of spatial frictions, in line with the ideas proposed by Thisse (2010) and recently studied by Behrens et al. (2014).

Also, the result that institutions matter for trade is of paramount importance. Since agglomeration economies cannot exist without trade, and institutions are important in determining the volume and composition of trade, institutions are also a driver of agglomeration. This link between institutions and agglomeration economies should be studied in depth. With the traditional literature on infrastructures as a way to change geography, and the incipient literature on how technological progress fosters the agglomeration of economic activity, institutional quality must also be considered as a way to overcome geography and as a source of agglomeration economies. In doing so, we must also take into account the interconnections between the three, since well-functioning institutions also creates a climate for better technological progress and better targeted infrastructure policy.

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Chapter 5

Conclusiones Generales (in Spanish)

De la investigación llevada a cabo en esta tesis se extraen tres principales y claras conclusiones que son relevantes para los oficiales del gobierno encargados de las políticas, así como se abren distintas preguntas de investigación a desarrollar en el futuro.

El primer mensaje es que la posición relativa de una localización en el espacio importa para la aglomeración de la actividad económica. Las localizaciones — ciudades, regiones, o países — que tienen una ventaja locaciones—es decir, una ventaje de primera naturaleza dada por la geografía y medida a través del índice de centralidad de la localización—aglomerará una mayor actividad económica atrayendo empresas y trabajadores de las regiones periféricas. En contra de la idea ampliamente extendida de que reduciendo los costes de transporte se contribuye a la cohesión regional y a una más igualitaria distribución de la renta a lo largo de las localizaciones, los responsables políticos tienen que tener esto en cuenta a la hora de diseñar la política de infraestructuras, ya que reducir la centralidad de una red de transporte puede no ser suficiente para reconfigurar la distribución de la actividad económica si la topología del espacio que configura la accesibilidad relativa entre las regiones apenas se modifica. Dado que la cohesión plena no es posible en una economía en la que hay diferentes localizaciones con diferente accesibilidad, la política de infraestructuras debe orientarse a reducir las disparidades en la accesibilidad por media de hacer que las regiones centrales sean cada vez menos centrales, y las regiones periféricas cada vez menos periféricas.

El segundo hallazgo principal es que la accesibilidad—centralidad—de una localización constituye una ventaja absoluta, como lo es el tamaño del mercado de dicha localización. Tener una ventaja locacional se traduce en aglomeración de la actividad económica—en línea con el resultado anterior—y en mayores salarios para dicha localización. Los patrones de especialización de la economía no vienen determinados por la accesibilidad de la localización, sino por las proporciones de gasto y otros factores. Esto es importante para los responsables políticos dado que la política de infraestructuras orientada a reconfigurar la red puede cambiar la distribución general de la actividad económica, pero no puede modificar la composición industrial de los lugares.

El último resultado es que la calidad de las instituciones nacionales afecta al volumen y a la composición del comercio internacional. Por sectores, la calidad institucional importa más para los bienes manufacturados y los servicios que para el sector primario: agricultura, materias primas y energía.

Esto puede explicarse porque los consumidores y las empresas necesitan *commodities* y recursos energéticos tanto para la vida básica como para la actividad económica, y por tanto las instituciones son menos importantes cuando se comercian estos bienes primarios. La inelasticidad de las instituciones se debe a la simple naturaleza de estos bienes que no requieren de muchas transformaciones de valor añadido y a los estándares institucionales desarrollados. Sin embargo, los países en desarrollo que quieran ser jugadores en la economía global, exportando bienes manufacturados más complejos y particularmente servicios, necesitan mejorar la calidad de sus instituciones para incrementar su participación en el comercio mundial.

Estas tres principales ideas abren nuevas oportunidades de investigación a futuro. El marco de modelado del análisis de la accesibilidad y la aglomeración de la actividad económica se puede extender de diferentes formas: mediante la inclusión de la heterogeneidad de empresas y trabajadores como en Melitz (2003), la ordenación del trabajo y emparejamiento basado en características observables y no observables, y por la inclusión de los costes de congestión como fuente de deseconomías de escala. Una extensión más desafiante es la integración del marco de modelado de la ciudad — procedente de la literatura sobre Economía Urbana — con el análisis de nueva economía geográfica de diferentes topologías de red llevado a cabo, y considerando diferentes fricciones espaciales, en línea con las ideas propuestas por Thisse (2010) y recientemente estudiadas en Behrens et al. (2014).

Además, el resultado de que las instituciones importan para el comercio es de suma importancia. Dado que las economías de aglomeración no pueden existir sin comercio, y las instituciones son importantes para determinar el volumen y la composición del comercio, las instituciones son también una fuente de aglomeración. El enlace entre instituciones y economías de aglomeración debe ser estudiado en profundidad. Con la literatura tradiciones de infraestructuras como una forma de cambiar la geografía, y la incipiente literatura de cómo el progreso tecnológico fomenta la aglomeración de la actividad económica, la calidad institucional también debe ser considerada como una forma de superar le geografía como una fuente de economías de aglomeración. Para llevarlo a cabo, debemos también tener en cuenta las interconexiones entre los tres, dado que unas instituciones con buen funcionamiento crean un clima para un mejor progreso tecnológico y unas políticas de infraestructuras mejor orientadas.

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