UNIVERSIDAD DE MURCIA

ESCUELA INTERNACIONAL DE DOCTORADO

Essays on New Economic Geography, Natural Resources and Income Transfers

Ensayos sobre Nueva Economía Geográfica, Recursos Naturales y Transferencias de Ingresos

D. José Rodolfo Morales

2019

UNIVERSIDAD DE MURCIA
ESCUELA INTERNACIONAL DE DOCTORADO

Essays on New Economic Geography, Natural Resources and Income Transfers

Ensayos sobre Nueva Economía Geográfica, Recursos Naturales y Transferencias de Ingresos

D. José Rodolfo Morales

Supervisor:

Prof. Dr. Mª Pilar Martínez García

2019

Agradecimientos

Al momento de escribir estas líneas, que aunque aparezcan al inicio son en realidad las últimas de esta tesis, me doy cuenta que los agradecimientos serán siempre de una forma u otra un tanto injustos con algunos. Y es que me sería imposible poner todos los nombres que quisiera, o incluso acordarme de algunas personas que de forma directa o indirecta me han ofrecido todo su apoyo durante estos años de doctorado. Sin embargo, creo que sería aún más injusto no intentarlo.

A la primera persona que quiero agradecer es desde luego a Pilar Martínez García, mi directora de tesis. No sólo agradecerle por su paciencia infinita, que sé que hace falta para trabajar conmigo, sino por la ayuda inconmensurable que significó reencauzar mi tesis en un momento en el que me encontraba bastante perdido. Desde luego, agradecerle también la confianza y libertad que me dio para decidir cada paso sin dejar de exigirme siempre un poco más. Y por sobre todo, agradecerle el tiempo que le ha dedicado a dirigir esta tesis en jornadas que de a ratos se volvían maratónicas; y por el tiempo que me ha dedicado a mí.

En segundo lugar, estoy contento de poder decir que tengo el gusto, y no el deber, de agradecer a muchos profesores de la facultad. A María Victoria Caballero por su ayuda con el primer capítulo de esta tesis, y en particular, por tomarse el tiempo para sentarse a discutir conmigo las implicaciones de los distintos modelos. También me gustaría agradecer a Arielle Beyaert quien, como coordinadora del Programa DEcIDE, me mostró desde un primer momento una gran confianza en la investigación que iniciaba dentro del programa; pero además, por todas esas palabras de ánimo en aquellos días en que las jornadas de trabajo se extendían hasta que la facultad cerraba sus puertas. A Isabel tengo que agradecerle sus consejos y palabras tranquilizadoras en los momentos que parecían más desalentadores. Y como no puede ser de otra forma, también agradecer a Pedro, a quien tanto mis compañeros como yo hemos enloquecido un poco durante estos años de doctorado.

En tercer lugar, no puedo estar más agradecido con Guiomar Martín, Javier de Frutos, y Francisco Cabo de la Universidad de Valladolid. A ellos los debería dedicar una hoja entera de agradecimientos si tratara de enumerar todo lo que hicieron por mí, y por enriquecer esta tesis; les estaré siempre infinitamente agradecido. A Daniela Torrente y Lucas Ferrero de la Universidad Nacional del Nordeste, por haberme invitado a compartir un mes de investigación con ellos, por darme la oportunidad de contarles mis avances y por las ideas para el tercer capítulo de mi tesis; muchas gracias. Gracias también a Pasquale Commendatore de la Universidad Federico II de Nápoles por recibirme dos meses enteros, por todo el tiempo dedicado a compartir y discutir ideas, y por hacerme avanzar a pasos agigantados en el último capítulo de la tesis. Y a Mabel Tidball del INRA por abrirme las puertas de su despacho en los inicios de esta investigación.

Quisiera además destacar la importancia de las ayudas para asistencias a congresos brindadas por el Ministerio de Educación, Cultura y Deporte de España a través de los proyectos ECO2014-52343-P y ECO2017-82227-P. Y reconocer también el apoyo de la *COST Action IS1104 "The EU in the new economic complex geography: models, tools and policy evaluation"*, que me permitió asistir a congresos y cursos que fueron de decisiva importancia para el avance de esta tesis.

Les agradezco también a mis compañeros de doctorado, y mis amigos, por toda su compañía y paciencia. En particular a Laura, con quien he compartido despacho todos estos años, pero también alegrías y frustraciones. A Irene y Ney, por ayudarme a olvidar ocasionalmente el doctorado, lo que paradójicamente muchas veces resulta ser bueno para la propia tesis.

En especial quiero agradecer a mi mamá, que siempre me ha apoyado y alentado, desde que me enseñó los números hasta el día en que me acompañó al aeropuerto para embarcarme en todo esto; y luego a la distancia continuó creyendo en mí. A mis hermanos y a mi abuela, que me han aguantado y alentado a continuar mediante sus palabras y actos. Y a mi papá y a Ana, las dos personas que he tenido más cerca estos años, y que probablemente se hayan llevado todo lo peor de mis malos humores en momentos de ofuscación. Ambos me han dado todo su apoyo incondicional, económico, psicológico, moral; han dedicado tiempo de sus vidas a asegurarse que nada me faltase jamás, y han estado siempre a mi lado, muchísimas gracias.

A mi papá

Contents

List of Figures

Preface

Economic activity and population is not evenly distributed around the globe. It is easy to find large cities or regions that concentrate most of the population, and other rural areas or countrysides where population and economic activity is less pronounced. According to the World Urbanization Prospect, the distribution of population is illustrated in the following figure:

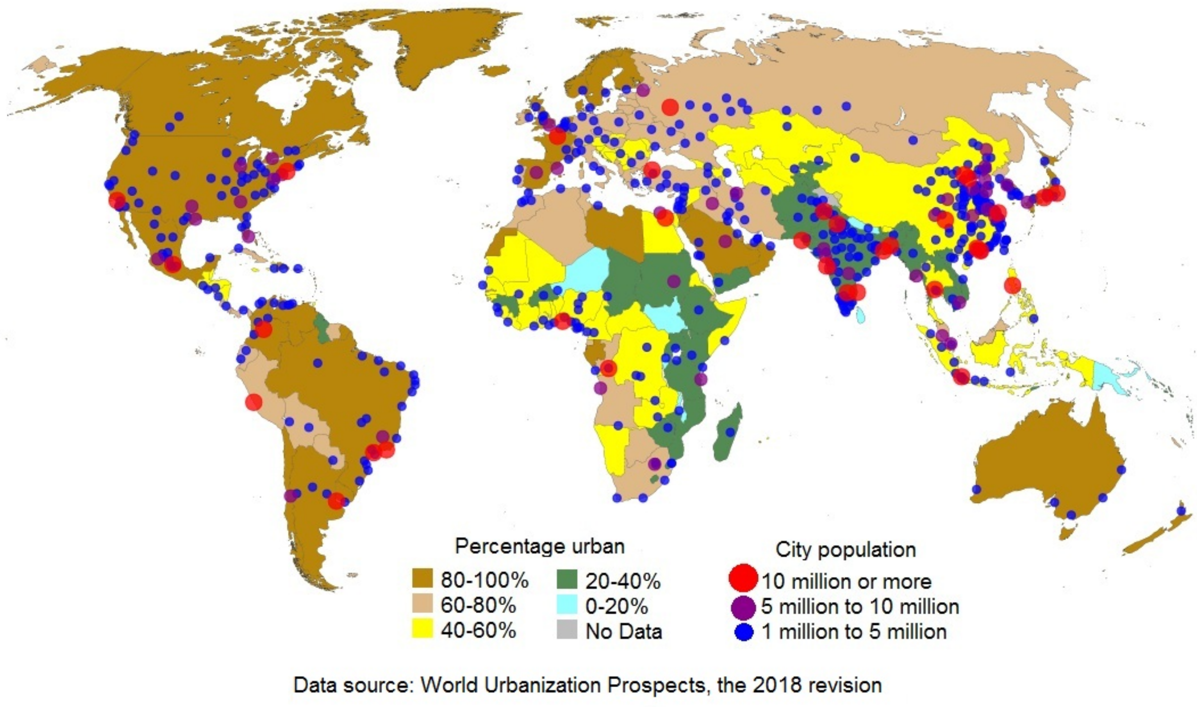

Figure 1: Urbanization and Agglomeration in 2018

Neoclassical economists explain these spatial patterns through comparative advantage. Differences in the productive structures of regions and nations are due to different endowments, i.e. labor, capital, natural resources, skills, etc. However, some empirical studies suggest that these endowments do not always explain the observed localization of the economic activity. For example, for the United Sates, Overman et al. (2001) point out that between 50% and 80% of the spatial distribution of economic activity could not be explained by natural advantages.

The incorporation of Marshallian externalities into the analysis can help to solve this discrepancy between the observed spatial distribution and the predictions of the neoclassical economists. The main idea is that agglomeration of production provides benefits to firms located in that region because of: knowledge spillover, the advantages of labor pools, and backward and forward linkages (Fujita, et al., 2001). However, with this explanation, another problem arises. Once agglomeration exists, there are benefits, but why did firms and population concentrate in first place? What is behind these externalities? The new economic geography (NEG) tries to answer these questions.

NEG recognizes that differences in the spatial distribution of the economic activity is the outcome of a differentiation process along time (Clark et al., 2018). This implies understanding the economic spatial configuration as the result of a process that confronts two types of forces: agglomeration and dispersion forces (Fujita and Thisse, 2002). NEG models explain how the geographical distribution of the economy is shaped as the result of the interaction of these forces, and offer microeconomics foundations of these forces.

The main NEG literature tools are increasing returns to scale, iceberg transport costs and factor mobility. Firms are willing to agglomerate in order to benefit from the economies of scale and to avoid incurring in excessive transport costs. Mobile factors follow firms looking for higher profits, which often leads to enlarging the market, which makes it even more attractive. Thus, the main contribution of these models to the economic literature is that with these tools and a general equilibrium they explain, through microeconomic foundations, the trade-off between agglomeration and dispersion forces (Neary, 2001) that underlies the external economies of scale.

Since Krugman's (1991) seminal work, where the Core-Periphery model was first introduced, many other new economic geography models have been developed. A survey of the theoretical and empirical advances in this field is given by Ottaviano and Puga (1998), Neary (2001), Overman, et al., (2001), and Candau (2008). Commendatore et al. (2018), classified NEG models according to their mobility assumptions: the Core-Periphery model (CP, Krugman, 1991); the footloose entrepreneur model (FE, Forslid, 1999; Ottaviano, 2001; Forslid and Ottaviano, 2003); the footloose capital model (Martin and Rogers 1995); the constructed capital model (Baldwin, 1999); and the vertical linkages model (Venables, 1996; and Krugman and Venables, 1995). Additionally, over the last decades the NEG literature has had a growing influence in other economic fields, like public policy (Baldwin, et al., 2005), growth and innovation (Clark, et al., 2018), international trade (Fujita, et al., 2001), and environmental economics (Pflüger, 2001; Zeng and Zhao, 2009; and Rauscher, 2009) among others.

The NEG literature has focused mainly on industrialized economies. However, environmental induced migratory flows from rural areas are gaining interest among citizens and academics. A number of well documented examples of migration and redistribution of economic activity have been motivated by the depletion of natural resources (Carr, 2009). One of the main objectives of this thesis is to identify the forces driving these migrations, providing the microeconomic foundations to understand the effect of the exploitation of natural resources, and their regenerative ability, on the spatial distribution of economic activity. To tackle this issue we have developed an extension of the CP model that incorporates notions from the environmental economic literature.

Moreover, international and interregional income transfers are widely established to compensate spatial economic disparities. According to the NEG literature, income transfers enlarge the market size of the recipient region, making it more attractive for firms to settle in. However, a negative relation between income transfers and industrial employment is sometimes observed. The Dutch disease literature advises that a large windfall of economic resources tends to harm the competitiveness in international markets. To provide a comprehensive explanation of the effects of income transfers on the spatial distribution of the industry we have extended the FE model by incorporating some key elements from the Dutch disease literature, such as the existence of non-tradable goods, like services.

The original CP model (Krugman, 1991) is a two-region, two-sector model. Industrial firms have increasing returns to scale in a monopolistic competitive framework. These firms employ only sectorial specific labor in their production (as marginal and fixed inputs), and industrial goods can be traded in the other region by incurring in iceberg transport costs. Agriculture is a perfectly competitive sector with constant returns to scale which employs specific agricultural labor as the only input in the production. Agricultural goods can be freely traded between regions. Because of the specific labor in each sector, there is no sectorial labor mobility in this model. Finally, in the long-run, industrial labor can migrate from one region to the other in search of a larger real wage. Chapters 1 and 2 extend this seminal model by incorporating renewable natural resources as raw materials in output production. This extension allows us to identify the migratory forces related to the depletion of the natural resources under different trade patterns.

The FE (Forslid, 1999; Ottaviano, 2001) shares many features with the CP model. The main differences are that, while labor continues to be the marginal input, for a firm to operate, a fixed quantity of entrepreneurs is needed. Thus, there are two differentiated inputs in the industrial production. The agricultural sector remains the same as in the CP model. However, labor is not specific to each sector in the FE model, which implies that there is sectorial labor mobility. But, only entrepreneurs can migrate between regions. The main advantage of the FE model is its tractability. Chapter 3 extends the FE model by incorporating some elements form the Dutch disease literature in order to evaluate the impact of income transfers.

New Economic Geography and Natural Resources

The new economic geography literature has focused mainly on industrialized economies, overlooking rural or resource based economies. However, in 1990, 25 million people migrated for environmental reasons or because of resource degradation (Carr, 2009). These migratory processes are also one of the main causes of the over exploitation of natural resources in rural areas and developing countries. They are the leading forces of agricultural expansion, causing deforestation. Since the middle of the 20th century, about 1.2 billion hectares of land in the world have suffered soil degradation (Swain, 1996), with the consequent declines in yields and harvests, so causing massive numbers of environment-induced migrants. Thus, to understand the distribution of the economic activity in resource based economies, it is necessary to take into account the interaction between the natural environment and the migratory processes. This is the aim of the first chapter of this thesis.

In Chapter 1 we modify the original CP model by introducing the dynamics of a renewable natural resource, which is extracted as a primary good and which has a regenerative ability. We also incorporate the double function of primary goods, both as a final consumption good and as an input for the industrial sector. It is assumed that agents are myopic in the sense that they extract the natural resource without taking into account its dynamics. Another important difference between our proposal and the original CP model is that labor can move freely between sectors. This a simple way to incorporate the relation between the economic activity and the dynamics of the natural resources. In this chapter we analyze the case of a non-tradable primary good and a tradable primary good with the same transport costs as the industrial sector.

Our main finding is that a renewable natural resource and its dynamics give rise to a new dispersion force, which we call the "resource effect". When population agglomerates in one of the regions, intermediate and final demands for primary goods rise and the pressure on the stock of natural resources increases. Despite its regenerative ability, the higher extraction of the resource compromises its long-run level, making primary goods expensive, and reducing nominal and real wages in the most populated region, thus, triggering a dispersion process. Additionally, the extractive productivity becomes a key parameter in determining the strength of the resource effect.

The aim of Chapter 2 is to provide a broader understanding of the interaction between population migration, trade, the distribution of the economic activity and natural resource exploitation. In order to do so, we extend the model proposed in Chapter 1, by allowing for specific and different trade costs in the primary and the industrial sectors. We focus on the symmetric or disperse equilibrium and analyze the leading forces that encourage and discourage its stability. We study five special cases of trade costs: non-tradable and perfectly tradable primary goods, non-tradable and perfectly tradable industrial goods, and primary and industrial goods traded at equal transport costs. Finally, we analyze the general case with specific transport costs in each sector.

Our results prove that, although the resource effect suffers some changes with the alteration in the tradability assumptions, it is an important factor modelling the spatial distribution of the economic activity. We find three channels nourishing resource effect: the labor productivity, the wage and the firms channels. When there is a difference in the stock of natural resources of the regions (as a consequence of different levels of harvesting):

- the primary sector of the region with the lower stock becomes less efficient, and their primary and industrial prices tend to rise (the labor productivity channel);
- secondly, due to the change in prices, the region with the lower stock suffers an interregional trade deficit, which reduces the nominal and real wages (the wage channel);
- and thirdly, due to the reduction in the labor costs, industrial profits become positive, attracting more firms, and the greater variety of industrial goods tends to reduce the industrial price index in the region (the firms channel).

Additionally, we find that the dispersive force of the resource effect increases its strength with high primary and industrial transport costs.

New Economic Geography and Income Transfers

New economic geography states that reductions in tariff and transport costs lead to a core-periphery structure of the economy. In this regard, international and interregional income transfers are recognized instruments for compensating spatial economic disparities. According to this literature, income transfers enlarge the market size of the recipient region. Thus, the smaller, or peripheral, region becomes more attractive for firms to settle in, and regional disparities are reduced. However, the Dutch Disease (DD) literature predicts exactly the opposite, a negative relation between transfers (or aid flows) and the tradable sector. According to this literature, a large windfall of economic resources tends to harm the tradable sectors. When the region competes with international prices (for exports and imports), the rise in the demand due to the received transfers translates into higher non-tradable prices. Thus, an appreciation of the real exchange rate takes place, and the region becomes less competitive in the international markets. The conclusions of the NEG and the DD literatures clash.

The aim of Chapter 3 is to study the effects of income transfers on the spatial distribution of the economic activity, by reconciling these two literatures. We modify the FE model by incorporating income transfers, a non-tradable sector, sectorial mobility of labor and a slightly differentiated agricultural good. The non-tradable sector and the sectorial labor (input) mobility are key elements of the DD literature. There are two regions: one is a net contributor and the other is a net recipient of transfers. The differentiated agricultural good means we can avoid inter-regional wage equalization while maintaining labor mobility between sectors.

What we find is that, in the short run we find that the agricultural and the non-tradable sectors shrink and expand, respectively, while de-industrialization takes place if transport costs are low enough. In this case, because of the high competition from foreign firms, the benefits of the transfers to the local industry are limited. In the long run, however, the changes in wages and in cost of living favor the recipient region. Thus, if the transport costs are high, the recipient region can end up attracting industrial firms, even if in the short run some de-industrialization has taken place. But, if the competition is strong (low transport costs), the Dutch disease, which took place in the short run, can overcome all other positive effects derived from the transfers, leading to a long-run DD. In this case, we observe that: either the number of industrial firms increases in the donor region or it becomes more difficult to reverse regional asymmetries. Thus, income transfers can create or even exacerbate regional disparities rather than mitigate them.

Resumen

La población y la actividad económica no se distribuyen de forma uniforme a lo largo y ancho del planeta. No es difícil encontrar grandes ciudades y regiones que concentran importantes poblaciones, mientras que existen áreas rurales donde la población y la actividad económica es más bien escaza. De acuerdo con *The World Urbanization Prospect*, la distribución de la población para el año 2018 se puede ilustrar con la siguiente figura:

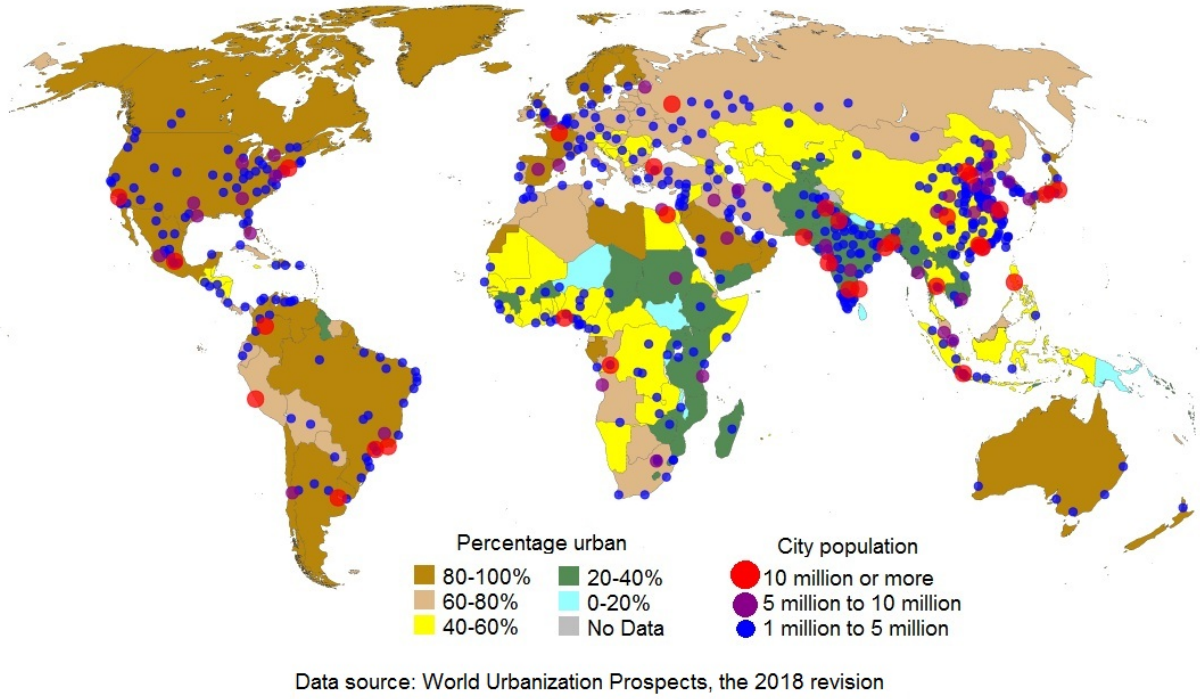

Figura 2: Urbanización y Aglomeración, año 2018

Los economistas neoclásicos explicaban estos patrones espaciales mediante el concepto de la ventaja comparativa. Las diferencias en las estructuras productivas de las regiones y de las naciones se debían a diferencias en sus dotaciones de trabajo, capital, recursos naturales, cualificaciones, etc. Sin embargo, hay estudios empíricos que sugieren que las diferencias en las dotaciones no siempre son suficientes para explicar la localización observada de la actividad económica. Por ejemplo, para los Estados Unidos, Overman et al. (2001) señala que entre el 50 % y el 80 % de la distribución espacial de la actividad económica no puede explicarse por las ventajas naturales.

La incorporación de externalidades Marshallianas al análisis ayuda a resolver la discrepancia observada entre la distribución espacial de la actividad económica y las predicciones de los modelos neoclásicos. La idea principal es que la concentración de la producción resulta beneficiosa para las empresas debido a la difusión del conocimiento, la especialización de los mercados de trabajo, y a la existencia de vínculos hacia atrás y hacia adelante (Fujita et al., 2001). Sin embargo, con esta explicación surge otro problema. Una vez que la concentración existe, esta resulta beneficiosa, pero ¿por qué las empresas y la población deciden concentrarse en primer lugar? ¿Qué hay detrás de las externalidades? La Nueva Economía Geográfica (NEG) intenta dar respuesta a estos interrogantes.

La literatura NEG reconoce que las diferencias en la distribución espacial de la actividad económica es en realidad el resultado de un proceso de diferenciación que tiene lugar a lo largo del tiempo (Clark et al., 2018). Esto implica entender que la configuración espacial de la economía es el resultado de un proceso de interacción entre dos tipos de fuerzas: fuerzas de aglomeración y fuerzas de dispersión (Fujita and Thisse, 2002). Los modelos de la literatura NEG explican cómo la distribución geográfica de la economía toma forma a través de la interacción de estas fuerzas, y además, aportan fundamentos microeconómicos a las mismas.

Las principales herramientas de las que se vale la literatura NEG son los rendimientos crecientes a escala a nivel de las empresas, los costes de transporte con forma de *iceberg*, y la movilidad de los factores productivos. Las empresas estarán dispuestas a aglomerarse para obtener un beneficio de las economías de escala y a la vez evitar incurrir en excesivos costes de transporte. Los factores productivos que puedan moverse seguirán a las empresas en busca de mayores remuneraciones. La concentración de trabajadores en una localización conlleva un aumento del mercado para las empresas que allí se sitúen, fomentando aún más la concentración. Por lo tanto, la principal contribución de los modelos NEG a la literatura económica ha sido que mediante estas herramientas, y en el marco del equilibrio general, consiguen dotar de fundamentos microeconómicos y explicar el *trade-off* entre las fuerzas de aglomeración y dispersión (Neary, 2001) que subyacen a las economías de escala externas a las firmas.

Desde que fue planteado por primera vez el modelo de Centro-Periferia (Krugman, 1991), muchos otros modelos NEG han sido desarrollados. Los trabajos de Ottaviano et al. (1998), Neary (2001), Overman et al. (2001) y Candau (2008) presentan una revisión de la literatura teórica y empírica en el campo de la literatura NEG. Por su parte, Commendatore et al. (2018) clasifican los modelos NEG atendiendo a los supuestos de movilidad de los factores como: modelo Centro-Periferia (CP, Krugman, 1991); modelo de emprendedores *footloose* (FE, Forslid, 1999; Ottaviano, 2001; Forslid and Ottaviano, 2003); modelo de capital *footloose* (Martin and Rogers, 1995); modelo de capital construido (Baldwin, 1999); y modelo de vínculos verticales (Venables, 1996; Krugman and Venables, 1995). Además, a lo largo de las últimas décadas, la literatura NEG ha tenido una creciente influencia en otros campos de la economía como la política económica (Baldwin, et al., 2005), el crecimiento y la innovación (Clark, et al., 2018), el comercio internacional (Fujita, et al., 2001), y la economía medioambiental (Pflüger, 2001; Zeng and Zhao, 2009; and Rauscher, 2009), por citar algunos.

La literatura NEG ha estudiado principalmente economías industrializadas. Sin embargo, los flujos migratorios inducidos por fenómenos medioambientales en áreas rurales han ido ganando interés entre ciudadanos y académicos. Existe un gran número de ejemplos de flujos migratorios y redistribución de la actividad económica motivados por la explotación y sobreexplotación de los recursos naturales (Carr, 2009). Uno de los principales objetivos de esta tesis es identificar las fuerzas que causan estos flujos migratorios, aportando fundamentos microeconómicos que permitan entender los efectos de la explotación de recursos naturales renovables en la distribución de la actividad económica. Con este propósito, hemos desarrollado una extensión del modelo CP incorporando nociones de la literatura de la economía medioambiental.

Por otra parte, las transferencias internacionales e interregionales son mecanismos ampliamente establecidos para compensar las disparidades económicas entre regiones. De acuerdo a la literatura NEG, las transferencias de ingresos aumentan el tamaño del mercado de la región receptora de fondos, haciendo de ésta una localización más atractiva para las empresas. Sin embargo, algunas veces se observa que existe una relación negativa entre las transferencias de ingresos y el empleo industrial. La literatura de la Enfermedad Holandesa (DD) advierte que una entrada importante de recursos económicos tiende a mermar la competitividad de la región receptora en los mercados internacionales. Para estudiar de forma más exhaustiva los efectos de las transferencias de ingresos en la localización de la industria, hemos extendido un modelo FE incorporando algunos elementos claves de la literatura de la DD, como la existencia de bienes no comercializables entre regiones.

El modelo CP original (Krugman, 1991) es un modelo de dos regiones y dos sectores. Las empresas industriales tienen rendimientos crecientes a escala e interactúan en un mercado de competencia monopolística. Para la producción industrial se emplea únicamente trabajo, que es específico para el sector (como coste fijo y coste marginal). Los bienes industriales pueden comercializarse entre regiones incurriendo en costes de transporte de tipo *iceberg*. El sector agrícola, cuya producción requiere el empleo de trabajo específico para el sector, es perfectamente competitivo, y con rendimientos constantes a escala. Los bienes agrícolas se comercializan libremente entre regiones sin costes de transporte. Debido a los supuestos de trabajos específicos en cada uno de los sectores, en este modelo no hay movilidad intersectorial del factor trabajo. Finalmente, en el largo plazo, los trabajadores de la industria pueden migrar de una región a otra en busca de mayores salarios reales. Los Capítulos 1 y 2 de esta tesis extienden este modelo mediante la incorporación de un recurso natural renovable, cuya extracción es utilizada como materia prima en la producción industrial. Esta extensión del modelo nos permite identificar las fuerzas migratorias que están relacionadas con la explotación de los recursos naturales para diferentes costes de transporte.

El modelo FE (Forslid, 1999; Ottaviano, 2001) comparte muchas de las características del modelo CP. Sin embargo, una de sus principales diferencias es que el coste fijo depende de una cantidad fija de emprendedores y no del factor trabajo. Por lo tanto, hay dos *inputs* diferenciados en el proceso de producción industrial. El sector agrícola se mantiene igual que en el modelo CP, con la única diferencia de que existe movilidad intersectorial del trabajo. En el largo plazo, sólo los emprendedores pueden migrar de una región a otra. El modelo FE es un modelo muy tratable, lo que se convierte en su mayor ventaja. El Capítulo 3 de esta tesis extiende el modelo FE mediante la incorporación de algunos elementos de la literatura de la DD, con el objetivo de evaluar el efecto que tienen las transferencias de ingresos en la distribución espacial de la actividad económica.

Nueva Economía Geográfica y Recursos Naturales

La literatura de la nueva economía geográfica se ha centrado principalmente en estudiar economías industrializadas pasando muchas veces por alto las economías rurales y aquellas basadas en recursos naturales. Sin embargo, en 1990, 25 millones de personas migraron debido a motivos medioambientales o a la degradación de recursos naturales (Carr, 2009). Estos procesos migratorios son a su vez la causa de la sobreexplotación de recursos naturales en áreas rurales y en países en desarrollo, y son el principal motivo de la expansión agrícola y la deforestación. Desde mediados del siglo XX, alrededor de 1200 millones de hectáreas de tierra en el mundo han sufrido deterioro de su fertilidad (Swain, 1996), con las consecuentes disminuciones en las cosechas y los rendimientos del suelo, provocando un gran número de migrantes medioambientales. Por tanto, para lograr entender la distribución de la actividad económica en las economías basadas en recursos naturales, es necesario considerar la interacción que existe entre el entorno natural y los flujos migratorios. Éste es el objetivo del primer capítulo de esta tesis.

En el Capítulo 1 modificamos el modelo CP original introduciendo la dinámica de un recurso natural renovable, el cual es extraído para servir como un bien primario. Este recurso tiene una tasa natural de regeneración. El bien primario tiene una doble función como bien de consumo final, y como bien intermedio en la producción industrial. En el modelo se supone que los agentes son *miopes*, esto es, extraen el recurso natural sin tener en cuenta la dinámica del mismo y su evolución a largo plazo. Otra diferencia importante entre el modelo propuesto y el modelo CP original es que permitimos la libre movilidad del trabajo entre sectores. Esta es una manera sencilla de incorporar la relación existente entre la actividad económica y la dinámica del recurso natural. En este primer capítulo analizamos tanto el caso de un bien primario no comercializable entre regiones, como el de un bien primario comercializable con costes de transporte iguales al de los bienes industriales.

El principal resultado es que el recurso natural renovable y su dinámica dan lugar a una nueva fuerza de dispersión que hemos llamado "*resource effect*". Cuando la población se concentra en una de las regiones, la demanda final e intermedia de bienes primarios aumenta, y la presión sobre el *stock* de recursos naturales se incrementa. A pesar de su tasa natural de regeneración, la mayor extracción del recurso compromete su nivel de largo plazo, encareciendo los bienes primarios, y reduciendo los salarios nominales y reales en la región más poblada, lo cual termina por desencadenar un proceso de dispersión de la población. Además, encontramos que el parámetro vinculado a la productividad en la extracción es determinante a la hora de definir la fuerza del *resource effect*.

El objetivo del Capítulo 2 es profundizar en la relación entre migración, comercio, distribución espacial de la actividad económica y la explotación de los recursos naturales. Para ello extendemos el modelo presentado en el Capítulo 1 incorporando costes de transporte diferenciados para el sector primario y el sector industrial. Analizamos las fuerzas determinantes de la estabilidad del denominado equilibrio simétrico o equilibrio de dispersión. En este capítulo presentamos cinco casos especiales de costes de transporte: bienes primarios no comercializables, bienes industriales no comercializables, bienes primarios perfectamente comercializables, bienes industriales perfectamente comercializables, y bienes primarios e industriales con costes de transporte iguales. Finalmente, analizamos el caso general de costes de transporte específicos para cada sector.

Los resultados obtenidos muestran que, aunque el *resource effect* sufre algunos cambios debido a los diferentes supuestos en los costes de transporte, continua siendo un factor importante para modelizar la distribución de la actividad económica. Identificamos además tres canales que componen el *resource effect*: el canal de la productividad del trabajo, el de los salarios y el del número de empresas. De manera que, cuando hay una diferencia en el *stock* de recursos naturales entre las regiones (como consecuencia de diferentes niveles de extracción):

- el sector primario de la región con menor *stock* se vuelve menos eficiente, y sus precios primarios e industriales tienden a aumentar (canal de la productividad del trabajo);

- en segundo lugar, debido al cambio en los precios, la región con un menor *stock* afronta un déficit comercial, lo que reduce los salarios nominales y reales (canal del salario);

- y tercero, debido a la reducción de los costes laborales, el beneficio de las empresas industriales aumenta, lo que atrae un mayor número de empresas, y la existencia de una mayor variedad de bienes industriales tiende a disminuir al índice de precios industriales en la región (canal del número de empresas).

Encontramos además que la fuerza de dispersión del *resource effect* se incrementa a medida que los costes de transporte del sector primario y del sector industrial son mayores.

Nueva Economía Geográfica y Transferencias de Ingresos

La nueva economía geográfica afirma que la reducción de los costes de transporte conduce a una distribución espacial de la economía del tipo centro-periferia. En este sentido, las transferencias de ingresos entre naciones y entre regiones se han convertido en reconocidos instrumentos para compensar las disparidades económicas. De acuerdo a la literatura NEG, las transferencias de ingresos aumentan el tamaño del mercado de la región receptora de fondos. De forma que la región más pequeña, o periférica, se vuelve más atractiva para el establecimiento de empresas, lo que tiende a reducir las disparidades económicas. Sin embargo, la literatura de la Enfermedad Holandesa (DD) predice exactamente lo contrario, es decir, la existencia de una relación negativa entre transferencias de ingresos y los sectores comercializables de la economía. De acuerdo a esta literatura, una entrada importante de recursos económicos tiende a dañar a los sectores comercializables. Cuando la región compite con precios fijados en los mercados internacionales, el aumento de la demanda debido a las transferencias recibidas se traslada en mayores precios de los bienes no comercializables y mayores salarios. Esto da lugar a una apreciación del tipo de cambio real, y la región receptora de fondos se vuelve menos competitiva en los mercados internacionales. Por lo tanto, las conclusiones de la literatura de la NEG y de la DD resultan contradictorias entre sí.

El objetivo del Capítulo 3 de esta tesis es estudiar el efecto de las transferencias de ingresos en la distribución espacial de la actividad económica mediante un enfoque que integre ambas literaturas (NEG y DD). Para ello presentamos un modelo FE extendido que incorpora transferencias de ingresos, un sector no comercializable, movilidad intersectorial del trabajo, y un bien agrícola diferenciado en cada región. El bien no comercializable y la movilidad intersectorial del trabajo (*input*) son elementos claves de la literatura de la DD. El modelo consta de dos regiones: una es donante o contribuidora neta, mientras que la otra es receptora neta de fondos. Por su parte, el bien agrícola diferenciado permite evitar la igualación de salarios entre regiones (característico de los modelos FE) y a la vez hacer posible la movilidad sectorial del trabajo.

Los resultados encontrados apuntan a que, en el corto plazo, puede tener lugar un proceso de desindustrialización si los costes de transporte resultan ser suficientemente bajos. En este caso, debido a que la competencia de las empresas extranjeras es alta, los beneficios que se obtienen de las transferencias de ingresos para la industria local son más bien escasos. En el largo plazo, sin embargo, los cambios operados en los salarios nominales y en el costo de vida favorecen a la región receptora de fondos. Por lo tanto, si los costes de transporte son altos, esta región puede terminar atrayendo nuevas empresas, aun cuando en el corto plazo haya operado un proceso de desindustrialización. Pero, si la competencia es fuerte (bajos costes de transporte) la DD que tiene lugar en el corto plazo puede anular todos los demás efectos positivos derivados de la transferencias de ingresos, conduciendo a una DD también en el largo plazo. Si este fuera el caso, se observaría que: o bien el número de empresas aumenta en la región donante, o bien se vuelve más difícil revertir las asimetrías regionales existentes. Por lo tanto, en lugar de mitigar las disparidades regionales, las transferencias de ingresos pueden crearlas o incluso exacerbarlas.

References

Baldwin, R. E. (1999). Agglomeration and endogenous capital. European Economic Review, 43(2), 253-280.

Baldwin, R., Forslid, R., Martin, P., & Robert-Nicoud, F. (2005). *Economic geography and public policy.* Princeton University Press.

Candau, F. (2008). Entrepreneur's Location Choice and Public Policies: A Survey of the New Economic Geography. Journal of Economic Surveys, 22(5), 909-952.

Carr, D. (2009). Population and deforestation: why rural migration matters. Progress in Human Geography, 33(3), 355-378.

Clark, G. L., Feldman, M. P., Gertler, M. S., & Wójcik, D. (Eds.). (2018). *The New Oxford Handbook of Economic Geography.* Oxford University Press.

Commendatore, P., Kubin, I., Bougheas, S., Kirman, A., Kopel, M., & Bischi, G. I. (2018). *The Economy as a Complex Spatial System.*

Forslid, R. (1999). Agglomeration with human and physical capital: An analytically solvable case. London: Centre for Economic Policy Research.

Forslid, R., & Ottaviano, G. I. (2003). An analytically solvable core-periphery model. Journal of Economic Geography, 3(3), 229-240.

Fujita, M., Krugman, P. R., & Venables, A. (2001). *The spatial economy: Cities, regions, and international trade.* MIT press. Cambridge, Massachusetts.

Fujita, M., & Thisse, J.-F. (2002). *Economies of Agglomeration: Cities, Industrial Locations, and Regional Growth.* Cambridge: Cambridge University Press.

Krugman, P. (1991). Increasing Returns and Economic Geography. *The Journal of Political Economy, 99*(3), 483-499.

Krugman, P., & Venables, A. J. (1995). Globalization and the Inequality of Nations. The quarterly journal of economics, 110(4), 857-880.

Martin, P., & Rogers, C. A. (1995). Industrial location and public infrastructure. Journal of international Economics, 39(3-4), 335-351.

Neary, J. P. (2001). Of hype and hyperbolas: introducing the new economic geography. Journal of economic Literature, 39(2), 536-561.

Ottaviano, G. I., & Puga, D. (1998). Agglomeration in the global economy: a survey of the 'new economic geography'. *The World Economy, 21*(6), 707-731.

Ottaviano, G. I. (2001). Monopolistic competition, trade, and endogenous spatial fluctuations. Regional Science and Urban Economics, 31(1), 51-77.

Overman, H., Redding, S., & Venables, A. (2001). The Economic Geography of Trade, Production, and Income: A Survey of Empirics. Centre for Economic Performance, LSE.

Pflüger, M. (2001). Ecological Dumping under Monopolistic Competition. Scandinavian Journal of Economics, 103(4), 689-706.

Rauscher, M. (2009). Concentration, separation, and dispersion: Economic geography and the environment. Thünen-series of applied economic theory, 109.

Swain, A. (1996). Environmental migration and conflict dynamics: focus on developing regions. Third World Quarterly, 17(5), 959-974.

Venables, A. J. (1996). Equilibrium locations of vertically linked industries. International economic review, 341-359.

Zeng, D. Z., & Zhao, L. (2009). Pollution havens and industrial agglomeration. Journal of Environmental Economics and Management, 58(2), 141-153.

This chapter has been published:
Martínez-García, M. P., & Morales, J. R. (2019) Resource effect in the Core-Periphery model, Spatial Economic Analysis.
Link: https://www.tandfonline.com/doi/abs/10.1080/17421772.2019.1572914

Chapter 1

The Resource Effect in the Core-Periphery Model

Contents

This chapter develops an extension of the Core-Periphery (CP) model (Krugman, 1991) by considering a competitive primary sector that extracts a renewable natural resource. The dynamics of the resource gives rise to a new dispersion force: the resource effect. If primary goods are not tradable, lower trade costs boost dispersion, and the agglomeration-dispersion transition is sudden or smooth depending on the productivity of the primary sector. Cyclic behaviors arise for high levels of productivity in resource extraction. If primary goods are tradable, in most cases, the symmetric equilibrium goes from stable to unstable as the openness of trade increases.

1.1. Introduction

The NEG literature has mainly focused on industrialized economies, overlooking rural or resource based economies. However, of the 80 million migrants worldwide in 1990, 25 million migrated for environmental reasons or because of resource degradation (Carr, 2009). Many of these migratory movements originated in rural or developing countries. Since the middle of the 20th century, about 1.2 billion hectares of land in the world have suffered soil degradation, with the consequent declines in yields and harvests, so causing massive numbers of environment-induced migrants (Swain, 1996). These migratory processes have important consequences on the spatial distribution of the economic activity, and an analysis of their provoking forces is merited. This is the aim of this chapter, which extends the benchmark Core-Periphery model (CP model) (Krugman, 1991) by incorporating a (renewable) natural resource.

There are a number of well documented examples of migration and redistribution of economic activity motivated by the depletion of renewable natural resources. Kirby (2004) describes the geographic movements of fleets and main harbours in the exploitation of oyster fisheries along the coasts in eastern and western North America, and eastern Australia. Andrew et al. (2003) reports how, in Chile, the reduction in the biomass and overexploitation of the sea urchin led to the appearance of new fleets, ports and processing facilities in the south, while the harvesting of the resource tended to diminish in the middle regions of the country. After several years of rapid expansion of the fisheries into the southernmost region, due to the renewing ability of the resource, the proportional contribution to the national harvest of the middle regions began to recover, which boosted the economic activity in the region again. In Madagascar, farmers clear their land with 'slash and burn' strategies, which lead to deforestation and soil degradation. They proceed to cultivate the land for a couple of years until the soil is exhausted, after which they move on to new unexploited lands (Jouanjean et al., 2014). Other examples can be found for Brazil, the Dominican Republic, Nicaragua and Costa Rica (Carr, 2009; Chambron, 1999) and for Guatemala and Sudan (Bilsborrow and DeLargy, 1990). Anderson et al.

(2011) provide an overview of the exploitation of the sea cucumber fisheries where the same behavioral pattern is observed: resource degradation in highly agglomerated regions triggers a process that forces population and economic activity away to new unexploited regions.

The resulting dispersion process depends heavily on the resource: its regenerative ability, the harvesting effort and the techniques used. These elements are not taken into account in NEG models (designed mainly for industrialized economies), where the only dispersion effects arise from the competition among industrial firms and the existence of transport costs. A comprehensive analysis should also take into account the effects of environment and resource degradation.

Transport cost is an important element in the NEG literature and it also plays an important role in the development of rural economies. Reduction in transportation costs, construction of new roads and infrastructures all facilitate access to distant regions. The profitability of the exploitation of natural resources in far away areas increases, which allows the expansion of the economic activity. For example, a curious land-use dynamics took place in Laos, the Philippines and Amazonia, where landowners intensified agriculture activities close to new or improved roads. At the same time, forests began to regenerate in regions farther away from the roads (Laurance et al., 2009). Reymondin et al. (2013) studies five infrastructure projects for Brazil, Paraguay, Peru, Panama and Bolivia, where these new roads led to forest exploitation, deforestation and expansion of the agricultural frontier to new, unexploited regions. Furthermore, in Brazil, Pfaff (1999) and in Bolivia, Kaimowitz, et al. (2002), highlight that unexploited soil of better quality together with new roads increased the probability of deforestation in order to expand agricultural exploitations for Brazil and Bolivia, respectively.

Therefore, the resulting spatial structure of the economic activity depends on the interaction between transport costs and the resource dynamics. Lower transport costs facilitate trade, which increases the profitability of exploiting distant areas, so encouraging migration and spatial expansion of the economic activity. Additionally, areas whose exploitation has declined, due to the shift in the economic activity, tend to experience a regeneration of their natural resources. Thus, a reduction in transport costs reinforces the dispersion effect driven by the resource dynamics.

Helpman (1998) studies how a fixed endowment (land) boosts the dispersion of the economic activity. Some extensions of this model are found in Suedekum (2006), Pflüger and Südekum (2008), Pflüger and Tabuchi (2010), Leite et al. (2013) and Cerina and Mureddu (2014). These models adjust well for industrialized economies, where congestion and competition for land (a fixed resource) is the driving force of dispersion. Population is the only dynamic factor. However, it does not seem sufficient for regions that base their economic activity on dynamic/renewable natural resources. In resource based economies the dispersion depends on two fundamental aspects: how the exploitation of the natural resource takes place and how well this resource regenerates itself. Thus, population and resource dynamics interact. An agglomerated equilibrium may be stable if the resource endowment is fixed, while it becomes unstable once the dynamics of the resource is taken into account. The resulting spatial distribution of the economic activity is completely different.

There have been some attempts to incorporate notions from environmental economics into NEG models. Pflüger (2001) studies the option of imposing taxes on emissions; Zeng and Zhao (2009) and Rauscher (2009) extend some NEG models to study the impact of pollution on the spatial configuration of the economy; Rieber and Tran (2009) investigate the consequences of unilateral environmental regulations; and Rauscher an Barbier (2010) highlight the conflict arising from competition for space between economic and ecological systems. Other attempts to shift the focus from the industrial sector to other sectors of an economy are Lanaspa and Sanz (1999), Berliant and Kung (2009), and Sidorov and Zhelobodko (2013). However, the regenerative ability of natural resources and the extractive efficiency of harvesting efforts is not considered.

To the best of our knowledge the literature has not incorporated these elements in NEG models. We modify the original CP model by introducing the dynamics of a renewable natural resource, which is extracted as a primary good (Clark, 1990; Vardas and Xepapadeas, 2015), and the double function of primary goods, both as an input for industrial production and as a final consumption good (Pflüger and Tabuchi, 2010). We assume that agents are myopic, that is, they extract the resource without taking into account its dynamics. This set-up is the most consistent with the examples found in the literature.

In our model, industrial goods are produced using the primary good as raw material and there is free labor mobility between sectors and regions. We study both non-tradable primary goods (fertile land, drinking water or perishable natural goods) and tradable primary goods (agricultural goods). Under the assumptions of non-tradability of the primary good and free labor mobility across sectors, the market size effect dominates the competition effect, as in Helpman (1998). Then, the renewable natural resource and its dynamics are the main mechanisms that drive dispersion, giving rise to the resource effect. The effect of transport cost on the stability of dispersion and agglomeration is reverted. This is compatible with the pattern described by the empirical literature: lower transport costs and resource degradation encourage migrations process and the distribution of the economic activity.

The extraction productivity of the primary sector determines the strength of the resource effect, determining how the transition from agglomeration to dispersion takes place. When dispersion forces are weak (low extraction productivity) there is an abrupt transition from agglomeration to dispersion, as the cases of the fishery industry pointed out before. When dispersion forces are strong, a smooth transition can take place, like the reported cases of slow depopulation driven by de decline in soil fertility. Moreover, if dispersion forces are strong enough (relative to transport costs), cyclical behavior may arise: an agglomeration process raises the primary demand, so encouraging larger extractions that compromise the long-term level of the resource and its future extractions.

Later, this primary price increases sufficiently to revert the migration process. This is compatible with the chase-and-flee cycle of Rauscher (2009) in the environmental literature, and also with the definitions of circular migration in the migration and economic labor literature (Newland, 2009).

If the primary good is tradable, the openness of trade affects the traditional dispersion-agglomeration forces and also the strength of the new one linked to the resource and its dynamics. Numerical analysis highlights some regularities. First, as the primary good becomes more tradable, the advantage of being in the region with the higher sustainable level of resource is reduced, which weakens the associated dispersion forces. Second, the predominant pattern observed for the symmetric equilibrium is the one that goes from stable to unstable as transport costs decreases.

The chapter is organized as follows: Section 1.2 introduces the model, Section 1.3 studies the case of non-tradable primary goods and in Section 1.4 trade of primary goods is allowed. Section 1.5 concludes.

1.2. The Model

A world with two regions ($j = 1, 2$) is considered. Two kinds of goods are assumed: manufactures, produced by an increasing-returns sector that can be located in either region, and a primary good that is extracted or harvested from a resource endowment by competitive firms in each region. The industrial sector uses two inputs to produce manufactures: labor and primary good. The primary sector uses only labor for the extraction of the resource. Hereinafter, the extracted goods from the primary sector will be called primary goods when their destination is to be consumed, and raw materials when their destination is to be used as inputs. Finally, to incorporate the dynamics of the natural resource and its relation with economic activity in a simple way, we assume that there is free labor mobility between industrial and primary sector. This assumption makes the model extremely tractable. Moreover, if there were no mobility at all between sectors, the dynamics of the resource and its long-run stock, as will be shown later, would be independent of changes in economic activity. Then, the model would be similar to Helpman (1998) and Pflüger and Tabuchi (2010).[1]

[1]The mobility of labor between sectors has been addressed by Puga (1998). The author assumes free mobility across sectors and regions. Labor dynamics in a specific sector of a region is driven by the relation between the real wage in that sector and a weighted average of the real wages in the other sector (within the same region) and real wages in the other region. In our paper, for the sake of simplicity, we have assumed that nominal wages within a region adjust immediately to become equal in the two sectors. Although the dynamics would be more complex, the steady states equilibria would remain the same.

1.2.1. Households

Households seek to maximize their utility, which takes the form of a nested Cobb-Douglas (across sectors) and CES (over the varieties) used in the original Krugman model (1991). Thus, a representative household in region 1 solves the following consumption problem:

$$\max_{c_{1i},c_{2i},c_{H_1},c_{H_2}} U_1 = \ln\left[C_{M_1}^{\mu} C_{H_1}^{1-\mu}\right] \tag{1.1}$$

$$\text{s.t. } w_1 = \int_0^{n_1} c_{1i}p_{1i}di + \int_0^{n_2} c_{2i}p_{2i}\tau di + p_{H_1}c_{H_1} + p_{H_2}c_{H_2}\nu \tag{1.2}$$

with parameter $\mu \in (0,1)$ and

$$C_{M_1} = \left(\int_0^{n_1} c_{1i}^{\frac{\sigma-1}{\sigma}} di + \int_0^{n_2} c_{2i}^{\frac{\sigma-1}{\sigma}} di\right)^{\frac{\sigma}{\sigma-1}} \tag{1.3}$$

$$C_{H_1} = \left(c_{H_1}^{\frac{\sigma-1}{\sigma}} + c_{H_2}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \tag{1.4}$$

where C_{M_1} and C_{H_1} are consumption indexes of industrial and primary goods respectively with $\sigma > 1$ (for simplicity we assume the same elasticity of substitution for both sectors); c_{ji} is the consumption of variety i produced in region j ($j = 1, 2$); n_j is the number of varieties existing in region j; because of free labor mobility, the salary is the same in both sectors and w_j is the income per household in region j; c_{H_1} and c_{H_2} are the consumptions of the primary or harvested good extracted in regions 1 and 2 respectively (Fujita et al., 2001, ch. 7); p_{ji} is the (fob) price of the variety i of the industrial good produced in region j; $\tau > 1$ and $\nu > 1$ are iceberg transport costs of industrial and primary goods, respectively; and finally, p_{H_j} is the price of the primary good of region j. The mirror-image problem is solved for households in region 2.

From the first order conditions of the maximization problem (1.1)-(1.2), the following demand functions are obtained:

$$c_{1i} = C_{M_1}\left(\frac{p_{1i}}{P_1}\right)^{-\sigma},\ c_{2i} = C_{M_1}\left(\frac{p_{2i}\tau}{P_1}\right)^{-\sigma} \text{ with } C_{M_1} = \frac{\mu w_1}{P_1} \tag{1.5}$$

$$c_{H_1} = C_{H_1}\left(\frac{p_{H_1}}{P_{H_1}}\right)^{-\sigma},\ c_{H_2} = C_{H_1}\left(\frac{p_{H_2}\nu}{P_{H_1}}\right)^{-\sigma} \text{ with } C_{H_1} = \frac{(1-\mu)\,w_1}{P_{H_1}} \tag{1.6}$$

where P_1 and P_{H_1} are the industrial and primary price indexes for region 1, that is,

$$P_1 = \left(\int_0^{n_1} p_{1i}^{1-\sigma} di + \int_0^{n_2} (p_{2i}\tau)^{1-\sigma} di\right)^{\frac{1}{1-\sigma}} \tag{1.7}$$

$$P_{H_1} = \left[p_{H_1}^{1-\sigma} + (p_{H_2}\nu)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{1.8}$$

Mirror-image formulas for P_2 and P_{H_2} hold for consumers in region 2.

1.2.2. Primary Sector

In the natural extractive sector, a primary firm seeks to maximize its benefits, in a perfect competitive market, choosing the amount of labor to employ in the extraction of the resource, subject to the extraction function for region j, given by

$$H_j = \epsilon S_j L_{H_j}, \quad \epsilon > 0 \tag{1.9}$$

where S_j is the available stock of the natural resource, L_{H_j} is the labor employed in the primary sector and ϵ is a productivity parameter in the extraction, assumed to be equal for both regions for the sake of simplicity. As is usual in environmental economic models, the productivity of labor depends positively on the available stock of the natural resource S_j. Firms are myopic, that is, they extract the resource without taking into account its dynamics. The extracted or harvested resource, H_j, can be consumed or used as a raw material for industrial production. The maximization of profits, in a competitive market with free entry, needs the following condition,[2]

$$p_{H_j} = w_j \frac{L_{H_j}}{H_j} = \frac{w_j}{\epsilon S_j} \tag{1.10}$$

where p_{H_j} is the price of the primary good and w_j is the salary in region j.

1.2.3. Industrial Sector

A firm in the industrial sector employs labor and raw materials to produce industrial goods, according to the production function

$$\begin{aligned} x_{ji} &= \left(\frac{1}{\beta}\right)\left(l_{x_{ji}} - f\right)^{\alpha} h_{ji}^{1-\alpha}, \quad 0 < \alpha < 1 && (1.11) \\ h_{ji} &= \left(h_{1ji}^{\frac{\sigma-1}{\sigma}} + h_{2ji}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} && (1.12) \end{aligned}$$

where $l_{x_{ji}}$ is labor used in producing variety i in region j, and x_{ji} is the output; h_{ji} is an index of raw materials employed in the production of variety i in region j; h_{kji} is the primary good extracted in region k employed in region j production of variety i. For the sake of simplicity we have assumed same elasticity substitution σ for primary goods. Parameter $\beta > 0$ is the marginal input requirement and f is a fixed cost. Note that if

[2] As reported by Adhikari et al. (2004) there still exist some examples of free access to forest resources in Nepal. Moreover, fisheries have proven difficult to regulate and an open-access externality of reasonable size still exists in Nordic Fisheries (Waldo et al., 2016). Poor regulation has resulted in both stock depletion and low economic returns, leading to the well known "Tragedy of the commons". Fishery, forestry, irrigation, water management, animal husbandry, biodiversity and climate change are the usual areas where the "Tragedy" has arisen (Laerhoven, 2007).

$\alpha = 1$, the production function (1.11) is the same as the one proposed by Krugman (1980, 1991), which involves a constant marginal cost and a fixed cost, giving rise to economies of scale. When $\alpha \in (0, 1)$ the use of the raw material is necessary for production and increases labor productivity.

It is assumed that there are a large number of manufacturing firms, each producing a single product in monopolistic competition (Dixit and Stiglitz, 1977). Given the definition of the manufacturing aggregate (1.3), the elasticity of demand facing any individual firm is $-\sigma$. Then, the profit-maximizing price behavior of a representative firm in region j is

$$p_{ji} = \frac{\sigma}{\sigma - 1}\beta\left(\frac{w_j}{\alpha}\right)^{\alpha}\left(\frac{P_{H_j}}{1-\alpha}\right)^{1-\alpha} \tag{1.13}$$

Since firms are identical and face the same wage and the same price of raw materials within a region, manufactured good prices are equal for all varieties in each region, so the subscript i can be dropped. Consequently, p_j $(j = 1, 2)$ will refer to region j specific industrial good price. Equally, resource demand is equal for all firms in the same region j, so we shall name the region j specific resource and labor demands per firm h_j and l_{x_j} $(j = 1, 2)$. Primary goods demand functions for the industrial sector in region 1 are

$$h_{11} = h_1^{1-\sigma}\left(\frac{1-\alpha}{\alpha}\frac{w_1\left(l_{x_1} - f\right)}{p_{H_1}}\right)^{\sigma} \quad \text{and} \quad h_{21} = h_1^{1-\sigma}\left(\frac{1-\alpha}{\alpha}\frac{w_1\left(l_{x_1} - f\right)}{\nu p_{H_2}}\right)^{\sigma} \tag{1.14}$$

and for region 2, h_{12} and h_{22} are mirror images of (1.14). Therefore,

$$h_j = \frac{1-\alpha}{\alpha}\frac{w_j}{P_{H_j}}\left(l_{x_j} - f\right) \text{ for } j = 1, 2. \tag{1.15}$$

Comparing the prices of representative products in (1.13), we have

$$p \equiv \frac{p_1}{p_2} = \left(\frac{w_1}{w_2}\right)^{\alpha}\left(\frac{P_{H_1}}{P_{H_2}}\right)^{1-\alpha} \tag{1.16}$$

Because there is free entry in the industrial sector, a firm's profits must equal zero. Using this condition and (1.13) and (1.15), it is obtained that

$$x_j = f\frac{\sigma - 1}{\beta}\alpha^{\alpha}\left(1-\alpha\right)^{1-\alpha}\left(\frac{w_j}{P_{H_j}}\right)^{1-\alpha} \tag{1.17}$$

$$l_{x_j} = f\left[1 + \alpha\left(\sigma - 1\right)\right]. \tag{1.18}$$

The aggregate labor employed in the industrial sector of region j is $L_{E_j} = n_j f\left[1 + \alpha\left(\sigma - 1\right)\right]$. Here again, if $\alpha = 1$, we obtain the same expression as in Krugman's model.

1.2.4. Dynamics

Natural Resources: The regions are assumed to be endowed with a renewable natural resource (S_j) whose dynamics follows a logistic growth function (Clark, 1990)

$$\dot{S}_j = gS_j \left(1 - \frac{S_j}{CC}\right) - H_j \tag{1.19}$$

where $g > 0$ is the intrinsic growth rate of the resource, that is, the rate at which the natural resource regenerates itself. The carrying capacity, $CC > 0$, is the maximum size of the resource that can be sustained. Because we are studying symmetric regions, both g and CC are assumed to be equal in both regions, which simplifies the model. Taking into account H_j, given by (1.9), into (1.19), the sustainable level of the resource (the positive steady-state level) is given by

$$S_j^* = \left(1 - \frac{\epsilon}{g} L_{H_j}\right) CC > 0 \text{ if and only if } L_{H_j} < g/\epsilon \tag{1.20}$$

which is globally stable for a given value of L_{H_j}. Otherwise, the only globally stable steady state is the null one.

Population Mobility: Workers are mobile between regions and choose to migrate if they gain in terms of individual welfare from doing so. We assume that $L_1 + L_2 = 1$ and, as is usual in NEG models, population reallocation follows the following dynamics:

$$\dot{L}_1 = L_1 (1 - L_1) \left(\frac{V_1}{V_2} - 1\right) \tag{1.21}$$

where V_j is the indirect utility, defined as the ratio of nominal wage w_j to the Cobb-Douglas average price index across sectors (Sidorov and Zhelobodko, 2013; Forslid and Ottaviano, 2003),[3]

$$V_j = \frac{w_j}{(P_j)^{\mu} \left(P_{H_j}\right)^{1-\mu}} \tag{1.22}$$

Therefore, the dynamic of the model will be driven by the differential system (1.19) for $j = 1, 2$ and (1.21).

1.3. A non-tradable primary good

In this section we present the case of a non-tradable primary good. This is the case of fertile land, drinking water or highly perishable products, for example. To do this we

[3]In Fujita et al. (2001) $\dot{L}_1 = L_1(V_1 - \bar{V})$ where $\bar{V} = L_1V_1 + (1 - L_1)V_2$ is the weighted average of indirect utilities. A simple manipulation derives that $\dot{L}_1 = L_1(1 - L_1)(V_1 - V_2)$, which is equivalent to (1.21) if we divide by V_2.

assume that $\nu \to \infty$. When primary trade costs are unaffordable, households and firms can only purchase primary goods extracted in the local region. Thus, index prices P_{H_1} and P_{H_2}, defined in (1.8) and in its mirror image formula for region 2, and (1.16), become

$$P_{H_j} = p_{H_j} \text{ for } j = 1, 2 \tag{1.23}$$

$$p = \left(\frac{w_1}{w_2}\right)\left(\frac{S_1}{S_2}\right)^{-(1-\alpha)} \tag{1.24}$$

where (1.10) has been taken into account. From (1.6) we have that, in region 1, household´s demand of primary good is

$$c_{H_2} = 0 \text{ and } c_{H_1} = C_{H_1} = \frac{(1-\mu)\, w_1}{p_{H_1}} \tag{1.25}$$

Mirror-image formulas hold for consumers in region 2.

Demand equations (1.14)-(1.15) can be simplified:

$$h_{12} = h_{21} = 0 \text{ and } h_j = \frac{1-\alpha}{\alpha}\frac{w_j}{p_{H_j}}\left(l_{x_j} - f\right) \text{ for } j = 1, 2. \tag{1.26}$$

1.3.1. Short-Run Equilibrium

In the short-run equilibrium, households maximize their utility, industrial and primary firms maximize their profits, there is free entry in both sectors, and market clearing conditions hold for the three markets: labor, primary and industrial goods.

As a result of the free labor mobility assumption, the labor market clearing condition states that

$$L_j = \int_0^{n_j} l_{x_{ij}} di + L_{H_j} = L_{E_j} + L_{H_j} \tag{1.27}$$

where L_j is the total population of region j.

In the primary sector, total harvesting, H_j, must satisfy the demand for final consumption of the primary good (1.25) and the demands of the industrial firms for raw materials (1.26), that is,

$$H_j = L_j\frac{(1-\mu)\, w_j}{p_{H_j}} + n_j\frac{1-\alpha}{\alpha}\frac{w_j}{p_{H_j}}\left(l_{x_j} - f\right) \tag{1.28}$$

Using equations (1.10), (1.18), and (1.27) we have that the primary sector clearing condition (1.28) implies

$$L_{H_j} = \frac{\sigma - \mu\left[1 + \alpha\left(\sigma - 1\right)\right]}{\sigma} L_j \tag{1.29}$$

$$L_{E_j} = \frac{\mu\left[1 + \alpha\left(\sigma - 1\right)\right]}{\sigma} L_j \tag{1.30}$$

$$n_j = \frac{\mu}{\sigma f} L_j \tag{1.31}$$

Trade is balanced if and only if the following equation is satisfied[4]:

$$TB = p\left(\frac{S_1}{S_2}\right)^{1-\alpha}\left(1+\frac{L_1}{1-L_1}p^{1-\sigma}\phi\right) - p^{1-\sigma}\left(\phi+\frac{L_1}{1-L_1}p^{1-\sigma}\right) = 0 \quad (1.32)$$

where $\phi \equiv \tau^{1-\sigma}$, with $\phi \in (0,1)$ is an index of the openness of trade. This equation has a unique positive solution. Using this solution and equation (1.24), the ratio of nominal wages can be obtained as a function of ϕ, L_1, S_1 and S_2.

As we move from the short-run to long-run equilibrium, however, some other features need to be taken into account. Workers are not interested in nominal wages but in real wages and they will migrate to the region with the highest welfare. Additionally, an increase in population will boost the use of natural resources for consumption and production, which provokes a dynamic adjustment of the natural environment. These two dynamic processes are explained in the following section.

1.3.2. Long-Run Equilibria

The usual agglomeration and dispersion forces of NEG literature (market size effect, Competition and Price index effects) arise in the model. As in Helpman (1998), a consequence of the nontradability of the primary good and the free labor mobility is that the market size effect always dominates the competition effect. In addition, as a result of the dynamics of the natural resources, a new dispersion force arises, as is proved in Proposition 1.

Note that, for a given level of L_j, the globally stable steady state value of the natural resource, given in (1.20), becomes

$$S_j^* = (1-\epsilon\theta L_j)\, CC \text{ if } \epsilon\theta L_j < 1 \text{ otherwise } S_j^* = 0 \quad (1.33)$$

where

$$\theta \equiv \frac{\sigma-\mu\left[1+\alpha\left(\sigma-1\right)\right]}{g\sigma} \quad (1.34)$$

and (1.29) have been used.

Thus, due to the role played by the workforce in the resource extraction, a higher population, L_j, tends to reduce the level of the sustainable natural resource ($S_j^* > 0$). The same can be said for the extractive productivity parameter in the primary sector, ϵ. The following proposition establishes the consequences for wages and primary good price.

Proposition 1 *When population increases in one region, natural resource dynamics leads to*

[4]This equation is obtained in the online Appendix A, available for readers interested in these details at the website of the journal. From now on, all the long derivations and proofs are presented in online appendixes.

*(*i*) lower nominal wages and*

*(*ii*) increase the price of primary goods and the industrial price index in that region.*

Proof. See the Appendix A. ■

This is the Resource Effect, and it has two channels that encourage dispersion through the consumers utility. Property (i) stands for the linkage between the primary and the industrial sector, and depends on α. Property (ii) affects the cost of living and its strength depends on μ.

Despite the similarities, the resource effect is different to the effects derived by Helpman (1998) and Ottaviano and Puga (1998). In these other models the dispersion forces are driven by region-specific supplies of the nontradable good (or factors), which are fixed stocks. Thus, an increase in the population diminishes the stock per capita (per firm), so raising the price. In the model developed in this chapter, the primary good is extracted or produced; it is not fixed. An increase in the population does not change the ratio H_j/L_j, in the short-run, due to the simultaneous increase in the extractive labor force (see equations (1.9) and (1.29)). However, in the long-run, the steady states stock decreases, and so, therefore, does the ratio H_j/L_j. The resource dynamic is essential for the existence of the resource effect.

Equation (1.21) can be simplified by replacing (1.22), and making use of P_1 definition in (1.7), its mirror image for P_2, (1.10), (1.23), (1.24), (1.31) and (1.32). Thus, the dynamic evolutions of the stocks of the natural resource and population between the two regions are driven by equations (1.19) with $j = 1, 2$ and (1.21) and can be rewritten as

$$\begin{aligned} \dot{L}_1 &= L_1 (1 - L_1) \left[\left(\frac{S_1}{S_2} \right)^{1-\mu\alpha-\mu(1-\alpha)/(1-\sigma)} p^{\mu(1-2\sigma)/(1-\sigma)} - 1 \right] && (1.35) \\ \dot{S}_1 &= g S_1 \left(1 - \frac{S_1}{CC} \right) - \epsilon g \theta S_1 L_1 && (1.36) \\ \dot{S}_2 &= g S_2 \left(1 - \frac{S_2}{CC} \right) - \epsilon g \theta S_2 (1 - L_1) && (1.37) \end{aligned}$$

where θ is defined by (1.34), and p is a function of the population size, according to equation (1.32).[5] A long-run equilibrium is a stationary point of the dynamic equation system (1.35)-(1.37), where workers do not have incentives to move from one region to the other and natural resource stocks remain constant. Furthermore, because we are

[5] Note that after some manipulations we have that

$$\frac{P_1}{P_2} = \left(\frac{\frac{L_1}{L_2} p^{1-\sigma} + \phi}{\frac{L_1}{L_2} \phi p^{1-\sigma} + 1} \right)^{1/(1-\sigma)} = p^{\sigma/(1-\sigma)} \left(\frac{S_1}{S_2} \right)^{(1-\alpha)/(1-\sigma)}$$

studying a renewable natural resource, we are interested in the set of parameters that allows at least one long-run sustainable solution ($S_j^* > 0$). To ensure this, we assume hereinafter that

$$\epsilon\theta < 2. \tag{1.38}$$

If parameters satisfy the sustainability condition (1.38), then there exists a symmetric interior equilibrium, characterized by the following values, where population is equally distributed:

$$L_1^* = 1/2,\ S_1^* = S_2^* = \left(1 - \epsilon\frac{\theta}{2}\right) CC,\ p^* = 1 \tag{1.39}$$

Note that if $\epsilon\theta < 1$, the symmetric (interior) equilibrium coexists with the following two agglomeration (boundary) equilibria:

$$L_1^* = 1,\ \ S_1^* = (1 - \epsilon\theta)\, CC,\ \ S_2^* = CC,\ \ p^* = \phi^{\frac{-1}{\sigma}} (1 - \epsilon\theta)^{-(1-\alpha)/\sigma} \tag{1.40}$$

and

$$L_1^* = 0,\ \ S_1^* = CC,\ \ S_2^* = (1 - \epsilon\theta)\, CC,\ \ p^* = \phi^{\frac{1}{\sigma}} (1 - \epsilon\theta)^{(1-\alpha)/\sigma} \tag{1.41}$$

When $\epsilon\theta \geq 1$, the agglomeration equilibria become.[6]

$$L_1^* = 0,\ \ S_1^* = CC,\ \ S_2^* = 0,\ \ p^* = 0 \tag{1.42}$$

Mirror-image values are obtained for $L_2^* = 0$.

1.3.3. Stability Properties

According to (1.39)-(1.42), economic activity can be equally distributed between the regions or concentrated in one of them. Which equilibrium will prevail depends on the stability properties, expressed in terms of the parameters of the model, in the following proposition.

Proposition 2 *The symmetric interior equilibrium is locally stable if the following condition is satisfied:*

$$\phi > \max\{\phi^B, \phi^H\} \tag{1.43}$$

with $\phi^B \equiv 1 - \frac{(\sigma-1)(\sigma(1-\mu\alpha)-\mu(1-\alpha))\,\epsilon\theta}{(2\sigma-1)\mu(1-\epsilon\frac{\theta}{2})+(\sigma-1)(1-\mu-\mu(1-\alpha))\epsilon\frac{\theta}{2}}$ *and* $\phi^H \equiv 1 - \frac{2\sigma(\sigma-1)g\left(1-\epsilon\frac{\theta}{2}\right)}{(2\sigma-1)\mu+(\sigma-1)g(1-\epsilon\frac{\theta}{2})}$.

Meanwhile, the agglomeration equilibria (1.40)-(1.41) are locally stable (stable nodes) if the following condition holds:

$$\phi < \phi^S \equiv (1 - \epsilon\theta)^{\frac{(\sigma-1)}{\mu(2\sigma-1)}[\sigma(1-\mu\alpha)-\mu(1-\alpha)]} \tag{1.44}$$

and agglomeration equilibrium (1.42) is always unstable.

[6] On replacing the symmetric equilibrium ($L_1^* = 1/2$, $S_1^* = S_2^* = (1-\epsilon\theta/2)CC$), and the agglomeration equilibria ($L_1^* = 1$, $S_1^* = (1-\epsilon\theta)CC$, $S_2^* = CC$ and $L_1^* = 0$, $S_1^* = CC$ and $S_2^* = (1-\epsilon\theta)CC$), in equation (1.32), the equilibrium price p^* is obtained. Thus, it is easy to confirm that the three differential equation system (1.35)-(1.37) vanishes for (1.39) and for (1.40)-(1.42).

Proof. See the Appendix A. ■

In the previous proposition the superscript B is for "break" and the superscript S is for "sustain" (maintaining the name used by Fujita et al., 2001). The superscript H is for Hopf, since at this point a Hopf bifurcation arises, as will be shown later.

Condition (1.43) defines a region of stability for the symmetric equilibrium (shaded region in Figure 1.1) in the space of parameters ϵ and ϕ. This stability region is not empty, although it can be greater or smaller depending on the parameters of the model. The downward sloping curve ϕ^B in the (ϵ, ϕ) space, is the boundary for the pitchfork bifurcation, and ϕ^H, upward sloping, is the boundary for the Hopf bifurcation. Both curves intersect at point $\bar{\epsilon}$.[7]

Figure 1.1 represents the stability condition (1.43) for parameters $\sigma = 2$, $\alpha = 0.6$, $\mu = 0.8$, and $g = CC = 1$.

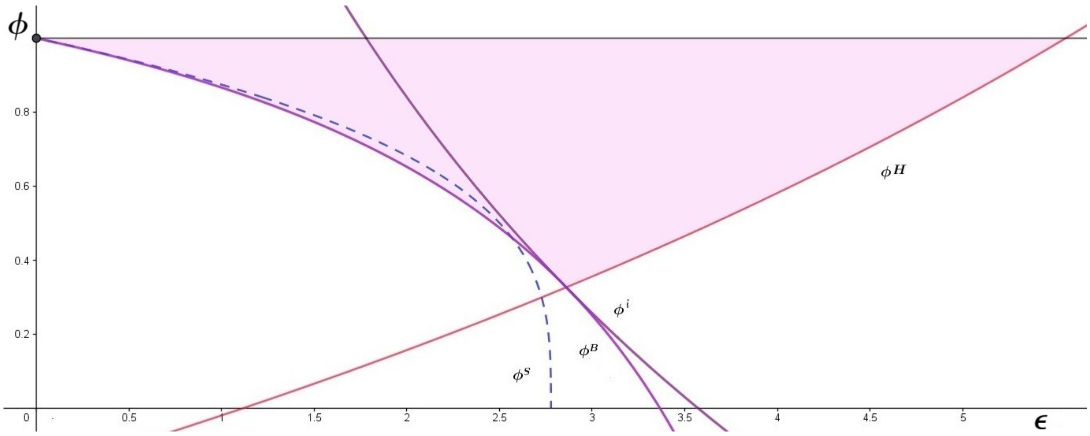

Figure 1.1: Stability region of the symmetric equilibrium

The symmetric equilibrium (1.39) is not necessarily the only interior equilibrium for the system (1.35)-(1.37). According to the value of the parameters, there could be two more interior equilibria around the symmetric one. The following proposition proves this result.

[7]

$$\bar{\epsilon} \equiv \frac{(\sigma-1)(1-\alpha)+\sigma(2+\theta)-\sqrt[2]{(\sigma-1)^2(1-\alpha)^2+\theta\left[2(1-\alpha)(\sigma-1)+\sigma(2+\theta)\right]}}{\theta(\sigma+(\sigma-1)(1-\alpha))} > 0 \qquad (1.45)$$

Proposition 3 *If $\phi^B, \phi^S \in (0,1)$ and $\epsilon < \bar{\epsilon}$, an increase in the openness of trade leads to:*

i) *a sudden change from agglomeration to dispersion for low levels of the extractive productivity, $\epsilon < \min\{\tilde{\epsilon}, \bar{\epsilon}\}$.*

ii) *a smooth change from agglomeration to dispersion for high levels of the extractive productivity, $\tilde{\epsilon} < \epsilon < \bar{\epsilon}$.*

where $\tilde{\epsilon} > 0$ is the intersection point of ϕ^B and ϕ^S.

Proof. See the Appendix A. ■

Proposition 3 proves that as transport cost decreases (ϕ increases) the stability of the symmetric equilibrium changes. This prominence of transport costs is not new in NEG models. What is new in our model is the emergence of a second actor: the extraction productivity in the primary sector, measured by ϵ. This parameter will determine if the transition is sudden (a subcritical pitchfork bifurcation) or smooth (a supercritical pitchfork bifurcation). Both phenomena are observed in the real world. As reported by Andrew et al. (2003), the rapid movement of fishing efforts (fleet, fishermen, processing facilities, etc.) to unexploited regions has occurred in many world fisheries. In contrast, a slow depopulation has been observed as the consequence of deforestation or soil fertility decline (Dazzi and Lo papa, 2013). Parameter ϵ plays an important role in environmental economic models that use the catch-per-unit-effort resource production function. Its value depends on both the natural resource in question and the technology employed. Therefore, these two facts matter for a sudden or a smooth structural change in the geographical distribution of the economic activity.

Additionally, the incorporation of the dynamics of natural resources into the original core periphery model leads to the appearance of periodic solutions, as is proved in the following proposition.

Proposition 4 *When $\phi^i < \phi < \phi^H$ migration flows adopt a cyclic behavior, where*

$$\phi^i \equiv 1 - 2\sigma \frac{\delta^i}{1+\delta^i} \tag{1.46}$$

and δ^i is defined in the Appendix A.

Proof. See Appendix A. ■

Note that ϕ^H and ϕ^i intersect at point $\bar{\epsilon}$. Thus, for $\epsilon > \bar{\epsilon}$ passing from the left to the right of curve ϕ^H, there are two complex conjugate eigenvalues that move from having negative real part to having positive real part, and the symmetric equilibrium loses its local stability. The proposition shows the emergence of cyclic behavior (a Hopf bifurcation) for relatively high values of the extractive productivity ($\epsilon > \bar{\epsilon}$).

The existence of cyclic behavior is new to the literature of CP models in continuous-time. However, the Policy Institute and the 2011 report of the European Migration Network recognize the existence of circular migration. In some cases it is due to environmental issues (Rauscher, 2009). Proposition 4 points again to the extraction productivity, ϵ, as a key parameter ($\epsilon > \bar{\epsilon}$), together with transport costs.

The following subsection describes the process of agglomeration-dispersion of the economic activity between two regions, focusing on the role of transport cost and primary sector productivity in the stability properties of the equilibria.

1.3.4. The role of transport cost and extraction productivity

The first result that stands out is that as the transport cost decreases (ϕ increases) the symmetric equilibrium changes from unstable to stable (Proposition 2). This is in contrast to the results found in the original CP model but in line with Krugman and Elizondo (1996), Helpman (1998) and Murata and Thisse (2005).

In the transition between instability and stability, the extraction productivity of the primary sector becomes important. As pointed out before, different values of ϵ can change the bifurcation pattern. Figure 1.1 gives a clear view of the role of ϵ. For a given transport cost, the larger the value of ϵ, the closer we are to the stability region of the symmetric equilibrium. So the dispersion force is a direct function of ϵ.

Note that this result is the opposite to what Tabuchi et al. (2016) find when they analyze an increase in the industrial productivity through a fall in the marginal labor requirement. Two differences are driving these opposite results. First, the model proposed by Tabuchi et al. (2016) has migration costs. This implies that the size of the gap between real wages matters in their model and not in ours. Thus, when industrial productivity increases in Tabuchi's model, the real wage gap widens, overcoming the effect of migration costs and giving place to further agglomeration. In our model the equilibrium implies real wage equalization, so an increase in the extraction productivity does not have a direct impact on prices through this channel.[8] Second, in our model, the extraction productivity has a second channel through which it can affect the equilibria: it has an indirect impact through the long-run stock of natural resources. This channel is not present in Tabuchi et al. (2016). Thus, in the case of $L_1 \neq 1/2$ an increase in the extraction productivity can change the ratio of indirect utilities, shifting dynamics and the possible equilibria. Hence, while an increase in the industrial productivity tends to magnify regional disparities, an increase in the extraction productivity tends to mitigate or even revert these disparities when there are no migration costs.

[8]Note that if in our model there were a real wage gap differential, and holding constant the stock of natural resources, an increase in ϵ would also widen this gap as in Tabuchi et al. (2016), and through the same direct channel. Nevertheless, the only possible equilibria where real wages are not equalized (in our model) are the agglomeration ones, where concentration has already reached its maximum.

The process depicted by Figure 1.2, the subcritical case, is characterized by a sudden change in spatial configuration (Fujita et al., 2001). This is because the non-symmetric interior equilibria connecting the agglomeration and symmetric solutions are unstable. In this case, the bifurcation diagram has a Krugman tomahawk shape, but the stability pattern is inverted.

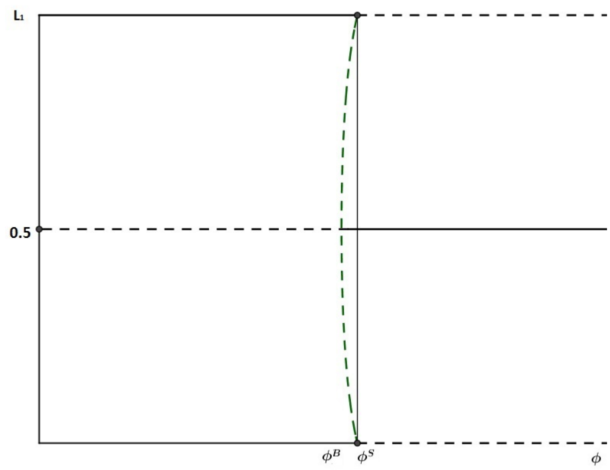

Figure 1.2: Subcritical pitchfork bifurcation ($\sigma = 2$, $\alpha = 0.6$, $\mu = 0.8$, $g = CC = 1$, $\epsilon = 2.2$)

If the extraction productivity of the primary sector is low enough, a value of $\epsilon < \min\{\tilde{\epsilon}, \bar{\epsilon}\}$ (subcritical bifurcation), then dispersion forces are weak, and for low values of ϕ (such that $\phi^H < \phi < \phi^B$) agglomeration equilibria are stable. As transport costs decrease the equilibrium moves to the right in Figure 1.2, and a subcritical bifurcation takes place at ϕ^B. The peculiarity of this pattern is that for $\phi \in \left(\phi^B, \phi^S\right)$ both agglomeration and dispersion equilibria are locally stable. This occurs precisely because dispersion forces are weak, so when the distribution of the economic activity is near to being fully agglomerated, the size of the market can still overcome the dispersion forces, even at relatively low transport costs. However, when the distribution of the economic activity is near the symmetric equilibrium, the market size effect is not very strong because the difference between the sizes of the markets is small. So, dispersion forces can overcome agglomeration forces.

The process depicted by Figure 1.3, the supercritical case, is characterized by a smooth change in the spatial configuration. This is because the interior non-symmetric equilibria are stable and connect the agglomeration and dispersion solutions. The bifurcation diagram closely resembles the one derived by Helpman (1998).

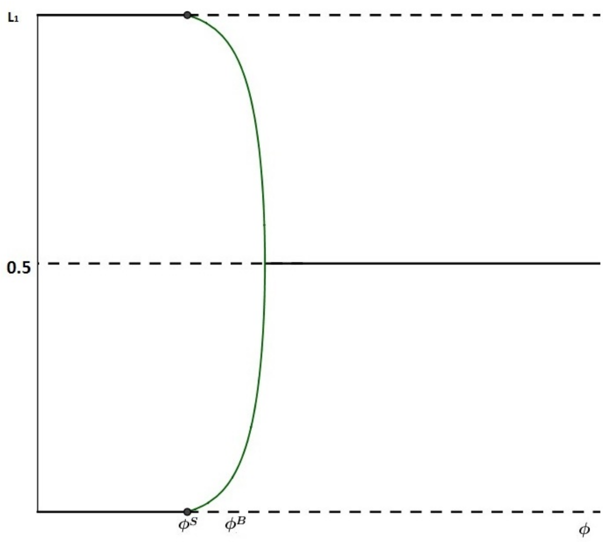

Figure 1.3: Supercritical pitchfork bifurcation ($\sigma = 2$, $\alpha = 0.6$, $\mu = 0.8$, $g = CC = 1$, $\epsilon = 2.75$)

If the extraction productivity is high enough, such that $\tilde{\epsilon} < \epsilon < \bar{\epsilon}$ (supercritical bifurcation), and the transport cost is $\phi^H < \phi < \phi^B$, agglomeration equilibria are stable. In this case, dispersion forces are stronger, so ϕ^S and ϕ^B are lower than in the subcritical case. As transport costs decrease the equilibrium moves to the right in Figure 1.3, and a supercritical bifurcation takes place at ϕ^B. The main difference is that for a $\phi \in \left(\phi^S, \phi^B\right)$ both agglomeration and dispersion equilibria are now locally unstable while the other two non-symmetric interior equilibria are locally stable. Why does this pattern occur? Dispersion forces are strong, so agglomeration equilibria become unstable at a low value of ϕ. At this point, however, the market size effect is still strong due to high transport costs, so the symmetric solution is also unstable. Meanwhile, the non-symmetric equilibria are stable because, if a new firm decides to move to the most populated region, the high extractive productivity in the resource sector causes a sharp increase in the primary prices and dispersion forces activate. In contrast, if a firm decides to move to the less populated region, this firm will have to pay high transport costs to have access to the larger market, and agglomeration forces are set in motion.

When $\phi < \phi^H$ and $\epsilon > \bar{\epsilon}$, the openness of trade is not high enough to guarantee the stability of the symmetric equilibrium, so this high transport cost triggers an agglomeration process. However, the population growth, together with a high extraction productivity (high value of ϵ), accelerate the depletion of the natural resource. The resource dynamics boosts the dispersion forces, first by slowing down the migration flow, and finally reversing it; all of which give rise to a circular behavior. This is consistent with Robinson et al.

(2008) who, in a different framework, find that the spatial characteristic of the extraction of a renewable resource ultimately results in cyclical dynamic extraction.

What we find with a renewable and extractable resource is that households move to the region with the higher real wages, and as the market gets bigger, the agglomeration of persons and firms accelerates, so raising the demand for primary goods. The primary sector extracts more natural resources to cope with the increase in demand, compromising its long-term stock, and the level of future extractions. Ultimately, the scarcity of the resource raises the primary prices enough to reverse the migration process. This scheme resembles the chase-and-flee cycle of location of Rauscher (2009), but through a different channel.[9]

The migration flow caused by this circular behavior is compatible with some of the ideas outlined on circular migration in the migration and economic labor literature. Newland (2009) refers to this phenomenon as a seasonal or periodic migration for work, for survival, or as a life-cycle process. Additionally, there have been some attempts to quantify the importance of circular migration and its impact in the origin and the destination countries, see, for example, Constant and Zimmermann (2012); and Agunias and Newland (2007) for other references.

1.4. A tradable primary good

In this section we present the case of a tradable primary good. To simplify the analysis we assume that the primary good is tradable at the same transport cost of industrial goods, that is, $\nu = \tau$.

1.4.1. Short-Run Equilibrium

The three markets (labor, industrial and primary goods) clear. Replicating the analysis followed in section 1.3, it is obtained that (see the Appendix B for a comprehensive explanation)

$$L_{E_1}w + L_{E_2} = \frac{\mu\left[1+\alpha(\sigma-1)\right]}{\sigma}\left(L_1 w + L_2\right) \tag{1.47}$$

$$L_{H_1}w + L_{H_2} = \frac{\sigma - \mu\left[1+\alpha(\sigma-1)\right]}{\sigma}\left(L_1 w + L_2\right) \tag{1.48}$$

$$n_j = \frac{L_{E_j}}{f\left[1+\alpha\left(\sigma-1\right)\right]} \quad \text{for } j = 1, 2. \tag{1.49}$$

[9]In Rauscher's (2009) chase-and-flee cycle, people prefers a clean and healthy environment, so they decided to stay away from industrial (polluting) activities; but, they are chased by the industries, which want to locate close to the market.

where $w \equiv w_1/w_2$. Moreover, trade between the two regions is balanced if and only if

$$\begin{aligned} TB &= \mu\left(\frac{z_{12}}{1+z_{12}}L_2 - \frac{1}{1+z_{11}}L_1 w\right) + (1-\mu)\left(\frac{q_{12}}{1+q_{12}}L_2 - \frac{1}{1+q_{11}}L_1 w\right) \quad (1.50) \\ &+ \frac{(1-\alpha)(\sigma-1)}{1+\alpha(\sigma-1)}\left(\frac{q_{12}}{1+q_{12}}L_{E_2} - \frac{1}{1+q_{11}}L_{E_1} w\right) = 0 \end{aligned}$$

where q_{11} is the ratio of region 1 expenditure on local primary good to that on primary good from region 2, and q_{12} is the expenditure of region 2 on region 1 primary good with respect to the primary good from region 2. The first term of equation (1.50) is the difference between industrial exports and imports of region 1, the second term is the difference between primary exports and imports of region 1 for final consumption, and the third term is the difference between primary (raw material) exports and imports of region 1 to be used as inputs by the industrial firms. Note that if the last two terms of equation (1.50) vanishes, which is the case if the primary good were not tradable, equation (1.50) would reduce to (1.32).

The symmetric equilibrium (1.39) satisfies equation (1.50) and the derivative at this point is

$$\frac{\partial TB}{\partial w}(L_1^*, S_1^*, S_2^*, w^*) = \frac{\phi(2\sigma-1+\phi)}{(1+\phi)^2} + \frac{\phi\Psi^*(\phi)}{(1-\phi)^2(1+\phi)}\left[(1+\phi)^2 + 2(\sigma-1)(2\alpha\phi+1-\phi)\right] > 0$$

with $L_1^* = 1/2$, $S_1^* = S_2^* = S^* = \left(1-\epsilon\frac{\theta}{2}\right)CC$, $w^* = 1$ and $\Psi^*(\phi) > 0$ is (1.95) evaluated at the symmetric equilibrium. Therefore, for a given value of ϕ, equation (1.50) implicitly defines w as a function of L_1, S_1 and S_2 in a neighborhood of the symmetric equilibrium.

Using the implicit differentiation in (1.50), we obtain, at the symmetric equilibrium, that

$$\frac{\partial w}{\partial L_1} = \frac{-4\left[1-\frac{1+\phi}{1-\phi}\Psi^*(\phi)\right]}{\frac{2\sigma-1+\phi}{1+\phi} + \frac{\Psi^*(\phi)}{(1-\phi)^2}\left[(1+\phi)^2+2(\sigma-1)(2\alpha\phi+1-\phi)\right]} \quad (1.51)$$

which can be negative or positive, depending on the value of ϕ. That is,

$$\frac{\partial w}{\partial L_1} \lesseqgtr 0 \text{ if and only if } \phi \lesseqgtr \hat{\phi} = \frac{\sigma(1-\mu)-\mu[1+\alpha(\sigma-1)]}{\sigma(1-\mu)+\mu[1+\alpha(\sigma-1)]} < 1 \quad (1.52)$$

In contrast to what happened in Section 1.3, now if the stock of the natural resources remains constant, the competition effect could be strong enough to dominate the market size effect for high values of transport costs (ϕ low enough).[10]

Additionally, implicit differentiation in (1.50) with respect to S_1 and S_2 gives, at the symmetric equilibrium, that

$$\frac{\partial w}{\partial S_1} = -\frac{\partial w}{\partial S_2} = \frac{1}{S^*}\frac{2(\sigma-1)\left[1+\Psi^*(\phi)(1-\alpha)\frac{1+\phi}{1-\phi}\right]}{2\sigma-1+\phi+\frac{\Psi^*(\phi)(1+\phi)}{(1-\phi)^2}\left[(1+\phi)^2+2(\sigma-1)(2\alpha\phi+1-\phi)\right]} > 0 \quad (1.53)$$

[10]Note that $\frac{\partial\hat{\phi}}{\partial\alpha} < 0$, which implies that an increase in α reinforces the market size effect. If α increases, the linkages between the two sectors weaken. So, there is a shift of firm expenditures from primary goods (coming form both regions) to labor (a completely local factor). This reinforces the effect of the market size.

The resource effect is reinforced. The original mechanisms described in Proposition 1 remain, but a new one appears. Note that now a reduction in the primary price due to an increase in S_1 encourages exports of region 1 that must be compensated with an increase in nominal wages of this region. All these mechanisms go in the same direction.

1.4.2. Long-Run Equilibrium

In the long-run the stock of natural resources does not remain constant; its temporary evolution obeys the differential equation (1.19) and population migrates from one region to the other according to (1.21). For the case of a tradable primary good, the ratio of indirect utilities is

$$\frac{V_1}{V_2} = \frac{w_1}{w_2}\left(\frac{P_1}{P_2}\right)^{-\mu}\left(\frac{P_{H_1}}{P_{H_2}}\right)^{-(1-\mu)} \tag{1.54}$$

where P_{H_j} is the resource price index for region $j = 1, 2$. From equations (1.8), its mirror image for region 2, and (1.54) it is clear that when the ratio S_1/S_2 decreases, the ratio of indirect utilities will diminish; and this result is equivalent to property (ii) in Proposition 1.

Hence, the differential equations system (1.19) for $j = 1, 2$ and (1.21) now takes the form:

$$\dot{L}_1 = L_1(1 - L_1)\left[\Delta(w, S_1, S_2) - 1\right] \tag{1.55}$$

$$\dot{S}_1 = S_1\left[g\left(1 - \frac{S_1}{CC}\right) - \epsilon L_{H_1}\right] \tag{1.56}$$

$$\dot{S}_2 = S_2\left[g\left(1 - \frac{S_2}{CC}\right) - \epsilon L_{H_2}\right] \tag{1.57}$$

with $\Delta(w, S_1, S_2)$ defined in the Appendix B (see equation (1.96)), $L_{H_1} = L_1$-L_{E_1}, $L_{H_2} = (g\theta L_1$-$L_{H_1})\,w + g\theta(1$-$L_1)$ according to equation (1.48) and w defined by the balanced trade equation (1.50) as a function of L_1, S_1 and S_2.

The three steady states defined in (1.39)-(1.41) are also steady states of the new system (1.55)-(1.57). However, the stability pattern of the symmetric equilibrium may differ from the case of a non-tradable primary good.

1.4.3. Stability properties

The shaded region in the examples of Figure 1.4 represent the stability regions of the symmetric equilibrium in the space (ϵ,ϕ) for the different sets of parameters.

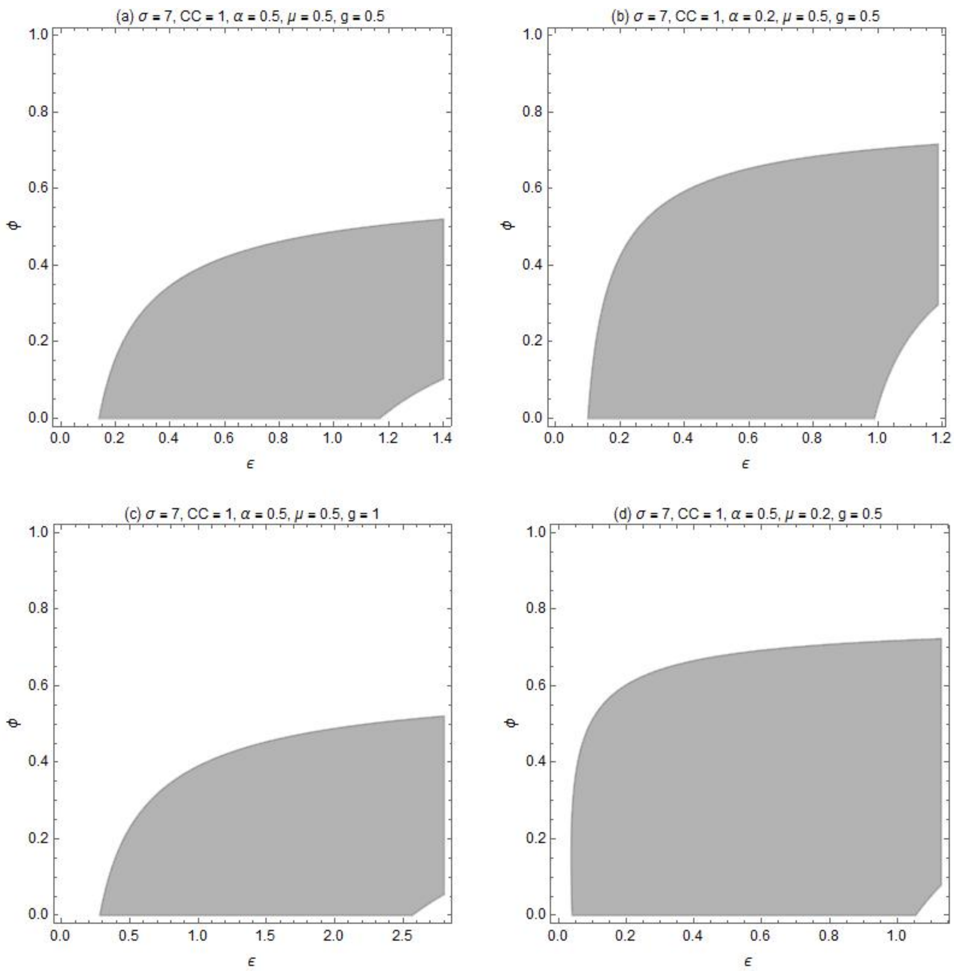

Figure 1.4: Stability region of the symmetric equilibrium (tradable primary good)

Note that, depending on the value of the parameters, several patterns for the symmetric equilibrium may appear. From Figures 1.4a - 1.4d, the predominant pattern is the one that goes from stable to unstable as transport costs decrease. Additionally, some regularities are observed and are worthy of mention.

First, when transport cost are very low, the symmetric equilibrium is unstable for all values of $\epsilon \in (0, 2/\theta)$. Because the primary good now can be exported to the other region (at a low transport cost), the advantage of having a lower primary price is limited. Second, when ϵ is low, the symmetric equilibrium is also unstable. This is due to the interaction between the tradability of the primary good and a low resource effect, caused by a low extractive productivity. Third, in the lower-right quadrant in the (ϵ, ϕ) space, transport costs are high and the tradability of the primary good is limited, then, as happened in Section 1.3, the symmetric equilibrium is unstable.

Finally, if the transport costs of the primary goods were different from those of the industrial goods, similar results could be obtained, but the interaction between the agglomeration and dispersion forces would depend on how these two transport costs relate and vary.

1.5. Conclusions

This chapter presents an extension of Krugman's CP model (1991) and attempts to provide a more comprehensive modelization of the traditional sector, usually treated as residual. Our results allow a better understanding of the migratory processes observed in resource based economies. The model incorporates two key features of the agricultural sector: the dynamics of the renewable natural resources, and the possibility of using raw materials as inputs in the industrial production. In Section 1.3, it is assumed that the primary good is not directly tradable between regions, in order to isolate the resource effect that arises in the model. In Section 1.4 we extend the analysis to the case of a tradable primary good. Another major difference between our model and the original CP model is the free labor mobility between sectors.

The core-periphery model presented in this chapter has all the effects of the traditional NEG models: market size effect, price index effect and competition effect. Once we incorporate the dynamics of the natural resources into the analysis, a new dispersion force arises: the resource effect. Under certain conditions, this dispersion force overcomes the agglomeration ones driven by the industrial price index and the market size effect, making the symmetric equilibrium stable. In real examples worldwide, it is observed that this force provokes environmental-induced migration (Andrew, 2003; Kirby, 2004; Jouanjean et al., 2014, among others).

If the primary good is not tradable, the effect of transport costs on the stability pattern of the traditional core-periphery models is reversed. For high transport costs one might expect agglomeration to take place (if the new dispersion force is not too strong). However, as transport cost decreases, imports become cheaper and the advantage of being in the largest region diminishes. For example, the construction of new roads increases the profitability of the exploitation of forest and soil in distant areas in Laos, the Philippines, Paraguay, Brazil, Peru, Panama and Bolivia, encouraging the expansion and dispersion of the economic activity (Laurence et al., 2009; and Reymondin et al., 2013).

Our model also gives insights into the transition between agglomeration and dispersion of the economic activity and highlights the role of the extraction productivity in the primary sector. The conditions for a pitchfork bifurcation and a Hopf bifurcation are determined. Depending on the productivity of the primary sector, the pitchfork bifurcation can be subcritical or supercritical, and these two patterns illustrate different processes. On the one hand, strong agglomeration forces (subcritical), imply a sudden change in the spatial distribution of the economic activity, as in the rapid shift that took place in the exploitation of the sea urchin fisheries in Chile (Andrew et al., 2003). On the other hand, strong dispersion forces (supercritical), imply a smooth change, as observed in the slow depopulation driven by the decline in soil fertility in Italy (Dazzi and Lo papa, 2013)

Another important result is the existence of a Hopf bifurcation, which makes the appearance of a branch of periodic solutions feasible, so introducing cyclic behavior in the dynamics. When the extraction productivity of the primary sector is too high , economic activity will tend to agglomerate in one region until the primary good becomes too expensive, and then a dispersion process takes place. However, due to the high extraction productivity, the stock of the resource takes longer to renew and, while this happens, more firms continue to arrive in the other region, so agglomeration is taking place now in this region. This is a completely new result in CP models in continuous-time.

If the primary good is tradable, several bifurcation patterns may appear, depending on the value of the parameters. Also, some regularities are observed. First, reductions in the transport costs of the primary goods weaken the dispersion forces associated to the resource, then, for low values of transport cost the dispersion equilibrium is unstable. Second, for low values of the extraction productivity, the symmetric equilibrium is also unstable. In most cases, the symmetric equilibrium goes from stable to unstable as the openness of trade increases.

1.6. References

Adhikari, M., Nagata, S. & Adhikari, M. (2004). Rural household and forest: an evaluation of household's dependency on community forest in Nepal. Journal of Forest Research, 9(1), 33-44.

Anderson, S. C., Flemming, J. M., Watson, R., & Lotze, H. K. (2011). Serial exploitation of global sea cucumber fisheries. Fish and Fisheries, 12(3), 317-339.

Agunias, D. R., & Newland, K. (2007). Circular migration and development: Trends, policy routes, and ways forward. Policy Briefs, Migration Policy Institute.

Andrew, N., Agatsuma, Y., Ballesteros, E., Bazhin, A., Creaser, E., Barnes, D., ... & Einarsson, S. (2003). Status and management of world sea urchin fisheries. Oceanography and Marine Biology-an Annual Review, 40, 343-425.

Baldwin, R., Forslid, R., Martin, P., Ottaviano, G., & Robert-Nicoud, F. (2003). Public policies and economic geography. Princeton: PUP.

Berliant, M., & Kung, F. C. (2009). Bifurcations in regional migration dynamics. Regional Science and Urban Economics, 39(6), 714-720.

Bilsborrow, R. E., & DeLargy, P. F. (1990). Land use, migration, and natural resource deterioration: The experience of Guatemala and the Sudan. Population and Development Review, 16, 125-147.

Carr, D. (2009). Population and deforestation: why rural migration matters. Progress in Human Geography, 33(3), 355-378.

Cerina, F., & Mureddu, F. (2014). Is agglomeration really good for growth? Global efficiency, interregional equity and uneven growth. Journal of Urban Economics, 84, 9-22.

Chambron, A. C. (1999). Bananas: The" Green Gold" of the TNCs. Hungry for Power, UK Food Group, London.

Clark, C. W. (1990) Mathematical Bioeconomics: the optimal management of renewable resources, 2nd ed., John Wiley & Sons, Inc., Hoboken, New Jersey.

Constant, A. F., & Zimmermann, K. F. (2012). The dynamics of repeat migration: a Markov chain analysis. International Migration Review, 46(2), 362–388.

Dazzi, C., & Papa, G. L. (2013). Soil threats. In The Soils of Italy (pp. 205-245). Springer Netherlands.

Dixit, A. K., & Stiglitz, J. E. (1977). Monopolistic competition and optimum product diversity. The American Economic Review, 67(3), 297-308.

European Migration Network (2011). Temporary and Circular Migration:empirical evidence, current policy practice and future options in the EU Members States. European Migration Network. European Commission.

Forslid, R., & Ottaviano, G. I. (2003). An analytically solvable core-periphery model. Journal of Economic Geography, 3(3), 229-240.

Fujita, M., Krugman, P. R., & Venables, A. (2001). The spatial economy: Cities, regions, and international trade. MIT press. Massachusetts.

Gandolfo, G. (1997). Economic Dynamics. Springer-Verlag. Berlin.

Guckenheimer, J., & Holmes, P. (1983). Nonlinear oscillations, dynamical systems, and bifurcations of vector fields. Applied Mathematical Series, 42. Springer, New York.

Helpman, E. (1998). The size of regions, in: Pines, D., Sadka, E. and Zilcha, I. (Eds),Topics in public economics, Cambridge University Press, Cambridge, pp.33-54.

Jouanjean, M. A., Tucker, J., & te Velde, D. W. (2014). Understanding the effects of resource degradation on socio-economic outcomes in developing countries. March 2014. Shaping policy for development Report odi.org

Kaimowitz, D., Méndez, P., Puntodewo, A., & Vanclay, J. K. (2002). Spatial regression analysis of deforestation in Santa Cruz, Bolivia.

Kirby, M. X. (2004). Fishing down the coast: historical expansion and collapse of oyster fisheries along continental margins. Proceedings of the National Academy of Sciences of the United States of America, 101(35), 13096-13099.

Krugman, P. (1980). Scale economies, product differentiation, and the pattern of trade. The American Economic Review, 70(5), 950-959.

Krugman, P. (1991). Increasing Returns and Economic Geography. The Journal of Political Economy, 99(3), 483-499.

Krugman, P., Elizondo, R. L. (1996), Trade policy and the third world metropolis, Journal of Development Economics, 49 (1), 137-150.

Laerhoven, F. V., & Ostrom, E. (2007). Traditions and Trends in the Study of the Commons. International Journal of the Commons, 1(1), 3-28.

Lanaspa, L. F., & Sanz, F. (1999). Krugman's core-periphery model with heterogeneous quality of land. Urban Studies, 36(3), 499-507.

Laurance, W. F., Goosem, M., & Laurance, S. G. (2009). Impacts of roads and linear clearings on tropical forests. Trends in Ecology & Evolution, 24(12), 659-669.

Leite, V., Castro, S. B., & Correia-da-Silva, J. (2013). A third sector in the core-periphery model: non-tradable goods. The Annals of Regional Science, 50(1), 71-108.

Martínez-García. M. P., & Morales, J. R. (2016). Resource effects in the Core-periphery model. Geocomplexity Discussion Papers, ISSN 2409-7497.

Murata, Y., Thisse, J. F. (2005), A simple model of economic geography à la Helpman-Tabuchi, Journal of Urban Economics, 58 (1), 137-155.

Newland, K. (2009): Circular Migration and Human Development. Human Development Research Paper (HDRP), Series , Vol. 42, No. 2009.

Ottaviano, G. I., & Puga, D. (1998). Agglomeration in the global economy: a survey of the 'new economic geography'. The World Economy, 21(6), 707-731.

Pfaff, A. S. (1999). What drives deforestation in the Brazilian Amazon?: evidence from satellite and socioeconomic data. Journal of Environmental Economics and Management, 37(1), 26-43.

Pflüger, M. (2001). Ecological Dumping under Monopolistic Competition. Scandinavian Journal of Economics, 103(4), 689-706.

Pflüger, M., & Südekum, J. (2008). Integration, agglomeration and welfare. Journal of Urban Economics, 63(2), 544-566.

Pflüger, M., & Tabuchi, T. (2010). The size of regions with land use for production. Regional Science and Urban Economics, 40(6), 481-489.

Rauscher, M. (2009). Concentration, separation, and dispersion: Economic geography and the environment. Thünen-series of applied economic theory, 109.

Rauscher, M., & Barbier, E. B. (2010). Biodiversity and geography. Resource and Energy Economics, 32(2), 241-260.

Reymondin, L., Argote, K., Jarvis, A., Navarrete, C., Coca, A., Grossman, D., ... & Suding, P. H. (2013). Road Impact Assessment Using Remote Sensing Methodology for Monitoring Land-Use Change in Latin America: Results of Five Case Studies. Inter-American Development Bank.

Rieber, A., & Tran, T. A. D. (2009). The Effects of Unilateral Environmental Regulations in a World with Capital Mobility and Trading Costs. Asia-Pacific Journal of Accounting & Economics, 16(3), 317-338.

Robinson, E. J., Albers, H. J., & Williams, J. C. (2008). Spatial and temporal modeling of community non-timber forest extraction. Journal of Environmental Economics and Management, 56(3), 234-245.

Sidorov, A. V., & Zhelobodko, E. (2013). Agglomeration and spreading in an asymmetric world. Review of Development Economics, 17(2), 201-219.

Suedekum, J. (2006). Agglomeration and regional costs of living. Journal of Regional Science, 46(3), 529-543.

Swain, A. (1996). Environmental migration and conflict dynamics: focus on developing regions. Third World Quarterly, 17(5), 959-974.

Tabuchi, T., Thisse, J.F. & Zhu, X. (2016). Does technological progress magnify regional disparities?. Forthcoming in International Economic Review.

Vardas, G., & Xepapadeas, A. (2015). Time Scale Externalities and the Management of Renewable Resources. Nota di Lavoro 27.2015, Milan, Italy: Fondazione Eni Enrico Mattei

Waldo, S., Jensen, F., Nielsen, M., Ellefsen, H., Hallgrimsson, J., Hammarlund, C., Hermansen, Ø & Isaksen, J. (2016). Regulating multiple externalities: the Case of Nordic Fisheries. Marine Resource Economics, 31(2), 233-257.

Zeng, D. Z., & Zhao, L. (2009). Pollution havens and industrial agglomeration. Journal of Environmental Economics and Management, 58(2), 141-153.

1.7. Appendix A

Proof of equation (1.32): Following Krugman (1991), $z_{11} \equiv \frac{n_1 c_{11} p_1}{n_2 c_{21} p_2 \tau}$ can be defined as the ratio of region 1 expenditure on local manufactures to that on manufactures from region 2. In a similar way, $z_{12} \equiv \frac{n_1 c_{12} p_1 \tau}{n_2 c_{22} p_2}$ is the expenditure of region 2 on region 1 industrial goods with respect to goods produced in region 2. Thus, the equilibria for the industrial sectors in both regions are

$$n_1 p_{H_1} h_1 + w_1 L_{E_1} = \mu \left\{ \frac{z_{11}}{1+z_{11}} L_1 w_1 + \frac{z_{12}}{1+z_{12}} L_2 w_2 \right\} \tag{1.58}$$

$$n_2 p_{H_2} h_2 + w_2 L_{E_2} = \mu \left\{ \frac{1}{1+z_{11}} L_1 w_1 + \frac{1}{1+z_{12}} L_2 w_2 \right\} \tag{1.59}$$

Using equations (1.26), (1.30) and (1.31), the previous two equations can be reduced to the single

$$TB = \overbrace{\frac{1}{1+z_{11}} L_1 w_1}^{\text{Imports of region 1}} - \overbrace{\frac{z_{12}}{1+z_{12}} L_2 w_2}^{\text{Exports of region 1}} = 0 \tag{1.60}$$

which guarantees that trade is balanced. Rearranging terms in equation (1.60) we have that

$$z_{12} \left(1 + z_{11}\right) \frac{L_2}{L_1} - \left(1 + z_{12}\right) w = 0 \tag{1.61}$$

where $w \equiv w_1/w_2$. Note that, from (1.31) and (1.5),

$$z_{11} \equiv \frac{n_1 c_{11} p_1}{n_2 c_{21} p_2 \tau} = \frac{L_1}{L_2} \left(\frac{p}{\tau}\right)^{1-\sigma} \quad \text{and} \quad z_{12} \equiv \frac{n_1 c_{12} p_1 \tau}{n_2 c_{22} p_2} = \frac{L_1}{L_2} \left(p\tau\right)^{1-\sigma} \tag{1.62}$$

where $p = p_1/p_2$ is defined in (1.24). Replacing (1.62) into (1.61), and taking into account (1.24), equation (1.32) is obtained.

Moreover, given L_1, S_1, S_2 and ϕ, function $p(S_1/S_2)^{1-\alpha}$ is an increasing straight line as a function of p (which takes the value 0 at $p = 0$) and $p^{1-\sigma}(\phi + L_1/(1-L_1)p^{1-\sigma})/(1 + L_1/(1-L_1)p^{1-\sigma}\phi)$ is a strictly increasing and convex function of p. Then, given the values of L_1, S_1, S_2 and ϕ, there exists a unique positive value p such that (1.32) is satisfied.

Proof of proposition 1: From equations (1.24) and (1.32) we have that

$$\hat{p} = \frac{np^{1-\sigma}(1-\phi^2)\hat{n} - (1-\alpha)\,\psi_1 \left(\hat{S}_1 - \hat{S}_2\right)}{\psi_1 + \psi_2} \tag{1.63}$$

$$\psi_1 \equiv \left(w/p^{1-\sigma}\right)\left(1 + np^{1-\sigma}\phi\right)^2 > 0 \tag{1.64}$$

$$\psi_2 \equiv (\sigma - 1)\left[\phi\left(1 + \left(np^{1-\sigma}\right)^2\right) + 2np^{1-\sigma}\right] > 0 \tag{1.65}$$

where $n \equiv n_1/n_2$, $w \equiv w_1/w_2$, and $\hat{x} \equiv dx/x$ for each variable x. Additionally, from (1.24) we have that

$$\hat{w} = \hat{p} + (1-\alpha)\left(\hat{S}_1 - \hat{S}_2\right)$$

Then, by using expression (1.63) we obtain

$$\hat{w} = \frac{\left(np^{1-\sigma}\right)\hat{n} + (1-\alpha)\,\psi_2\left(\hat{S}_1 - \hat{S}_2\right)}{\psi_1 + \psi_2} \tag{1.66}$$

Moreover, from (1.7), (1.10) and (1.24), we have that

$$\begin{aligned} \hat{P} &= \frac{np^{1-\sigma}\left(1-\phi^2\right)}{\left(np^{1-\sigma}+\phi\right)\left(np^{1-\sigma}\phi+1\right)}\left(\hat{p} - \frac{\hat{n}}{\sigma-1}\right) \\ \hat{p}_H &= \hat{p} - \alpha\left(\hat{S}_1 - \hat{S}_2\right) \end{aligned}$$

where $P \equiv P_1/P_2$ and $p_H \equiv p_{H_1}/p_{H_2}$. Replacing expression (1.63) we arrive to

$$\hat{P} = -\frac{1-\phi^2}{\left(np^{1-\sigma}\right)^{-1}}\frac{\left[\psi_1\text{-}\left(\sigma\text{-}1\right)np^{1-\sigma}+\psi_2\right]\hat{n} + \left(1\text{-}\alpha\right)\left(\sigma\text{-}1\right)\psi_1\left(\hat{S}_1 - \hat{S}_2\right)}{\left(\sigma-1\right)\left(np^{1-\sigma}+\phi\right)\left(np^{1-\sigma}\phi+1\right)\left(\psi_1+\psi_2\right)} \tag{1.67}$$

$$\hat{p}_H = \frac{\left(np^{1-\sigma}\right)\hat{n} - \left(\psi_1 + \alpha\psi_2\right)\left(\hat{S}_1 - \hat{S}_2\right)}{\psi_1 + \psi_2} \tag{1.68}$$

where $\psi_2 - (\sigma-1)\,np^{1-\sigma} > 0$. In the three expressions (1.66)-(1.68), the resource effect are the terms associated to $\left(\hat{S}_1 - \hat{S}_2\right)$. Note that, if population increases in region 1, the steady state values S_j^*, given by (1.33), vary

$$\frac{dS_1^*}{dL_1} \leq 0, \quad \frac{dS_2^*}{dL_1} \geq 0$$

Since S_j^*, $j = 1, 2$, are globally stable, the natural resources S_j, $j = 1, 2$, will adjust immediately to their long-run values. Thus, $\hat{S}_1 - \hat{S}_2 < 0$, which implies that, due to the resource dynamics, the ratio of nominal wages decreases (property (i)), according to (1.66). Additionally, the ratio of industrial price indexes and the ratio of primary prices increases (property (ii)), according to (1.67) and (1.68) respectively.

Obviously, while the stock of natural resources moves to its long-run level S_j^*, the remaining variables of the model move simultaneously. The final effect on the indirect utilities will be the addition of the previous effect, linked to the resource, and the usual ones: competition, market size and price index effects.

Proof of proposition 2: The Jacobian matrix of the dynamic system (1.35)-(1.37) at the symmetric solution (1.39) is

$$J^*_{1/2} = \begin{pmatrix} a & b & -b \\ -c & d & 0 \\ c & 0 & d \end{pmatrix} \tag{1.69}$$

with

$$a = \frac{\mu(2\sigma-1)}{\sigma-1}\frac{(1-\phi)}{2\sigma-(1-\phi)},\ b = \frac{1}{4S^*}\left(1-\mu+\mu(1-\alpha)\frac{2\sigma-(1+\phi)}{2\sigma-(1-\phi)}\right),\ c = \epsilon\theta g S^*,\ d = -\frac{gS^*}{CC}. \tag{1.70}$$

where $S^* = (1\text{-}\epsilon\theta/2)CC$.The characteristic polynomial is equal to $P(\lambda)$=(d-λ)[λ^2-(a+d)λ+ ad+2bc], so the eigenvalues can be explicitly calculated and the three of them are negative if and only if (1.43) is satisfied.

In the case of the agglomeration equilibrium (1.40), the Jacobian matrix is

$$J^*_1 = \begin{pmatrix} 1-(1-\epsilon\theta)^{1-\mu\alpha-\mu(1-\alpha)/\sigma}\,\phi^{-\frac{\mu(2\sigma-1)}{\sigma(\sigma-1)}} & 0 & 0 \\ -\epsilon\theta g S^*_1 & -g\,(1-\epsilon\theta) & 0 \\ \epsilon\theta g S^*_2 & 0 & -g \end{pmatrix}.$$

Hence, the three eigenvalues are negative if and only if condition (1.44) is satisfied. The same condition ensures the stability of the equilibrium (1.41).

The case of agglomeration equilibrium (1.42) though, can not be analyzed through the Jacobian matrix. Nevertheless, it is always unstable. Note that if $S_1 \to CC$ and $S_2 \to 0$, a solution with L_1 diminishing while $p \to 0$ is not reachable and (1.42) is unstable.

Proposition 3[11] If $\phi^B, \phi^S \in (0,1)$ and $\epsilon < \bar{\epsilon}$, there exist two interior non-symmetric equilibria that bifurcate from the symmetric equilibrium at the value $\phi = \phi^B$. At this point, the stability properties of the symmetric equilibrium change and a pitchfork bifurcation appears. If $\epsilon\theta < 1$, the two branches of the bifurcation (new equilibria) converge to the agglomeration equilibria at $\phi = \phi^S$. Furthermore,

(i) if $\epsilon < \min\{\tilde{\epsilon}, \bar{\epsilon}\}$, the pitchfork bifurcation is subcritical; that is, the equilibria on the branches are locally unstable.

(ii) if $\tilde{\epsilon} < \epsilon < \bar{\epsilon}$ the pitchfork bifurcation is supercritical; that is, the equilibria on the branches are locally stable.

where $\tilde{\epsilon} > 0$ is the intersection point of ϕ^B and ϕ^S.

[11]This proposition has been stated in section 1.3.3 in economic terms. Here, in order to follow the proof, we have restated it using more technical language.

Proof of proposition 3: It is necessary to prove the existence of the non-symmetric interior equilibria and only two branches of non-symmetric interior equilibria exist. To prove their existence, we look for a pitchfork bifurcation of the symmetric equilibrium, following Guckenheimer and Holmes (1983) and Forslid and Ottaviano (2003). Note that a pitchfork bifurcation only takes place when $\epsilon < \bar{\epsilon}$. Otherwise, if $\epsilon > \bar{\epsilon}$, the curve ϕ^B separates two regions for which the symmetric equilibrium is unstable (a saddle point vs. an unstable node).

The following steps are taken: 1. The variables are changed so that the system has a fixed point at the origin $(0,0,0)$; 2. A new parameter (γ) is defined such that for $\gamma = 0$ the Jacobian matrix has an eigenvalue equal to zero; 3. A change of coordinates is made using the eigenvectors; 4. A Taylor second order approximation of the center manifold is made; 5. The derivatives that prove the existence of a pitchfork bifurcation are calculated; and 6. The sign of the derivatives is analyzed, which determines if the bifurcation is subcritical or supercritical

Step 1: Note that $\left|J^*_{1/2}\right| = 0$ if and only if $\phi = \phi^B$, then the symmetric equilibrium (1.39) becomes non-hyperbolic at $\phi = \phi^B$ and it is characterized by a one-dimensional center manifold. For mathematical tractability, variables L_1, S_1 and S_2 are changed to $l = L_1 - 1/2$, $s_1 = S_1 - CC\,[1 - \epsilon\theta/2]$ and $s_2 = S_2 - CC\,[1 - \epsilon\theta/2]\,$, so the new system would have a fixed point at the origin $(0,0,0)$.

Step 2: We define a new parameter $\gamma \equiv \mu(2\sigma - 1)\left(\frac{1-\phi}{2\sigma-(1-\phi)} - \frac{1-\phi^B}{2\sigma-(1-\phi^B)}\right)$, so $\gamma = 0$ if and only if $\phi = \phi^B$. If this is the case, we shall call the Jacobian matrix $J^*_{(1/2,0)}$ and, for the cases where $\gamma \neq 0$, this matrix will be called $J^*_{(1/2,\gamma)}$. The dynamics of l, s_1 and s_2 are given by

$$\begin{pmatrix} \dot{l} \\ \dot{s}_1 \\ \dot{s}_2 \end{pmatrix} = J^*_{\left(\frac{1}{2},\gamma\right)} \begin{pmatrix} l \\ s_1 \\ s_2 \end{pmatrix} + \begin{pmatrix} g^l(l,s_1,s_2) \\ g^{s_1}(l,s_1,s_2) \\ g^{s_2}(l,s_1,s_2) \end{pmatrix}$$

where $g^l(l,s_1,s_2)$, $g^{s_1}(l,s_1,s_2)$ and $g^{s_2}(l,s_1,s_2)$ form the non-linear part of the system.

Note that the following property is satisfied:

$$J^*_{\left(\frac{1}{2},\gamma\right)} = J^*_{\left(\frac{1}{2},0\right)} + \gamma \begin{pmatrix} \frac{1}{\sigma-1} & \frac{1-\alpha}{4\sigma S^*} & -\frac{1-\alpha}{4\sigma S^*} \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}.$$

where $S^* = (1 - \epsilon\theta/2)CC$. The matrix $J^*_{(1/2,0)}$ has the following eigenvalues: 0,-g(1-$\epsilon\frac{\theta}{2}$), and $\mu(2\sigma-1)(1-\phi^B)/\left[(\sigma-1)(2\sigma-(1-\phi^B))\right] - g(1-\epsilon\frac{\theta}{2})$.

Step 3: Using the eigenvectors as a basis for a new coordinate system (u, v, and w), we set

$$\begin{pmatrix} l \\ s_1 \\ s_2 \end{pmatrix} = Q \begin{pmatrix} u \\ v \\ w \end{pmatrix} \text{ with } Q = \begin{pmatrix} \frac{1}{\epsilon\theta CC} & 0 & \frac{2\sigma(1-\alpha\mu)-\mu(1-\alpha)}{gCC(2-\epsilon\theta)[\epsilon\theta(1+\alpha(\sigma-1))+2\sigma(1-\epsilon\theta)]} \\ -1 & 1 & -1 \\ 1 & 1 & 1 \end{pmatrix},$$

where Q is the matrix of eigenvectors of $J^*_{(1/2,0)}$. Then,

$$\begin{pmatrix} \dot{u} \\ \dot{v} \\ \dot{w} \end{pmatrix} = Q^{-1} J^*_{(1/2,0)} Q \begin{pmatrix} u \\ v \\ w \end{pmatrix} + \gamma Q^{-1} \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} Q \begin{pmatrix} u \\ v \\ w \end{pmatrix} \tag{1.71}$$

$$+Q^{-1} \begin{pmatrix} g^l((u,v,w)^t Q^t) \\ g^{s_1}((u,v,w)^t Q^t) \\ g^{s_2}((u,v,w)^t Q^t) \end{pmatrix} \tag{1.72}$$

Step 4: Let $v = h_1(u,\gamma) = a_1u^2 + b_1u\gamma + c_1\gamma^2$ and $w = h_2(u,\gamma) = a_2u^2 + b_2u\gamma + c_2\gamma^2$ be the second order Taylor approximation of the invariant center manifold . Taking this into account in (1.71) we obtain that $\dot{u} = f(u,\gamma) + \mathcal{O}(3)$, where $\mathcal{O}(3)$ means terms of order u^3, $u^2\gamma$, $u\gamma^2$ and γ^3.

Moreover,

$$\dot{v} = \left(\frac{\partial h_1}{\partial u}, \frac{\partial h_1}{\partial \gamma}\right) \begin{pmatrix} \dot{u} \\ \dot{\gamma} \end{pmatrix} = (2a_1u + b_1\gamma)\,\dot{u} + (b_1u + 2c_1\gamma)\,\dot{\gamma} \tag{1.73a}$$

$$\dot{w} = \left(\frac{\partial h_2}{\partial u}, \frac{\partial h_2}{\partial \gamma}\right) \begin{pmatrix} \dot{u} \\ \dot{\gamma} \end{pmatrix} = (2a_2u + b_2\gamma)\,\dot{u} + (b_2u + 2c_2\gamma)\,\dot{\gamma} \tag{1.73b}$$

$$\dot{\gamma} = 0 \tag{1.73c}$$

Step 5: We can directly calculate $\frac{\partial \dot{u}}{\partial u}$, $\frac{\partial^3 \dot{u}}{\partial u^3}$, and $\frac{\partial^2 \dot{u}}{\partial u \partial \gamma}$ in the center manifold for ($u = 0$ and $\gamma = 0$) by using expressions (1.73a), (1.73b), and $\dot{u}$ from the system (1.71). For calculating these derivatives we have used the Taylor polynomial of order three of p, implicitly defined by (1.32) as a function of S_1/S_2 and L_1, at the symmetric equilibrium.

$$\frac{\partial \dot{u}}{\partial u}(0,\gamma) = \frac{\partial f}{\partial u}(0,\gamma) = 0 \tag{1.74}$$

$$\frac{\partial^2 \dot{u}}{\partial u \partial \gamma}(0,0) < 0 \tag{1.75}$$

These results together indicate a pitchfork bifurcation. The first derivative (1.74) implies that $u = 0$ is always an equilibrium, and that $\dot{u}$ rotates above this equilibrium. The cross derivative (1.75) shows in which direction the equilibrium loses its stability. From the analysis of $J^*_{\frac{1}{2}}$ in Proposition 2 and the definition of γ, it is known that the equilibrium $u = 0$ is stable when $\gamma < 0$, and unstable when $\gamma > 0$. Then, the cross derivative (1.75) is negative.

Note that ϕ^B and ϕ^S take the value 1 at $\epsilon = 0$ and both curves decreace as ϵ increases. At $\epsilon = \theta^{-1}$ function $\phi^B > \phi^S = 0$. Moreover, $\partial^2\phi^S/\partial\epsilon^2 > \partial^2\phi^B/\partial\epsilon^2$ at $\epsilon = 0$, therefore, there exists a value $0 < \tilde{\epsilon} < \theta^{-1}$ such that $\phi^B < \phi^S$ if $\epsilon < \tilde{\epsilon}$ and $\phi^B > \phi^S$ if $\epsilon > \tilde{\epsilon}$. At $\tilde{\epsilon}$ the sign of the following derivative changes.

$$\frac{\partial^3 \dot{u}}{\partial u^3}(0,0) = \frac{16[\sigma\text{-}\mu(1+\alpha(\sigma\text{-}1))]}{\mu^3 C C^3 \left(1\text{-}\frac{\epsilon\theta}{2}\right)^3} \frac{A\,(\epsilon\theta)^2 + B\,\epsilon\theta + C}{\det Q\,(2\sigma\text{-}1)^2 \epsilon\theta[\epsilon\theta(1+\alpha(\sigma\text{-}1)) + 2\sigma(1\text{-}\epsilon\theta)]} \tag{1.76}$$

where $C = 12\mu^2(\sigma\text{-}1)(2\sigma\text{-}1)(1\text{-}\mu\text{-}\sigma(1\text{-}\mu\alpha)) < 0$, A and B are constants that depend on σ, μ and α.

The sign of the third derivative (1.76) indicates if the bifurcation is subcritical or supercritical. This issue will be studied in step 6.

Once the existence of two non-symmetric equilibria is granted, it is necessary to prove that there are only two branches of interior non-symmetric equilibria. According to equation (1.35), the non-symmetric interior equilibria should satisfy the following equation for $L_1 \neq \frac{1}{2}$,

$$p = \left[\frac{1-\epsilon\theta L_1}{1-\epsilon\theta\,(1-L_1)}\right]^{-\rho} \text{ with } \rho \equiv \frac{(1-\alpha\mu)\,(\sigma-1) + \mu\,(1-\alpha)}{\mu\,(2\sigma-1)} \tag{1.77}$$

where p is a function of L_1 and ϕ defined by equation (1.32), that can be restate as,

$$\phi\,(L_1, S_1, S_2, p) = p^{-(1-\sigma)} \frac{(1-L_1)\,p\,(S_1/S_2)^{1-\alpha} - L_1 p^{2(1-\sigma)}}{(1-L_1) - L_1 p\,(S_1/S_2)^{1-\alpha}} \tag{1.78}$$

Substituting (1.78) into (1.77) we obtain a map that assigns a unique value of ϕ for each value of L_1, as depicted in Figure 1.2. Indeed, equation (1.77) defines ϕ as a continuous and differentiable function of L_1, if $L_1 \neq \frac{1}{2}$,

$$\phi(L_1) = \left[\frac{1-\epsilon\theta L_1}{1-\epsilon\theta(1-L_1)}\right]^{-\rho(\sigma-1)} \frac{(1-L_1)\left[\frac{1-\epsilon\theta L_1}{1-\epsilon\theta(1-L_1)}\right]^{1-\alpha-\rho} - L_1\left[\frac{1-\epsilon\theta L_1}{1-\epsilon\theta(1-L_1)}\right]^{2\rho(\sigma-1)}}{(1-L_1) - L_1\left[\frac{1-\epsilon\theta L_1}{1-\epsilon\theta(1-L_1)}\right]^{1-\alpha-\rho}} \tag{1.79}$$

Note that $\phi(0) = \phi(1) = (1-\epsilon\theta)^{\frac{\sigma-1}{\mu(2\sigma-1)}[\sigma(1-\mu\alpha)-\mu(1-\alpha)]} = \phi^S$. This implies that the non-symmetric equilibria emerging from the bifurcation and the ones characterized by equation (1.77) form two branches that are born at ϕ^B and converge to ϕ^S if the economy agglomerates ($L_1 = 0$ or $L_1 = 1$).

Step 6. The sign of the third derivative $\frac{\partial^3 \dot{u}}{\partial u^3}(0,0)$ indicates whether the bifurcation is subcritical or supercritical. The denominator in (1.76) is positive. Therefore, the third derivative is negative (positive) if $\epsilon < \tilde{\epsilon}$ ($\tilde{\epsilon} < \epsilon < \bar{\epsilon}$), predicting a subcritical pitchfork bifurcation (supercritical).

Proposition 4[12] If $\phi > \phi^i$, the critical value ϕ^H is a Hopf bifurcation point of system (1.35)-(1.37).

[12] This proposition has been stated in section 1.3.3 in economic terms. Here, in order to follow the proof, we have restated it using more technical language.

Proof of proposition 4: The eigenvalues of (1.69) are

$$\lambda_{1,2} = \frac{(a+d) \pm \sqrt{(a+d)^2 - 4(ad+2bc)}}{2a} \text{ and } \lambda_3 = d < 0$$

with a, b, c and d defined in (1.70).

Let us define a new parameter $\eta \equiv \phi - \phi^H = -\frac{2\sigma-1+\phi}{\frac{\mu(2\sigma-1)}{\sigma-1}+g(1-\epsilon\frac{\theta}{2})}(a+d)$. Note that $\eta = 0$ if and only if $\phi = \phi^H$ and, if this is the case, $\lambda_{1,2}$ are two conjugate eigenvalues with zero real part.

According to Gandolfo (1997, page 477), the system has a family of periodic solutions if

- (i) it possesses a pair of simple complex conjugate eigenvalues $\theta(\eta) \pm \omega(\eta)i$, that become pure imaginary at the critical value η_0, and no other eigenvalues with zero real part exist
- (ii) and
$$\left.\frac{\partial\theta(\eta)}{\partial\eta}\right|_{\eta_0} \neq 0$$

Eigenvalues $\lambda_{1,2}$ are simple complex conjugate if $(a+d)^2 < 4\,(ad+2bc)$, that is

$$\left(\frac{\mu(2\sigma-1)}{\sigma-1}(\delta-\delta^H)\right)^2 < 4\mu(2\sigma-1)g\left(\frac{1-\alpha}{\sigma}\frac{\epsilon\theta}{2} - \frac{1-\epsilon\theta/2}{\sigma-1}\right)(\delta-\delta^B) \tag{1.80}$$

where $\delta = (1-\phi)/(2\sigma-(1-\phi))$, $\delta^H = (1-\phi^H)/(2\sigma-(1-\phi^H))$ and $\delta^B = (1-\phi^B)/(2\sigma-(1-\phi^B))$ which is equivalent to condition

$$\delta < \delta^i \tag{1.81}$$

where δ^i is the solution of the quadratic equation $(a+d)^2 - 4\,(ad+2bc) = 0$ that satisfies $\delta^i \leq \delta^B$. Note that if $\delta^H = \delta^B$ then $\delta^i = \delta^H = \delta^B$. The previous condition is equivalent to $\phi > \phi^i$.

Moreover, if $\eta_0 = 0$ condition (i) is satisfied. Additionally, given that $a+d$ =-$\eta(\frac{\mu}{\sigma-1}$ (2σ-1)+$\frac{gS^*}{CC}$)/(2σ-1+ϕ), condition (ii) is also satisfied. Then, $\eta_0 = 0$ is a Hopf bifurcation point.

1.8. Appendix B

Short-Run Equilibrium

Equilibrium in the industrial sectors. We define

$$z_{11} \equiv \frac{n_1 c_{11} p_1}{n_2 c_{21} p_2 \tau} = \left(\frac{p}{\tau}\right)^{1-\sigma} \frac{L_{E_1}}{L_{E_2}} \quad \text{and} \quad z_{12} \equiv \frac{n_1 c_{12} p_1 \tau}{n_2 c_{22} p_2} = (p\tau)^{1-\sigma} \frac{L_{E_1}}{L_{E_2}} \tag{1.82}$$

where $p = p_1/p_2$. Thus, the equilibrium for the industrial sectors in both regions requires

$$n_1 \overbrace{(p_{H_1} h_{11} + \tau p_{H_2} h_{12})}^{\frac{1-\alpha}{\alpha} w_1 (l_{x_1} - f)} + w_1 L_{E_1} = \mu \left\{ \frac{z_{11}}{1+z_{11}} L_1 w_1 + \frac{z_{12}}{1+z_{12}} L_2 w_2 \right\} \tag{1.83}$$

$$n_2 \underbrace{(\tau p_{H_1} h_{21} + p_{H_2} h_{22})}_{\frac{1-\alpha}{\alpha} w_2 (l_{x_2} - f)} + w_2 L_{E_2} = \mu \left\{ \frac{1}{1+z_{11}} L_1 w_1 + \frac{1}{1+z_{12}} L_2 w_2 \right\} \tag{1.84}$$

Taking into account (1.18) and industrial demands for primary goods h_{jk} in (1.14)-(1.15) the previous system of equations transforms into

$$\frac{\sigma}{1+\alpha(\sigma-1)} L_{E_1} w_1 = \mu \left\{ \frac{z_{11}}{1+z_{11}} L_1 w_1 + \frac{z_{12}}{1+z_{12}} L_2 w_2 \right\} \tag{1.85}$$

$$\frac{\sigma}{1+\alpha(\sigma-1)} L_{E_2} w_2 = \mu \left\{ \frac{1}{1+z_{11}} L_1 w_1 + \frac{1}{1+z_{12}} L_2 w_2 \right\} \tag{1.86}$$

Dividing by salaries w_j, adding both equations and taking into account that $L_1 + L_2 = 1$ we obtain (1.47) and (1.48). Moreover,

$$L_{E_1} = \frac{\mu \left[1 + \alpha(\sigma-1)\right]}{\sigma} (L_1 w + L_2) \frac{\lambda}{1+\lambda w} \quad \text{and} \quad L_{E_2} = \frac{L_{E_1}}{\lambda} \tag{1.87}$$

with

$$\lambda \equiv \frac{L_{E_1}}{L_{E_2}} = p^{-(1-\sigma)} \frac{\frac{\phi}{p^{1-\sigma}/w - \phi} - \frac{1}{1-\phi p^{1-\sigma}/w} \frac{L_1 w}{L_2}}{\frac{\phi}{1-\phi p^{1-\sigma}/w} \frac{L_1 w}{L_2} - \frac{1}{p^{1-\sigma}/w - \phi}}$$

Equilibrium in the primary good sectors. The equilibrium in the primary sector requires that harvesting equals the demand of primary good from consumers and from the industrial sector. That is,

$$\begin{aligned}
H_1 &= L_1\frac{(1-\mu)\,w_1}{P_{H_1}}\left(\frac{p_{H_1}}{P_{H_1}}\right)^{-\sigma}+n_1\frac{1-\alpha}{\alpha}\frac{w_1}{P_{H_1}}\left(l_{x_1}-f\right)\left(\frac{p_{H_1}}{P_{H_1}}\right)^{-\sigma} \qquad (1.88)\\
&+L_2\tau\frac{(1-\mu)\,w_2}{P_{H_2}}\left(\frac{\tau p_{H_1}}{P_{H_2}}\right)^{-\sigma}+n_2\tau\frac{1-\alpha}{\alpha}\frac{w_2}{P_{H_2}}\left(l_{x_2}-f\right)\left(\frac{\tau p_{H_1}}{P_{H_2}}\right)^{-\sigma}\\
H_2 &= L_2\frac{(1-\mu)\,w_2}{P_{H_2}}\left(\frac{p_{H_2}}{P_{H_2}}\right)^{-\sigma}+n_2\frac{1-\alpha}{\alpha}\frac{w_2}{P_{H_2}}\left(l_{x_2}-f\right)\left(\frac{p_{H_2}}{P_{H_2}}\right)^{-\sigma} \qquad (1.89)\\
&+L_1\tau\frac{(1-\mu)\,w_1}{P_{H_1}}\left(\frac{\tau p_{H_2}}{P_{H_1}}\right)^{-\sigma}+n_1\tau\frac{1-\alpha}{\alpha}\frac{w_1}{P_{H_1}}\left(l_{x_1}-f\right)\left(\frac{\tau p_{H_2}}{P_{H_1}}\right)^{-\sigma}
\end{aligned}$$

Moreover, from (1.88)-(1.89), taking into account (1.9), (1.10) and (1.18) it is obtained that

$$\begin{aligned}
L_{H_1}\frac{w_1}{w_2} &= \frac{q_{11}}{1+q_{11}}\left\{(1\text{-}\mu)L_1+\frac{(1\text{-}\alpha)(\sigma\text{-}1)}{1+\alpha(\sigma\text{-}1)}L_{E_1}\right\}\frac{w_1}{w_2}+\frac{q_{12}}{1+q_{12}}\left\{(1\text{-}\mu)L_2+\frac{(1\text{-}\alpha)(\sigma\text{-}1)}{1+\alpha(\sigma\text{-}1)}L_{E_2}\right\} \qquad (1.90)\\
L_{H_2} &= \frac{1}{1+q_{11}}\left\{(1\text{-}\mu)L_1+\frac{(1\text{-}\alpha)(\sigma\text{-}1)}{1+\alpha(\sigma\text{-}1)}L_{E_1}\right\}\frac{w_1}{w_2}+\frac{1}{1+q_{12}}\left\{(1\text{-}\mu)L_2+\frac{(1\text{-}\alpha)(\sigma\text{-}1)}{1+\alpha(\sigma\text{-}1)}L_{E_2}\right\} \qquad (1.91)
\end{aligned}$$

where the following definitions should be taken into account:

$$\begin{aligned}
q_{11} &\equiv \frac{\left(n_1h_{11}+L_1c_{H_{11}}\right)p_{H_1}}{\left(n_1h_{21}+L_1c_{H_{21}}\right)p_{H_2}\tau}=\left(\frac{w}{\tau}\right)^{1-\sigma}\left(\frac{S_1}{S_2}\right)^{-(1-\sigma)} \qquad (1.92)\\
q_{12} &\equiv \frac{\left(n_2h_{12}+L_2c_{H_{12}}\right)p_{H_1}\tau}{\left(n_2h_{22}+L_2c_{H_{22}}\right)p_{H_2}}=(w\tau)^{1-\sigma}\left(\frac{S_1}{S_2}\right)^{-(1-\sigma)} \qquad (1.93)
\end{aligned}$$

whose interpretations, for the primary goods, are similar to z_{11} and z_{12}.

Balanced trade equation. Replacing L_{E_1} and L_{E_2} from (1.85) and (1.86) into (1.90) and (1.91), and taking into account that $q_{11}/(1+q_{11})=1-1/(1+q_{11})$ we get

$$\begin{aligned}
&\mu L_{H_1}w-\left[\frac{\sigma}{1+\alpha(\sigma\text{-}1)}-\mu\right]L_{E_1}w=(1\text{-}\mu)\left(\frac{q_{12}}{1+q_{12}}L_2-\frac{1}{1+q_{11}}L_1w\right)\\
&+\frac{\mu(1\text{-}\alpha)(\sigma\text{-}1)}{\sigma}\left[\frac{q_{12}}{1+q_{12}}\left(\frac{1}{1+z_{11}}L_1w+\frac{1}{1+z_{12}}L_2\right)-\frac{1}{1+q_{11}}\left(\frac{z_{11}}{1+z_{11}}L_1w+\frac{z_{12}}{1+z_{12}}L_2\right)\right]
\end{aligned}$$

Applying that $1/(1+z_{12})=1-z_{12}/(1+z_{12})$ and $z_{11}/(1+z_{11})=1-1/(1+z_{11})$, together with (1.47)-(1.48),

$$\begin{aligned}
&\mu L_{H_1}w-\mu\frac{L_{H_1}w+L_{H_2}}{L_{E_1}w+L_{E_2}}L_{E_1}w=(1\text{-}\mu)\left(\frac{q_{12}}{1+q_{12}}L_2-\frac{1}{1+q_{11}}L_1w\right)\\
&+\frac{\mu(1\text{-}\alpha)(\sigma\text{-}1)}{\sigma}\left[\left(\frac{1}{1+z_{11}}L_1w-\frac{z_{12}}{1+z_{12}}L_2\right)\left(\frac{q_{12}}{1+q_{12}}+\frac{1}{1+q_{11}}\right)+\frac{q_{12}}{1+q_{12}}L_2-\frac{1}{1+q_{11}}L_1w\right]
\end{aligned}$$

Rearranging the terms:

$$\mu\left(L_1 w - \frac{L_{E_1}w}{L_{E_1}w{+}L_{E_2}}\right) - \frac{\mu(1\text{-}\alpha)(\sigma\text{-}1)}{\sigma}\left(\frac{1}{1{+}z_{11}}L_1 w - \frac{z_{12}}{1{+}z_{12}}L_2\right)\left(\frac{q_{12}}{1{+}q_{12}}{+}\frac{1}{1{+}q_{11}}\right) = \left[1-\mu{+}\frac{\mu(1\text{-}\alpha)(\sigma\text{-}1)}{\sigma}\right]\left(\frac{q_{12}}{1{+}q_{12}}L_2 - \frac{1}{1{+}q_{11}}L_1 w\right)$$

Therefore, the following equation is obtained, which guarantees that trade is balanced (imports of region j equals exports of region j),

$$\left(\frac{1}{1+z_{11}}\frac{L_1 w}{L_2} - \frac{z_{12}}{1+z_{12}}\right)\Psi = \left(\frac{q_{12}}{1+q_{12}} - \frac{1}{1+q_{11}}\frac{L_1 w}{L_2}\right) \tag{1.94}$$

which is equivalent to equation (1.50). Function Ψ, is given by

$$\Psi = \frac{\mu - \frac{\mu(1-\alpha)(\sigma-1)}{\sigma}\left(\frac{q_{12}}{1+q_{12}} + \frac{1}{1+q_{11}}\right)}{1-\mu+\frac{\mu(1-\alpha)(\sigma-1)}{\sigma}} \tag{1.95}$$

Dynamics Population dynamics depends on the ratio of indirect utilities V_j given by

$$\begin{aligned}
\frac{P_1}{P_2} &= \left(\frac{n_1 p_1^{1-\sigma}+n_2(p_2\tau)^{1-\sigma}}{n_1(p_1\tau)^{1-\sigma}+n_2 p_2^{1-\sigma}}\right)^{\frac{1}{1-\sigma}} = \left(\frac{\lambda p^{1-\sigma}+\phi}{\phi\lambda p^{1-\sigma}+1}\right)^{\frac{1}{1-\sigma}} \\
\frac{P_{H_1}}{P_{H_2}} &= \left(\frac{p_{H_1}^{1-\sigma}+\left(p_{H_2}\tau\right)^{1-\sigma}}{\left(p_{H_1}\tau\right)^{1-\sigma}+p_{H_2}^{1-\sigma}}\right)^{\frac{1}{1-\sigma}} = \left(\frac{w^{1-\sigma}\left(\frac{S_1}{S_2}\right)^{-(1-\sigma)}+\phi}{\phi w^{1-\sigma}\left(\frac{S_1}{S_2}\right)^{-(1-\sigma)}+1}\right)^{\frac{1}{1-\sigma}}
\end{aligned}$$

and the dynamic evolutions of the stocks the natural resources and population in the two regions are driven by equations (1.55)-(1.57), with

$$\Delta(w,S_1,S_2) = w\left(\frac{\lambda p^{1-\sigma}+\phi}{\phi\lambda p^{1-\sigma}+1}\right)^{\frac{-\mu}{1-\sigma}}\left(\frac{w^{1-\sigma}(S_1/S_2)^{-(1-\sigma)}+\phi}{\phi w^{1-\sigma}(S_1/S_2)^{-(1-\sigma)}+1}\right)^{-\frac{1-\mu}{1-\sigma}} \tag{1.96}$$

where, as in (1.16)

$$p = w^{\alpha}\left(\frac{w^{1-\sigma}(S_1/S_2)^{-(1-\sigma)}+\phi}{\phi w^{1-\sigma}(S_1/S_2)^{-(1-\sigma)}+1}\right)^{\frac{1-\alpha}{1-\sigma}}$$

The Jacobian matrix of system (1.55)-(1.57) evaluated at dispersion equilibrium (symmetric equilibrium) has the form

$$J^*_{1/2} = \begin{pmatrix} a & b & -b \\ -c & d & e \\ c & e & d \end{pmatrix} \tag{1.97}$$

with $a{=}\frac{1}{4}\left.\frac{\partial\Delta}{\partial L_1}\right|_{1/2}$, $b{=}\frac{1}{4S^*}\left.\frac{\partial\Delta}{\partial(S_1/S_2)}\right|_{1/2}$, $c{=}\epsilon S^*\left.\frac{\partial L_{H_1}}{\partial L_1}\right|_{1/2}$, $e{=}\epsilon\left.\frac{\partial L_{H_1}}{\partial(S_1/S_2)}\right|_{1/2}$ and $d{=}-\frac{gS^*}{CC}-e$. That is,

$$\begin{aligned}
a &= \tfrac{1}{2}\left(\tfrac{(1\text{-}\mu)\phi}{1+\phi}\text{-}\tfrac{\mu(1+\alpha(\sigma\text{-}1))\phi}{(\sigma\text{-}1)(1\text{-}\phi)}\right)\tfrac{\partial w}{\partial L_1}+\tfrac{\mu}{\sigma\text{-}1}\\
b &= \tfrac{1}{2}\left(\tfrac{(1\text{-}\mu)\phi}{1+\phi}\text{-}\tfrac{\mu(1+\alpha(\sigma\text{-}1))\phi}{(\sigma\text{-}1)(1\text{-}\phi)}\right)\tfrac{\partial w}{\partial S_1}+\tfrac{1}{4S^*}\left(\mu(1\text{-}\alpha)+(1\text{-}\mu)\tfrac{1\text{-}\phi}{1+\phi}\right)\\
c &= \epsilon S^*\left[\tfrac{\mu(1+\alpha(\sigma\text{-}1))\phi}{\sigma(1\text{-}\phi)^2}\left(\sigma\text{-}\tfrac{1\text{-}\phi}{2}\text{-}2(1\text{-}\alpha)(\sigma\text{-}1)\tfrac{\phi}{1+\phi}\right)\tfrac{\partial w}{\partial L_1}+1\text{-}\tfrac{\mu(1+\alpha(\sigma-1))(1+\phi)}{\sigma(1\text{-}\phi)}\right]\\
e &= \epsilon S^*\tfrac{\mu(1+\alpha(\sigma\text{-}1))\phi}{\sigma(1\text{-}\phi)^2}\left(\sigma\text{-}\tfrac{1\text{-}\phi}{2}\text{-}2(1\text{-}\alpha)(\sigma\text{-}1)\tfrac{\phi}{1+\phi}\right)\tfrac{\partial w}{\partial S_1}\text{-}\epsilon(1\text{-}\alpha)(\sigma\text{-}1)\tfrac{\mu(1+\alpha(\sigma\text{-}1))\phi}{\sigma(1\text{-}\phi^2)}\\
d &= -\tfrac{gS^*}{CC}-e<0
\end{aligned}$$

where $\partial w/\partial L_1$ and $\partial w/\partial S_1$ are given by (1.51) and (1.53).

The value $d+e=-gS^*/CC<0$ is an eigenvalue of matrix (1.97). Its characteristic polynomial is $P(\mathcal{L})=(d+e-\mathcal{L})\left[\mathcal{L}^2-(a+d-e)\mathcal{L}+2bc+a\,(d-e)\right]$. Then, the symmetric equilibrium is stable if and only if

$$2bc+a(d-e)>0 \tag{1.98}$$

$$a+d-e<0 \tag{1.99}$$

Chapter 2

Disentangling the Resource Effect in NEG Models

Contents

This chapter develops an extension of the Core-Periphery model with an extractive primary sector proposed by Martínez-García and Morales (2019) by allowing for specific transport costs in the primary and the industrial sectors. We focus on the interaction between the so called "resource effect" and transport costs, identifying three channels: wage, firms and primary productivity channels. The resource effect is stronger the higher the extractive productivity and the both transport costs are. We also find that, depending on primary transport costs and the extractive productivity, the symmetric equilibrium presents the following patterns as industrial transport costs diminishes: unstable-stable, stable-unstable-stable, and stable-unstable.

2.1. Introduction

International organizations and scientific committees are trying to attract the attention of politicians and citizens to world environmental problems and their far-reaching consequences for the future of humanity. In particular, they draw attention to the environmental-induced population movements within and across borders (McAuliffe et al., 2017).

Likewise, population growth, either natural growth or by migration, is one of the main causes of the overexploitation of natural resources in rural areas (FAO 2012; FAO, 2018). It is one of the leading forces of agricultural expansion, which causes deforestation in developing regions (FAO, 2012; González-Val and Pueyo, 2019). Additionally, trade of raw materials is also pointed out by environmental economists as one of the key issues for sustainable development. The increasing demand for raw materials from industrialized economies adds pressure on the rural environment and the natural resources. Trade openness often boosts production and consumption, which increase the extraction and harvesting of natural resources (Chichilnisky, 1994; Brander and Taylor, 1997a, 1997b; 1998a, 1998b; Karp et al., 2001; Barbier, 2005; Bulte and Barbier, 2005). Sometimes the effects on a local environment are positive if trade favours less intensive polluting/extracting activities. However, trade implies a reallocation of the intensive industries in other locations, where overexploitation takes place (Nordström and Vaughan, 1999).

On the other hand, the new economic geography (NEG) literature (Krugman 1991; Fujita et al., 2001; Baldwin et al., 2005; among others) claims that population, trade and industrialization are not mutually independent. Furthermore, Martínez-García and Morales (2019) show that trade of raw materials and renewable natural resources depletion also interact with migratory movements and industrialization.

The interactions between population, trade, economic activity and natural resources are especially relevant for developing economies (González-Val and Pueyo, 2019; Martínez-

García and Morales, 2019). Sometimes, population migrate away from rural areas to swelling urban areas in the search for better living standards (Farrell, 2017). Urbanization takes place at the expense of rural depopulation. This concentration of population in big urban areas is particularly pronounced in east and south Asia, Africa, Latin America (Li, Westlund and Liu, 2019), although not exclusively. Consequently, urban regions grow faster and sometimes their natural resource carrying capacity is exceeded. There are documented examples of villages and cities that emerge as a consequence of a natural resource discovery and disappear once the natural resource is exhausted (Takatsuka, Zeng and Zhao, 2015). Furthermore, in many countries of the world, the decline of rural regions is a proven empirical fact (Li, Westlund and Liu, 2019).

The opposite process has taken place in some developed countries (US, UK, Canada and Australia). Small rural communities grew faster than some metropolitan areas between 1970 and 1990. This process, known in the literature as counterurbanization, again has its main driver in migration flows (Mitchell, 2004). It is characterized by the reallocation of metropolitan or urban residents to small rural areas (dispersion).

The aim of this chapter is to provide a broader understanding of the interaction between population migration, trade, the distribution of the economic activity and natural resource exploitation. Particularly, we look for the leading forces that encourage and discourage the dispersion of population and economic activity in resource-based economies. The CP model by Martínez-García and Morales (2019) brings together the traditional effects of NEG models and the new one related with the natural resource- the *resource effect*. This paper considers either a non-tradable primary good, produced from a renewable natural resource, or a tradable primary good at the same transport cost as industrial goods. In the current chapter, we extend this model by allowing primary and industrial trade costs to take any value. This extension enables us to distinguish three channels that nourish the resource effect: the wage channel, the firms channel, and primary labor productivity channel. Different trade assumptions reinforce, weaken or vanish any of these channels.

Natural resources and the consequences of their exploitation and trade remain underexplored in NEG literature. There are some examples such as Takatsuka et al., (2015) that study the consequences of the resource use as an input. Unlike our model, theirs assumes that the resource is produced, not extracted or harvested from a renewable stock with a limited reproductive capacity. The result is a static model, where neither population nor the resource stocks change, which makes the model unable to explain environmental induced migratory movements or reallocation of firms. Riekhof et al., (2018) incorporate a renewable natural resource into an endogenous growth model, to study the relation between international trade, resource conservation and economic growth. Although this model captures the scale effects of economic growth over resource depletion, it does not allow for population migration. González-Val and Pueyo (2019) also incorporate a renewable natural resource in a two-region, two-sector model. However, they focus on economic growth rather than migration by employing a footloose capital model, in which, population is fixed to the regions and the capital moves according to nominal profits. They study the case where regions are asymmetric.

In the CP model proposed by Martínez-García and Morales (2019), there are two initially equal regions, endowed with renewable natural resources that can represent rural areas. There are two productive sectors in each region: an industrial sector and an extractive primary sector, and labor is perfectly mobile between sectors. The industrial sector employs labor and the extracted primary good as inputs for production. Primary firms extract or harvest the primary good from a given stock of renewable natural resources. The model also incorporates transport costs, enabling the interaction of trade with the other elements: population and natural resources. Additionally, population can migrate from one region to the other, allowing us to study the rural depopulation when the initial symmetry between the regions is broken, and to approximate the idea of counterurbanization when the symmetry is a stable equilibrium. As in the original CP model (Krugman, 1991; Fujita et al., 2001), migration takes place when there exists a real wage gap between the regions which is determined by the NEG effects. This is consistent with the economic component of the rural-urban migration, where living standards are the main driver of population movements.

The traditional NEG effects that drive population migration are present in our model: *the market size*, *the competition* and *the price index effects*. Then, if a firm decides to relocate their production from one region to the other, first, the rise in the labor demand increases wages, so attracting more workers, which increases expenditure in industrial goods and, ultimately, leads to more firms (the market size effect). Second, the same relocation of the production tends to reduce local potential profits, due to the higher competition for the local market, so discouraging the relocation decision (the competition effect). And, finally, the rise in the number of local varieties, due to the relocation, reduces the industrial price index in that region, and this reduces the cost of living and attracts more population (the price index effect). Additionally, as a result of incorporating the resource dynamics, the extension of the CP model by Martinez-García and Morales (2019) exhibits a new dispersion force, called *the resource effect*, that depends heavely on the extractive productivity of the primary sector. The more populated region tends to have lower long-run stock of natural resource, making the price of the primary good more expensive, which ultimately reduces the real wage and triggers a migratory process to the other region.

Martinez-García and Morales (2019) present two cases in their article. In the first, a non-tradable primary good is assumed. One of their main results is that for high industrial transport costs, the economic activity is agglomerated in one region, while for low industrial transport costs dispersion prevails. In the second, both primary and industrial goods are tradable at the same transport costs. For this particular case, it is found that, although the resource effect and the extractive productivity continue to be important, the stability pattern is reversed: for high transport costs the dispersion equilibrium is stable, while for low transport costs this equilibrium is unstable. The drastic change in the results proves the prominence of the assumptions on the tradability of the primary good in the resulting effect. In the current chapter, we analyze the resource effect in different trade set-ups, allowing for the existence of different transport costs in each sector, which can go from zero (perfect tradability) to infinity (non tradability). Our main findings suggest that, traditional NEG effects (market size, competition and price index effects) follow the standard behavior. However, if the primary good is non-tradable, the market size overcomes the competition effect, while, if industrial goods are non-tradable, the result is exactly the opposite. On the other hand, if industrial goods are perfectly tradable, traditional NEG effects vanish.

We distinguish three channels of the resource effect: the labor productivity, the wage and the firms channel. When there is a difference in the stock of natural resouces of the regions, as consequence of different levels of harvesting, the primary sector of the region with the lower stock becomes less efficient, and its primary and industrial prices tend to rise, so reducing the real wage of that region. Secondly, due to the change in prices, the region with the lower stock suffers an interregional trade deficit, which reduces the nominal and real wages. Thirdly, due to the reduction in the labor costs, industrial profits become positive, so attracting more firms, and the greater variety of industrial goods tends to reduce the industrial price index in the region, which increases the real wage.

Additionally, we find that the resource effect increases its strength with the extractive productivity, as was pointed out by Martínez-García and Morales (2019), but now also with high primary and industrial transport costs. Regarding the stability of a dispersion equilibrium, that is, the stability of an equilibrium where both regions end up being equal (symmetric equilibrium), we find some regularities. Due to the resource effect, if primary transport cost decreases faster than industrial transport cost, the equilibrium could go from stable to unstable and to stable again. However, in the special case of equal trade costs, this last stable phase is not present because the resource effect loses strength as both transport costs decrease.

The remainder of chapter is organized as follows: Section 2.2 presents the main equations of the model, Section 2.3 studies the stability of the equilibrium. In order to identify the agglomeration and dispersion forces operating in the model, we study three particular cases: a non-tradable primary good, a costless primary trade, and a primary transport cost equal to the industrial transport cost. Finally, we study the general case with positive and different transport costs for industrial and primary goods. There are two other extreme cases: non-tradable industrial goods and perfectly tradable industrial goods (Sections 2.7 and 2.8). These are useful to understand the general case. Section 2.4 concludes.

2.2. The Model

We make use of the CP model extension with renewable natural resources developed in Martínez-García and Morales (2019). There are two regions ($j = 1, 2$) that produce two different types of goods: industrial and primary. Labor serves as input in both sectors. Additionally, primary goods are used as raw material for industrial production. The industrial sector operates in a monopolistic competition framework (Dixit and Stiglitz, 1977), and industrial goods are tradable between regions with an iceberg transport cost. The primary sector extracts the natural resource from a renewable natural resource stock. Primary goods are homogeneous within each region and slightly differentiated across regions (Fujita et al., 2001), they are commercialized in perfect competition, and they can be exported and imported with an iceberg transport cost. This model also assumes free labor mobility between the industrial and the primary sector, and between regions

Households: A representative household from region 1 seeks to maximize its utility, which takes the form of a nested Cobb-Douglas and CES function (Krugman, 1991),

$$U_1 = \ln\left(C_{M_1}^{\mu} C_{H_1}^{1-\mu}\right) \tag{2.1}$$

with $\mu \in (0, 1)$ and,

$$C_{M_1} = \left(\int_0^{n_1} c_{1i}^{\frac{\sigma-1}{\sigma}} di + \int_0^{n_2} c_{2i}^{\frac{\sigma-1}{\sigma}} di\right)^{\frac{\sigma}{\sigma-1}} \tag{2.2}$$

$$C_{H_1} = \left(c_{H_1}^{\frac{\sigma-1}{\sigma}} + c_{H_2}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \tag{2.3}$$

where C_{M_1} and C_{H_1} are composite industrial and primary goods respectively, with an elasticity of substitution $\sigma > 1$; c_{ji} is the consumption of the corresponding variety i produced by region j ($j = 1, 2$); n_j is the number of varieties of industrial goods in region j; c_{H_1} and c_{H_2} are the consumptions of primary goods produced in region 1 and 2 respectively.

The corresponding industrial and primary price indexes for region 1 are

$$P_1 = \left(\int_0^{n_1} p_{1i}^{1-\sigma} di + \int_0^{n_2} (p_{2i}\tau)^{1-\sigma} di\right)^{\frac{1}{1-\sigma}} \tag{2.4}$$

$$P_{H_1} = \left(p_{H_1}^{1-\sigma} + (p_{H_2}\nu)^{1-\sigma}\right)^{\frac{1}{1-\sigma}} \tag{2.5}$$

where p_{ij} is the (fob) price of variety i produced in region j; p_{H_j} is the (fob) price of the primary good produced in region j; $\tau \geq 1$ and $\nu \geq 1$ are the industrial and primary iceberg transport costs, respectively. Mirror-image formulas hold for consumers in region 2.

Primary Sector: Primary firms extracts primary goods from a regional endowment of natural resources, S_j. They seek to maximize its benefits, in a perfect competition market, subject to the following harvest function,

$$H_j = \epsilon S_j L_{H_j}, \quad \epsilon > 0 \tag{2.6}$$

where L_{H_j} is the labor employed in the primary sector. The labor productivity in the extractions ($\gamma_j = \partial H_j / \partial L_{H_j}$) depends on a productivity parameter ϵ and on the stock of natural resources, S_j. The free entry condition leads to,

$$p_{H_j} = \frac{w_j}{\gamma_j} = \frac{w_j}{\epsilon S_j} \tag{2.7}$$

Industrial Sector: Each firm produces a single variety of industrial goods, and seeks to maximize its profits in a monopolistic market, subject to the following production function,

$$x_{ji} = \left(\frac{1}{\beta}\right) \left(l_{x_{ji}} - f\right)^{\alpha} h_{ji}^{1-\alpha}, \quad 0 < \alpha < 1 \tag{2.8}$$

with

$$h_{ji} = \left(h_{1ji}^{\frac{\sigma-1}{\sigma}} + h_{2ji}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$$

where $l_{x_{ji}}$ is the labor employed in producing variety i in region j, x_{ji} is the output; h_{ji} is a composite raw material employed in the production of variety i in region j; h_{kji} is the primary good extracted in region k employed in region j to produce of variety i. Parameters $\beta > 0$ and $f > 0$ are the marginal input requirement and the fixed cost. Parameter $\alpha \in (0, 1)$ is the proportion of labor required in the production. Then, the optimal price is (for a detailed explanation, see the Appendix)

$$p_j = \frac{\sigma}{\sigma - 1} \beta \left(\frac{w_j}{\alpha}\right)^{\alpha} \left(\frac{P_{H_j}}{1-\alpha}\right)^{1-\alpha} \tag{2.9}$$

where we omit the subscript i since all firms in the same region set equal prices. Additionally,

$$x_j^* = \frac{f w_j}{p_j / \sigma} \tag{2.10}$$

$$l_{x_j}^* = f \left[1 + \alpha (\sigma - 1)\right] \tag{2.11}$$

Then, the number of industrial firms in region j is

$$n_j = \frac{L_{E_j}}{f \left[1 + \alpha (\sigma - 1)\right]} \tag{2.12}$$

where $L_{E_j} = \int_0^{n_i} l_{x_{ji}} di$ is the total labor employed in the industrial sector in each region.

2.2.1. Short-Run Equilibrium

In the equilibrium the three markets (labor, industrial and primary goods) clear. The labor market equilibrium condition is

$$L_j = L_{E_j} + L_{H_j} \quad j = 1, 2 \tag{2.13}$$

where L_{E_j} and L_{H_j} are the total labor employed in the industrial and primary sectors of region j, respectively. On equalizing industrial supply and demand, the industrial equilibrium conditions for each region, in terms of wages of region 2 are

$$\frac{\sigma}{1+\alpha(\sigma-1)} L_{E_1} w = \mu \left\{ \frac{n_1 p_1^{1-\sigma}}{P_1^{1-\sigma}} L_1 w + \frac{\phi n_1 p_1^{1-\sigma}}{P_2^{1-\sigma}} L_2 \right\} \tag{2.14}$$

$$\frac{\sigma}{1+\alpha(\sigma-1)} L_{E_2} = \mu \left\{ \frac{\phi n_2 p_2^{1-\sigma}}{P_1^{1-\sigma}} L_1 w + \frac{n_2 p_2^{1-\sigma}}{P_2^{1-\sigma}} L_2 \right\} \tag{2.15}$$

where $w \equiv w_1/w_2$ and $\phi \equiv \tau^{1-\sigma} \in [0,1]$ is a parameter that represents the openness of industrial trade (for a more detailed explanation of these equilibrium conditions, see the Appendix). Hereinafter we take as numerarie the labor in region 2 ($w_2 = 1$). On normalizing the total population ($L_1 + L_2 = 1$) we obtain

$$L_{E_1} = \frac{\mu\left[1+\alpha(\sigma-1)\right]}{\sigma} (L_1 w + L_2) \frac{n}{1+nw} \quad \text{and} \quad L_{E_2} = \frac{L_{E_1}}{n} \tag{2.16}$$

with

$$n = p^{-(1-\sigma)} \frac{\frac{\phi}{p^{1-\sigma}/w-\phi} - \frac{1}{1-\phi p^{1-\sigma}/w}\frac{L_1 w}{L_2}}{\frac{\phi}{1-\phi p^{1-\sigma}/w}\frac{L_1 w}{L_2} - \frac{1}{p^{1-\sigma}/w-\phi}} \tag{2.17}$$

where $n \equiv n_1/n_2 = L_{E_1}/L_{E_2}$. Additionally, from the full employment condition (2.13)

$$L_{H_1} = L_1 - \frac{\mu\left[1+\alpha(\sigma-1)\right]}{\sigma} (L_1 w + L_2) \frac{n}{1+nw} \text{ and } L_{H_2} = 1 - L_1 - \frac{L_{E_1}}{n} \tag{2.18}$$

In the primary sector, the market equilibrium conditions in each region are

$$L_{H_1} w = \frac{p_{H_1}^{1-\sigma}}{P_{H_1}^{1-\sigma}} \left[(1-\mu)L_1 + \frac{(1-\alpha)(\sigma-1)}{1+\alpha(\sigma\text{-}1)} L_{E_1}\right] w + \frac{\kappa p_{H_1}^{1-\sigma}}{P_{H_2}^{1-\sigma}} \left[(1-\mu)L_2 + \frac{(1-\alpha)(\sigma-1)}{1+\alpha(\sigma\text{-}1)} L_{E_2}\right] \tag{2.19}$$

$$L_{H_2} = \frac{\kappa p_{H_2}^{1-\sigma}}{P_{H_1}^{1-\sigma}} \left[(1-\mu)L_1 + \frac{(1-\alpha)(\sigma-1)}{1+\alpha(\sigma\text{-}1)} L_{E_1}\right] w + \frac{p_{H_2}^{1-\sigma}}{P_{H_2}^{1-\sigma}} \left[(1-\mu)L_2 + \frac{(1-\alpha)(\sigma-1)}{1+\alpha(\sigma\text{-}1)} L_{E_2}\right] \tag{2.20}$$

where $\kappa \equiv \nu^{1-\sigma} \in [0,1]$ is a parameter that represents the openness of the primary trade (for a more detailed explanation of these equilibrium conditions, see the Appendix).

Substracting from equation (2.14) region 1's total demand for industrial goods ($\mu L_1 w$) it is obtained that

$$\frac{\sigma}{1+\alpha(\sigma-1)} L_{E_1} w - \mu L_1 w = \mu \left\{ \frac{\phi n_1 p_1^{1-\sigma}}{P_2^{1-\sigma}} L_2 - \frac{\phi n_2 p_2^{1-\sigma}}{P_1^{1-\sigma}} L_1 w \right\} \tag{2.21}$$

We know that domestic absorption minus total demand equals the imports requirement (second term in the right hand side of (2.21)). Then, from (2.21), total supply of industrial goods produced in region 1 minus its aggregate industrial demand must equal net industrial exports. Equation (2.21) also indicates that, even when the industrial market is at equilibrium, regions can have an industrial trade surplus or a deficit.

Proceeding in a similar way with expression (2.19), making use of the full employment condition (2.13) and subtracting region 1's total demand for primary goods (from households and firms), $(1-\mu)L_1 w + \frac{(1-\alpha)(\sigma-1)}{1+\alpha(\sigma-1)} L_{E_1} w$, we have that

$$\begin{aligned} L_{H_1}w - (1-\mu)L_1 w - \tfrac{(1-\alpha)(\sigma-1)}{1+\alpha(\sigma-1)} L_{E_1} w &= \frac{\kappa p_{H_1}^{1-\sigma}}{P_{H_2}^{1-\sigma}} \left[(1-\mu)L_2 + \tfrac{(1-\alpha)(\sigma-1)}{1+\alpha(\sigma-1)} L_{E_2}\right] \\ &\quad - \frac{\kappa p_{H_2}^{1-\sigma}}{P_{H_1}^{1-\sigma}} \left[(1-\mu)L_1 + \tfrac{(1-\alpha)(\sigma-1)}{1+\alpha(\sigma-1)} L_{E_1}\right] w \end{aligned} \tag{2.22}$$

Likewise, equation (2.22) says that, region 1's total supply minus total demand for primary goods must be equal to net primary exports of region 1. And that the primary market can be at equilibrium even when there is a primary trade imbalance.

Additionally, using the full employment condition (2.13) and the left hand sides of conditions (2.21) and (2.22), we have

$$\tfrac{\sigma}{1+\alpha(\sigma-1)} L_{E_1} w - \mu L_1 w = -\left[L_{H_1}w - (1-\mu)L_1 w - \tfrac{(1-\alpha)(\sigma-1)}{1+\alpha(\sigma-1)} L_{E_1} w\right] \tag{2.23}$$

This expression says that region 1's excess of supply of industrial goods must be equal to its excess of demand for primary goods. Alternatively, when both markets, industrial and primary, are at equilibrium, the trade surplus in one of these markets must equal the trade deficit in the other.

Thus, by combining the equilibrium conditions (2.21) and (2.22), and expression (2.23), the trade balance equation can be obtained:

$$\begin{aligned} TB &= \mu\left(\tfrac{\phi n p^{1-\sigma}}{n p^{1-\sigma}\phi+1} L_2 - \tfrac{\phi}{n p^{1-\sigma}+\phi} L_1 w\right) + (1-\mu)\left(\tfrac{\kappa p_H^{1-\sigma}}{p_H^{1-\sigma}\kappa+1} L_2 - \tfrac{\kappa}{p_H^{1-\sigma}+\kappa} L_1 w\right) \\ &\quad + \tfrac{(1-\alpha)(\sigma-1)}{1+\alpha(\sigma-1)} \left(\tfrac{\kappa p_H^{1-\sigma}}{p_H^{1-\sigma}\kappa+1} L_{E_2} - \tfrac{\kappa}{p_H^{1-\sigma}+\kappa} L_{E_1} w\right) = 0 \end{aligned} \tag{2.24}$$

where $p \equiv p_1/p_2$ and $p_H \equiv p_{H_1}/p_{H_2}$. From (2.4), (2.5), (2.7) and (2.9), we have

$$p = w^{\alpha} P_H^{1-\alpha} \tag{2.25}$$

$$p_H = \frac{w}{\gamma} = \frac{w}{S_1/S_2} \tag{2.26}$$

$$P_H \equiv \frac{P_{H_1}}{P_{H_2}} = \left(\frac{p_H^{1-\sigma}+\kappa}{p_H^{1-\sigma}\kappa+1}\right)^{\frac{1}{1-\sigma}} \text{ and } P \equiv \frac{P_1}{P_2} = \left(\frac{n p^{1-\sigma}+\phi}{n p^{1-\sigma}\phi+1}\right)^{\frac{1}{1-\sigma}} \tag{2.27}$$

where $\gamma \equiv \gamma_1/\gamma_2$. For given values of L_1, S_1 and S_2, (2.24) is a function of the ratio of wages w. Trade between the two regions is balanced if and only if the balance trade equation (2.24) is satisfied. Note that the setup of this model is similar to that of Martínez-García and Morales (2019), but with $\kappa \in [0,1]$. One of the solutions for the balance trade equation is the symmetric equilibrium, where both regions are equal:

$$L_1^* = 1/2,\ S_1^* = S_2^*,\ w^* = p^* = 1 \tag{2.28}$$

At the symmetric equilibrium, the labor employed in each sector is equal between the regions and the number of industrial firms is also equal ($L_{H_1} = L_{H_2}$, $L_{E_1} = L_{E_2}$, $n_1 = n_2$). For tractability, equation (2.24) is rewritten as[1]

$$TB = \phi\left(\frac{np^{1-\sigma}}{np^{1-\sigma}\phi+1} - \frac{1}{np^{1-\sigma}+\phi}\frac{L_1 w}{L_2}\right)\Psi + \kappa\left(\frac{p_H^{1-\sigma}}{\kappa p_H^{1-\sigma}+1} - \frac{1}{p_H^{1-\sigma}+\kappa}\frac{L_1 w}{L_2}\right) = 0 \tag{2.29}$$

where

$$\Psi \equiv \frac{\mu - \frac{\mu(1-\alpha)(\sigma-1)}{\sigma}\kappa\left(\frac{p_H^{1-\sigma}}{\kappa p_H^{1-\sigma}+1} + \frac{1}{p_H^{1-\sigma}+\kappa}\right)}{1-\mu+\frac{\mu(1-\alpha)(\sigma-1)}{\sigma}} \tag{2.30}$$

The derivative of expression (2.29) at the symmetric equilibrium is

$$\frac{\partial TB}{\partial w}(L_1^*, S_1^*, S_2^*, w^*) = -\frac{(2\sigma-1+\kappa)\kappa}{(1+\kappa)^2} - \frac{\phi\Psi^*(\kappa)}{(1+\phi)}\left\{1 + \frac{2(\sigma-1)}{1+\phi}\left[\alpha + (1-\alpha)\frac{1-\kappa}{1+\kappa}\right]\right\} < 0 \tag{2.31}$$

where $\Psi^*(\kappa) > 0$ is (2.30) evaluated at the symmetric equilibrium. Therefore, for given values of ϕ and κ, equation (2.29) implicitly defines w as a function of L_1, S_1 and S_2 in a neighborhood of the symmetric equilibrium.

Using the implicit differentiation in (2.29), we obtain, at the symmetric equilibrium, that

$$\frac{dw^*}{dL_1} = \frac{4(1-\phi)\frac{\mu\sigma+\kappa[\sigma-\mu(1-\alpha)(\sigma-1)]\phi-\kappa\{\sigma-\mu[1+\alpha(\sigma-1)]\}}{(1+\kappa)(1+\phi)\{\sigma-\mu[1+\alpha(\sigma-1)]\}}}{\frac{(2\sigma-1+\kappa)\kappa(1-\phi)^2}{(1+\kappa)^2(1+\phi)} + \phi\Psi^*(\kappa)\left\{1+\frac{2(\sigma-1)}{1+\phi}\left[\alpha+(1-\alpha)\frac{1-\kappa}{1+\kappa}\right]\right\}} \tag{2.32}$$

which can be negative or positive, depending on the value of ϕ and κ. That is,

$$\frac{dw^*}{dL_1} \lesseqgtr 0 \text{ if and only if } \phi \lesseqgtr \hat{\phi} = \kappa\frac{\sigma-\mu[1+\alpha(\sigma-1)]}{\mu\sigma+\kappa[\sigma-\mu(1-\alpha)(\sigma-1)]} \leq 1 \tag{2.33}$$

As is proved later on, the sign of this derivative determines if the the market size effect is stronger or weaker than the competition effect. Note that if $\kappa = 0$, the primary good is non-tradable, as in the first model by Martínez-García and Morales (2019), and ϕ is always higher than $\hat{\phi} = 0$. Moreover, if $\kappa = 1$, the primary good is perfectly tradable, as in Krugman (1991).

[1]For a step-by-step development of this alternative form of the balance trade equation, see Appendix B by Martínez-García and Morales (2019).

Additionally, implicit differentiation in (2.29) with respect to S_1 and S_2 gives, at the symmetric equilibrium, that

$$\frac{dw^*}{dS_1} = -\frac{dw^*}{dS_2} = \frac{\frac{2(\sigma-1)}{S^*}\left[\frac{\kappa(1-\phi)^2}{(1+\kappa)^2(1+\phi)}+(1-\alpha)\Psi^*(\kappa)\frac{\phi(1-\kappa)}{(1+\phi)(1+\kappa)}\right]}{\frac{(2\sigma-1+\kappa)\kappa(1-\phi)^2}{(1+\kappa)^2(1+\phi)}+\phi\Psi^*(\kappa)\left\{1+\frac{2(\sigma-1)}{1+\phi}\left[\alpha+(1-\alpha)\frac{1-\kappa}{1+\kappa}\right]\right\}} > 0 \tag{2.34}$$

The stock of natural resource in region j always has a positive effect on the relative value of wage in region j with respect to the wage in the other region, as in the paper by Martínez-García and Morales (2019), that is when $\kappa = 0$ or $\kappa = \phi$. Nevertheless, this sign is not sufficient to maintain the prevalence of the dispersive force of the resource effect for all values of κ and ϕ. As we will prove later, in some scenarios the resource dynamics could work against the stability of the symmetric equilibrium. In spite of that, in what follows it is shown that, depending on transport costs, the resource effect favours dispersion, and that this dispersion force continues to be very important to determine the spatial distribution of the economic activity.

2.2.2. Long-Run Equilibrium

Each region is endowed with a stock of a renewable natural resource that evolves through time following a logistic growth function (Clark, 1990).

$$\dot{S}_j = gS_j\left(1 - \frac{S_j}{CC}\right) - H_j \tag{2.35}$$

where $g > 0$ and $CC > 0$ are the intrinsic growth rate and the carrying capacity respectively, and H_j, defined by (2.6), is the extraction of the natural resource in region $j = 1, 2$. If, and only if, $L_{H_j} < g/\epsilon$, the positive long-run level

$$S_j^* = CC\left(1 - \frac{\epsilon}{g}L_{H_j}\right) > 0 \tag{2.36}$$

is globally stable. Note that when population changes, the extraction H_j changes, and the dynamics of the resource (2.35) will drive the stock S_j to its new long-run level S_j^*. Using (2.17) and (2.18), S_j^* at the symmetric equilibrium (2.28) is

$$S_j^* = S_s^* = \left(1 - \epsilon\frac{\theta}{2}\right)CC > 0 \quad \text{if and only if } \epsilon < 2/\theta \tag{2.37}$$

where

$$\theta \equiv \frac{\sigma - \mu\left[1 + \alpha\left(\sigma - 1\right)\right]}{g\sigma} \tag{2.38}$$

Condition $\epsilon < 2/\theta$ ensures the sustainability of the natural resource, that is $S_s^* > 0$ at the symmetric equilibrium. We assume that this condition holds throughout the chapter.

Additionally, population migrates from one region to the other if people gain in terms of individual welfare. Hence, the temporal evolution of the variables is driven by the following differential equations system:

$$\begin{aligned} \dot{L}_1 &= L_1 (1 - L_1) [\Delta - 1] && (2.39) \\ \dot{S}_1 &= S_1 \left[g \left(1 - \frac{S_1}{CC} \right) - \epsilon L_{H_1} \right] && (2.40) \\ \dot{S}_2 &= S_2 \left[g \left(1 - \frac{S_2}{CC} \right) - \epsilon L_{H_2} \right] && (2.41) \end{aligned}$$

where Δ is the ratio of indirect utilities, that is

$$\Delta \equiv \frac{w_1}{w_2} \left(\frac{P_1}{P_2} \right)^{-\mu} \left(\frac{P_{H_1}}{P_{H_2}} \right)^{-(1-\mu)} = w P^{-\mu} P_H^{-(1-\mu)} \tag{2.42}$$

where $P \equiv P_1/P_2$ and $P_H \equiv P_{H_1}/P_{H_2}$ are the ratios of the industrial and primary price indexes; L_{H_1} and L_{H_2} are given by (2.18) and the ratio of wages, w, is defined by the balanced trade equation (2.24), as a function of L_1, and the ratio S_1/S_2 in a neighborhood of the symmetric equilibrium, that is, $w = w(L_1, S_1/S_2)$. A long-run equilibrium is a stationary point of the system (2.39)-(2.41) where the population does not have incentives to migrate and the stocks of natural resources do not change over time. The symmetric equilibrium defined in (2.28) and (2.37) is a steady state of this differential equations system.

2.3. Stability of the Symmetric Equilibrium

The symmetric equilibrium (2.28) and (2.37) will be achieved and maintained in the long-run whenever the dispersion effects overcome the agglomerative ones. That is, its stability depends on the interaction of the traditional NEG forces and the resource effect.

Note that the dynamics of the resources (2.40) and (2.41) will always drive the resource stocks S_j to their globallly stable levels S_j^*. Therefore, the stability of the symmetric equilibrium depends on the ratio of indirect utilities. Differentiating it at the symmetric equilibrium,

$$\hat{\Delta}\Big|_{\frac{1}{2}} = \overbrace{\frac{1}{2} \left[\frac{dw^*}{dL_1} - \mu \frac{dP^*}{dL_1} - (1-\mu) \frac{dP_H^*}{dL_1} \right] \hat{L}_1}^{\text{traditional NEG forces}} + \overbrace{\left[\frac{dw^*}{dS} - \mu \frac{dP^*}{dS} - (1-\mu) \frac{dP_H^*}{dS} \right] \hat{S}}^{\text{resource effect}} \tag{2.43}$$

where $\hat{x} \equiv dx/x$, $S \equiv S_1/S_2$, and the subscript 1/2 means that it is evaluated at the symmetric equilibrium.

Traditional NEG effects are collected in the first square brackets of expression (2.43). In the second square brackets we find the resource effect (through the ratio of wages and the ratio of price indexes).

Expression (2.43) points out that the resource effect depends on the relative change of the natural resource stocks, $\hat{S}$. This part is of great importance because it establishes a link between the extractive productivity ϵ and the strength of the resource effect. Note that, from (2.36),

$$S^* = \frac{1 - \frac{\epsilon}{g} L_{H_1}}{1 - \frac{\epsilon}{g} L_{H_2}} \tag{2.44}$$

Differentiating S^* with respect to L_1 at the symmetric equilibrium,

$$\frac{dS^*}{dL_1} = -\frac{2\epsilon/g}{1 - \epsilon\theta/2} \frac{dL^*_{H_1}}{dL_1} \gtrless 0 \text{ if and only if } \frac{dL^*_{H_1}}{dL_1} \lessgtr 0, \tag{2.45}$$

given that $dL^*_{H_2}/dL_1 = -dL^*_{H_1}/dL_1$.

Thus, if the labor in the primary sector of region 1 increases, the ratio of the long-run levels of natural resources will decrease with L_1. This was always the case in Martínez-García and Morales (2019). However, when $\kappa \in [0, 1]$ this primary labor force could diminish. Moreover,

$$\frac{d^2 S^*}{dL_1 d\epsilon} = \frac{1}{\epsilon\,(1 - \epsilon\theta/2)} \frac{dS^*}{dL_1} \tag{2.46}$$

When the extractive productivity increases, a change in the population has a larger impact (in absolute value) on the resource stocks. That is, high values of ϵ are associated with a stronger resource effect, regardless of whether it encourages dispersion or not.

The following proposition states the conditions under which the resource effect favours the dispersion of the economic activity.

Proposition 1 *In a close neighborhood of the symmetric equilibrium (2.28) and (2.37), when population increases in one region, natural resource dynamics encourages the dispersion of the population, at least for high and low values of ϕ.*

Proof. See the proof in the Appendix. ■

The resource effect is the result of adding the impact of the resource on the three components of the indirect utility function: the ratio of wages and the ratio of the cost of living (ratio of industrial and primary price indexes). These are the channels pointed out by Martínez-García and Morales (2019) for a non-tradable primary good ($\kappa = 0$). However, as is shown later in this chapter, if primary goods are tradable with $\kappa \in [0, 1]$, the impact of the resource on the cost of living stimulates several opposing forces, making its contribution to the resource effect unclear. For example, as S rises, the labor in the primary sector becomes more productive in region 1 than in 2, making the raw materials cheaper, which allows the industrial price index to decrease. But, at the same time, the industrial price index suffers an increase caused by the higher wages and the lower number of firms. Something similar happens with the primary price index. In order to reduce these ambiguities, in this chapter we distinguish three channels for the resource effect: *(i) the wages channel, w; (ii) the firms channel, n;* and *(iii) the primary labor productivity channel,* γ. Thus, the second square brackets of expression (2.43), can be restated as

$$\overbrace{\left[1-\mu\frac{\partial P^*}{\partial p}\frac{\partial p^*}{\partial w}-(1-\mu)\frac{\partial P_H^*}{\partial p_H}\frac{\partial p_H^*}{\partial w}\right]\frac{dw^*}{dS}}^{\text{wage channel}}\underbrace{-\left(\mu\frac{\partial P^*}{\partial n}\right)\frac{dn^*}{dS}}_{\text{firms channel}}\overbrace{-\left[\mu\frac{\partial P^*}{\partial p}\frac{\partial p^*}{\partial p_H}+(1-\mu)\frac{\partial P_H^*}{\partial p_H}\right]\frac{\partial p_H^*}{\partial \gamma}\frac{d\gamma^*}{dS}}^{\text{primary labor productivity channel}} \quad (2.47)$$

where n is defined by (2.17), but taking into account (2.25)-(2.27), we have that n depends on S and w that is, $n(S,w)$, and

$$\frac{dn^*}{dS}=\frac{\partial n^*}{\partial S}+\frac{\partial n^*}{\partial w}\frac{dw^*}{dS}>0$$

The wage channel, takes into account how nominal wages change when the ratio of natural resources varies, and how prices change, p and p_H, as a response to the wage adjustment. The effect of the ratio of natural resources through this channel is always positive. The second channel collects the changes in the number of firms as the ratio of natural resources increases or decreases. It has a negative impact on the resource effect because the reduction in labor costs tends to attract more firms into the market. And the last channel, which is positive, comes from the effect of the resource on the primary labor productivity, which affects primary prices. With this reordering of the components, each channel ends up having an unambiguous impact on the overall resource effect.

Similarly to the decomposition performed to the resource effect in (2.47), the first square brackets of expression (2.43) can be manipulated to obtain the traditional NEG effects:

$$\overbrace{\left[1-\mu\frac{\partial P^*}{\partial p}\frac{\partial p^*}{\partial w}-(1-\mu)\frac{\partial P_H^*}{\partial p}\frac{\partial p_H^*}{\partial w}\right]\frac{dw^*}{dL_1}}^{\text{market size effect }-\text{ competition effect}}\underbrace{-\mu\frac{\partial P^*}{\partial n}\frac{dn^*}{dL_1}}_{\text{price index effect}} \quad (2.48)$$

The first term is the net result of the market size effect minus the competition effect. The last term of expression (2.48) is the (industrial) price index effect, which is always positive, where

$$\frac{dn^*}{dL_1}=\frac{\partial n^*}{\partial L_1}+\frac{\partial n^*}{\partial w}\frac{dw^*}{dL_1}>0$$

The expression in the square brackets in (2.48) is always positive, so, the sign of the derivative dw^*/dL_1 determines which effect is stronger between the market size and the competition effects.

Expressions (2.43), (2.47) and (2.48) give a clear explanation of the interacting forces. In the next three subsections we use these expressions to study the stability of the symmetric equilibrium through a series of numerical examples. The analytical conditions that determine the stability of this equilibrium are stated in the Appendix.

2.3.1. Non-Tradable primary good

Taking into account the price equations (2.25) and (2.27) and the channels identified in expressions (2.47) and (2.48), equation (2.43) takes the form:

$$\begin{aligned}\hat{\Delta}\Big|_{\frac{1}{2}} &= \tfrac{1}{2}\left\{\left[1-\mu\tfrac{1-\phi}{1+\phi}-(1-\mu)\right]\tfrac{dw^*}{dL_1}+\mu\tfrac{1-\phi}{1+\phi}\tfrac{dn^*/dL_1}{\sigma-1}\right\}\hat{L}_1 \\ &\quad+\left\{\left[1-\mu\tfrac{1-\phi}{1+\phi}-(1-\mu)\right]\tfrac{dw^*}{dS}+\left[\mu(1-\alpha)\tfrac{1-\phi}{1+\phi}+(1-\mu)\right]\right\}\hat{S}\end{aligned} \tag{2.49}$$

where for $\kappa=0$, $n=L_1/(1-L_1)$. Then, at the symmetric equilibrium,

$$\frac{dw^*}{dL_1} = 4\frac{1-\phi}{2\sigma-1+\phi}>0 \tag{2.50}$$

$$\frac{dn^*}{dL_1} = \frac{1}{(1-L_1)^2}>0 \text{ and } \frac{dn^*}{dS}=0 \tag{2.51}$$

$$\frac{dw^*}{dS} = 2\frac{(1-\alpha)(1+\phi)}{2\sigma-1+\phi}>0 \tag{2.52}$$

The first term in the square brackets of expression (2.49) is the difference between the market size and the competition effect, while, the second term is the industrial price index effect. As derivative (2.50) is positive, at the symmetric equilibrium, the market size effect predominates over the competition effect. This result is generalized outside the symmetric equilibrium in Proposition 2.

Proposition 2 *If the stock of natural resources remains constant, an increment in population in one of the two regions will raise the relative wage for this region.*

Proof. See the proof in the Appendix. ∎

Thus, due to the non-tradability of the primary good and the sectorial mobility of labor, among traditional NEG forces, agglomeration ones are always stronger (for a more comprehensive explanation, see the proof of Proposition 2 in the Appendix).

The terms inside the second curly brackets of expression (2.49) form the resource effect, with two of the three channels identified in expression (2.47). In this case, the firms channel is null.

Note that an increment in population leads to a reduction in S^* (expression (2.44)), given that $dL_{H_j}/dL_j > 0$ (equation (2.80) in the Appendix), that is,

$$\frac{dS^*}{dL_1} = \frac{d\left[\frac{1-\epsilon\theta L_1}{1-\epsilon\theta(1-L_1)}\right]}{dL_1} = \frac{-2\epsilon\theta\left(1-\epsilon\theta/2\right)}{\left[1-\epsilon\theta\left(1-L_1\right)\right]^2} < 0 \tag{2.53}$$

which is negative since $\epsilon < 2/\theta$ is assumed since (2.37).

To explain the resource effect and its channels, we use the example of a decrease in the ratio of natural resources provoked by an increase of L_1. Thus, if there is an exogenous decrease in the ratio of natural resource stocks, the primary labor force becomes less efficient in the extraction, making the primary good more expensive in the region with a lower stock of resource. Because industrial firms use primary goods as raw materials, industrial costs rise together with the ratio of industrial prices. Thus, the cost of living becomes higher (primary labor productivity channel). Additionally, the expensive industrial goods discourage sales and cause a trade deficit. The excess of supply forces prices and wages down (wage channel). As a consequence, industrial and primary prices will decrease, but not as much as to compensate the initial increase. The reason for this is that as the ratio of wages reduces, net exports grow because prices fall, but also because of the reduction in the income of region 1. To sum up, as a result of the resource dynamics, nominal wages fall, and primary and industrial prices increase, causing the ratio of real wages to decrease. Thus, both channels of the resource effect present in expression (2.49) encourage the dispersion of the economic activity.[2]

The other channel identified in (2.47), the firms channel, vanishes in this case ($dn^*/dS = 0$). When the ratio of natural resources decrease, a commercial deficit appears for region 1 (trade imbalance), because the supply exceeds the demand for industrial goods. Profits of industrial firms become losses, and because of this, some firms decide to drop out of the market. However, fewer firms means less industrial labor; and, at the same time, less primary labor in order to satisfy the lower demand for raw materials. Thus, the trade imbalance provokes a disequilibrium in the labor market (excess of supply), which generates a downward pressure on the ratio of wages. As labor costs decrease, relative industrial prices, p, fall, which raises the demand, and also discourages region 1´s imports through a reduction of the region's income. The wage adjustment stops when the labor market returns to its equilibrium, that is, when all the incentives to dismiss industrial workers disappear. Ultimately, this means that the interregional trade is balanced again. Throughout this process, the number of firms first decreases and then increases, ending the adjustment at the same level as before the change in the ratio of resources.

The shaded region in Figure 2.1 is the stability region of the symmetric equilibrium in the space (ϵ,ϕ). For this, and the other figures in the chapter, the standard values

[2]Martínez-García and Morales (2019) prove that for $\kappa = 0$ the resource effect acts as a dispersion force beyond the surroundings of the symmetric equilibrium

used are $\sigma = 7$, $\mu = 0.5$ and $\alpha = 0.5$, which are the values used whenever the parameter values are not specified in the figure.

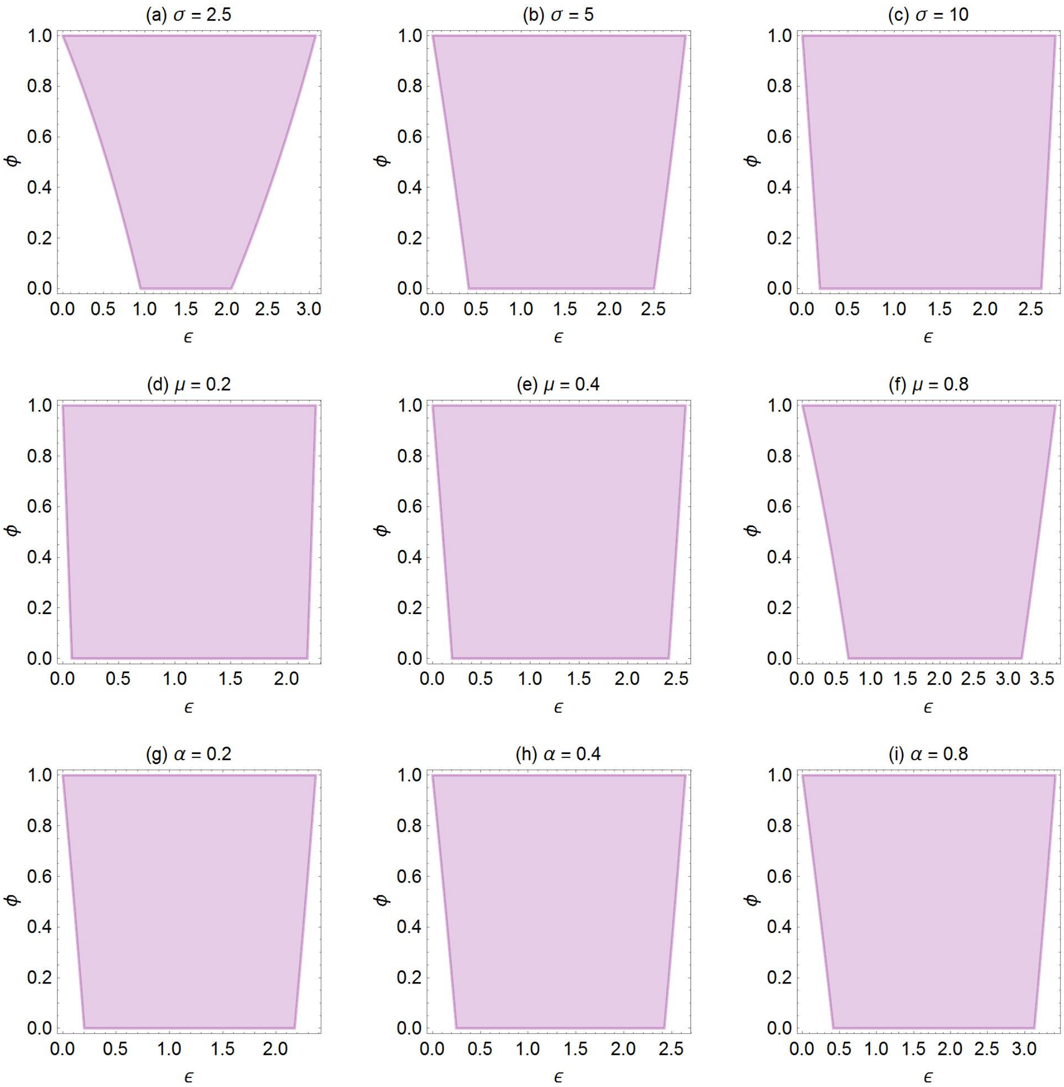

Figure 2.1: Stability Region: non-tradable primary good

Figure 2.1 shows that the symmetric equilibrium is unstable for low values of ϵ and ϕ.[3] When ϵ increases, it becomes stable because the resource effect is stronger according

[3]The unstable region of the symmetric equilibrium for high values of ϵ is studied in Martínez-García and Morales (2019).

to expressions (2.53) and (2.46). However, as the industrial transport cost diminishes the symmetric equilibrium also becomes stable, contrary to what happens in the original CP model (Krugman, 1991).

As is shown in Proposition 2, the market size effect always dominates the competition effect, because there is no fixed income in any region. Therefore, when $\kappa = 0$, the only role of industrial transport costs is to reinforce the market size effect. This explains the stability pattern of the equilibrium in Figure 2.1: when transport cost are high, the symmetric equilibrium can be unstable.

Thus, when ϵ and ϕ are low, starting at the symmetric equilibrium, if one firm decides to move its production to the other region, it will find a larger local market (market size effect). The advantages of the market size offset the limited access to the foreign market due to the high transport costs (competition effect). Additionally, the larger region has a wider range of industrial varieties which reduces the cost of living (industrial price index effect). In the long-run, the higher number of firms and the larger population will reduce the stock of natural resources in that region, which triggers the process described before for the resource effect. In this case, the resource effect encourages the stability of the symmetric equilibrium. However, because ϵ is low, its strength is limited, and it will only dominate over the agglomeration forces if ϕ increases (the agglomeration forces lose strength) or if ϵ increases (the resource effect becomes stronger).

2.3.2. Costless primary trade

In this subsection we assume free trade for agricultural goods, that is $\kappa = 1$. This assumption is common in the majority of new economic geography models. However, because there is sectorial mobility, the labor employed in the primary sector can change along with changes in the regional population. Ultimately, this implies that the resource extraction is not fixed like it is primary production in the traditional CP model.[4]

When primary goods are perfectly tradable, expression (2.43) can be written as

$$\hat{\Delta}\Big|_{\frac{1}{2}} = \frac{1}{2}\left[\left(1\text{-}\frac{\mu\alpha(1\text{-}\phi)}{1+\phi}\right)\frac{dw^*}{dL_1}+\frac{\mu(1\text{-}\phi)}{1+\phi}\frac{dn^*/dL_1}{\sigma-1}\right]\hat{L}_1+\left[\left(1\text{-}\frac{\mu\alpha(1\text{-}\phi)}{1+\phi}\right)+\frac{\mu(1\text{-}\phi)}{1+\phi}\frac{\partial n^*/\partial w}{\sigma-1}\right]\frac{dw^*}{dS}\hat{S} \qquad (2.54)$$

where $dw^*/dL_1 \gtreqless 0$ and $dw^*/dS > 0$ can be obtained from expressions (2.32) and (2.34),

[4] The footlose entrepreneur model (Ottaviano, 1996; Forslid, 1999) also assumes labor mobility between sectors. However, labor is not mobile between regions; only entrepreneurs can migrate.

and

$$\frac{dn^*}{dL_1} = 4\frac{1+\phi}{1-\phi} - \frac{2\phi\left[1+\phi+2\alpha\left(\sigma-1\right)\right]}{\left(1-\phi\right)^2}\frac{dw^*}{dL_1} > 0 \tag{2.55}$$

$$\frac{dn^*}{dS} = \frac{\partial n^*}{\partial w}\frac{dw^*}{dS} = -\frac{2\sigma-1+\phi}{\left(1-\phi\right)^2}\frac{dw^*}{dS} < 0 \tag{2.56}$$

$$\frac{dw^*}{dL_1} \gtrless 0 \text{ if and only if } \phi \gtrless \hat{\phi}\left(\kappa=1\right) \equiv \frac{\sigma-\mu\left[1+\alpha(\sigma-1)\right]}{\sigma+\mu\left[1+\alpha(\sigma-1)\right]}$$

From these expressions, some features of the working effects can be pointed out. The (industrial) price index effect holds its sign ($dn^*/dL_1 > 0$, see expression (2.70) in the Appendix), even when $dw^*/dL_1 > 0$. Among the traditional forces, a necessary condition for dispersion is that the competition effect dominates the market size effect ($dw^*/dL_1 < 0$), and this only occurs for high values of transport costs ($\phi < \hat{\phi}$). Thus, traditional forces have the standard behavior when the primary good is perfectly tradable.

The resource effect, as a whole, and contrary to the case in subsection 2.3.1, can be positive (encouraging dispersion) or negative (encouraging agglomeration) depending on transport costs. First, a decrease in the ratio of natural resources leads to a lower primary labor productivity, which makes the ratio of primary prices rise. However, due to the perfect tradability, firms and consumers in both regions face the same primary price index, which implies that they lose equally from the changes in the primary productivity of region 1. Thus, the free trade assumption in the primary sector vanishes the primary labor productivity channel. Nevertheless, the higher primary price changes the interregional trade, so decreasing primary exports of the region with the lower stock of natural resources. The surpluss supply generates a downward pressure on primary prices, hence on wages (wage channel) and industrial prices. Because the fall of the ratio of wages also discourages imports (through a lower income of region with the less abundant natural resource), the wage adjustment does not fully compensate the initial increase in the price of primary goods. Thus, although the interregional trade is balanced again, the composition has changed, the resource abundant region (region 2) becomes a net primary exporter and a net industrial importer.[5]

Second, a decrease in the stock of natural resources tends to raise the number of industrial firms (firms channel) through the decrease in wages ($dn^*/dw < 0$). Note that the fall of the ratio of wages due to the lower primary labor productivity tends to reduce the industrial prices of the region, causing an increase in the demand of each industrial variety. At this new level of sales, industrial profits are positive, and new firms are willing to enter in the market. Ultimately, the increase in the competition reduces the sales again

[5]Note that all the effects derived from changes in the resource stocks come through the channel of the wage adjustment ($dw^*/dS \geq 0$). Due to the perfect tradability assumption of the primary good, there are no direct effects on expression (2.54).

until the zero profit condition is reached. This channel, which is not present in the non-tradable case, makes the industrial price index fall, so reducing the cost of living (firms channel). This channel of the resource effect favours the agglomeration of the economic activity when transport costs are high ($\phi < \hat{\phi}$). Thus, in contrast to the non-tradable case, when the primary good is perfectly tradable, the dispersion force of the resource effect is weak and it can become an agglomeration force for same values of the industrial trade costs (see Lemma 1 in the Appendix).

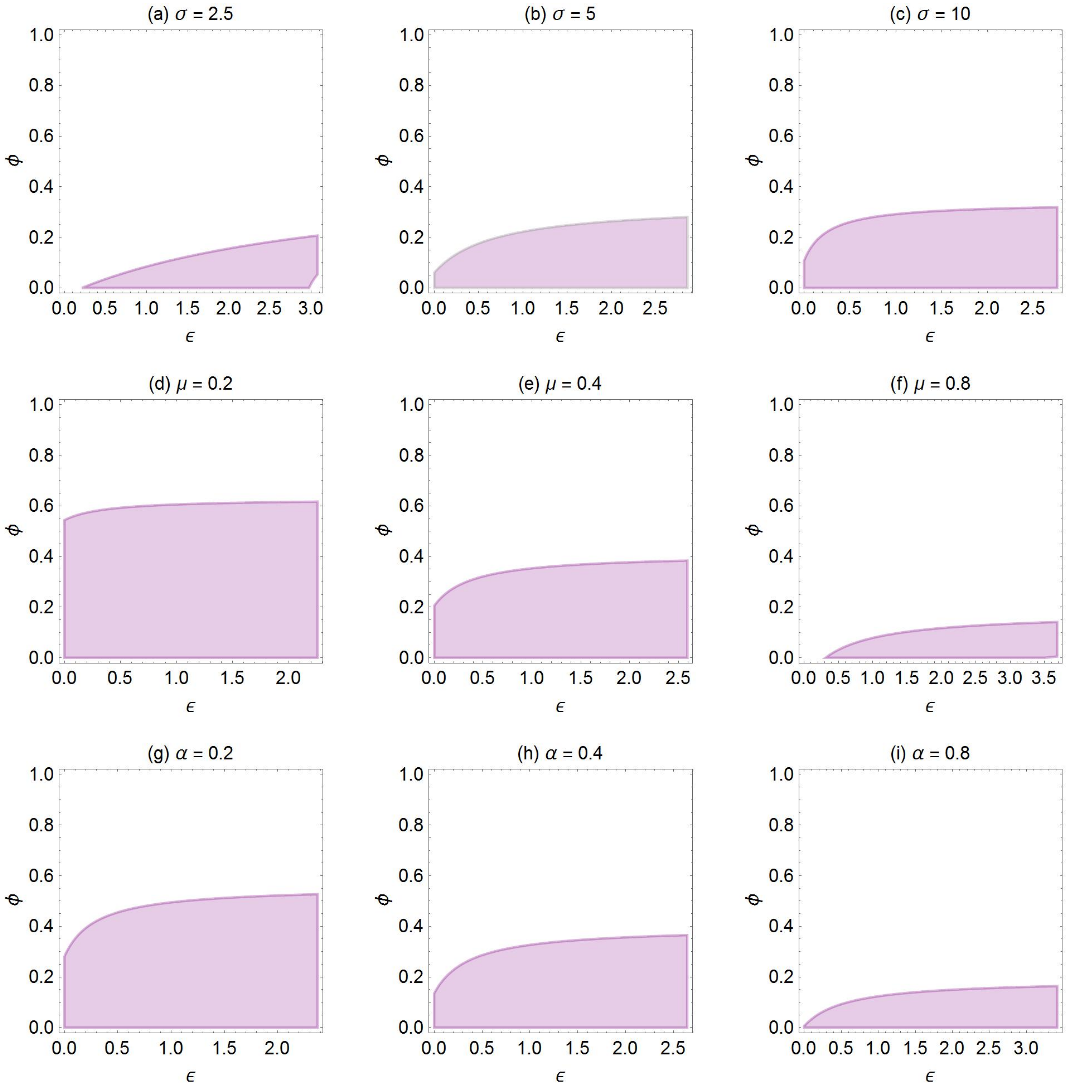

Figure 2.2: Stability Region: costless primary trade

The shaded regions in the examples of Figure 2.2 represent the stability regions of the symmetric equilibrium in the space (ϵ,ϕ) for the different sets of parameters. The symmetric equilibrium changes from stable to unstable as ϕ increases. When transport costs are high, the dispersion forces (competition and resource effect) dominate, and we find that the symmetric equilibrium is stable. As transport costs diminishes, the advantages of being closer to the larger market offset the disadvantages of the higher competition. Additionally, the dispersion force of the resource effect depends on the wage adjustment, which loses its strength as ϕ approaches the unity, according to the following expressions:

$$\frac{d^2w^*}{dSd\phi} = -\frac{2\mu[1+\alpha(\sigma-1)]\{\sigma-\mu[1+\alpha(\sigma-1)]\}(\sigma-1)(1-\phi)[1+3\phi+2\alpha(\sigma-1)(1+\phi)]}{\left\{\sigma(1-\phi)^2\{\sigma-\mu[1+\alpha(\sigma-1)]\}+2\phi\mu[1+\alpha(\sigma-1)][2\alpha(\sigma-1)+(1+\phi)]\right\}^2} < 0 \qquad (2.57)$$

$$\lim_{\phi\to 1}\frac{dw^*}{dS} = 0 \qquad (2.58)$$

When the extraction productivity, ϵ, is high, the effect of the population on the long-run level of the natural resource is accentuated, and the resource effect becomes stronger, as pointed out by expressions (2.45) and (2.46). In Figures 2.2 (a) - (i) the stability regions become greater as ϵ becomes higher. On the other side, high economies of scale (low σ) increase the strength of the price index effect. As a result of these forces, we can observe in Figure 2.2 (a) that for low σ and low ϵ the symmetric equilibrium is always unstable. This pattern also takes place when the proportion of income devoted to industrial goods (μ) is high. The price index and the market size effects are strengthened (Figure 2.2 (f)).

2.3.3. Identical trade costs

In order to incorporate an intermediate case between non-tradable and perfectly tradable primary goods, we assume here that primary goods are tradable at the same transport costs of industrial goods, that is $\tau = \nu$ (or $\phi = \kappa$). In this simplified case equation (2.43), together with (2.47) and (2.48), can be rewritten as

$$\begin{aligned}\hat{\Delta}\Big|_{\frac{1}{2}} &= \left\{\left[1-\mu\tfrac{1-\phi}{1+\phi}\left(\alpha+(1-\alpha)\tfrac{1-\phi}{1+\phi}\right)-(1-\mu)\,\tfrac{1-\phi}{1+\phi}\right]\tfrac{dw^*}{dL_1}+\mu\tfrac{1-\phi}{1+\phi}\tfrac{dn^*/dL_1}{\sigma-1}\right\}\tfrac{\hat{L}_1}{2} \qquad (2.59)\\ &+\left\{\left[1-\tfrac{\mu(1-\phi)}{1+\phi}\left(\alpha+\tfrac{(1-\alpha)(1-\phi)}{1+\phi}\right)-\tfrac{(1-\mu)(1-\phi)}{1+\phi}\right]\tfrac{dw^*}{dS}+\tfrac{1-\phi}{1+\phi}\left[\tfrac{\mu(1-\alpha)(1-\phi)}{1+\phi}+(1-\mu)+\mu\tfrac{dn^*/dS}{\sigma-1}\right]\right\}\hat{S}\end{aligned}$$

where $dw^*/dL_1 \gtrless 0$ and $dw^*/dS > 0$ can be obtained from expressions (2.32) and (2.34), and

$$\frac{dn^*}{dL_1} = 4\tfrac{1+\phi}{1-\phi} - \tfrac{2\phi\{(1-\phi)(2\sigma-1-\phi)+4[1+\alpha(\sigma-1)]\phi\}}{(1-\phi)^2(1+\phi)}\frac{dw^*}{dL_1} > 0 \quad (2.60)$$

$$\frac{dn^*}{dS} = 4(1-\alpha)(\sigma-1)\tfrac{\phi(1+\phi)}{(1-\phi)^2} - \tfrac{2\phi\{(1-\phi)(2\sigma-1-\phi)+4[1+\alpha(\sigma-1)]\phi\}}{(1-\phi)^2(1+\phi)}\frac{dw^*}{dS} < 0 \quad (2.61)$$

$$\frac{dw^*}{dL_1} \gtrless 0 \text{ if and only if } \phi \gtrless \hat{\phi}(\kappa = \phi) \equiv \frac{\sigma(1-\mu) - \mu[1+\alpha(\sigma-1)]}{\sigma(1-\mu) + \mu[1+\alpha(\sigma-1)]}$$

where dn^*/dL_1 and dn^*/dS are positive and negative, respectively (see expressions (2.70) and (2.71) in Appendix).

Although there are now more forces involved, the (industrial) price index effect continues to favour the agglomeration ($dn^*/dL_1 > 0$), the expression in the first square brackets in (2.59) remains positive. Thus, among the traditional NEG forces, a necessary condition for dispersion is that the competition effect dominates the market size effect ($dw^*/dL_1 < 0$). This only occurs for high levels of transport costs, $\phi < \hat{\phi}(\kappa = \phi)$. In spite of the effect coming from the primary price index (the last term in the first square brackets of expression (2.59)), traditional NEG forces keep the same behavior as in the case of the perfectly tradable primary good.

On the other hand, compared to the case of a perfectly tradable primary good, the resource effect is now reinforced. The existence of transport costs in the primary sector makes the primary price index differ between regions, and now firms and households can benefit from being in a resource-abundant region. As a result of this, when $\phi = \kappa$, the resource effect acts always as a dispersion force around the symmetric equilibrium (see Lemma 2 in Appendix).

The primary labor productivity and the firms channels are responsible for the reinforcement of the resource effect. First, a lower stock of natural resources tends to reduce the productivity of the labor force employed in the extraction, causing the ratio of primary prices to rise. Households in the region with the less abundant natural resource lose more from this higher price (second term in the last square brackets of (2.59)) than households in the resource-abundant region. Additionally, firms in this region also lose more from the higher cost than foreign firms (from region 2), increasing their prices, and reducing again the indirect utility (first term in the last square brackets of (2.59)). Second, the higher cost for industrial firms leads them to incur losses, which encourages the exit of firms from the market ($\partial n^*/\partial S > 0$, first term in expression (2.61)), so raising the cost of living in the region. This is the firms channel, and although, it continues to discourage dispersion ($dn^*/dS < 0$), its strength is weakened in this case.

The stability region for the symmetric equilibrium (Figure 2.3) is similar to that obtained for the case $\kappa = 1$. The main difference is that the instability observed for low values of ϵ and σ (or high values of μ) in the case of perfectly tradable primary goods, seems to be more persistent when $\kappa = \phi$ (Figures 2.3 (a) - (c) and 2.3 (e) - (i)). Only when the proportion of income devoted to industrial goods (μ) is very low do we find that the stability region extends to $\epsilon = 0$ (Figure 2.3 (d)).

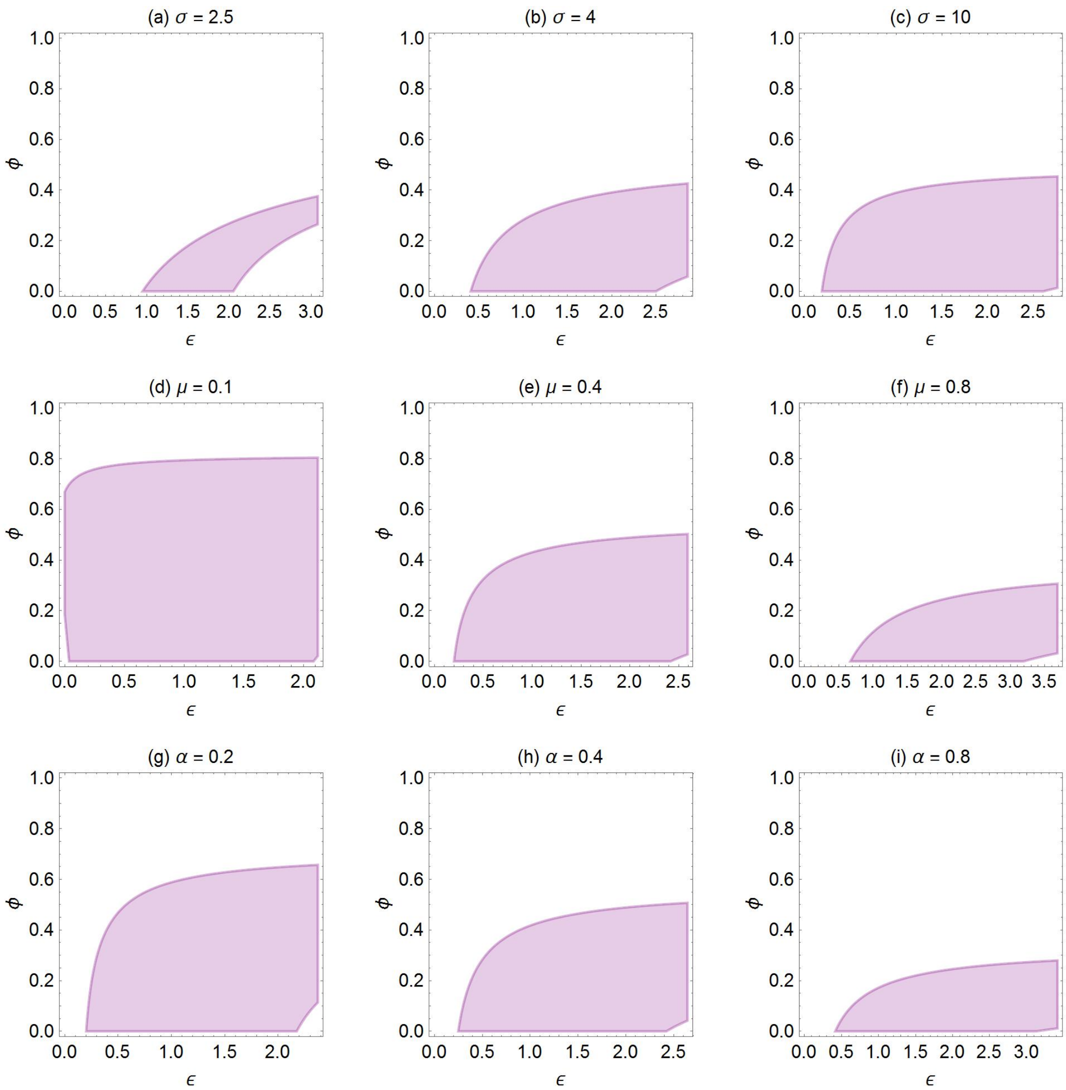

Figure 2.3: Stability Region: identical trade costs

2.3.4. Different trade costs

Finally, we return to the general case where primary goods and industrial goods face different transport costs, ν and τ, respectively (or $\kappa \equiv \nu^{1-\sigma}$ and $\phi \equiv \tau^{1-\sigma}$). Once more, expression (2.43) can be rewritten as

$$\begin{aligned}\hat{\Delta}\Big|_{\frac{1}{2}} &= \left\{\left[1-\tfrac{\mu(1-\phi)}{1+\phi}\left(\alpha+\tfrac{(1-\alpha)(1-\kappa)}{1+\kappa}\right)-\tfrac{(1-\mu)(1-\kappa)}{1+\kappa}\right]\tfrac{dw^*}{dL_1}+\tfrac{\mu(1-\phi)}{1+\phi}\tfrac{dn^*/dL_1}{\sigma-1}\right\}\tfrac{\hat{L}_1}{2} \\ &+\left\{\left[1-\tfrac{\mu(1-\phi)}{1+\phi}\left(\alpha+\tfrac{(1-\alpha)(1-\kappa)}{1+\kappa}\right)-\tfrac{(1-\mu)(1-\kappa)}{1+\kappa}\right]\tfrac{dw^*}{dS^*}+\tfrac{1-\kappa}{1+\kappa}\left[\tfrac{\mu(1-\alpha)(1-\phi)}{1+\phi}+1-\mu\right]+\tfrac{\mu(1-\phi)}{1+\phi}\tfrac{dn^*/dS}{\sigma-1}\right\}\hat{S}\end{aligned} \tag{2.62}$$

where $dw^*/dL_1 \gtrless 0$, $dw^*/dS > 0$, $dn^*/dL_1 > 0$ and $dn^*/dS < 0$ can be obtained from expressions (2.32), (2.34), (2.70) and (2.71).

Expression (2.62) is similar to the one obtained in subsection 2.3.3. The only difference is that now the forces associated with the primary price index incorporate the corresponding transport costs. However, the economic intuition remains unchanged. Thus, to avoid repetition, in this section we skip the detailed explanation of the forces that take place.

Regarding the stability of the equilibrium, there are many aspects that can be analyzed. We focus mainly on the resource effect by studying the relation between openness of trade (ϕ and κ) and one of the key parameters- the extractive productivity, ϵ. Figure 2.4 presents the stability region of the symmetric equilibrium in the space (ϵ,κ) for different values of ϕ.

What stands out first is that the equilibrium is usually unstable for low values of ϵ, and as the extractive productivity increases, the shaded region enlarges. This has been observed in all the cases studied before. The higher the ϵ, the stronger the resource effect.

Second, for low values of ϕ the stability region runs all the way from $\kappa = 0$ to $\kappa = 1$ (for some values of ϵ), but this pattern changes as ϕ increases. Both, standard NEG forces and the resource effect are responsible for this. On the one hand, the competition weakens as industrial and primary transport costs decrease and increase, respectively. Since the balance trade equation (2.24) always decreases with the ratio of wages (expression (2.31)), the role of transport costs can be seen in the following expression:

$$\frac{\partial TB}{\partial L_1}\bigg|_{1/2} = 2\left\{\mu\frac{\phi}{1-\phi} - (1-\mu)\frac{\kappa}{1+\kappa} - \frac{\mu(1-\alpha)(\sigma-1)}{\sigma}\frac{\kappa}{1+\kappa}\frac{1+\phi}{1-\phi}\right\} \tag{2.63}$$

One of each term corresponds with the different terms in equation (2.24). The positive sign of the first term implies that as population increases in region 1, the exports of industrial goods produced in the region grow more than imports. As the industrial sector becomes more open, the trade imbalance widens. The negative signs of the other two terms imply a primary trade deficit for region 1, because of the larger size of the market.[6] As κ increases, the primary sector becomes more open, and hence the primary trade deficit widens. When the negative sign prevails, there is a trade deficit, and the ratio of wages has to come down in order to restore the balance. The opposite happens when the

[6] Note that the primary good is homogenous within each region, and slightly differentiated across them. This implies that even when the primary sectors have different sizes, there is no love-of-variety, as there is in the industrial sector.

positive sign prevails. Thus, high values of κ and low values of ϕ favour dispersion, and low values of κ and high values of ϕ work against dispersion, exactly as shown in Figure 2.4.[7]

On the other hand, changes in the stability region's shape are also the results of the interaction between how the resource affects prices (primary and industrial), and how the wage adjustment affects interregional trade, i.e., the consequence of the initial shock and the adjustment process. Let us start with the last one. To understand this, assume that the population in region 1 increases and this leads to a lower ratio of natural resources, then, through the resource effect, region 2 has a commercial surplus, which generates a downward pressure on the ratio of wages. Interregional trade tends to balance again, because wages reduce relative prices and income in region 1. However, when ϕ is low, industrial firms sell mainly locally, so, to increase imports and reduce exports of region 2, a higher adjustment is needed. Thus, the resource effect loses some strength as the industrial trade opens. Nevertheless, it seems that the resource effect weakens only for high values of κ. This has to do with how the resources affect prices. The closer the primary trade, the higher the impact of the resource on industrial prices, thus, the higher the trade imbalance and the adjustment needed. This explains why the resource effect remains even when ϕ is low, as long as κ is low too. But, when the primary trade is open, the resource stocks have a lower impact on industrial prices, and the trade imbalance becomes less pronounced. Summing up, in all the panels of Figure 2.4 low values of κ imply a major trade imbalance and vice versa. Instead, for Figure 2.4 (a) - (c), the low values of ϕ imply a higher wage adjustment requirement, and vice versa (Figures 2.4 (d) - (i)). The interaction between these two factors explains why the resource effect weakens as ϕ increases, but for only high values of κ.

Third, in Figure 2.4 (f) - (i), the shaded region expands. Agglomeration forces lose strength faster than the resource effect as industrial trade opens (for low values of κ). As expected, the equilibrium is stable for low values of κ, because the primary trade costs increase the impact of the resources. However, if we kept drawing the stability region for higher values of ϕ, we would find that agglomeration forces keep loosing strength and that the equilibrium becomes stable even for values of κ very close to one. This can be easily checked by looking at Figure 2.6, where we present the stability region of the symmetric equilibrium in the space (κ, ϕ) for different values of the extractive productivity ϵ (the dashed line is $\hat{\phi}$).

[7]Note that higher values of ϕ also reinforce the negative sign of the primary trade imbalance; however, the net effect of the parameter in $\partial TB^*/\partial L_1$ is positive, that is, favoring a trade surplus.

Both forces in expression (2.63) are equalized when $\phi = \hat{\phi}$, defined by expression (2.33), or when $\kappa = \hat{\kappa}$, where

$$\hat{\kappa} = \frac{\mu\sigma\phi}{\sigma - \mu\left[1 + \alpha\left(\sigma - 1\right)\right] - \left\{\sigma\left(1 - \mu\right) + \mu\left[1 + \alpha\left(\sigma - 1\right)\right]\right\}\phi}$$

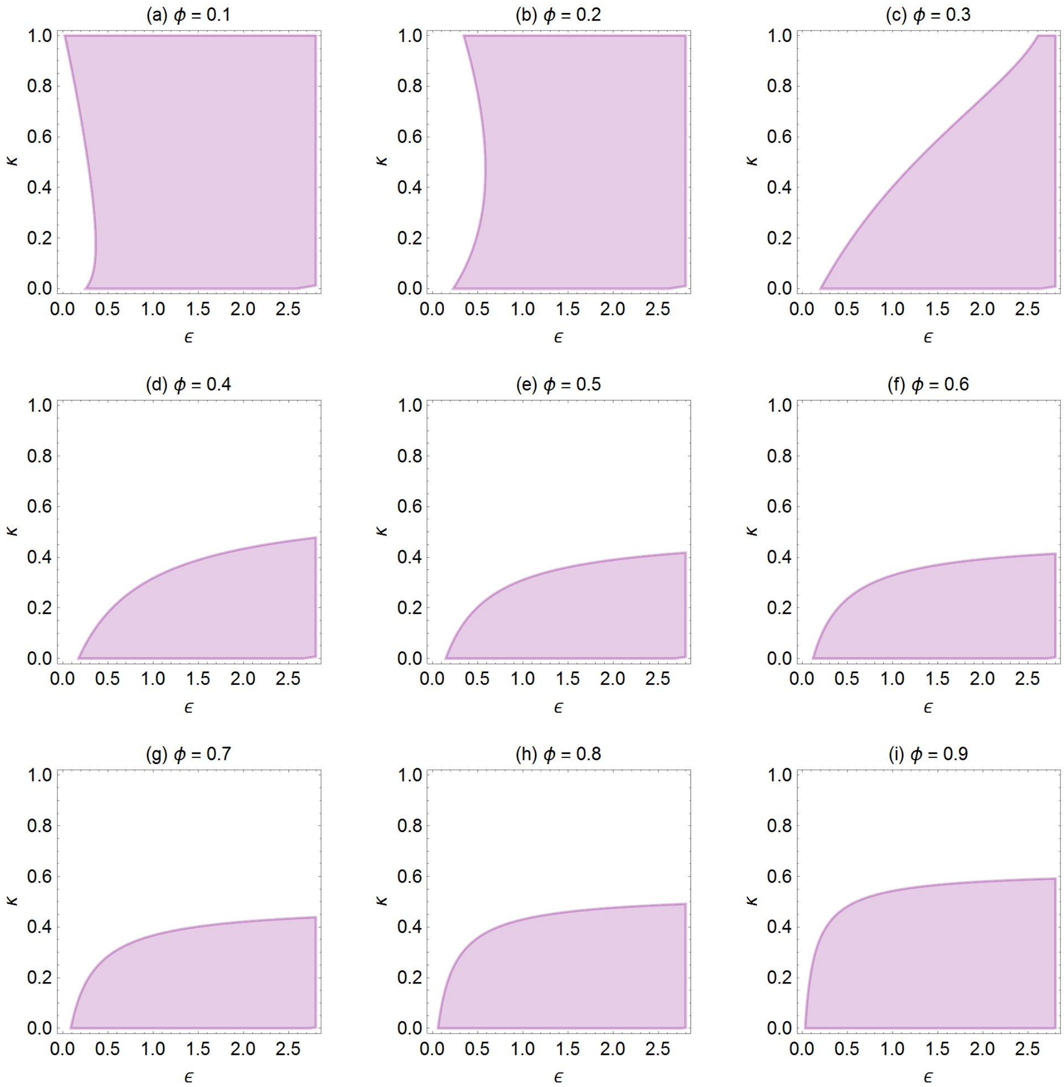

Figure 2.4: Stability Region: different trade costs (ϵ,κ)

Fourth, by looking at Figures 2.4 (a) and (b), it is clear that there is a range of values for ϵ such that as κ increases the symmetric equilibrium goes from stable, to unstable, and to stable again. This pattern takes place for low-intermediate values of the extractive productivity, for which the resource effect is not too strong. For this range of ϵ, when κ is low, the resource effect is reinforced, making the equilibrium stable, but as κ increases this dispersion force loses strength faster than the competition effect grows, and the equilibrium becomes unstable (see Figure 2.6 (d) for a neat example of this). However, when κ is high enough, the competition effect dominates the market size effect and, eventually, over the other agglomeration forces, making the equilibrium stable again.

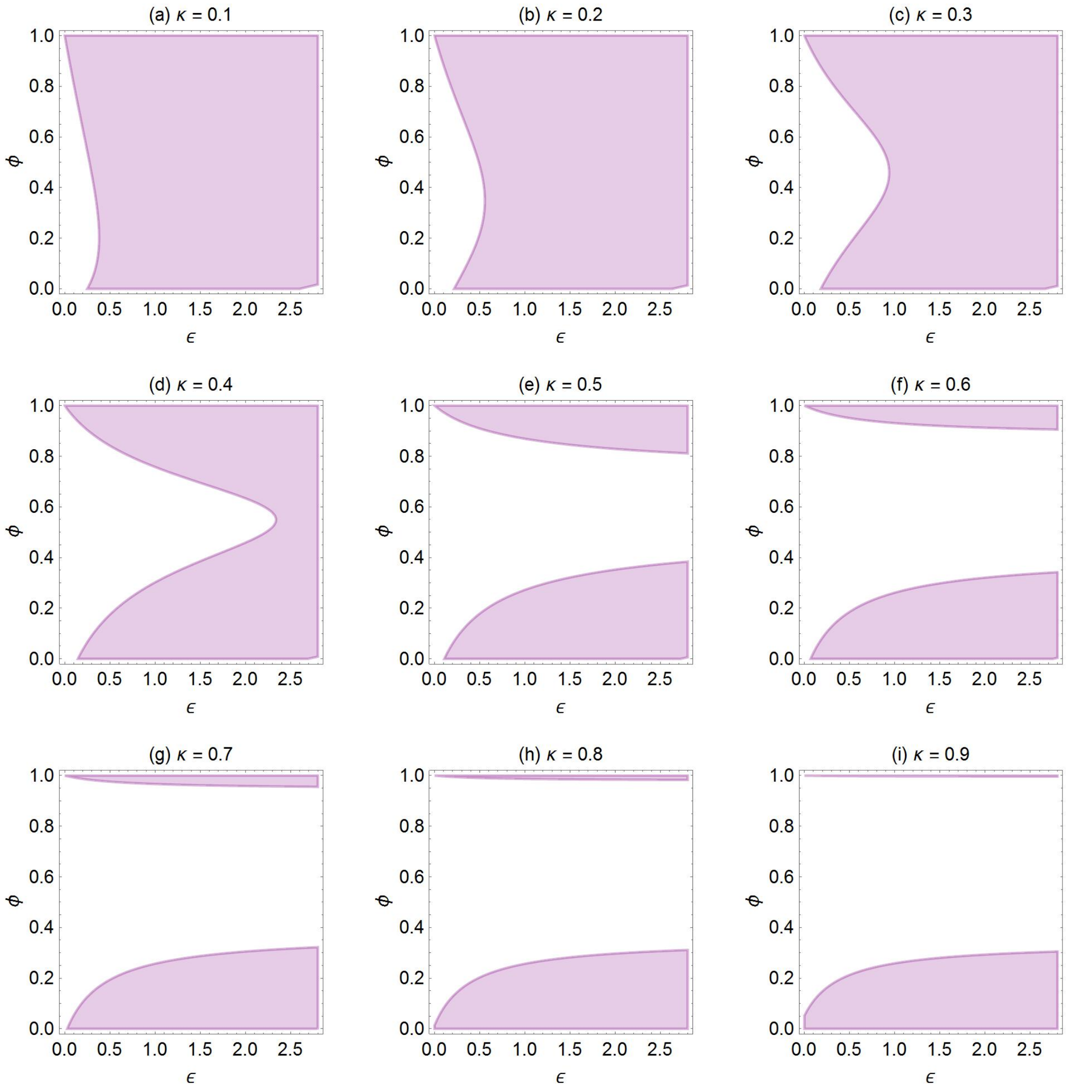

Figure 2.5: Stability Region: different trade costs (ϵ,ϕ)

Another way to analyze the stability of the symmetric equilibrium is through the space (ϵ,ϕ). Figure 2.5 presents this for different values of κ. For low values of the primary openness of trade, the equilibrium is stable for a considerable wide range of ϵ (Figures 2.5 (a) - (c)). However, as κ increases, a breach of instability appears and widens (from the left to the right), mainly by reducing the stability region at higher values of ϕ. This breach has its causes in the forces indicated earlier. Reductions in primary transport costs weaken the resource effect, especially for high values of ϕ, because of the interaction between the reduced trade imbalance and the low adjustment required. The shaded

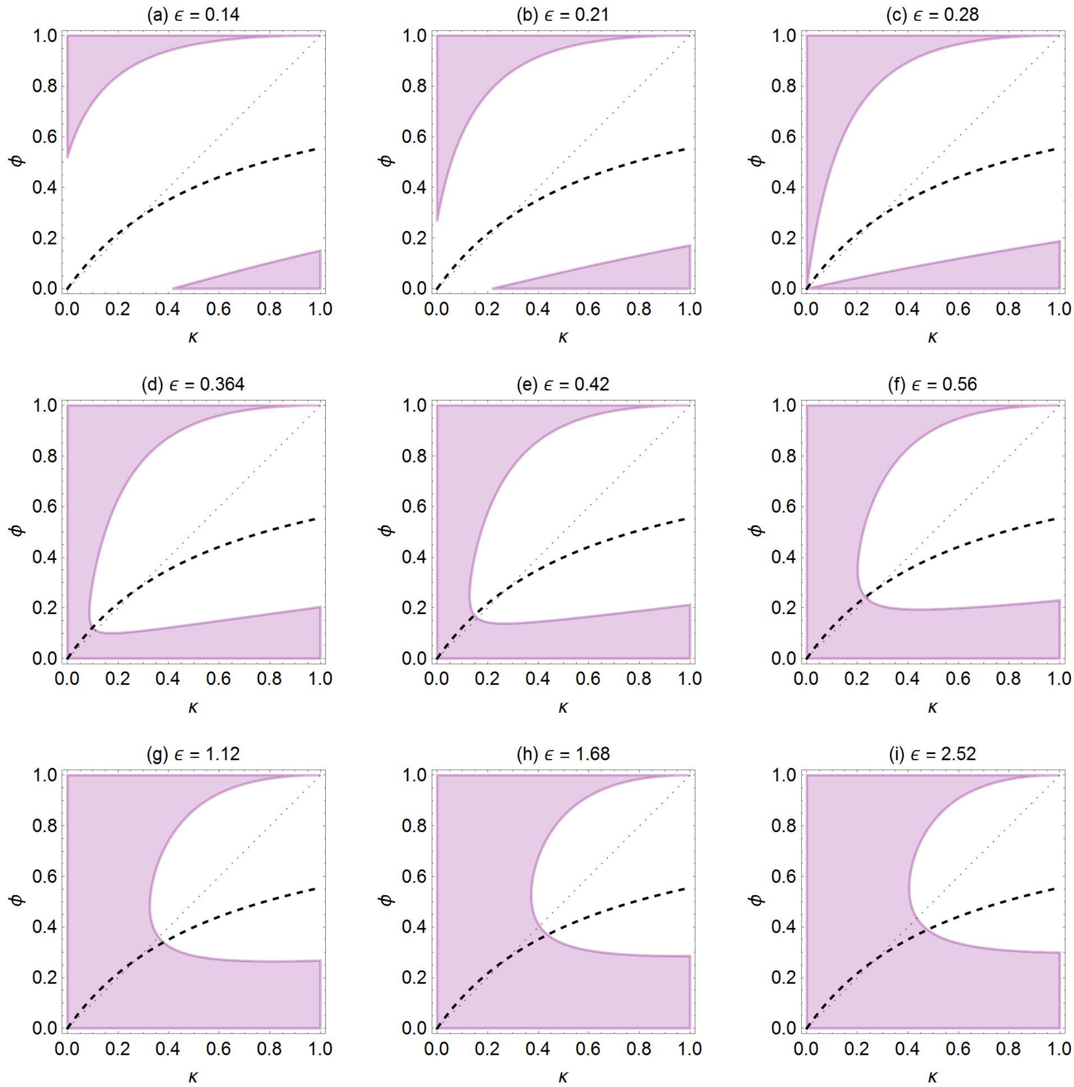

Figure 2.6: Stability Region: different trade costs (κ,ϕ)

region for low values of ϕ is the result of the competition effect and the resource effect, that preserves its strength when industrial transportation costs are high. The shaded region for high values of ϕ is due only to the resource effect, since $\phi > \hat{\phi}$. Recall that agglomeration forces also lose strength as industrial transport cost decreases; ultimately, when $\phi = 1$ traditional NEG forces (dispersion and agglomeration) vanish, and only the resource effect remains, as long as $\kappa < 1$ (see the case of a perfectly tradable industrial good in Section 2.8). Also note that both the upper and lower stability regions increase with the extractive productivity, ϵ.[8]

[8]When $\phi = \kappa = 1$ all the effects vanish. This can be seen by making both equal to 1 in expressions

Figure 2.6 summarizes all the possible cases studied: non-tradable and perfectly tradable cases, identical trade cost, and the intermediate case (where the dashed line plots $\hat{\phi}$ and the dotted line plots $\phi = \kappa$). Although, there are many scenarios, Figure 2.6 shows that the stability region has a regular shape. Additionally, the extractive productivity proves to be an important parameter for the stability of the equilibrium.

2.4. Conclusions

This chapter focuses the on so called resource effect and its interaction with primary and industrial transport costs. We make use of an extension of the CP model that incorporates renewable natural resources, proposed by Martínez-García and Morales (2019), but with a specific transport cost in each sector. We make a deep study of the stability pattern of the symmetric equilibrium and the dispersion and agglomeration effects.

Our results suggest that although the resource effect suffers some changes with the alteration in the tradability assumptions, it remains an important factor in the spatial distribution of the economic activity. Furthermore, the resource effect acts as a dispersion force for high and low values of industrial transport costs, while for intermediate levels of transport costs it could favour the instability of the symmetric equilibrium, working against the dispersion.

We identify three different channels nourishing the resource effect: wage, firms and primary labor productivity channels. Through these, the dynamics of the natural resources impacts on the distribution of the economic activity. When the ratio of natural resources decreases, the primary labor productivity falls and primary prices rise. The ratio of wages diminishes due to the trade imbalance generated by the change in primary prices; and the number of firms increases because of the lower ratio of wages.

When industrial and primary goods face their own specific transport costs, the traditional NEG effects (market size, competition and price index effects) exhibit a standard behavior. However, if the primary good is assumed to be non-tradable, the sectorial labor mobility causes the market size effect to overcome the competition effect. If industrial goods are assumed to be non-tradable, then, the competition effect becomes stronger than the market size; while if industrial goods are perfectly tradable, with zero transport costs, all the traditional NEG effects vanish, and the only remaining active force is the resource effect. In this last case, the symmetric equilibrium is always stable. In all three cases, the firms channel of the resource effect vanishes.

We also found that, the dispersion force of the resource effect is stronger, the higher the extractive productivity, and both transport costs are. The stability of the symmetric equilibrium shows some interesting regularities as a consequence of the interaction of the resource effect and the traditional NEG forces. On the one hand, when the extractive productivity is low, we find three different stability patterns as industrial transport costs

(2.32), (2.34) and (2.62).

decreases. First, if primary transport costs are high, the symmetric equilibrium goes from unstable to stable. Second, if primary transport costs are low, the opposite occurs. If primary transport costs are intermediate, we observe that the symmetric equilibrium goes from stable, to unstable, and to stable again. On the other hand, when the extractive productivity is high, the second and the third patterns remain as before, but the first one changes. In this case, if the extractive productivity and primary transport costs are high, the symmetric equilibrium is always stable.

2.5. References

Baldwin, R., Forslid, R., Martin, P., & Robert-Nicoud, F. (2005). *Economic geography and public policy*. Princeton University Press.

Barbier, E. B. (2005). Natural resources and economic development. Cambridge University Press.

Brander, J., & Taylor, M. (1997a). International Trade and Open-Access Renewable Resources: The Small Open Economy Case. The Canadian Journal of Economics / Revue Canadienne D'Economique, 30(3), 526-552.

Brander, J. A., & Taylor, M. S. (1997b). International trade between consumer and conservationist countries. Resource and Energy Economics, 19(4), 267-297.

Brander, J. A., & Taylor, M. S. (1998a). Open access renewable resources: trade and trade policy in a two-country model. Journal of International Economics, 44(2), 181-209.

Brander, J. A., & Taylor, M. S. (1998). The simple economics of Easter Island: A Ricardo-Malthus model of renewable resource use. American economic review, 119-138.

Bulte, E. H., & Barbier, E. B. (2005). Trade and renewable resources in a second best world: an overview. Environmental and Resource Economics, 30(4), 423-463.

Chichilnisky, G. (1994). North-South Trade and the Global Environment. American Economic Review 84(4), 851-874.

FAO. 2012. The State of the World's Forests 2012. Rome.

FAO. 2018. The State of the World's Forests 2018 - Forest pathways to sustainable development. Rome.

Farrell, K. (2017). The rapid urban growth triad: a new conceptual framework for examining the urban transition in developing countries. Sustainability, 9(8), 1407.

Fujita, M., Krugman, P. R., & Venables, A. (2001). The spatial economy: Cities, regions, and international trade. MIT press. Massachusetts.

González-Val, R., & Pueyo, F. (2019). Natural resources, economic growth and geography. Economic Modelling.

Karp, L., Sacheti, S., & Zhao, J. (2001). Common ground between free-traders and environmentalists. International Economic Review, 42(3), 617-648.

Krugman, P. (1991). Increasing Returns and Economic Geography. The Journal of Political Economy, 99(3), 483-499.

Li, Y., Westlund, H., & Liu, Y. (2019). Why some rural areas decline while some others not: An overview of rural evolution in the world. Journal of Rural Studies.

Martínez-García, M. P., & Morales, J. R. (2019) Resource effect in the Core–Periphery model, Spatial Economic Analysis.

McAuliffe, M., Kitimbo, A., Goossens, A. M., & Ullah, A. A. (2017) Understanding Migration Journeys from Migrants Perspectives. World Migration Report 2018 (IOM), Geneva.

Mitchell, C. J. (2004). Making sense of counterurbanization. Journal of rural studies, 20(1), 15-34.

Nordström, H., & Vaughan, S. (1999). Trade and Environment, Special Studies 4. World Trade Organisation (WTO), Geneva.

Riekhof, M. C., Regnier, E., & Quaas, M. F. (2018). Economic growth, international trade, and the depletion or conservation of renewable natural resources. Journal of Environmental Economics and Management.

Takatsuka, H., Zeng, D. Z., & Zhao, L. (2015). Resource-based cities and the Dutch disease. Resource and Energy Economics, 40, 57-84.

2.6. Appendix

Households: A representative household in region 1 chooses c_{1i}, c_{2i}, c_{H_1} and c_{H_2} to maximize its utility function (2.1) together with expressions (2.2) and (2.3), subject to its balance constraint,

$$w_1 = \int_0^{n_1} c_{1i} p_{1i} di + \int_0^{n_2} c_{2i} p_{2i} \tau di + p_{H_1} c_{H_1} + p_{H_2} c_{H_2} \nu$$

where, due to the perfect sectorial mobility, the wage, w_1, is equal to the individual income of region 1. From the first order conditions of this maximization problem, the following functions are obtained:

$$c_{1i} = C_{M_1} \left(\frac{p_{1i}}{P_1}\right)^{-\sigma}, \ c_{2i} = C_{M_1} \left(\frac{p_{2i}\tau}{P_1}\right)^{-\sigma} \text{ with } C_{M_1} = \frac{\mu w_1}{P_1} \tag{2.64}$$

$$c_{H_1} = C_{H_1} \left(\frac{p_{H_1}}{P_{H_1}}\right)^{-\sigma}, \ c_{H_2} = C_{H_1} \left(\frac{p_{H_2}\nu}{P_{H_1}}\right)^{-\sigma} \text{ with } C_{H_1} = \frac{(1-\mu)\, w_1}{P_{H_1}} \tag{2.65}$$

with the industrial and primary price indexes defined in expressions (2.4) and (2.5). Households in region 2 solve a mirror-image problem.

Primary Sector: Imposing the free entry condition in the primary sector, and taking into account the harvest function (2.6),

$$p_{H_j} H_j - L_{H_j} w_j = 0 \rightarrow p_{H_j} \epsilon S_j L_{H_j} - L_{H_j} w_j = 0$$

the price rule (2.7) is obtained from this expression.

Industrial Sector: From the profit maximization of industrial firms, and by considering the elasticity of substitution ($-\sigma$), the optimal price rule (2.9) is obtained, together with,

$$h_{11} = h_1^{1-\sigma} \left(\frac{1-\alpha}{\alpha} \frac{w_1 \left(l_{x_1} - f\right)}{p_{H_1}}\right)^{\sigma} \quad \text{and} \quad h_{21} = h_1^{1-\sigma} \left(\frac{1-\alpha}{\alpha} \frac{w_1 \left(l_{x_1} - f\right)}{\nu p_{H_2}}\right)^{\sigma} \tag{2.66}$$

with

$$h_j = \frac{1-\alpha}{\alpha} \frac{w_j}{P_{H_j}} \left(l_{x_j} - f\right) \quad \text{for} \quad j = 1, 2. \tag{2.67}$$

where h_{11} and h_{21} are the demand functions of region 1's industrial sector of primary goods produced in regions 1 and 2, respectively; h_j is region j's demand for the composite raw material (primary good); and the primary price index, P_{H_j} is given by expression (2.5). Imposing the free entry condition (zero profits) and taking into account expressions (2.9) and (2.67), the optimal output (2.10) and the labor demand (2.11) are obtained. Taking into account the labor demand (2.11), the number of industrial firms is determined by expression in (2.12). Mirror-image formulas hold for region 2.

Short-run Equilibrium: If c_{11} and c_{12} are the individual demands from region 1 and 2 for a variety i of industrial goods produced in region 1, the market equilibrium condition for region 1 is

$$x_1^* = c_{11}L_1 + \tau c_{12}\left(1 - L_1\right)$$

Using the supply of an individual firm (2.10), and the demand functions (2.64), the equilibrium condition in the industrial market for region 1, in terms of w_2, is

$$n_1 \frac{fw}{p_1/\sigma} = n_1\mu\left[\frac{p_1^{-\sigma}}{P_1^{1-\sigma}}L_1 w + \frac{\phi p_1^{-\sigma}}{P_2^{1-\sigma}}L_2\right]$$

By replacing expression (2.12) in the left hand side of the previous condition, expression (2.14) is obtained. Equilibrium equation (2.15) for region 2's industrial market is obtained following the same reasoning.
If $c_{H_{11}}$ and $c_{H_{12}}$ are the individual demands of households from regions 1 and 2 for primary goods produced in region 1, and h_{11} and h_{12} are the demands of each individual firm from region 1 and 2 for primary goods produced in region 1. The primary market equilibrium condition for region 1 is

$$H_1 = c_{H_{11}}L_1 + \nu c_{H_{12}}\left(1 - L_1\right) + h_{11}n_1 + \nu h_{12}n_2$$

Thus, using the total primary supply H_1 and the total demand for primary goods produced in region 1, from expressions (2.65), (2.66) and (2.67), the equilibrium condition for the primary sector in region 1, in terms of w_2, is

$$H_1 = \frac{p_{H_1}^{-\sigma}}{P_{H_1}^{1-\sigma}}\left[(1-\mu)L_1 + \frac{(1-\alpha)(\sigma-1)}{1+\alpha(\sigma\text{-}1)}L_{E_1}\right]w + \frac{\kappa p_{H_1}^{-\sigma}}{P_{H_2}^{1-\sigma}}\left[(1-\mu)L_2 + \frac{(1-\alpha)(\sigma-1)}{1+\alpha(\sigma\text{-}1)}L_{E_2}\right]$$

Using the primary price rule (2.7), expression (2.19) is obtained. Expression (2.20) is obtained following the same procedure for the primary sector in region 2.

Long-run Equilibrium and Dynamics: The dynamic evolutions of the population and the stocks of the natural resources in the two regions are driven by equations (2.39)-(2.41). The ratio of the industrial and primary price indexes are defined by (2.27) and

$$\frac{P_{H_1}}{P_{H_2}} = \left[\frac{p_{H_1}^{1-\sigma} + \left(p_{H_2}\nu\right)^{1-\sigma}}{\left(p_{H_1}\nu\right)^{1-\sigma} + p_{H_2}^{1-\sigma}}\right]^{\frac{1}{1-\sigma}} = \left[\frac{w^{1-\sigma}\left(\frac{S_1}{S_2}\right)^{-(1-\sigma)} + \kappa}{\kappa w^{1-\sigma}\left(\frac{S_1}{S_2}\right)^{-(1-\sigma)} + 1}\right]^{\frac{1}{1-\sigma}}$$

Then, expression (2.42) can be rewritten as

$$\Delta = w\left(\frac{np^{1-\sigma} + \phi}{\phi np^{1-\sigma} + 1}\right)^{\frac{-\mu}{1-\sigma}}\left[\frac{w^{1-\sigma}(S_1/S_2)^{-(1-\sigma)} + \kappa}{\kappa w^{1-\sigma}(S_1/S_2)^{-(1-\sigma)} + 1}\right]^{-\frac{1-\mu}{1-\sigma}} \tag{2.68}$$

where, as in (2.25),

$$p = w^{\alpha}\left[\frac{w^{1-\sigma}(S_1/S_2)^{-(1-\sigma)}+\kappa}{\kappa w^{1-\sigma}(S_1/S_2)^{-(1-\sigma)}+1}\right]^{\frac{1-\alpha}{1-\sigma}}$$

Conditions for Stability: for $\kappa \in (0,1]$ and $\phi \in (0,1]$, the Jacobian matrix of the differential system evaluated at the symmetric equilibrium has the form

$$J^*_{1/2} = \begin{pmatrix} a & b & -b \\ -c & d & e \\ c & e & d \end{pmatrix} \tag{2.69}$$

with $a=\frac{1}{4}\left.\frac{\partial\Delta}{\partial L_1}\right|_{\frac{1}{2}}$, $b=\frac{1}{4S_s^*}\left.\frac{\partial\Delta}{\partial(S_1/S_2)}\right|_{\frac{1}{2}}$, $c=\epsilon S_s^*\left.\frac{\partial L_{H_1}}{\partial L_1}\right|_{\frac{1}{2}}$, $e=\epsilon\left.\frac{\partial L_{H_1}}{\partial(S_1/S_2)}\right|_{\frac{1}{2}}$ and $d=-\frac{gS_s^*}{CC}-e$. That is,

$$\begin{aligned}
a &= \tfrac{1}{4}\left\{1-\mu\tfrac{1-\phi}{1+\phi}\left[\alpha+\tfrac{(1-\alpha)(1-\kappa)}{1+\kappa}\right]-\tfrac{(1-\mu)(1-\kappa)}{1+\kappa}\right\}\tfrac{dw^*}{dL_1}+\tfrac{\mu}{4}\tfrac{1-\phi}{1+\phi}\tfrac{dn^*/dL_1}{\sigma-1}\\
b &= \tfrac{1}{4}\left\{1-\tfrac{\mu(1-\phi)}{1+\phi}\left[\alpha+\tfrac{(1-\alpha)(1-\kappa)}{1+\kappa}\right]-\tfrac{(1-\mu)(1-\kappa)}{1+\kappa}\right\}\tfrac{dw^*}{dS_1}+\tfrac{1}{4S_s^*}\left\{\tfrac{1-\kappa}{1+\kappa}\left[\tfrac{\mu(1-\phi)}{1+\phi}+(1-\mu)\right]+\tfrac{\mu(1-\phi)}{(\sigma-1)(1+\phi)}\tfrac{dn^*}{dS_1}\right\}\\
c &= \epsilon S_s^*\left\{\tfrac{\mu[1+\alpha(\sigma-1)]\phi}{\sigma(1-\phi)^2}\left[\sigma-\tfrac{1-\phi}{2}-2(1-\alpha)(\sigma-1)\tfrac{\phi}{1+\phi}\right]\tfrac{dw^*}{dL_1}+1-\tfrac{\mu[1+\alpha(\sigma-1)](1+\phi)}{\sigma(1-\phi)}\right\}\\
e &= \epsilon S_s^*\tfrac{\mu[1+\alpha(\sigma-1)]\phi}{\sigma(1-\phi)^2}\left[\sigma-\tfrac{1-\phi}{2}-2(1-\alpha)(\sigma-1)\tfrac{\phi}{1+\phi}\right]\tfrac{dw^*}{dS_1}-\epsilon(1-\alpha)(\sigma-1)\tfrac{\mu[1+\alpha(\sigma-1)]\phi}{\sigma(1-\phi^2)}\\
d &= -\tfrac{gS_s^*}{CC}-e<0
\end{aligned}$$

where dw^*/dL_1 and dw^*/dS_1 are given by (2.32) and (2.34), and

$$\begin{aligned}
\frac{dn^*}{dL_1} &= \frac{4(1+\kappa)\left[1+\alpha(\sigma-1)\right]^2\Psi^*}{\sigma(1-\kappa)+2[1+\alpha(\sigma-1)]\kappa}\,\frac{\frac{\frac{(2\sigma-1+\kappa)(1-\phi)}{\sigma(1+\kappa)^2}+\phi\left[1-\frac{(1-\mu)(1-\kappa)}{1+\kappa}\right]\left\{1+2\frac{\sigma-1}{1+\phi}\left[\alpha+\frac{(1-\alpha)(1-\kappa)}{1+\kappa}\right]\right\}}{\sigma-\mu[1+\alpha(\sigma-1)]}}{\mu\sigma\left\{\frac{(2\sigma-1+\kappa)\kappa(1-\phi)^2}{(1+\kappa)^2(1+\phi)}+\phi\Psi^*\left\{1+2\frac{\sigma-1}{1+\phi}\left[\alpha+(1-\alpha)\frac{1-\kappa}{1+\kappa}\right]\right\}\right\}}>0 &(2.70)\\
\frac{dn^*}{dS_1} &= \frac{-4(\sigma-1)\phi[\kappa+\phi+\alpha(2\sigma-1-\kappa)]}{\mu S_s^*(1+\kappa)^2(1+\phi)\left\{\frac{(2\sigma-1+\kappa)\kappa(1-\phi)^2}{(1+\kappa)^2(1+\phi)}+\phi\Psi^*\left\{1+\frac{2(\sigma-1)}{1+\phi}\left[\alpha+(1-\alpha)\frac{1-\kappa}{1+\kappa}\right]\right\}\right\}}<0 &(2.71)\\
\Psi^* &= \frac{\mu-\frac{\mu(1-\alpha)(\sigma-1)}{\sigma}\frac{2\kappa}{1+\kappa}}{1-\mu+\frac{\mu(1-\alpha)(\sigma-1)}{\sigma}} &(2.72)
\end{aligned}$$

The value $d+e=-gS_s^*/CC<0$ is an eigenvalue of matrix (2.69). Its characteristic polynomial is $P(\lambda)=(d+e-\lambda)\left[\lambda^2-(a+d-e)\lambda+2bc+a\,(d-e)\right]$. Thus, the symmetric equilibrium is stable if and only if

$$\begin{aligned}
2bc+a(d-e) &> 0 &(2.73)\\
a+d-e &< 0 &(2.74)
\end{aligned}$$

The stability of the symmetric equilibrium for the case of non-tradable primary goods ($\kappa=0$) is studied in Martínez-García and Morales (2019). The stability of the symmetric equilibrium for the case of a non-tradable industrial good ($\phi = 0$) is presented later in Section 2.7.

Proof of Proposition 1: When the population changes, the labor employed in the extraction of natural resources also changes, affecting the ratio of the long-run levels of the resource (2.44). The resource effect is determined by the second part of expression (2.43). To see its sign as population changes, we have to differentiate this expression with respect to L_1. Considering that at the symmetric equilibrium $dL^*_{H_2}/dL_1 = -dL^*_{H_1}/dL_1$, and that S^* is determined by (2.44), we have that

$$\left.\frac{\partial\hat{\Delta}}{\partial S}\right|_{1/2}\frac{dS^*}{dL_1} = -\frac{2\frac{\epsilon}{g}}{1-\epsilon\theta/2}\left[\frac{dw^*}{dS} - \mu\frac{dP^*}{dS} - (1-\mu)\frac{dP^*_H}{dS}\right]\frac{dL^*_{H_1}}{dL_1} \gtrless 0 \tag{2.75}$$

If this expression is negative, the resource effect acts as a dispersion force, and vice versa. The sign depends on the expression inside the square brackets and on the derivative of the primary labor. On differentiating equation (2.18) with respect to L_1,

$$\frac{dL^*_{H_1}}{dL_1}=1-\frac{(1+\kappa)\left[1+\alpha(\sigma\text{-}1)\right]^3\Psi^*}{\{\sigma(1\text{-}\kappa)+2[1+\alpha(\sigma\text{-}1)]\kappa\}}\frac{\frac{\sigma\text{-}\mu[1+\alpha(\sigma-1)]}{\sigma}\frac{(2\sigma\text{-}1+\kappa)(1\text{-}\phi)}{(1+\kappa)^2}+\phi\left[1\text{-}(1\text{-}\mu)\frac{1\text{-}\kappa}{1+\kappa}\right]\left\{1+2\frac{\sigma\text{-}1}{1+\phi}\left[\alpha+(1\text{-}\alpha)\frac{1\text{-}\kappa}{1+\kappa}\right]\right\}}{\sigma^2\left\{\frac{(2\sigma\text{-}1+\kappa)\kappa(1\text{-}\phi)^2}{(1+\kappa)^2(1+\phi)}+\frac{\Psi^*}{\phi-1}\left\{1+2\frac{\sigma\text{-}1}{1+\phi}\left[\alpha+(1\text{-}\alpha)\frac{1\text{-}\kappa}{1+\kappa}\right]\right\}\right\}} \tag{2.76}$$

Note that the denominator of the second term is positive, so, after some tedious manipulations, this expression can be restated as

$$\frac{dL^*_{H_1}}{dL_1}=\{\sigma-\mu\left[1+\alpha(\sigma-1)\right]\}\frac{A\phi^2+B\phi+C}{D}$$

where $D > 0$ since the dominator of the second term of (2.76) is positive, and

$$\begin{aligned}
A &= \mu\sigma+\kappa^2\left[\sigma-(1-\alpha)(\sigma-1)\right]+\kappa\{\sigma+\mu\left[1+\alpha(\sigma-1)\right]\}(2\sigma-1)>0\\
B &= \sigma\{(1-\kappa)\left[\mu(1\text{-}\kappa)+2\mu\alpha\kappa-2\kappa(1+\alpha(\sigma\text{-}1))\right]+2\sigma\left[2\kappa-\mu(1\text{-}\kappa)(1-\kappa+2\alpha\kappa)\right]\}\gtrless 0\\
C &= \kappa\{\sigma-\mu\left[1+\alpha(\sigma-1)\right]\}(2\sigma-1+\kappa)>0
\end{aligned}$$

Then,

$$\begin{aligned}
\frac{dL^*_{H_1}}{dL_1}(\phi=0) &= C>0\\
\frac{dL^*_{H_1}}{dL_1}(\phi=1) &= A>0
\end{aligned}$$

By evaluating the terms in the square brackets of expression (2.75) at $\phi = 0$ and $\phi = 1$,

$$\begin{aligned}
\left.\left[\frac{dw^*}{dS}-\mu\frac{dP^*}{dS}-(1-\mu)\frac{dP^*_H}{dS}\right]\right|_{\phi=0} &= \left[1-\frac{(1-\mu)(1-\kappa)}{1+\kappa}\right]\frac{dw^*}{dS}-\frac{(1-\mu)(1-\kappa)}{1+\kappa}>0\\
\left.\left[\frac{dw^*}{dS}-\mu\frac{dP^*}{dS}-(1-\mu)\frac{dP^*_H}{dS}\right]\right|_{\phi=1} &= \left[1\text{-}\mu\left(\alpha+\frac{(1\text{-}\alpha)(1\text{-}\kappa)}{1+\kappa}\right)\text{-}\frac{(1\text{-}\mu)(1\text{-}\kappa)}{1+\kappa}\right]\frac{dw^*}{dS}+\frac{(1\text{-}\mu\alpha)(1\text{-}\kappa)}{1+\kappa}>0
\end{aligned}$$

which are both positive since expression (2.34) is positive and $\frac{dw}{dS} = \frac{dw}{dS_1}S_2$. Thus, expression (2.75) is negative for $\phi = 0$ and $\phi = 1$, which implies that the resource effect acts as a dispersion force for low and high values of industrial transport costs.

Proof of Proposition 2: When $\kappa = 0$, then $n = L_1/(1 - L_1)$, $P_H = p_H$ and $w = p\left(S_1/S_2\right)^{1-\alpha}$. Equation (2.29) can be restated as

$$TB = p\left(\frac{S_1}{S_2}\right)^{1-\alpha} - p^{1-\sigma}\frac{\frac{L_1}{1-L_1}p^{1-\sigma} + \phi}{\frac{L_1}{1-L_1}p^{1-\sigma}\phi + 1} = 0 \tag{2.77}$$

Then, by differentiating this expression and using the definition (2.25), we obtain

$$\frac{dw^*}{dL_1} = \frac{dp^*}{dL_1} = \frac{\left(\frac{S_1}{S_2}\right)^{1-\alpha} + \frac{(\sigma-1)p^{-\sigma}\left\{\phi\left[1+\left(\frac{L_1}{1-L_1}p^{1-\sigma}\right)^2\right]+2\frac{L_1}{1-L_1}p^{1-\sigma}\right\}}{\left(\frac{L_1}{1-L_1}p^{1-\sigma}\phi+1\right)\left(\frac{L_1}{1-L_1}p^{1-\sigma}+\phi\right)}}{\frac{p^{2(1-\sigma)}(1-\phi)(1-L_1)^2}{\left(\frac{L_1}{1-L_1}p^{1-\sigma}\phi+1\right)^2}} > 0 \tag{2.78}$$

This occurs for two reasons. On the one hand, the non-tradability assumption of the primary good tends to reinforce the market size effect (primary income depends on industrial wages). Note that the price of the resource is a function of industrial wages (equation (2.26)).[9]
On the other hand, by solving the equilibrium condition for the primary sector (2.19) when $\kappa = 0$, we have that

$$L_{H_j}w_{H_j} = (1-\mu)\left(L_{E_j}w_j + L_{H_j}w_{H_j}\right) + \frac{(1-\alpha)(\sigma-1)}{1+\alpha(\sigma-1)}L_{E_j}w_j \tag{2.79}$$

where w_{H_j} is wage in the primary sector. The sectorial free labor mobility implies $w_j = w_{H_j}$, and by taking into account the full employment condition (2.13),

$$L_{H_j} = g\theta L_j \tag{2.80}$$

where θ is defined in expression (2.38).

Thus, when there is sectorial labor mobility and the primary good is non-tradable, the population working in the primary sector is proportional to the total population of

[9] This is independent of the assumption of labor mobility across sectors. Without this assumption, primary income would remain dependent on industrial income as well. Primary income in this case can be obtained from expression (2.79), which assumes different sectorial wages,

$$w_{H_j}L_{H_j} = \frac{\sigma - \mu\left[1+\alpha(\sigma-1)\right]}{\mu\left[1+\alpha(\sigma-1)\right]}w_jL_{E_j},$$

where w_{H_j} is the primary wage when there is no labor mobility.

the region. Thus, there is no fixed market or fixed income in the regions as there was in Krugman (1991), which weakens the competition effect.

Additionally, agglomeration forces lose strength when transport costs decrease. This can be seen by differentiating the ratio of wages with respect to L_1 and ϕ at the symmetric equilibrium:

$$\frac{d^2 w^*}{dL_1 d\phi} = -\frac{8}{(2\sigma - 1 + \phi)^2} < 0$$

If the barriers to international trade are low, then it becomes less important where companies decide to locate their production.

Lemma 1 *When $\kappa = 1$, the resource effect favours agglomeration only for intermediate levels of transport costs $\phi \in \left(\tilde{\phi}, \hat{\phi}\right)$.*

Proof of Lemma 1: When $\kappa = 1$,

$$\frac{dL^*_{H_1}}{dL_1} = \frac{\{\sigma-\mu[1+\alpha(\sigma-1)]\}(1-\phi)\{\sigma-\mu[1+\alpha(\sigma-1)]-\{\sigma+\mu[1+\alpha(\sigma-1)]\}\phi\}}{\sigma(1-\phi)^2\{\sigma-\mu[1+\alpha(\sigma-1)]\}+2\phi\mu[1+\alpha(\sigma-1)][2\alpha(\sigma-1)+1+\phi]} \gtreqless 0 \quad \text{if and only if} \quad \phi \lesseqgtr \hat{\phi}.$$

So, according to (2.45),

$$\frac{dS^*}{dL_1} \gtreqless 0 \quad \text{if and only if } \phi \gtreqless \hat{\phi}.$$

Additionally, taking into account (2.56) the second square brackets of expression (2.54) can be rewritten as

$$\frac{\mu[1+\alpha(\sigma-1)]+\mu+\sigma-1}{(\sigma-1)(1-\phi)} \left(\tilde{\phi} - \phi\right) \frac{dw^*}{dS} \tag{2.81}$$

where

$$\tilde{\phi} \equiv \frac{(1-\mu\alpha)(\sigma-1)}{\mu[1+\alpha(\sigma-1)] + \mu + \sigma - 1} \in (0,1) \quad \text{and} \quad \tilde{\phi} < \hat{\phi}\,(\kappa = 1) \tag{2.82}$$

Then,

$$\begin{aligned}
\text{if } \phi &< \tilde{\phi} < \hat{\phi} \Longrightarrow \left.\frac{\partial \Delta}{\partial S}\right|_{1/2} \frac{dS^*}{dL_1} < 0 \\
\text{if } \tilde{\phi} &< \phi < \hat{\phi} \Longrightarrow \left.\frac{\partial \Delta}{\partial S}\right|_{1/2} \frac{dS^*}{dL_1} > 0 \\
\text{if } \tilde{\phi} &< \hat{\phi} < \phi \Longrightarrow \left.\frac{\partial \Delta}{\partial S}\right|_{1/2} \frac{dS^*}{dL_1} < 0
\end{aligned}$$

where the negative signs imply that the resource effect acts as a dispersion force, and the positive sign implies that the resource effect acts against dispersion.

Lemma 2 *When $\kappa = \phi$, the resource effect acts as a dispersion force around the symmetric equilibrium for all $\phi \in (0,1)$. That is, an increase (decrease) of L_1 from the symmetric equilibrium tends to reduce (increase) the ratio of indirect utilities through the resource channel.*

Proof of Lemma 2: The resource effect when $\kappa = \phi$ around the symmetric equilibrium is determined by the product of the expression in the second curly brackets in equation (2.59) times $\hat{S} \equiv dS/S$. Then, by making use of expressions (2.16), (2.18), (2.34), (2.44), and (2.71), and derivating with respect to L_1, we can evaluate the resource effect at the symmetric equilibrium,

$$\left(\frac{\partial \Delta}{\partial S}\frac{dS^*}{dL_1}\right)\Bigg|_{\frac{1}{2}} = \frac{\Omega_1(\phi)}{\Gamma(\phi)}\frac{\Omega_2(\phi)}{\sigma\Gamma(\phi)} > 0$$

with

$$\begin{aligned}
\Omega_1(\phi) &= (1\text{-}\phi)^2 \left\{(1\text{-}\mu\alpha)\left[\sigma{+}\mu(1\text{-}\alpha)(\sigma\text{-}1)(2\sigma\text{-}1)\right] - \left[1\text{-}\mu\text{-}\mu(1\text{-}\alpha)\right]\left[\sigma\text{-}\mu(1\text{-}\alpha)(\sigma\text{-}1)\right]\phi\right\} \\
\Omega_2(\phi) &= (1\text{-}\phi)^2 \left\{\sigma\text{-}\mu\left[1{+}\alpha(\sigma\text{-}1)\right]\right\}\left\{\sigma(2\sigma\text{-}1{+}\phi){+}\mu(1\text{-}\alpha)(\sigma\text{-}1)(2\sigma\text{-}1\text{-}\phi)\right\} \\
\Gamma(\phi) &= \sigma(1\text{-}\phi)^2(2\sigma\text{-}1{+}\phi){+}\mu(1\text{-}\phi)\left\{(2\sigma\text{-}1)(1\text{-}\alpha)(\sigma\text{-}1)(1\text{-}\phi){+}3(\sigma\text{-}1)\phi{+}\alpha(\sigma\text{-}1)\phi\right\} \\
&\quad {+}\mu\phi^2\left[\phi{+}7{+}8\alpha^2(\sigma\text{-}1)^2\right]{+}\mu\sigma(1\text{-}\phi)\phi(4{+}\phi){+}\mu\alpha(\sigma\text{-}1)\phi\left\{4(1\text{-}\phi)(2\sigma\text{-}1){+}15\phi{+}\phi^2\right\}
\end{aligned}$$

where $\Omega_1(\phi) > 0$, $\Omega_2(\phi) > 0$, and $\Gamma(\phi) > 0$.

2.7. A note on non-tradable industrial goods

When $\phi = 0$, using the full employment condition, equations (2.14)-(2.15) can be simplified to,

$$L_{E_j} = \frac{\mu\left[1+\alpha\left(\sigma-1\right)\right]}{\sigma}L_j$$

Therefore,

$$L_{H_j} = \frac{\sigma-\mu\left[1+\alpha\left(\sigma-1\right)\right]}{\sigma}L_j$$

These are equal to L_{E_j} and L_{H_j} when the primary good is non-tradable in Martínez-García and Morales (2019). The corresponding balance trade equation can be obtained from (2.19)-(2.20) or by setting $\phi = 0$ in equation (2.29),

$$TB\left(\phi=0\right) = \frac{\kappa p_H^{1-\sigma}}{\kappa p_H^{1-\sigma}+1} - \frac{\kappa}{p_H^{1-\sigma}+\kappa}\frac{L_1 w}{L_2} \tag{2.83}$$

Since there is no industrial trade, primary trade must be balanced. The derivative of equation (2.83) with respect to w in the symmetric equilibrium is

$$\frac{\partial TB}{\partial w} = \frac{\left(2\sigma-1+\kappa\right)\kappa}{\left(1+\kappa\right)^2} > 0$$

which implies that the balance trade equation implicitly defines w for a given value of κ, S_1 and S_2. The dynamic system is given by

$$\begin{aligned} \dot{L}_1 &= L_1\left(1-L_1\right)\left\{w\left(n^{\frac{1}{1-\sigma}}p\right)^{-\mu}\left[\tfrac{w^{1-\sigma}\left(S_1/S_2\right)^{-(1-\sigma)}+\kappa}{\kappa w^{1-\sigma}\left(S_1/S_2\right)^{-(1-\sigma)}+1}\right]^{-\frac{1-\mu}{1-\sigma}}-1\right\} \\ \dot{S}_1 &= gS_1\left(1-\frac{S_1}{CC}\right)-\epsilon g\theta S_1 L_1 \\ \dot{S}_2 &= gS_2\left(1-\frac{S_2}{CC}\right)-\epsilon g\theta S_2\left(1-L_1\right) \end{aligned} \tag{2.84}$$

where, in this case, $n \equiv n_1/n_2 = L_1/\left(1-L_1\right)$. The Jacobian matrix of the linearized system at the symmetric equilibrium can be written as

$$J^*_{1/2} = \begin{pmatrix} a & b & -b \\ -c & d & 0 \\ c & 0 & d \end{pmatrix}$$

with

$$a = \tfrac{\mu}{\sigma-1} - \tfrac{2(1-\mu\alpha)\kappa}{2\sigma-1+\kappa}, \quad b = \tfrac{(1-\mu\alpha)(2\sigma-1-\kappa)}{4S_s^*(2\sigma-1+\kappa)}, \quad c = \epsilon\tfrac{\sigma-\mu[1+\alpha(\sigma-1)]}{\sigma}S_s^*, \quad d = -\tfrac{gS_s^*}{CC}$$

where $S_s^* = (1 - \epsilon\theta/2)\, CC$. The characteristic polynomial is equal to $P(\lambda) = (d-\lambda)[\lambda^2 - (a+d)\lambda + ad + 2bc]$. The eigenvalues can be analytically obtained, and the three of them are negative if and only if the following conditions are satisfied:

$$\begin{aligned}(2\sigma-1)\left(\tfrac{\mu}{\sigma-1} - \tfrac{gS_s^*}{CC}\right) &< \left[\tfrac{gS_s^*}{CC} - \tfrac{\mu}{\sigma-1} + 2(1-\mu\alpha)\right]\kappa \\ (2\sigma-1)\left[\tfrac{\mu}{\sigma-1}\tfrac{gS_s^*}{CC} - (1-\mu\alpha)\tfrac{\epsilon\theta g}{2}\right] &< \left\{(1-\mu\alpha)\tfrac{\epsilon\theta g}{2} + \tfrac{gS_s^*}{CC}\left[\tfrac{\mu}{\sigma-1} - 2(1-\mu\alpha)\right]\right\}\kappa\end{aligned}$$

For this case, expression (2.43) is

$$\begin{aligned}\hat{\Delta}\Big|_{\frac{1}{2}} &= \left\{\left[1-\mu\left(\alpha + (1-\alpha)\tfrac{1-\phi}{1+\phi}\right) - (1-\mu)\tfrac{1-\kappa}{1+\kappa}\right]\tfrac{dw^*}{dL_1} + \mu\tfrac{dn^*/dL_1}{\sigma-1}\right\}\tfrac{\hat{L}_1}{2} \\ &\quad + \left\{\left[1-\mu\left(\alpha + (1-\alpha)\tfrac{1-\kappa}{1+\kappa}\right) - (1-\mu)\tfrac{1-\kappa}{1+\kappa}\right]\tfrac{dw^*}{dS} + (1-\mu\alpha)\tfrac{1-\kappa}{1+\kappa}\right\}\hat{S}\end{aligned}$$

where, at the symmetric equilibrium,

$$\begin{aligned}\frac{dw^*}{dL_1} &= -4\frac{1+\kappa}{2\sigma-1+\kappa} < 0 \\ \frac{dw^*}{dS} &= 2\frac{\sigma-1}{2\sigma-1+\kappa} > 0 \\ \frac{dS_1^*}{dL_1} &= -\frac{dS_2^*}{dL_1} = -\epsilon\theta < 0 \\ \frac{dn^*}{dL_1} &= \frac{1}{(1-L_1)^2} > 0 \ \text{ and } \ \frac{dn^*}{dS} = 0\end{aligned}$$

From these expressions we know that the competition effect is stronger than the market size effect. The resource effect always acts as a dispersion force (Proposition 1). The industrial price index effect is the key agglomeration force and is reinforced, because wages do not have any impact on the number of industrial firms. To see that the industrial price index is the main driver of agglomeration, we can eliminate the factor $n^{-\frac{\mu}{1-\sigma}}$ from the differential equation (2.84). Then, we obtain the same Jacobian matrix for the linearized system with a single difference, now,

$$a = -\tfrac{2(1-\mu\alpha)\kappa}{2\sigma-1+\kappa}$$

Then,

$$\begin{aligned}a+d &= -\left[\tfrac{2(1-\mu\alpha)\kappa}{2\sigma-1+\kappa} + \tfrac{gS_s^*}{CC}\right] < 0 \\ 2bc + ad &= \tfrac{(1-\mu\alpha)\left[(2\sigma-1-\kappa)\frac{\epsilon\theta g}{2} + 2\kappa\frac{gS_s^*}{CC}\right]}{2\sigma+\kappa} > 0\end{aligned}$$

which implies that, when the industrial price index is not considered, the three eigenvalues of the resulting Jacobian matrix are negative.

The shaded region in Figure 2.7 is the stability region of the symmetric equilibrium in the space (ϵ,κ) for $\sigma = 7$, $\mu = 0.5$ and $\alpha = 0.5$, whenever the parameter values are not specified in the figure.

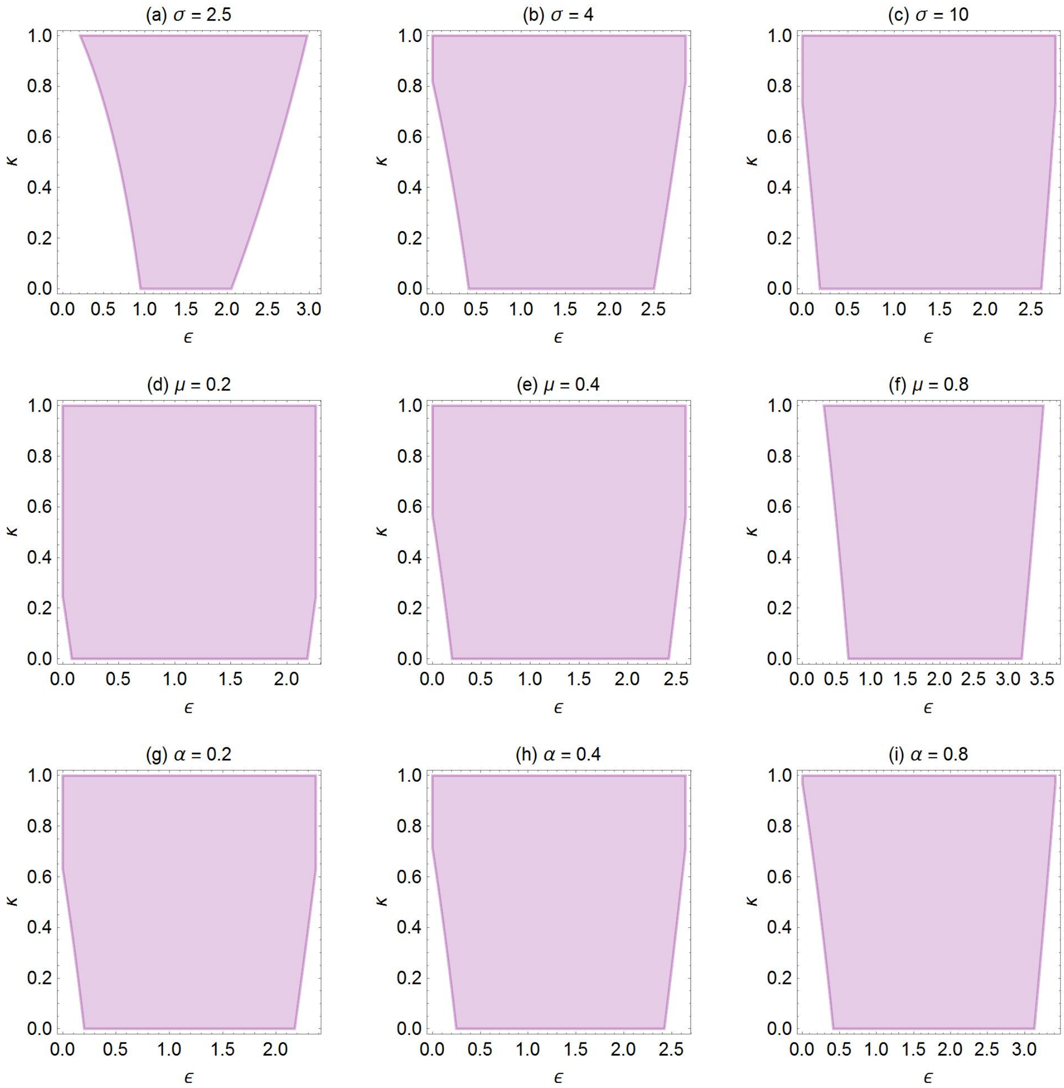

Figure 2.7: Stability Region: non-tradable industrial goods

2.8. A note on perfectly tradable industrial goods

When $\phi = 1$, taking into account that $n = L_{E_1}/L_{E_2}$, equations (2.14)-(2.15) can be simplified into the following implicit equation:

$$R(w) = w - p^{1-\sigma} = 0$$

Then, by using expressions (2.25), (2.26) and (2.26), it can be rewritten as

$$R(w) = w - w^{\alpha(1-\sigma)} \left[\frac{w^{1-\sigma}\left(\frac{S_1}{S_2}\right)^{\sigma-1} + \kappa}{w^{1-\sigma}\left(\frac{S_1}{S_2}\right)^{\sigma-1}\kappa + 1} \right]^{1-\alpha} = 0 \tag{2.85}$$

with its derivative evaluated at the symmetric equilibrium equal to

$$\frac{\partial R(w)}{\partial w} = \frac{\sigma(1-\kappa) + 2[1+\alpha(\sigma-1)]\kappa}{1+\kappa} > 0$$

which implies that $R(w)$ implicitly defines w in a close neighborhood of the symmetric equilibrium. Note that neither the size of the population (L_1) nor the number of industrial firms (n_1,n_2) affects wages. This happens because, in case $\phi = 1$, the demand for any industrial good, independently of its origin, is a function of the world income and a common industrial price index ($P_j = P_1 = P_2$). The market equilibria are

$$\begin{aligned} x_1^* &= \mu\left(\frac{Y^w}{n_1 p^{1-\sigma} + n_2}\right) p^{-\sigma} \\ x_2^* &= \mu\left(\frac{Y^w}{n_1 p^{1-\sigma} + n_2}\right) \end{aligned}$$

where $Y^w = L_1 w + 1 - L_1$. Any change in population sizes or the number of firms has the same proportional impact on both industrial markets. Then, the pressure on prices due to excess demand or supply caused by these factors does not impact on the ratio of industrial prices. On the other hand, if the ratio of stock of natural resources increases, industrial prices in region 1 tend to diminish, which translates into an excess demand in that region. As a result, there is an upward pressure on prices and wages. The corresponding balance trade equation, as in the previous case, can be obtained from (2.19)-(2.20) or by setting $\phi = 0$ in equation (2.29),

$$TB = \frac{1}{np^{1-\sigma}+1}\left(\frac{L_1 w}{L_2} - np^{1-\sigma}\right)\Psi + \left(\frac{\kappa}{p_H^{1-\sigma}+\kappa}\frac{L_1 w}{L_2} - \frac{\kappa p_H^{1-\sigma}}{\kappa p_H^{1-\sigma}+1}\right) = 0 \tag{2.86}$$

and its derivative with respect to n, evaluated at the symmetric equilibrium is

$$\frac{\partial TB^*}{\partial n} = -\frac{\mu}{2(1+\kappa)}\frac{\sigma(1-\kappa) + 2[1+\alpha(\sigma-1)]\kappa}{\sigma - \mu[1+\alpha(\sigma-1)]} < 0$$

Thus, expression (2.86) implicitly defines n around the symmetric equilibrium. Furthermore, by using relation (2.85), we have that

$$n = \frac{\left(\Psi + \frac{\kappa}{p_H^{1-\sigma}+\kappa}\right)\frac{L_1 w}{L_2} - \frac{\kappa p_H^{1-\sigma}}{\kappa p_H^{1-\sigma}+1}}{w\left(\Psi + \frac{\kappa p_H^{1-\sigma}}{\kappa p_H^{1-\sigma}+1} - \frac{\kappa}{p_H^{1-\sigma}+\kappa}\frac{L_1 w}{L_2}\right)}$$

Taking into account the implicit function (2.85), the dynamic system in this case is

$$\begin{aligned}
\dot{L}_1 &= L_1(1-L_1)\left(w^{\frac{1-\mu}{\sigma-1}\frac{1+\alpha(\sigma-1)}{1-\alpha}}-1\right) \\
\dot{S}_1 &= S_1\left[g\left(1-\frac{S_1}{CC}\right)-\epsilon\left(L_1-L_{E_1}\right)\right] \\
\dot{S}_2 &= S_2\left[g\left(1-\frac{S_2}{CC}\right)-\epsilon\left(1-L_1-L_{E_1}/n\right)\right]
\end{aligned}$$

where L_{E_1} is determined by expression (2.16). The Jacobian matrix of the previous system at the symmetric equilibrium can be written as

$$J_{1/2} = \begin{pmatrix} 0 & b & -b \\ -c & d & e \\ c & e & d \end{pmatrix}$$

where

$$\begin{aligned}
b &= \frac{(1-\kappa)\sigma g\theta}{4S_s^*\{\sigma(1-\kappa)+2[1+\alpha(\sigma-1)]\kappa\}}, \quad c=\frac{\epsilon(1-\kappa)\sigma g\theta S_s^*}{\sigma(1-\kappa)+2[1+\alpha(\sigma-1)]\kappa} \\
e &= \frac{\epsilon\kappa[1+\kappa+\alpha(2\sigma-1-\kappa)][1+\alpha(\sigma-1)]g\theta(\sigma-1)}{2\{\sigma(1-\kappa)+2[1+\alpha(\sigma-1)]\kappa\}^2}, \quad d=-\frac{gS_s^*}{CC}-e
\end{aligned}$$

Then, $P(\lambda)=(\lambda-d-e)\left[\lambda^2-(d-e)\lambda+2bc\right]$ is the corresponding characteristic polynomial. Furthermore, provided that $\kappa\in(0,1)$ and $S_s^*>0$, that is, $\epsilon<2/\theta$, then

$$\begin{aligned}
d-e &< 0 \\
2bc &> 0
\end{aligned}$$

Thus, the three eigenvalues of the characteristic polynomial are negative. For this case, expression (2.43) is

$$\hat{\Delta}\Big|_{\frac{1}{2}} = \left[\frac{dw}{dS}-(1-\mu)\frac{1-\kappa}{1+\kappa}\left(\frac{dw}{dS}-1\right)\right]\hat{S}$$

where we have that at the symmetric equilibrium

$$\begin{aligned}
\frac{dw^*}{dS} &= \frac{(1-\alpha)(\sigma-1)}{1+(\sigma-1)\left[\alpha+(1-\alpha)\frac{1-\kappa}{1+\kappa}\right]}\frac{1-\kappa}{1+\kappa}>0 \\
\frac{dS_1^*}{dL_1} &= -\frac{dS_2^*}{dL_1}=-\frac{\epsilon\sigma\theta CC}{\sigma(1-\kappa)+2[1+\alpha(\sigma-1)]}<0 \\
\frac{dn^*}{dS} &= -\frac{2\kappa(\sigma-1)\{\sigma-\mu[1+\alpha(\sigma-1)]\}[(1-\alpha)(1+\kappa)+2\alpha\sigma]}{\mu\{\sigma(1-\kappa)+2[1+\alpha(\sigma-1)]\}^2}<0
\end{aligned}$$

From these expressions, the only active force when the population experiences a minor deviation is the resource effect, and it favours the dispersion (Proposition 1). Although $dn^*/dS<0$, due to the perfect tradability of the industrial good, the firms channel vanishes in this case.

Chapter 3

Perpetuating Regional Asymmetries through Income Transfers

Contents

This chapter studies the effect of income transfers on the distribution of economic activity through a modified footloose entrepreneurs model. Our model incorporates some key features of the Dutch disease literature: sectoral mobility and non-tradable goods. We find that a Dutch disease can emerge in the short and long run when the competition is high (low transport costs). For intermediate levels of competition, Dutch disease appears only in the short run. And, for low levels, the recipient region always benefits from the income transfers. We prove that, the Dutch disease in the short run affects long-run results; whereas regional mobility (New Economic Geography) can reverse a short-run deindustrialization scenario.

3.1. Introduction

Since Krugman's seminal work (Krugman, 1991), there has been a better understanding of the forces that shape the geographical distribution of economic activity. New Economic Geography (NEG) states that, reductions in tariff and transport costs lead to a core-periphery structure of the economy. In this regard, international and interregional income transfers are recognized instruments to compensate spatial economic disparities; e.g. the European Union spends almost one third of its budget on these kinds of programs (Baldwin. et al. 2005).

According to the NEG literature, income transfers enlarge the market size of the recipient region. Thus, the smaller or peripheral region becomes more attractive for firms to settle in, and regional disparities are reduced. The market size effect is the key element behind this mechanism. For example, Bickenbach et al. (2013) point out that public transfers toward East Germany increase the market potential of this region and nourish the dispersion of the economic activity. For the Chilean economy, Modrego et al. (2014) simulate a positive shock in the market potential of Santiago, which reassembles the public transfers program applied in the country. Their results suggest that the number of firms will increase, especially in the beneficiary region and the surrounding area.

However, a negative relation between income transfers and industrial employment is sometimes observed. As an example, Figure 3.1 depicts the negative correlation between growth rates of the industrial labor (industry plus manufacturing, divided by total labor) and the disposable income (divided by primary income[1]) for the European regions (NUTS2) between 2005 and 2014. Although, it is a simple correlation, it raises the question of the effectiveness of transfers; which is no new concern for economists. Moreover, Yanno and Nugent (1999) show that aid flows are associated with contractions of the tradable sectors, for the cases of Burkina Faso, Congo, Lesotho, Liberia, Senegal and Yemmen. Bulir and Lane (2002) also present some evidence of the decline of tradable

[1]According to Eurostat definitions.

sector for a sample of aid-dependent countries. Subramanian and Rajan (2005) find that aid flows deteriorate the competitiveness of the tradable sectors in developing countries. For Uganda, Adam (2005) also finds some evidence of a reduction in the tradable sectors for the short run only, pointing out that in the long run this reduction is exceeded by the positive effects. Choueiri et al. (2008) study the effects of the EU transfers on the new state members. They detect that transfers to household's income tend to deteriorate the balance of trade and decrease the ratio of tradable to non-tradable prices. Baskaran et al. (2017) find that intergovernmental transfers do not encourage economic growth in West German states over the period 1975-2005.

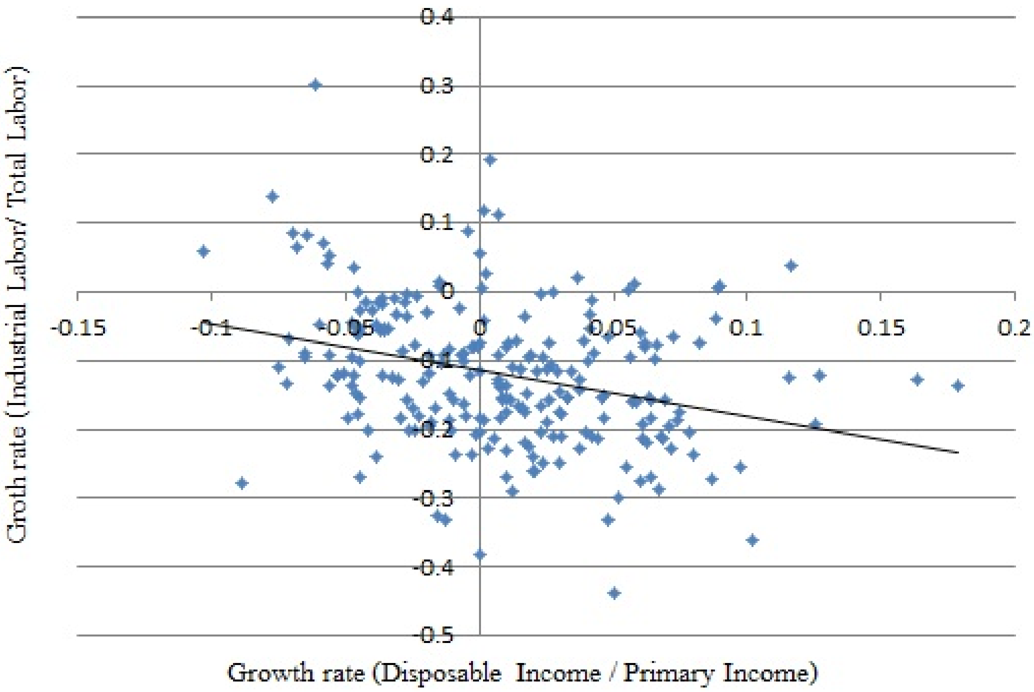

Figure 3.1: Industry and Income Transfers (2005-2014). Source: Eurostat

Most of these studies rely on the Dutch disease (DD) literature for a possible explanation of the negative relation observed between transfers (aid flows) and the tradable sector. This literature first appeared to explain the de-industrialization process faced by the Netherlands as a consequence of the discovery of important gas reserves in the North Sea in the 1960s. Since then, the DD literature has spread to the study of other kinds of booms, like foreign aid (White, 1992; Nkusu, 2004; Selaya et al., 2010; Taguchi, 2017), income and fiscal transfers (Gabrisch, 1997; Breau et al., 2016), remittance flows

(Bourdet et al, 2006; Chowdhury et al., 2014; Uddin et al., 2017), public expenditure (Adam et al., 2003), capital inflows (Athukorala et al., 2003; Lartey, 2007; Moosa, 2017).

The basic models of the DD are the Salter-Swan model (Swan, 1960, 1963) or Salter-Swan-Corden-Dornbusch model (Corden and Neary 1982; Dornbusch, 1991; Corden, 1994) which consist of a small open economy with two tradable sectors (booming or resource sector, and a lagging or manufacturing sector) and a non-tradable sector (service sector), with perfect competition in all of them. According to this literature, a technical improvement in the booming sector has two effects: the *resource movement* and the *spending effects*. The marginal product of labor increases in the booming sector, attracting labor at the expense of the other two sectors (*resource movement effect*). On the other side, the extra income coming from the booming sector is spent partially in the non-tradable sector, which increases the price of non-tradable goods, and wages of the economy (*spending effect*). Thus, an appreciation of the real exchange rate takes place, and the country becomes less competitive in the international markets, harming the tradable sectors (Corden and Neary, 1982; Corden, 1984; Van Wijnbergen, 1986; Krugman, 1987; Yano and Nugent, 1999). Noticeably, if instead of a technical improvement, the boom is a large windfall of economic resources, such as fiscal or income transfers, aid flows, remittances, public expenditure, or capital flows, only the spending effect is present.

The conclusions of the NEG and the DD literatures clash, at least in their theoretical developments. The aim of this chapter is to study the effects of income transfers on the spatial distribution of the economic activity, by reconciling these two literatures. We modify the Footloose Entrepreneur Model (Forslid and Ottaviano, 2003)[2], by introducing some key features: income transfers, a non-tradable sector, sectoral mobility of labor, and a slightly differentiated agricultural good. One of the main results is that transfers are not always beneficial for the recipient region. Under some conditions they can create or even exacerbate regional disparities, rather than mitigate them.

Although the study of income transfers in NEG models is not widespread- probably because the results seems straightforward through the market potential - there are some interesting works in the field. Baldwin et al. (2005) developed a footloose capital (FC) model that considers an income transfer from one region to the other. They find that transfers tend to boost industrial activity in the recipient region unless there are some differences between the endowments of labor and capital within each region. Additionally, there are some related works that study unproductive public expenditure in a NEG framework. In these models, the public expenditure is devoted to consumption goods in order to analyze the market potential (see Commendatore et al., 2018 for a survey on productive and unproductive public expenditures in NEG models). When these public expenditures are “liberalized” the public sector of one region can purchase goods produced in the other region, which can be seen as a transfer of incomes between the regions.

[2]The first versions of the Footloose Entrepreneur Model were developed independently by Ottaviano (2001) and Forslid (1999).

Trionfetti (1997) proposed a Core-Periphery model (Krugman, 1991) with unproductive public expenditure. When he considers the case of transfers between regions, the demand for industrial goods produced in the recipient region increases due to the higher income in that region, but it also reduces due to the fall in the foreign demand. If the net result is an increase (resp. decrease) in the demand, the number of firms in the recipient region would increase (resp. decrease) because of what he called the *pull effect*, which is the result of a higher market potential. Trionfetti (2001) extends the NEG model proposed by Krugman and Venables (1995) by incorporating unproductive public procurements. He finds that liberalized public expenditure is irrelevant to determine the industrialization pattern between the regions. Brülhart et al. (2004) show that an economy with a large home-biased public expenditure on its own industry, which can be seen as a net recipient of transfers, tends to have a larger number of firms (pull effect), and it also reduces the likelihood of industrial agglomeration in the other economy (spread effect). All these results are in line with the standard predictions of the NEG models: a higher income or demand increases the market potential and attracts more industrial firms to the net recipient region. However, none of these works tries to explain how the effects of transfers described by the new economic geography and the Dutch disease literatures interact.

One of the reasons why NEG models do not usually incorporate the effects described in the Dutch disease literature could be that some of the main assumptions need to be relaxed. For example, in the original Core-Periphery (CP) model (Krugman, 1991) sectoral mobility should be included. This simple change leads to many difficulties. Because of sectoral mobility, in the long-run the whole population could move to the other region, and the periphery would be completely unpopulated. Additionally t,he competition effect becomes weaker as the fixed market disappears. Furthermore, if after incorporating sectoral mobility, the agricultural sector remains unchanged, the agriculture price equalization would imply wage equalization within and between regions, which overrides the spending effect. On the other hand, the Footloose Capital (FC) and Footloose Entrepreneur (FE) models (Martin and Rogers, 1995; Forslid and Ottaviano, 2003) already incorporate labor mobility between sectors. Nevertheless, to obtain results similar to a Dutch disease, the agricultural sector needs to be modified (or discarded) in order to avoid wage equalization. However, the equalization of wages across sectors and regions is what makes them tractable.

In this chapter, we present a modified FE model (Forslid and Ottaviano, 2003) that considers some of the assumptions made by the DD literature. First, we incorporate a non-tradable sector with constant returns to scale, which is a key element of the DD mechanism (Corden et al., 1982). Second, following Fujita et al. (1999), we assume that the agricultural goods are homogenous within each region, but slightly differentiated between regions. This assumption is made to avoid inter-regional wage equalization, which allows differences between non-tradable prices of the regions. And third, we incorporate inter-regional transfers. A particular feature of the setup of the model is that each sector has a different transport cost: agricultural goods are freely tradable, industrial goods face an iceberg transport cost, and services are non-tradable.

A similar model to the one proposed in this chapter can be found in Moncarz, et al.(2017). The authors study how intergovernmental transfers affect manufacturing production in an FC model. However, there are same important differences between our model and theirs. First, in addition to the non-tradable sector, they incorporate a public sector whose only mission is to hire workers, so competing with the private sector for the labor force. Second, they remove the agricultural sector. And third, all their results rely on numerical simulations. Our model presents a more general structure by maintaining the agricultural sector. This difference becomes important in the short-run analysis.[3] Additionally, we obtain analytical results which give us a better understanding of the links between the two literatures, and the effects of transfers in the short and long run. Finally, we use an FE model instead of a FC model. This allows the study of transfers in the case of either stable or unstable solutions.

Another work that brings the DD effect into a NEG model is that proposed by Takatsuka et al. (2015), who study the impact of a resource boom in the distribution of the economic activity by introducing a different natural resource in each region (avoiding wage equalization) that is used as an input in the industrial production and as a final consumption good. The DD in Takatsuka et al. (2015) appears due to a shock in the demand (final or intermediate) for resource goods of one of the regions, which draws labor from the industrial sector and increases the wage in that region. On the other hand, as long as the resource good is also used as an industrial input, the firms in the region that experience the boom have an advantage because they are closer to the source of their main input. In the model proposed in this chapter, the shock comes in the form of an increase in the disposable income without changing the preferences of households and without imposing any assumption about a preference for one good over the others. Additionally, the model presented here is a modified FE model, as opposed to the static model of Takatsuka et al. (2015), which allows us to differentiate between the short run, when firms can adjust their level of production, and the long run, when migration of entrepreneurs is allowed. And, as pointed out before, the FE model permits the study of stable and unstable solutions which is not possible with a static model.

What we find is that income transfers play a double role in the model. On the one hand, the increase in the disposable income of the recipient region attracts firms, due to the market size effect, in accordance with the NEG literature predictions. On the other, the expenditure shock increases the wages of workers, making industrial production more expensive, which shrinks the industrial activity, as explained by the DD literature.

Although our model has large open economies and monopolistic competition in the

[3]The Dutch disease or de-industrialization in the short run could occur in our model as a result of the economic configuration of the regions. The bigger the non-tradable sector and the higher the competition, the higher the probability of ending up in a de-industrialization scenario. However, in Moncarz, et. al 2017, the Dutch disease always takes place in the short run, and is not a result of the economic configuration.

industrial sector, contrary to standard DD models, due to the difference in the trade cost of the sectors, a DD can occur. Using the terminology of the DD literature, the increase in the disposable income of the recipient region causes a spending effect in the service sector, as expected, but also in the industrial sector. Income transfers increase the market potential of the recipient region where, at the same time, transport costs make the local industrial goods more attractive, leading to a rise in their demands. The wage, and the industrial and service prices rise, so lowering the competitiveness and shrinking all the sectors of the recipient region. A DD emerges if the effect of the higher prices offsets the spending effect in the industrial sector (market size effect).

In particular, in the short run we find that the agricultural and the non-tradable sectors shrink and expand, respectively, while de-industrialization takes place if transport costs are low enough. In this case, because of the high competition from foreign firms, the benefits of the transfers to the local industry are limited. In the long run, however, the changes in wages and in cost of living favor the recipient region. Thus, if the transport costs are high, the recipient region can end up attracting industrial firms, even if in the short run some de-industrialization has taken place. But, if the competition is strong (low transport costs), the Dutch disease, which took place in the short run, can overcome all other positive effects derived from the transfers, leading to a long-run DD. In this case, we observe that: either the number of industrial firms increases in the donor region or it becomes more difficult to reverse regional asymmetries. Thus, income transfers can create or even exacerbate regional disparities rather than mitigate them.

The remainder of the chapter is organized as follows: section 3.2 introduces the model; section 3.3 studies the short run and the effect of transfers on the regional economic structure; section 3.4 analyses the long run and the effect of transfers on the location of industry. Section 3.5 concludes.

3.2. The Model

We use the FE model, following Forslid et al. (2003) with two regions and three sectors: industrial, agricultural and services. As in the original FE model, there are two types of population. Entrepreneurs (H_j), that are mobile between regions; and workers (L_j) that can not move between regions but can freely move between sectors within the same region (this is also a feature of the original model).

The industrial sector has increasing returns to scale, with a fixed cost in entrepreneurs and variable cost in workers. There is monopolistic competition (Dixit and Stiglitz, 1977); and goods are tradable between regions with iceberg transport costs. The agricultural sector has constant returns to scale, and only employs workers. Following Fujita et al. (1999), there is perfect competition within the region, but products are slightly differentiated between regions. The reason for this assumption is to avoid wage equalization of workers. While the CP model assumes no mobility between sectors, and the FE model allows sectoral mobility, but wages are equalized, we incorporate the mobility and avoid equalization of wages. Also, agricultural goods are freely tradable between the regions. The service sector, or non-tradable sector, also has constant returns to scale, employing only workers. There is perfect competition, and services are non-tradable between regions.

Finally, there is a supra-regional authority whose only function is to collect taxes and assign transfers between the regions. This authority maintains a balanced budget.

3.2.1. Households

Households seek to maximize their utility, which has the form of a nested Cobb-Douglas (across sectors) and CES (over the varieties) used in the original Krugman model (1991). Thus, a representative household in region 1 solves the following consumption problem,

$$\max_{c_{1i},c_{2i},c_{A_1},c_{A_2},C_{s_1}} U_1 = C_{M_1}^{\mu_1} C_{s_1}^{\mu_2} C_{A_1}^{1-\mu} \tag{3.1}$$

$$\text{s.t. } y_1^d = \int_0^{n_1} c_{1i} p_{1i} di + \int_0^{n_2} c_{2i} p_{2i} \tau di + \tfrac{1}{2} c_{A_1} p_{A_1} + \tfrac{1}{2} c_{A_2} p_{A_2} + C_{s_1} p_{s_1} \tag{3.2}$$

with

$$C_{M_1} = \left(\int_0^{n_1} c_{1i}^{\frac{\sigma-1}{\sigma}} di + \int_0^{n_2} c_{2i}^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}} \tag{3.3}$$

$$C_{A_1} = \left(\frac{1}{2} c_{A_1}^{\frac{\sigma-1}{\sigma}} + \frac{1}{2} c_{A_2}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{3.4}$$

where C_{M_1} and $C_{A_1}$are consumption indexes of industrial and agricultural goods respectively; C_{s_1} is the consumption of services; c_{ji} is the consumption of variety i produced in region j; n_j are the number of varieties in region j; c_{A_j} is the consumption of agricultural good produced in region j; y_j^d is the disposable income per household; p_{ji} is the (fob) price of each industrial good; p_{s_1} is the price of the services in region 1; p_{A_j} is the price of the agricultural good produced in region j; $\mu \equiv \mu_1 + \mu_2 \in (0, 1)$ are the proportion of the disposable income devoted to expenditure in each type of goods and services; $\sigma > 1$ is the elasticities of substitution of the industrial and agricultural goods (which are assumed to be equal for analytical purposes); and $\tau > 1$ is the iceberg transport cost. The same problem is solved by households in region 2.

From the first order conditions of the maximization problem (3.1)-(3.4), the following demand functions are obtained:

$$C_{M_1} = \mu_1 \frac{y_j^d}{P_1}, \; C_{s_1} = \mu_2 \frac{y_j^d}{p_{s_1}}, \; C_{A_1} = (1-\mu)\frac{y_j^d}{P_A} \tag{3.5}$$

$$c_{1i} = C_{M_1}\left(\frac{p_{1i}}{P_1}\right)^{-\sigma}, \; c_{2i} = C_{M_1}\left(\frac{p_{2i}\tau}{P_1}\right)^{-\sigma} \tag{3.6}$$

$$c_{A_1} = C_{A_1}\left(\frac{p_{A_1}}{P_A}\right)^{-\sigma}, \; c_{A_2} = C_{A_1}\left(\frac{p_{A_2}}{P_A}\right)^{-\sigma} \tag{3.7}$$

where P_1 and P_A are the price indexes for region 1, that is,

$$P_1 = \left(\int_0^{n_1} p_{1i}^{1-\sigma} di + \int_0^{n_2} (p_{2i}\tau)^{1-\sigma} di\right)^{\frac{1}{1-\sigma}} \tag{3.8}$$

$$P_A = \left(\frac{1}{2} p_{A_1}^{1-\sigma} + \frac{1}{2} p_{A_2}^{1-\sigma}\right)^{\frac{1}{1-\sigma}} \tag{3.9}$$

Mirror-image formulas hold for consumers in region 2. Additionally, because agricultural goods are assumed to be freely tradable between regions, the agricultural price index is the same for both regions.

3.2.2. Agricultural Sector

The agricultural good is produced with constant returns to scale in perfect competition. We assume that one unit of labor is required to produce one unit of agricultural good. Due to the free entry condition profits of a firm i in country j, π_{ij}, must equal cero, with

$$\begin{aligned} \pi_{A_{ji}} &= p_{A_j} A_{ji} - w_j l_{A_j} \\ \text{then, } p_{A_j} &= w_j \end{aligned}$$

where w_j is the nominal wage paid to workers in region j; A_{ij} is the production of each firm in region j; and l_{A_j} is the labor employed by each agricultural firm. Because we assume that the number of agricultural firms in each region is equal to 1/2, total agricultural employment and production in each region is $L_{A_j} = l_{A_j}/2 = A_j = A_{ij}/2$. Note that the mobility of workers between regions equalizes nominal wages within each region.

3.2.3. Industrial Sector

A firm i in the industrial sector of region j employs workers ($l_{x_{ji}} = \beta x_{ji}$) and a fixed amount of entrepreneurs (f) to produce industrial goods, x_{ji}. The resulting cost function involves a constant marginal cost and a fixed cost, giving rise to increasing returns to scale.

$$Cost = fw_{H_j} + (\beta x_{ji})\, w_j \tag{3.10}$$

where w_{H_j} is the wage of the entrepreneurs in region j to produce variety i, and x_{ji} is the output.

It is assumed that there is a large number of manufacturing firms, each producing a single product in monopolistic competition. Given the definition of the manufacturing aggregate (3.3), the elasticity of demand facing any individual firm is $-\sigma$. Then, the profit-maximizing price behavior of a representative firm in region j is

$$p_{ji} = \beta \frac{\sigma}{\sigma - 1} w_j \tag{3.11}$$

Since firms are identical and they face the same wage, manufactured good prices are equal for all varieties in each region and we can drop the superscript i. Similar equations apply in region 2. Comparing the prices of representative products, we have that

$$\frac{p_1}{p_2} = \frac{w_1}{w_2} \tag{3.12}$$

Because there is free entry in the sector, a firm's profits must equal zero. Using this condition, the price rule (3.11) and $l_{x_{ji}} = \beta x_{ji}$, it is obtained that

$$x^*_{ji} = x^*_j = \frac{(\sigma - 1)\, f}{\beta} \left(\frac{w_{H_j}}{w_j} \right) = \frac{f w_{H_j}}{p_j / \sigma} \tag{3.13}$$

$$l^*_{x_{ji}} = l^*_{x_j} = (\sigma - 1)\, f \left(\frac{w_{H_j}}{wj} \right) \tag{3.14}$$

The output and labor employed per firm is the same in each region, so we can drop the subscript i. Note that the number of firms times the entrepreneurs per firm must equal the total number of entrepreneurs available in the region. Also, the number of firms times the workers per firm must equal the labor employed in the industrial sector. So, the number of firms must be

$$n_j = \frac{H_j}{f} = \frac{L_{E_j}}{(\sigma - 1)\, f} \left(\frac{w_j}{w_{H_j}} \right) \tag{3.15}$$

$$\text{and} \qquad w_{H_j} = \frac{L_{E_j}}{H_j} \frac{w_j}{\sigma - 1} \tag{3.16}$$

where $L_{E_j} = \int_0^{n_j} l_{x_{ji}} di$ is the aggregate labor employed in the industrial sector of region j. The last expression (3.16) is the operating profit of each entrepreneur of a representative firm.

3.2.4. Service Sector

As in the agricultural sector, services are produced with constant returns to scale in perfect competition. One unit of labor is required to produce one unit of services. Because of the free entry condition the price of the services is

$$p_{s_j} = w_j \tag{3.17}$$

3.3. Short-Run Equilibrium

In equilibrium, households maximize their utility, firms maximize their profits, there is free entry in all sectors, the supra-regional authority maintains a balanced budget, and market clearing conditions hold for the four markets: labor, agricultural goods, industrial goods and services.

The balanced budget of the supra-regional authority can be written as

$$BB = t_1 Y_1 + t_2 Y_2 - T_1 - T_2 = 0$$

where t_j is the tax rate imposed on households of region j, and T_j is the income transfer received by households of region j.

For simplification, we assume that only region 1 pays taxes, and only region 2 receives transfers, such that

$$t_1 = t \in (0,1) \text{ and } t_2 = 0 \tag{3.18}$$

$$T_1 = 0 \text{ and } T_2 = tY_1 \tag{3.19}$$

Thus, we can refer to t as the tax rate paid by region 1, or the rate of transfers received by region 2.

Agricultural market: total supply must equal total demand, aggregating the demand functions (3.7) and using the total output of the agricultural sector ($A_j = L_{A_j}$),

$$L_{A_j} = \frac{(1-\mu)}{2} \left(\frac{p_{A_j}}{P_A} \right)^{1-\sigma} \frac{\left(Y_1^d + Y_2^d\right)}{w_j} \tag{3.20}$$

Service market: total supply must equal total demand. Using C_{s_1} from expression (3.5),

$$L_{s_j} = \mu_2 \frac{Y_j^d}{w_j} \tag{3.21}$$

where L_{s_j} is the total labor employed in the non-tradable sector of region j.

Labor market: as a result of the free labor mobility assumption between the three sectors, and by using equations (3.20) and (3.21), the labor market clearing condition states that

$$\begin{aligned} L_j &= L_{E_j} + L_{A_j} + L_{s_j} && (3.22) \\ L_{E_j} &= L_j - \frac{(1-\mu)}{2}\left(\frac{p_{A_j}}{P_A}\right)^{1-\sigma}\frac{\left(Y_1^d + Y_2^d\right)}{w_j} - \mu_2\frac{Y_j^d}{w_j} && (3.23) \end{aligned}$$

Industrial market: Using the demand equations (3.6), the industrial price index (3.8), the equilibria for both industrial sectors are

$$\begin{aligned} x_1^* &= \mu_1 p_1^{-\sigma}\left(\frac{Y_1^d}{P_1^{1-\sigma}} + \frac{Y_2^d}{P_2^{1-\sigma}}\tau^{1-\sigma}\right) && (3.24) \\ x_2^* &= \mu_1 p_2^{-\sigma}\left(\frac{Y_1^d}{P_1^{1-\sigma}}\tau^{1-\sigma} + \frac{Y_2^d}{P_2^{1-\sigma}}\right) && (3.25) \end{aligned}$$

Using equations (3.13)-(3.16), (3.18)-(3.19), and (3.20)-(3.23) the previous two equations can be reduced to the unique one:

$$CA_2 \equiv \overbrace{\mu_1\left[\frac{\phi n_2 p_2^{1-\sigma}}{P_1^{1-\sigma}}Y_1^d - \frac{\phi n_1 p_1^{1-\sigma}}{P_2^{1-\sigma}}Y_2^d\right]}^{\text{net industrial trade}} + \overbrace{\frac{(1-\mu)}{2P_A^{1-\sigma}}\left[\frac{Y_1^d}{p_{A_2}^{\sigma-1}} - \frac{Y_2^d}{p_{A_1}^{\sigma-1}}\right]}^{\text{net agricultural trade}} + \overbrace{(tY_1)}^{\text{net } T} = 0 \qquad (3.26)$$

where $\phi \equiv \tau^{1-\sigma} \in (0,1)$ is an index of openness. Equation (3.26) guarantees that the current account of region 2 is balanced. In the first square brackets we have industrial exports and imports of region 2. In the second square brackets, we have the agricultural exports and imports respectively of region 2. And in the last brackets, we have the value of the net transfers received by region 2. Note that the current account for region 1 is $CA_1 = -CA_2$.

Regarding the incomes, on normalizing $L_1 + L_2 = 1$ and $H_1 + H_2 = 1$, total regional incomes are

$$\begin{aligned} Y_1 &= H w_{H_1} + L w_1 && (3.27) \\ Y_2 &= (1-H)\, w_{H_2} + (1-L)\, w_2 && (3.28) \end{aligned}$$

where, to simplify notation, we make $H_1 = H$ and $L_1 = L$, while

$$Y_1^d = (1-t)\, Y_1 \quad \text{and} \quad Y_2^d = Y_2 + tY_1 \qquad (3.29)$$

Equation (3.26), together with expressions (3.27)-(3.29), implicitly defines the ratio of nominal wages ($w \equiv w_1/w_2$) as a function of H (see Proof of Proposition 1 at the Appendix).

Proposition 1 *The current account equation (3.26) defines a positive relation between the proportion of entrepreneurs, H, and the ratio of nominal wages, w.*

Proof. See the Appendix. ■

As the number of firms increases in one of the regions, labor demand rises, and the competition among the firms for labor causes a rise in nominal wages.

3.3.1. Income transfers in the short-run

The aim of this section is to understand what happens to the regions in the short-run, when income transfers increase. Particularly, we want to understand how the productive structures of the regions change if t increases. The effect of the rate of transfers over nominal wages is established in the following proposition.

Proposition 2 *An increase in the tax rate of region 1, that is, an increase in the rate of income transfers, t, tends to diminish the ratio of nominal wages, w, for each value of H, and increase the total transfer received by region 2, T_2.*

Proof. See the Appendix. ■

The change in the ratio of nominal wages comes through two channels or effects: an spending effect on the service sector (as in the DD literature) and an spending effect on the industrial sector (the market size effect in the NEG literature). First, looking at expressions (3.27)-(3.29), an increase in the rate of transfers tends to rise the disposable income of region 2, and reduces the disposable income of region 1. This causes a trade imbalance (commercial deficit) in the first two terms of current account equation (3.26), while transfers increase in the third term. However, part of the expenditure is devoted to non-tradable goods, which implies that, in region 1, the trade surplus is not enough to pay the transfers. The current account deficit in region 1 causes a downward pressure on prices and wages. This is the spending effect (in the service sector) from the DD literature, and depends on the existence of a non-tradable sector ($\mu_2 > 0$).[4]

Second, because of transport costs, households have preference for locally produced goods. Then, when an income transfer takes place, the industrial sector of region 2 gains more from the higher disposable income of region 2 than what it loses from the lower disposable income of region 1. The opposite happens in region 1. As a consequence, the industrial trade imbalance is higher than in the case of costless trade. This additional spending effect on the industrial sector is the market size effect from the NEG literature, and depends on the existence of transport costs ($\phi < 1$).[5]

In addition, the second part of Proposition 2 has some important implications. On the one hand, total transfers ($T_2 = tY_1$) increase in spite of the reduction in the wage

[4] This channel can be *shut down* by setting $\mu_2 = 0$. In this case, all expenditure goes to tradable goods.

[5] This channel can be *shut down* by making $\phi = 1$.

ratio that diminishes income of region 1. On the other hand, disposable income of region 2 increases because of the change in the wage ratio and also because of the increase in transfers.

Now we can address the short-run effect of income transfers. We can focus on region 2, the recipient region. All changes in region 1 are equal but of the opposite sign. We can analyze this in two steps.

In the first step, when t increases, the transfers received by region 2 rise, which implies a positive shock on Y_2^d. In the industrial goods markets, the changes in the disposable incomes cause a decrease in the demand of the industrial goods produced in region 1 and an increase in the ones produced in region 2. This is due to the existence of transport costs. In the non-tradable sector, demand increases in region 2 and decreases in region 1. No change is observed in the agricultural sector. Because agricultural goods are not subject to trade costs, the increase in the households' demand of region 2 is completely compensated by a decrease in households' demand of region 1.

However, these new equilibria in each of the good markets imply an excess of labor demand in region 2. Then, in the second step, in order equilibrate the labor market, wages of region 2 rise (a decrease of w). As region 2 wages go up, supply in each good market contracts, until all markets are again at equilibrium. Thus, at the new equilibrium the nominal wage ratio (w) is lower, and income transfers (T_2) are higher.

Additionally, as anticipated, the productive structure of the regions also changes. Clearly, the agricultural sector of region 2 shrinks. The case of the non-tradable sector is less evident. However, because the employment on the non-tradable sector depends only on the disposable income, this sector expands (see the proof of Proposition 2 in the Appendix). Non-tradable goods do not face any competition from foreign goods, thus they benefit from the large demand expansion.

Finally, the industrial sector is the most difficult to explore analytically. In the following proposition we study the effect of transfers on the industrial sector in the symmetric equilibrium, which is defined as

$$L = 1 - L = 1/2, \quad H = 1 - H = 1/2 \quad t = 0 \text{ and } w = 1 \tag{3.30}$$

Note that the symmetric equilibrium is a solution of equation (3.26).

Proposition 3 *At the symmetric equilibrium, if the rate of income transfers, t, increases marginally from zero, then there exists a value ϕ^{sr} such that the industrial sector will:*

- *i) shrink in region 1 (decrease of L_{E_1}) and expand in region 2 (increase of L_{E_2}) for low openness of trade ($\phi < \phi^{sr}$);*
- *ii) expand in region 1 (increase of L_{E_1}) and shrink in region 2 (decrease of L_{E_2}) for high openness of trade ($\phi > \phi^{sr}$).*

Proof. See the Appendix. ■

These results are in line with the argumentations made before. The higher the trade costs are, the lower are the trade between regions (low competition and low openness of trade). As a consequence, the reduction in the disposable income of region 1, Y_1^d, has a minor negative effect on the demand of industrial goods produced in region 2. Thus, the majority of the transfer received by region 2 is expended locally. The result is a large expansion of the demand of industrial goods produced in region 2. The subsequent contraction of the supply in this region does not manage to reverse this initial expansion. In the extreme case of prohibitive trade costs, the industrial sector behaves like the non-tradable sector.

The opposite happens when trade costs are low (high openness of trade). The demand expansion is limited because of the large competition. Meanwhile, the excess of labor demand puts pressure on wages to rise (in region 2), causing a contraction in the supply, and as a consequence of this, the industrial sector shrinks. In the extreme case of free trade, the industrial sector, as a whole, behaves like the agricultural sector.

Additionally, the size of each sector is important to determine the effects of the change in the tax rate. The following proposition states the relation between the shrink/expansion of the industrial sector, and the size of the non-tradable sector.

Proposition 4 *As the proportion of disposable income devoted to the consumption of non-tradable goods increases (μ_2 increases), the ϕ^{sr} threshold diminishes.*

Proof. Using the equation $U(\phi) = 0$ (polynomial (3.49) in the Appendix) and the implicit differentiation, we obtain

$$\frac{\partial \phi^{sr}}{\partial \mu_2} = -\frac{2\phi^{sr}\left[\phi^{sr} + (2\sigma - 1)\right] + \sigma\left[1 - (\phi^{sr})^2\right]}{2\left[2\mu_2 + \sigma(1-\mu)\right]\phi^{sr} + 2\mu_2(2\sigma - 1)} < 0$$

■

The larger μ_2, the greater the impact of the demand shock on the non-tradable sector. In region 2, the positive demand shock benefits the non-tradable sector more in the first place, while the increase in the demand for industrial goods is going to be smaller. Then, in order to avoid deindustrialization in this region, lower competition is needed to ensure that the supply contraction does not reverse the weak demand expansion. The opposite happens in region 1.[6]

On the other hand, if there is no service sector ($\mu_2 = 0 \rightarrow \phi^{sr}_{(\mu_2=0)} = 1$), the results are straightforward. In region 2, the positive demand shock affects only the industrial

[6] Another way of interpreting this is by focusing on the agricultural sector. Increasing μ_2 while holding constant μ_1 is equivalent to a reduction of proportion of disposable income devoted to agricultural consumption $(1 - \mu)$. Because this proportion is relatively small, the contraction of the supply will have a larger effect on the other sectors of the economy, which makes the industrial sector more likely to shrink.

sector, which generates an upward pressure on the wages of the region. As wages in region 2 increase, the supply of agricultural goods and industrial goods contracts (prices go up) until a new equilibrium is reached. The agricultural sector must shrink, thus the industrial sector must expand (this is true at all the equilibria, not only at the symmetric one). In region 1, the agricultural sector always expands, so the industrial sector always shrinks.

Moreover, even when the industry expands, an income transfer policy makes the economy of the recipient region more dependent. The region becomes more industrialized at the expense of agriculture. Nevertheless, the overall base economic activities (agriculture plus industry) face a contraction. The income generated by the inter-regional trade diminishes (total net export falls) as a consequence of the shifts operated in the economic structure of the region. The trade deficit requires the transfers in order to maintain the equilibrium of the current account.

Summarizing the results of this subsection, because each sector has different transport costs, when an income transfer policy is applied, independently of the name given to each of the sectors: i) the one with higher competition (null or low transport cost) faces a contraction; ii) the one with lower competition (infinite or high transport costs) experiences an expansion; and iii) the sector with intermediate competition (intermediate transport costs) can shrink or expand depending on the strength of the spending effect on the non-tradable sector and the market size effect.

3.4. Dynamics and Long Run

Entrepreneurs are mobile between regions and they choose to migrate if they gain in terms of real profits from doing so. The entrepreneurs reallocation is driven by the following dynamics:

$$\dot{H} = H\left(1 - H\right)\left(\frac{V_1}{V_2} - 1\right) \tag{3.31}$$

where,

$$V_j = \frac{w_{H_j}}{P_j^{\mu_1} p_{s_j}^{\mu_2} P_A^{1-\mu}} \quad j = 1, 2 \tag{3.32}$$

is the indirect utility (real profits) of an entrepreneur in region j.

Transfers (and taxes) are deliberately excluded from the real profits in (3.32). The reason behind this is that we are only interested in the effect of income transfers. If they were included into the real profits there would be an additional effect in consideration: a tax/subsidy policy directly apply to industrial firms.

Using equations (3.8)-(3.9), (3.15), (3.16), and $w \equiv w_1/w_2 = p_1/p_2$, the entrepreneurs dynamics can be restated as

$$\dot{H} = H(1-H)\left\{\frac{L_{E_1}}{L_{E_2}}\frac{1-H}{H}w^{1-\mu_2}\left[\frac{Hw^{1-\sigma}+(1-H)\phi}{H\phi w^{1-\sigma}+(1-H)}\right]^{\frac{\mu_1}{\sigma-1}} - 1\right\} \tag{3.33}$$

All interior solutions of equation (3.33) must satisfy: $0 < H < 1$ and $\dot{H} = 0$. That is, the ratio $V \equiv V_1/V_2$ is

$$V(H,w) = \frac{L_{E_1(w)}}{L_{E_2(w)}}\frac{1-H}{H}w^{1-\mu_2}\left[\frac{Hw^{1-\sigma}+(1-H)\phi}{H\phi w^{1-\sigma}+(1-H)}\right]^{\frac{\mu_1}{\sigma-1}} = 1. \tag{3.34}$$

Note that the symmetric equilibrium (3.30) is also a solution of equation (3.34). Additionally, since the number of entrepreneurs per firm, f, is equal for both regions, the ratio (3.34) is also the ratio of operating real profits of firms.

3.4.1. Equilibria and Stability

A long-run equilibrium is a stationary point of the dynamic equation (3.33), where entrepreneurs do not have incentives to move from one region to the other. For analytical simplicity we are going to study the stability properties of the symmetric equilibrium recalling that the conclusions are valid in a close neighborhood of this equilibrium.

We make use of the *black-hole-condition* (BHC: $d \equiv \frac{\mu_1}{\sigma-1} \geq 1$) and the *no-black-hole-condition* (NBHC: $d \equiv \frac{\mu_1}{\sigma-1} < 1$) defined for the original FE model (Forslid and Ottaviano, 2003), for classification purposes. However, contrary to the original FE model, in ours there always exist a range of ϕ such that the dispersion equilibrium is stable, even when the BHC holds. The following proposition states the stability properties of the symmetric equilibrium.

Proposition 5 *The symmetric equilibrium presents the following stability properties:*

i) when the black hole condition holds ($d \geq 1$), there exists a threshold for the openness of trade (ϕ^r), such that, the symmetric equilibrium is unstable for $\phi \in (0,\phi^r)$, and stable for $\phi \in (\phi^r, 1)$;

ii) when the no black hole condition holds, and $\bar{d} < d < 1$, there exist two thresholds for the openness of trade (ϕ^b and ϕ^r), such that, the symmetric equilibrium is stable for $\phi \in \left(0,\phi^b\right)$, is unstable for $\phi \in \left(\phi^b,\phi^r\right)$, and is stable for $\phi \in (\phi^r, 1)$;

iii) when the no black hole condition holds and $d \leq \bar{d}$, the symmetric equilibrium is stable for all $\phi \in (0,1)$.

Proof. See the Appendix. ■

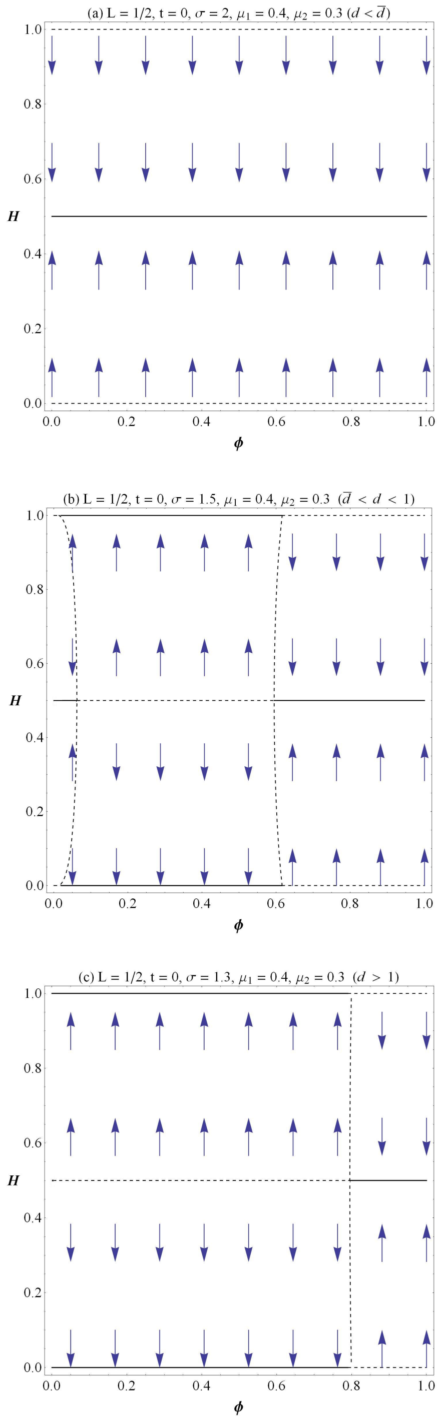

Figure 3.2: Bifurcation Diagrams

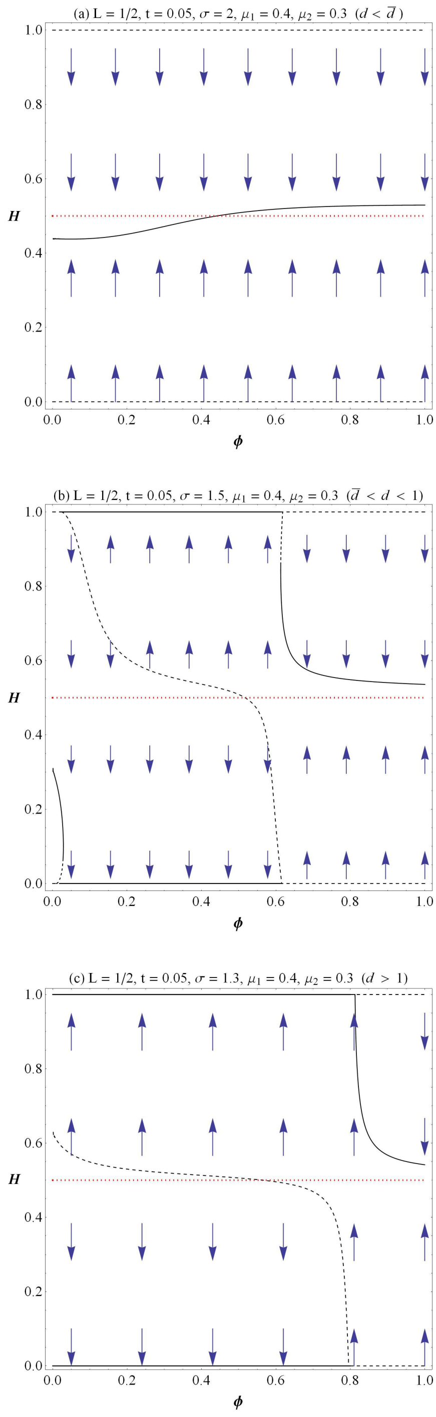

Figure 3.3: "Broken" Bifurcation Diagrams

When trade costs are high and the NBHC holds, and economies of scale are high enough ($\bar{d} < d < 1$), the market crowding effect dominates and industrial activity is disperse. For intermediate levels of trade costs, agglomeration takes place due to the market size and the cost of living effects. And for low levels of transport costs, the effect of the factor market competition induces a new dispersion phase (Ottaviano and Puga, 1998). This last dispersion phase takes place due to the competition for the limited labor supply. If the BHC holds ($d \geq 1$), for high and intermediate values of transport costs, agglomeration forces dominate (black hole, in the original FE model). However, for low transport cost the factor market competition exceeds the agglomeration forces and dispersion becomes stable. At the other extreme, when the NBHC holds and economies of scale are very low ($d \leq \bar{d} < 1$) agglomeration forces are too weak compared to the market crowding effect, first, and the factor market competition, after. As a result, the symmetric equilibrium is stable for all values of the openness of trade (ϕ). These three cases are depicted in Figure 3.2, where the solid lines indicate the stable equilibria, and the dashed lines indicate the unstable equilibria. The corresponding vector fields are also plotted in the same figure for further illustration of the stability properties.

Additionally, when the symmetric equilibrium is unstable (according to Proposition 5) there are other non-symmetric equilibria ($H \neq 1/2$) that are stable (see the proof of Lemma 1 in the Appendix). These could be interior asymmetric ($1/2 < H < 1$ and $0 < H < 1/2$) or agglomeration equilibria ($H = 0, 1$). From now on, we call these two types of equilibria: non-symmetric equilibria ($H \neq 1/2$).

3.4.2. Income transfers in the long run

In this section we address the effect of income transfers if entrepreneurs are allowed to migrate. Instead of asking how workers move from one sector to the other, what we ask here is how firms relocate when transfers are applied. For the sake of simplicity we will continuing studying the symmetric equilibrium, and analyze a marginal increase in t from zero. Again, the properties derived for the symmetric equilibrium hold in a close neighborhood of this equilibrium.

Proposition 6 *When the tax rate t increases marginally from zero, there are four possible cases for the symmetric equilibrium: the equilibrium is stable and H increases (SH^+); the equilibrium is stable and H decreases (SH^-); the equilibrium is unstable and H increases (UH^+); and the equilibrium is unstable and H decreases (UH^-). Furthermore, there exists a value ϕ^{lr} such that:*

i) When the NBHC holds, for low openness of trade, $\phi < \min\left[\phi^{lr}, \phi^{b}\right]$, regions are in case SH^-, and for high openness of trade, $\phi > \max\left[\phi^{lr}, \phi^{r}\right]$, regions are in case SH^+.

ii) When the BHC holds, for low openness of trade, $\phi < \min\left[\phi^{lr}, \phi^{r}\right]$, regions are in case UH^{+}, and for high openness of trade, $\phi > \max\left[\phi^{lr}, \phi^{r}\right]$, regions are in case SH^{+}.

Proof. See the Appendix. ■

The four cases defined by Proposition 6 imply that "broken" bifurcation diagrams arise. Figure 3.3 ilustrates these for the same cases depicted in Figure 3.2; $H = 1/2$ is also plotted (red dotted line) as reference.

In addition to the two properties of Proposition 6, some regularities emerge for the intermediate levels of the openness of trade. Figures 3.4 (a) - (e) depict, in the space (μ_2, ϕ), the different cases that emerge when $d < 1$, $d = 1$ and $d > 1$ (see the Appendix for the analytical derivation of the figures). These figures show the stable and unstable regions of the symmetric equilibrium, and they also depict the DD regions for the short and for the long run.

The effects of transfers in the ratio of real operating profits can be seen through expression (3.35), that can be positive or negative. In a close neighborhood of the symmetric equilibrium (3.30), if $\phi < \phi^{lr}$ transfers tend to reduce the ratio of real profits, and if $\phi > \phi^{lr}$ transfers tend to increase the ratio of real profits.

$$\frac{dV/dt}{V} = \overbrace{\left[\frac{\frac{dL_{E_1}}{dt}}{L_{E_1}} - \frac{\frac{dL_{E_2}}{dt}}{L_{E_2}}\right]}^{\text{short-run}} + \overbrace{\left[\frac{\left.\frac{dw}{dt}\right|_{CA_2=0}}{w}\right] - \left[\frac{\mu_2}{w} + \mu_1 \frac{\frac{\partial(P_1/P_2)}{\partial w}}{P_1/P_2}\right] \left.\frac{dw}{dt}\right|_{CA_2=0}}^{\text{long-run}} \tag{3.35}$$

Additionally, the overall effect of expression (3.35) can be decomposed into three elements. The expression in the first square brackets is the volume effect derived from a change in employment, that is, changes in the operating profits due to changes in the volume of production. The expression in the second square brackets is the effect of the price on the operating profits. And the expression in the third square brackets is the change in the cost of living: non-tradable price and industrial price index. Moreover, the changes in the labor force are the results of the changes already studied in the short run (Proposition 3). Thus, expression (3.35) not only determines the effect on the indirect utilities, but also summarizes the linkages between the short and the long run.

However, the efficiency of the transfer can not be measured only by the effect over the real profits. The aim of an income transfers policy is to attract firms to the recipient region. To understand how firms move, it is necessary to consider also the stability of the equilibrium. Bringing these elements together, we arrive at the four cases defined in Proposition 6. Figure 3.4 shows that these four cases emerge from intersection of the stable/unstable regions with the (long-run) DD/no-DD regions.

In the case SH^{-} ($\phi < \min\left[\phi^{lr}, \phi^{b}\right]$ or $\phi^{r} < \phi < \phi^{lr}$), the implementation of the transfers decreases the ratio of real profits, and in the new stable equilibrium the number of firms in the recipient region is higher. The transfer policy prevents firms moving to region 1 by turning region 2 into a more attractive destination in terms of real profits. This can arise even if industrial employment diminishes in the short run.[7]

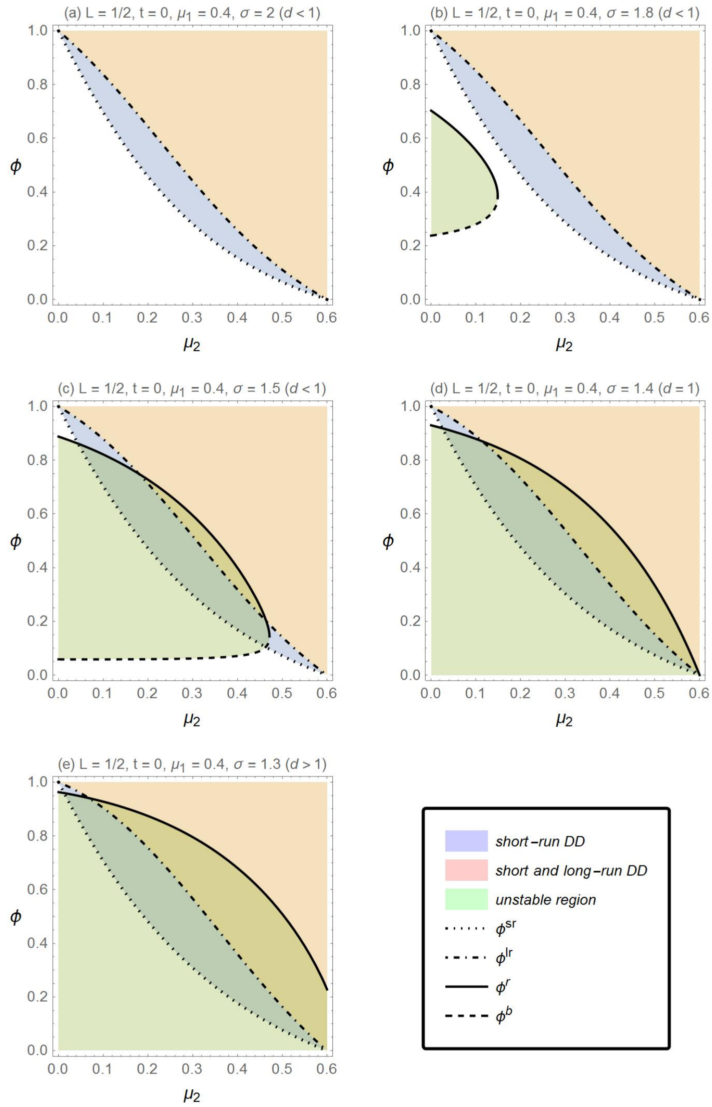

Figure 3.4: Stable, Unstable and Dutch Disease regions

When transport cost are low ($\phi > \max\left[\phi^{lr}, \phi^{r}\right]$), the case SH^{+} arises. Expression (3.35) becomes positive, and the ratio of indirect utilities increases with the implementation of the transfers. In the new stable equilibrium, the number of firms increases in region 1. Thus, the transfer policy makes region 1 more attractive. This can only arise if industrial employment increases in region 1 in the short run.

[7]The long-run effect in expression (3.35) is always negative, while the short-run effect is positive or negative, depending on $\phi \gtrless \phi^{sr}$.

The other two cases UH^{+} ($\phi^{b} < \phi < \min\left[\phi^{lr}, \phi^{r}\right]$) and UH^{-} ($\max\left[\phi^{lr}, \phi^{b}\right] < \phi < \phi^{r}$) take place when the equilibrium is unstable and expression (3.35) is negative or positive, respectively. The change in the unstable equilibrium can be seen as a movement of the boundary that defines the basin of attraction of the non-symmetric equilibria.

Thus, when the implementation of transfers increase the attractiveness of region 1, the stable symmetric equilibrium shifts towards $H > 1/2$, creating regional disparities (Figure 3.5 (b)), while the unstable symmetric equilibrium shifts towards $H < 1/2$, displacing the boundary of the basin of attraction (Figure 3.5 (d)), making it more difficult to leave the non-symmetric equilibrium, and thus, perpetuating pre-exiting regional asymmetries.

Income transfers have the opposite effect to that intended at the time of implementation. In the short run industrial employment is lost, and in the long run, firms move away to the other region (from region 2 to region 1) if the equilibrium is stable, or the asymmetries are perpetuated, if the equilibrium is unstable.

On the other hand, when transfers increase the attractiveness of region 2 (the recipient region), exactly the opposite happens. In the short run the transfer policy can have a positive or a negative impact on the industrial employment. In the long run firms will move to the recipient region, if the equilibrium is stable (Figure 3.5 (a)), or the boundaries of the basin of attraction will shift, favoring the recipient region (Figure 3.5 (c)).

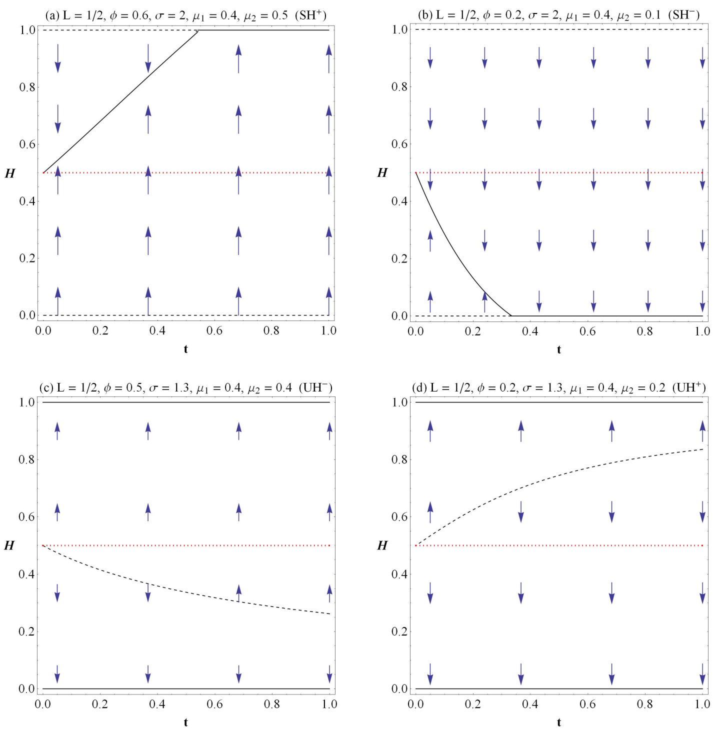

Figure 3.5: Bifurcation Diagrams in the space (t, H)

3.5. Conclusions

This chapter analyzes the effects of the implementation of transfers in a NEG model that incorporates some of the key features of the DD literature. We modify the footloose entrepreneur model by adding a non-tradable (service) sector. There is a supra regional authority that collects taxes and makes transfers from one region to the other exogenously. The main differences between the model proposed here and others from the NEG literature is the combination of the following elements: a non-tradable sector, labor mobility across sectors and slightly differentiated agricultural goods.

Under this setup, income transfers play a double role in the model. On the one hand, the increase in the disposable income of the recipient region causes a spending effect on the non-tradable sector, increasing wages and making industrial production more expensive, as pointed out by the DD literature. On the other hand, the income transfers increase the market potential through the market size effect described by the NEG literature. A DD emerge if the disadvantages of the higher production costs (spending effect) offsets the advantages from a higher market potential (market size effect).

In the short-run, deindustrialization can take place for low values of transport cost. The high foreign competition limits the beneficial effects of the transfers, which are ultimately surpassed by the increase in the production costs. The last one comes as a consequence of the competition between the industrial and the non-tradable sector for the labor force.

In the long run, changes in the prices (wages) and in the cost of living favor the recipient region by increasing industrial nominal and real profits. If there is no de-industrialization in the short run, firms will move to the recipient region. If there is de-industrialization in the short run, the recipient region will only end up attracting firms if the positive effects of prices and the cost of living are stronger than the Dutch disease effect. To ensure this, low competition is needed. But, if the competition is very high, the transfers will create or even exacerbate regional disparities instead of reducing them.

We also find that short-run results, which are associated with the Dutch disease literature, condition the long-run results, which are associated with the New Economic Geography literature. The contributions of the DD literature to the NEG literature is that wage adjustments are important and that transfers have not always positive effects for the regional economies because of sectoral mobility. The contribution of the NEG literature to the DD literature is that, through the same wage adjustments, a previous short run de-industrialization could end up being a long-run industrialization because of the inter-regional mobility.

3.6. References

Adam, C., & Bevan, D. (2003). Aid, Public Expenditure and Dutch Disease (No. 2003-02). Centre for the Study of African Economies, University of Oxford.

Adam, C. (2005). Exogenous Inflows and Real Exchange Rates: Theoretical Quirk or Empirical Reality?. In IMF Seminar on Foreign Aid and Macroeconomic Management, Maputo, Mozambique, March (pp. 14-15).

Choueiri, N., Schadler, S., Elkan, R. v. & Allard, C. (2008), Macroeconomic Effects of EU Transfers in New Member States. IMF Working Papers, Vol. 8, pp. 1-57.

Athukorala, P. and Rajapatirana, S. (2003), Capital Inflows and the Real Exchange Rate: A Comparative Study of Asia and Latin America. World Economy, 26: 613-637

Baldwin, R., Forslid, R., & Martin, P. (2005). *Economic geography and public policy.* Princeton University Press.

Baskaran, T., Feld, L. P. & Necker, S. (2017): Depressing dependence? Transfers and economic growth in the German states, 1975–2005, Regional Studies.

Bickenbach, F. & Bode, E. (2013) New Economic Geography and Reunified Germany at Twenty: A Fruitful Match?, Spatial Economic Analysis, 8:2, 120-153.

Breau, S. & Saillant, R. (2016) Regional income disparities in Canada: exploring the geographical dimensions of an old debate, Regional Studies, Regional Science, 3:1, 463-481.

Bourdet Y. & Falck, H. (2006) Emigrants' remittances and Dutch Disease in Cape Verde, International Economic Journal, 20:3, 267-284.

Brülhart, M. & Trionfetti, F. (2004) Public expenditure, international specialization and agglomeration, European Economic Review, 48:4, 851-881.

Bulir, A. & Lane, T. (2002) Aid and Fiscal Management. IMF Working Paper No. 02/112.

Chowdhury, M. B. & Rabbi, F. (2014) Workers' remittances and Dutch Disease in Bangladesh, The Journal of International Trade & Economic Development: An International and Comparative Review, 23:4, 455-475.

Commendatore, P., Kubin, I., Bougheas, S., Kirman, A., Kopel, M., & Bischi, G. I. (2018). The Economy as a Complex Spatial System: Macro, Meso and Micro Perspectives. Springer.

Corden, W. M. (1984). Booming Sector and Dutch Disease Economics: Survey and Consolidation. Oxford Economic Papers, 36(3), 359-80.

Corden, W. M. (1994). Economic policy, exchange rates, and the international system. Oxford: Oxford University Press.

Corden, W., & Neary, J. (1982). Booming Sector and De-Industrialisation in a Small Open Economy. The Economic Journal, 92(368), 825-848.

Dixit, A., & Stiglitz, J. (1977). Monopolistic Competition and Optimum Product Diversity. The American Economic Review, 67(3), 297-308.

Dornbusch, R. (1991). Exchange rates and inflation. Cambridge: Mit Press.

Forslid, R. (1999). Agglomeration with human and physical capital: An analytically solvable case. London: Centre for Economic Policy Research.

Forslid, R., & Ottaviano, G. I. (2003). An analytically solvable core-periphery model. Journal of Economic Geography, 3(3), 229-240.

Fujita, M., Krugman, P. R., & Venables, A. (2001). *The spatial economy: Cities, regions, and international trade.* Cambridge: MIT press.

Gabrisch, H. (1997) Eastern enlargement of the European union: Macroeconomic effects in new member states, Europe-Asia Studies, 49:4, 567-590.

Krugman, P. (1987). The narrow moving band, the Dutch disease, and the competitive consequences of Mrs. Thatcher: Notes on trade in the presence of dynamic scale economies. Journal of development Economics, 27(1-2), 41-55.

Krugman, P. (1991). Increasing Returns and Economic Geography. *The Journal of Political Economy, 99*(3), 483-499.

Krugman, P. & Venables, A. J. (1995) Globalization and the Inequality of Nations, The Quarterly Journal of Economics, 110:4, 857–880.

Lartey, E. K. K. (2007) Capital inflows and the real exchange rate: An empirical study of sub-Saharan Africa, The Journal of International Trade & Economic Development: An International and Comparative Review, 16:3, 337-357.

Martin, P., & Rogers, C. A. (1995). Industrial location and public infrastructure. Journal of international Economics, 39(3-4), 335-351.

Modrego, F., McCann, P., Foster, W. E. & Olfert, M. R. (2014) Regional Market Potential and the Number and Size of Firms: Observations and Evidence from Chile, Spatial Economic Analysis, 9:3, 327-348.

Moncarz, P. E., Freille, S., Figueras, A. J., & Grión, N. C. (2017). Do intergovernmental transfers affect the distribution of manufacturing production across regions in federal countries? Theory and evidence for Argentina. Regional & Federal Studies, 27(4), 359-392.

Moosa, I. A. (2017): Does financialization retard growth? Time series and cross-sectional evidence, Applied Economics.

Nkusu, M. (2004). Aid and the Dutch disease in low-income countries: Informed diagnoses for prudent prognoses (No. 2004-2049). International Monetary Fund.

Ottaviano, G. I., & Puga, D. (1998). Agglomeration in the global economy: a survey of the 'new economic geography'. *The World Economy, 21*(6), 707-731.

Ottaviano, G. I. (2001). Monopolistic competition, trade, and endogenous spatial fluctuations. Regional Science and Urban Economics, 31(1), 51-77.

Rajan, R. G., & Subramanian, A. (2005). What undermines aid's impact on growth? (No. w11657). National Bureau of Economic Research.

Selaya P. & Thiele, R. (2010) Aid and Sectoral Growth: Evidence from Panel Data, The Journal of Development Studies, 46:10, 1749-1766

Swan, T. W. (1960), Economic Control in a Dependent Economy, Economic Record, 36: 51-66.

Swan, T. W. (1963). Longer-run problems of the balance of payments. The Australian Economy: A volume of readings, 384-95. Melbourne: Cheshire Press.

Taguchi, H. (2017). Analysis of 'Dutch Disease Effects' on Asian Economies, Emerging Issues in Economics and Development, Musa Jega Ibrahim, IntechOpen.

Trionfetti, F. (1997). Public Expenditure and Economic Geography. Annales D'Économie Et De Statistique, (47), 101-120.

Trionfetti, F. (2001), Public Procurement, Market Integration, and Income Inequalities. Review of International Economics, 9: 29-41.

Uddin, Md. B. & Murshed, S. M. (2017) International transfers and Dutch Disease: evidence from South Asian countries, Journal of the Asia Pacific Economy, 22:3, 486-509.

Van Wijnbergen, S. (1986). Macroeconomic aspects of the effectiveness of foreign aid: On the two-gap model, home goods disequilibrium and real exchange rate misalignment. Journal of International Economics, 21(1-2), 123-136.

White, H. (1992) The macroeconomic impact of development aid: A critical survey, The Journal of Development Studies, 28:2, 163-240.

Yano, M., & Nugent, J. B. (1999). Aid, nontraded goods, and the transfer paradox in small countries. American Economic Review, 89(3), 431-449.

3.7. Appendix

Proof of Proposition 1: First, and hereinafter, we take as numerarie the labor in region 2, then, $w_2 = p_{s_2} = p_{A_2} = 1$ and $p_2 = \beta\frac{\sigma}{\sigma-1}$. Furthermore,

$$w \equiv \frac{p_1}{p_2} = \frac{p_{A_1}}{p_{A_2}} = \frac{p_{s_1}}{p_{s_2}} = \frac{w_1}{w_2} = w_1 \tag{3.36}$$

Using expressions (3.16), (3.20)-(3.23), (3.29) and replacing these in (3.27) and (3.28) we have

$$\begin{aligned}
Y_1 &= \frac{\sigma}{\sigma-\mu_1}\left[Lw + \frac{t\mu_2 Lw}{\sigma-1+\mu_2(1-t)} + \frac{1-\mu}{2P_A^{1-\sigma}}\frac{Lw-(1\text{-}L)\,p_A^{1-\sigma}}{\sigma-1+\mu_2(1-t)}\right] && (3.37)\\
Y_2 &= \frac{\sigma}{\sigma-\mu_1}\left[(1\text{-}L) - \frac{t\mu_2 Lw}{\sigma-1+\mu_2(1-t)} + \frac{1-\mu}{2P_A^{1-\sigma}}\frac{(1\text{-}L)\,p_A^{1-\sigma}-Lw}{\sigma-1+\mu_2(1-t)}\right] && (3.38)\\
Y^w &= Y_1 + Y_2 = Y_1^d + Y_2^d \quad \text{and} \quad Y^w = \frac{\sigma}{(\sigma-\mu_1)}\left[Lw + (1-L)\right] && (3.39)
\end{aligned}$$

Using (3.8)-(3.9), (3.36), (3.15), and (3.37)-(3.39) the current account equation (3.26) can be rewritten as:

$$\begin{aligned}
CA_2(H,w) \equiv s_y(1-t) \quad & \left\{\mu_1\phi\left[\frac{Hw^{1-\sigma}}{H\phi w^{1-\sigma}+1-H} + \frac{1-H}{Hw^{1-\sigma}+(1-H)\phi}\right] + (1-\mu)\right\}\\
+ts_y- \quad & \left[\mu_1\phi\frac{Hw^{1-\sigma}}{H\phi w^{1-\sigma}+1-H} + (1-\mu)\frac{w^{1-\sigma}}{1+w^{1-\sigma}}\right] = 0 \qquad (3.40)
\end{aligned}$$

where $s_y \equiv Y_1(w)/Y^w(w)$. Implicit differentiation of (3.40) leads to

$$\left.\frac{dw}{dH}\right|_{CA_2=0} = -\frac{\frac{\partial CA_2}{\partial H}}{\frac{\partial CA_2}{\partial w}} \tag{3.41}$$

where,

$$\frac{\partial CA_2}{\partial H} = -\frac{\mu_1\phi w^{1-\sigma}}{(Hw^{1-\sigma}\phi+1-H)^2}\left\{1 - s_y(1-t)\frac{(1-\phi^2)\left[\left(Hw^{1-\sigma}\right)^2-(1-H)^2\right]}{[Hw^{1-\sigma}+(1-H)\phi]^2}\right\} < 0 \tag{3.42}$$

the second term in curly brackets could be negative or positive, but in the last case, it will always be lower than one, thus, the expression is always negative. Additionally,

$$\begin{aligned}
\frac{\partial CA_2}{\partial w} = \; & \frac{\mu_1\phi(\sigma-1)H(1-H)}{w^{\sigma}(Hw^{1-\sigma}\phi+1-H)^2}\left\{1 - s_y(1-t)\frac{(1-\phi^2)\left[\left(Hw^{1-\sigma}\right)^2-(1-H)^2\right]}{[Hw^{1-\sigma}+(1-H)\phi]^2}\right\} + \frac{(1-\mu)(\sigma-1)w^{-\sigma}}{(1+w^{1-\sigma})^2}\\
& + \frac{\partial s_y}{\partial w}\left\{1 - \mu(1-t) + \mu_1\phi(1-t)\left[\frac{Hw^{1-\sigma}}{Hw^{1-\sigma}\phi+1-H} + \frac{1-H}{Hw^{1-\sigma}+(1-H)\phi}\right]\right\} \qquad (3.43)
\end{aligned}$$

Note that,

$$\begin{aligned}
\frac{\partial Y_1}{\partial w} &= \frac{\sigma}{\sigma-\mu_1}\left\{L+\frac{\mu_2 tL}{\sigma-1+\mu_2(1-t)}+\frac{1-\mu}{(1+w^{1-\sigma})^2}\frac{L\left(\sigma w^{1-\sigma}+1\right)+(1-L)(\sigma-1)w^{-\sigma}}{\sigma-1+\mu_2(1-t)}\right\}>0\\
\frac{\partial Y^w}{\partial w} &= \frac{\sigma}{\sigma-\mu_1}L
\end{aligned}$$

On comparing these expressions we observe that, $\frac{\partial Y_1}{\partial w}>\frac{\partial Y^w}{\partial w}$, and $Y^w>Y_1$, thus,

$$\frac{\partial s_y}{\partial w}=\frac{\frac{\partial Y_1}{\partial w}Y^w-\frac{\partial Y^w}{\partial w}Y_1}{\left(Y^w\right)^2}>0 \tag{3.44}$$

Then, we have that

$$\frac{\partial CA_2}{\partial w}>0 \tag{3.45}$$

Considering the signs of (3.42) and (3.45), (3.41) must always be positive.

Proof of Proposition 2: From expressions (3.37) and (3.39) we have that

$$\frac{\partial s_y}{\partial t}=\frac{\partial Y_1/\partial t}{Y^w}=\frac{\mu_2}{\sigma-1+\mu_2\left(1-t\right)}s_y \tag{3.46}$$

Then, deriving the current account equation (3.40) with respect to t,

$$\frac{\partial CA_2}{\partial t}=\frac{s_y}{\sigma-1+\mu_2(1-t)}\left\{(\sigma-1+\mu_2)-(\sigma-1)\left[\frac{\mu_1 Hw^{1-\sigma}\phi}{Hw^{1-\sigma}\phi+1-H}+\frac{\mu_1(1-H)\phi}{Hw^{1-\sigma}+(1-H)\phi}+(1-\mu)\right]\right\} \tag{3.47}$$

The sum in the square brackets is equal to or lower than 1, and $[(\sigma-1+\mu_2)-(\sigma-1)(\mu_1+1-\mu)]>0$. Thus, the expression is always positive. Then:

$$\left.\frac{dw}{dt}\right|_{CA_2=0}=-\frac{\frac{\partial CA_2}{\partial t}}{\frac{\partial CA_2}{\partial w}}<0$$

For the second part of the proposition, we can divide equation (3.19) by (3.39), such that

$$\frac{T_2}{Y^w}=ts_y \quad \text{and} \quad \frac{Y^w-T_2}{Y^w}=(1-ts_y)$$

Deriving this expressions and expression (3.39) with respect to t,

$$\begin{aligned}
\frac{d\left(ts_y\right)}{dt} &= t\frac{\partial s_y}{\partial t}+s_y+t\frac{\partial s_y}{\partial w}\left.\frac{dw}{dt}\right|_{CA_2=0}=\frac{\sigma-1+\mu_2}{\sigma-1+\mu_2(1-t)}s_y+t\frac{\partial s_y}{\partial w}\left.\frac{dw}{dt}\right|_{CA_2=0}>0\\
\frac{d\left(1-ts_y\right)}{dt} &= -\frac{d\left(ts_y\right)}{dt}<0\\
\frac{dY^w}{dt} &= \frac{\sigma}{\sigma-\mu_1}L\left.\frac{dw}{dt}\right|_{CA_2=0}<0
\end{aligned}$$

On looking at equations (3.43)-(3.47), it is clear that the first expression is always positive, while the last two are always negative. Thus, if T_2/Y^w increases and $(Y^w - T_2)/Y^w$ decreases as t rises, dT_2/dt must be positive.

Proceeding in the same way for the disposable incomes,

$$\frac{Y_1^d}{Y^w} = \frac{(1-t)\,Y_1}{Y^w} = (1-t)\,s_y \quad \text{and} \quad \frac{Y_2^d}{Y^w} = 1-(1-t)\,s_y$$

by differentiating these expressions with respect to t we obtain

$$\begin{aligned}
\frac{d\left[(1-t)\,s_y\right]}{dt} &= -\frac{\sigma-1}{\sigma-1+\mu_2\,(1-t)}s_y + (1-t)\,\frac{\partial s_y}{\partial w}\,\frac{dw}{dt}\bigg|_{CA_2=0} < 0 \\
\frac{d\left[1-(1-t)\,s_y\right]}{dt} &= -\frac{d\left[(1-t)\,s_y\right]}{dt} > 0
\end{aligned}$$

Then, taking into account that $dY^w/dt < 0$, the last two expressions imply that

$$\frac{dY_1^d}{dt} < 0 \quad \text{and} \quad \frac{dY_2^d}{dt} > 0$$

Proof of Proposition 3: The change in the industrial sector as a proportion of the labor force in the sector is:

$$\frac{dL_{E_j}/dt}{L_{E_j}} = \frac{\partial L_{E_j}/\partial t}{L_{E_j}} + \frac{\partial L_{E_j}/\partial w}{L_{E_j}}\,\frac{dw}{dt}\bigg|_{CA_2=0} \gtrless 0$$

Using equations (3.23), (3.29), (3.37), (3.38), (3.43) and (3.47), the previous expression for region 1 at the symmetric equilibrium (3.30) is equal to,

$$\frac{dL_{E_1}/dt}{L_{E1}}\bigg|_{sym} = \frac{\sigma U\,(\phi)}{Z(\phi)} \gtrless 0 \tag{3.48}$$

where $U\,(\phi)$, and $Z(\phi) > 0$ for $\phi \geq 0$ $(dZ(\phi)/d\phi > 0)$, are polynomials,

$$\begin{aligned}
U\,(\phi) &= \left[2\mu_2+\sigma\,(1-\mu)\right]\phi^2+2\mu_2\,(2\sigma-1)\,\phi-\sigma\,(1-\mu) \gtrless 0 && (3.49)\\
Z(\phi) &= (\sigma-1+\mu_2)\left[4\mu_1\,(\sigma-1)\,\phi+(1-\mu)\,(\sigma-1)\,(1+\phi)^2\right] && (3.50)\\
&\quad +(\sigma-1+\mu_2)\left[1+\tfrac{\sigma(1-\mu)}{\sigma-1+\mu_2}\right]\left[(1-\mu_2)\,(1+\phi)^2-\mu_1\left(1-\phi^2\right)\right] > 0 && (3.51)
\end{aligned}$$

where $Z\,(\phi) > 0$ for all $\phi \in [0,1]$. Then, the sign of expression (3.48) depends only on the numerator. The polynomial (3.49) has a unique positive root: $P(\phi = \phi^{sr}) = 0$ with $\phi^{sr} \in (0,1)$, and

$$\phi^{sr} = \frac{-\mu_2\,(2\sigma-1)+\sqrt{\left[\mu_2\,(2\sigma-1)\right]^2+\sigma\,(1-\mu)\left[2\mu_2+\sigma\,(1-\mu)\right]}}{\left[2\mu_2+\sigma\,(1-\mu)\right]} \tag{3.52}$$

Moreover, evaluating expression (3.48) for the extreme cases of $\phi = 0$ and $\phi = 1$ we have that

$$\begin{aligned}
\left.\frac{dL_{E_1}/dt}{L_{E1}}(\phi = 0)\right|_{sym} &= -\frac{\sigma}{(\sigma - \mu_1)} < 0 \\
\left.\frac{dL_{E_1}/dt}{L_{E1}}(\phi = 1)\right|_{sym} &= \frac{\mu_2 \sigma}{(1 - \mu_2)(\sigma - \mu_1)} > 0
\end{aligned}$$

Then, expression (3.48) is negative for $0 \le \phi < \phi^{sr}$ and positive for $\phi^{sr} < \phi \le 1$. Proceeding in the same way for region 2, (and by symmetry) we have that

$$\left.\frac{dL_{E_2}/dt}{L_{E2}}\right|_{sym} = -\left.\frac{dL_{E_1}/dt}{L_{E1}}\right|_{sym} = -\frac{\sigma U(\phi)}{Z(\phi)} \gtrless 0$$

Proof of Proposition 5: We divided the proof in two parts. In the first part we prove the existence of the thresholds ϕ^b and ϕ^r that determine the stability/instability of the symmetric equilibrium. In the second part, we obtain an analytical expression for these thresholds.

Part 1: By differentiating equation (3.33) with respect to H, we obtain

$$\frac{d\dot{H}}{dH} = (1 - 2H)\left(\frac{V_1}{V_2} - 1\right) + H(1 - H)\frac{d(V_1/V_2)}{dH} \gtrless 0$$

where the first term vanishes at the symmetric equilibrium, and the second term can be rewritten as

$$\left.\frac{d\dot{H}}{dH}\right|_{sym} = H(1 - H)\left[\frac{\partial V}{\partial H} - \frac{\partial V}{\partial w}\frac{\partial CA_2/\partial H}{\partial CA_2/\partial w}\right] \gtrless 0 \tag{3.53}$$

If this expression is negative, the equilibrium is stable, and if it is positive the equilibrium is unstable. Evaluating expression (3.53) at the interior symmetric equilibrium (3.30) we obtain

$$\frac{d(V_1/V_2)}{dH} = -4\frac{[1-d+\phi(1+d)]}{1+\phi} + \frac{4\mu_1 \frac{\phi}{(1+\phi)^2}\left[\frac{\sigma^2(1-\mu)}{\mu_1(\sigma-1+\mu_2)} + 1 - \mu_2 - \frac{\mu_1(1-\phi)}{(1+\phi)}\right]}{\frac{\mu_1(\sigma-1)\phi}{(1+\phi)^2} + \frac{(1-\mu)(\sigma-1)}{4} + \frac{1}{4}\left[1 + \frac{\sigma(1-\mu)}{\sigma-1+\mu_2}\right]\left(1 + \mu_2 + \mu_1\frac{1-\phi}{1+\phi}\right)} \tag{3.54}$$

where $d \equiv \frac{\mu_1}{\sigma - 1}$. Evaluating (3.54) at $\phi = 1$ we obtain,

$$\frac{d(V_1/V_2)}{dH}(\phi = 1) = -4\frac{\mu_1(\sigma - 1 + \mu_2)^2}{\sigma(\sigma - \mu_1)(1 - \mu_2)} < 0 \tag{3.55}$$

Thus, when $\phi = 1$, the symmetric equilibrium is always stable. Additionally, evaluating expression (3.54) at $\phi = 0$ we have

$$\frac{d(V_1/V_2)}{dH}(\phi = 0) = 4\left[\frac{\mu_1}{\sigma - 1} - 1\right] \tag{3.56}$$

Which implies that, if the BHC holds, the symmetric equilibrium is unstable for $\phi = 0$, and stable otherwise. Furthermore, expression (3.54) can be rewritten as

$$\frac{d\left(V_1/V_2\right)}{dH} = \frac{P(\phi)}{K(\phi)} = \frac{-A\phi^3 + B\phi^2 + C\phi + D}{K(\phi)} \gtrless 0 \tag{3.57}$$

where

$$A \equiv (1+d)\left[\left(1+\frac{\sigma(1-\mu)}{\sigma-1+\mu_2}\right)(1-\mu_2+\mu_1) + (1-\mu)(\sigma-1)\right] > 0 \tag{3.58}$$

$$B \equiv 4\mu_1\left[\frac{\sigma(1-\mu)}{\sigma-1+\mu_2}+1-\mu_2+\mu_1\right] - 2(1+d)\left[\frac{\sigma(1-\mu)(\sigma-\mu_1)}{\sigma-1+\mu_2}+\mu_1(\sigma-1)\right] \tag{3.59}$$

$$-(1-d)\left\{\left[\frac{\sigma(1-\mu)}{\sigma-1+\mu_2}+1\right](1-\mu_2+\mu_1) + (1-\mu)(\sigma-1)\right\}$$

$$C \equiv 4\mu_1\left[\frac{\sigma^2(1-\mu)}{\mu_1(\sigma-1+\mu_2)}+1-\mu\right] - (1+d)\frac{\sigma(1-\mu)(\sigma-\mu_1)}{\sigma-1+\mu_2} \tag{3.60}$$

$$-2(1-d)\left[\frac{\sigma(1-\mu_2)(\sigma-\mu_1)}{\sigma-1+\mu_2} + \mu_1(\sigma-1)\right] \tag{3.61}$$

$$D \equiv (d-1)\frac{\sigma(1-\mu)(\sigma-\mu_1)}{\sigma-1+\mu_2} \tag{3.62}$$

$$K(\phi) \equiv \frac{4\mu_1(\sigma-1)\phi+(1-\mu)(\sigma-1)(1+\phi)^2+\left(1+\frac{\sigma(1-\mu)}{(\sigma-1+\mu_2)}\right)\left[(1-\mu_2)(1+\phi)-\mu_1\left(1-\phi^2\right)\right]}{4(1+\phi)^{-1}} > 0 \tag{3.63}$$

Since expression (3.63) is positive for all values of $\phi \geq 0$, we have to study only $P(\phi)$ to determine the sign of the expression (3.54). As $\phi \to \infty$, $P(\phi) \to -\infty$; and as $\phi \to -\infty$, $P(\phi) \to \infty$. Moreover, if $d \gtrless 1$, then $D \gtrless 0$. Also, when $d \geq 1$, $C > 0$, then there exist a threshold $\bar{\mu}_1(\sigma, \mu_2) \in (0, \min[1, \sigma-1])$ for the parameter μ_1, which can be expressed as $\bar{d} \equiv \frac{\bar{\mu}_1(\sigma,\mu_2)}{\sigma-1}$, such that if $\bar{d} < d < 1$, then $C > 0$, and there exist two real positive roots of the polynomial $P(\phi)$. And whenever $C < 0$, $B < 0$, according to expression (3.64) there are, therefore, no real positive roots.

$$B - C = -2\mu_1\frac{[(1+\mu_1)+2(1-\mu_2)]\sigma^2-[(1+\mu_1)+(1+3\mu_1)(1-\mu_2)]\sigma+(1-\mu_2)(1+2\mu_1)}{(\sigma-1)(\sigma-1+\mu_2)} < 0 \tag{3.64}$$

Part 2: In order to obtain a closed form for the thresholds (ϕ^b and ϕ^r) we have to consider that $\phi^* = -1$ is always a solution of $P(\phi) = 0$. Then, we can rewrite the polynomial as

$$P(\phi) = -(\phi+1)\left[\phi^2 - (Tr)\phi + (Det)\right] \tag{3.65}$$

where, $Tr \equiv \frac{B}{A} + 1$ and $Det \equiv -\frac{D}{A}$. Thus, the other two roots of $P(\phi)$ are:

$$\phi^b = \frac{Tr - \sqrt{(Tr)^2 - 4Det}}{2} \tag{3.66}$$

$$\phi^r = \frac{Tr + \sqrt{(Tr)^2 - 4Det}}{2} \tag{3.67}$$

If $(Tr)^2 - 4Det > 0$, we have three cases: 1) if $Tr > 0$ and $Det > 0$, then $0 < \phi^b < \phi^r < 1$; 2) if $Tr \lesseqgtr 0$ and $Det < 0$, then $\phi^b < 0 < \phi^r < 1$ and 3) if $Tr < 0$ and $Det > 0$, then $\phi^b < \phi^r < 0$. If $(Tr)^2 - 4Det = 0$, then $\phi^b = \phi^r \in [0, 1)$. If $(Tr)^2 - 4Det < 0$, then ϕ^b and ϕ^r are conjugated complexes.

Additionally, from these relations, we can implicitly define $\bar{\mu}_1(\sigma, \mu_2) \in (0, \min[1, \sigma - 1])$ as the value(s) of μ_1 that ensure that the following conditions are fulfilled:

$$Tr^2 - 4Det = 0 \text{ with } Tr > 0 \text{ and } Det > 0 \tag{3.68}$$

$$\mu_1 - (\sigma - 1) < 0 \tag{3.69}$$

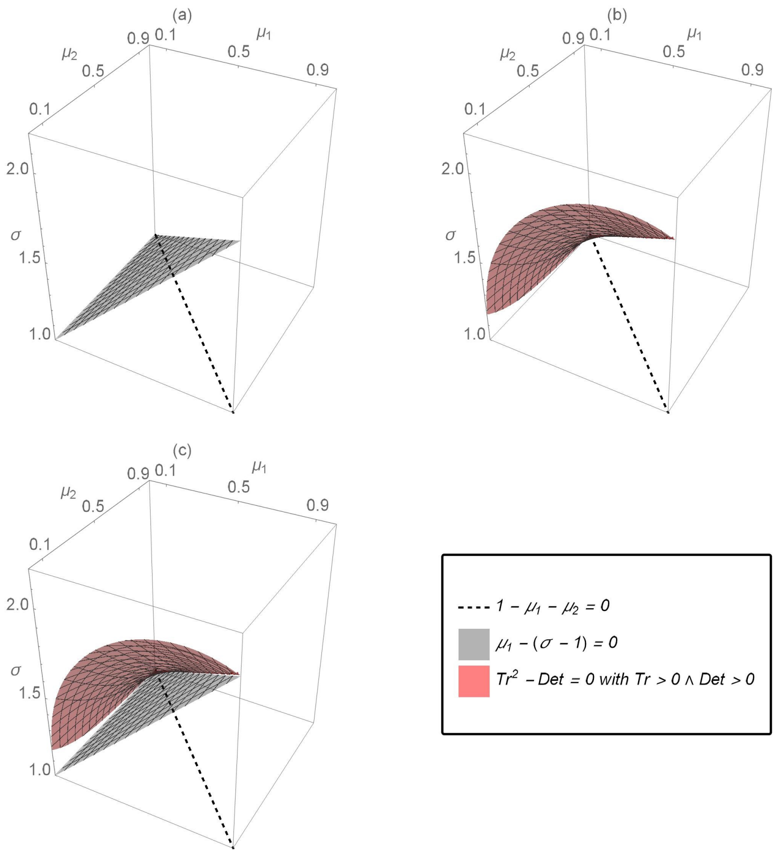

Figure 3.6: Regions of Bifurcation Points in the space (μ_1, μ_2, σ)

The region above the plane in Figure 3.6 (a) corresponds to $d < 1$ (condition (3.69)). Only the parameter values below the dashed line of Figure 3.6 in the plane (μ_1, μ_2) are feasible due to parameter restriction: $\mu_1 + \mu_2 \equiv \mu \in (0, 1)$. The red surface in Figure 3.6 (b) depicts condition (3.68). Below this surface $Tr^2 - 4Det > 0$, and above

$Tr^2 - 4Det < 0$. Then, for each value of σ and μ_2, there exist a value $\mu_1 = \bar{\mu}_1(\sigma, \mu_2)$ such that $Tr^2 - 4Det = 0$. Moreover, Figure 3.6 (c) divides the space of parameters (μ_1, μ_2, σ) in three regions: 1) below the gray plane, $d > 1$ and the symmetric equilibrium has a only one bifurcation point, ϕ^r; 2) above the gray plane and below the red surface, $\bar{d} < d < 1$ and the symmetric equilibrium has two bifurcation points, ϕ^b and ϕ^r; and 3) above the red surface, $d < \bar{d} < 1$ and the symmetric equilibrium is stable for all values of ϕ.

Lemma 1 *Non-symmetric equilibria ($H \neq 1/2$) present the following stability properties:*

i) If d ≥ 1 there is a threshold for the openness of trade, ϕ^{ss}, such that, the agglomeration equilibria, $H = 0, 1$, are stable for $\phi < \min[\phi^{ss}, 1]$ and unstable otherwise.

ii) If d < 1 there are two thresholds for the openness of trade ($\phi^s \leq \phi^{ss}$), such that, if $\phi^{ss} \in \mathbb{R}$, the agglomeration equilibria, $H = 0, 1$, are stable for $\min[\phi^s, 0] < \phi < \max[\phi^{ss}, 1]$, and unstable otherwise.

Proof. Evaluating expression (3.34) at $H = 1$, $L = 1/2$ and $t = 0$ we obtain

$$\lim_{H \to 1} V = \left[\frac{L_{E_1(H=1)} \left(w_{(H=1)} \right)^{1-\mu_2}}{\phi^{\frac{\mu_1}{\sigma-1}}} \right] \lim_{H \to 1} \left(\frac{1-H}{L_{E_2}} \right) - 1 \tag{3.70}$$

where $w_{(H=1)}$ and $L_{E_1(H=1)}$ can be obtained by solving the current account equation (3.40) when $H = 1$, which is equal to,

$$(1-\mu)\,\sigma w_{(H=1)} - (1-\mu_2)(\sigma-\mu_1)\, w_{(H=1)}^{1-\sigma} - \mu_1(\sigma - 1 + \mu_2) = 0 \tag{3.71}$$

This expression has a unique positive solution for the wage ratio: $w_{(H=1)} > 1$. Using this solution and equations (3.23) and (3.29) to (3.39), $L_{E_1(H=1)} > 0$ is obtained. Additionally, making $L_{E_2} = 0$ we arrive to the same condition (3.71). Thus, when $H \to 1$, $L_{E_2} \to 0$, and expression (3.70) can be written as

$$\lim_{H \to 1} V = \frac{L_{E_1(H=1)} \left(w_{(H=1)} \right)^{1-\mu_2}}{\phi^{\frac{\mu_1}{\sigma-1}}} \frac{\frac{2+\left(w_{(H=1)}\right)^{1-\sigma}+\left(w_{(H=1)}\right)^{\sigma-1}}{(1-\mu)\sigma(\sigma-1)}}{\frac{\sigma-1+\left(w_{(H=1)}\right)^{\sigma}+\sigma w_{(H=1)}}{2(\sigma-\mu_1)(\sigma-1+\mu_2)w_{(H=1)}} \left.\frac{\partial CA_2/\partial H}{\partial CA_2/\partial w}\right|_{(H=1)}} - 1$$

A stable agglomeration equilibrium, $H = 1$, requires the previous expression to be equal or larger than zero. Then, the following condition is obtained for the stability of the agglomeration equilibrium, $H = 1$,

$$\Psi - s_{y(H=1)}\phi^{d+1} - \left(1 - s_{y(H=1)}\right)\phi^{d-1} \geq 0 \tag{3.72}$$

where

$$\Psi \equiv L_{E_1} w^{1-\mu_2} \frac{\frac{2+w^{1-\sigma}+w^{\sigma-1}}{(1-\mu)\sigma(\sigma-1)}}{\frac{\sigma-1+w^{\sigma}+\sigma w}{2(\sigma-\mu_1)(\sigma-1+\mu_2)w}} \frac{\frac{(1-\mu)(\sigma-1)w^{-\sigma}}{(1+w^{1-\sigma})^2} + (1-\mu_2)\frac{\partial s_y}{\partial w}}{\frac{\mu_1}{w^{1-\sigma}}}\Bigg|_{H=1} > 0 \tag{3.73}$$

Ψ depends only on the parameters: μ_1, μ_2, and σ. Condition (3.72) implicitly defines ϕ^s and ϕ^{ss}, with $\phi^s \leq \phi^{ss}$. Additionally, considering that $w_{(H=1)} = 1/w_{(H=0)}$ an equivalent condition can be obtained for $H \rightarrow 0$. Then, we have that: 1) if $d \geq 1$ (ϕ^s does not exist), the agglomeration equilibria, $H = 0, 1$, are stable for $\phi \in (0, \min[\phi^{ss}, 1])$, and 2) if $d < 1$ and $\phi^{ss} \in \mathbb{R}$ (then also $\phi^s \in \mathbb{R}$), the agglomeration equilibria, $H = 0, 1$, are stable for $\phi \in (\min[\phi^s, 0], \max[\phi^{ss}, 1])$.

Furthermore, when $\phi^{ss} > \phi^b$ and/or $\phi^s < \phi^r$ there must exist other asymmetric interior equilibria ($0 < H < 1/2$ and $1/2 < H < 1$) that are stable for $\phi \in (\phi^b, \phi^{ss})$ and/or $\phi \in (\phi^s, \phi^r)$. ■

Proof of Proposition 6: By fully differentiating the system (3.40)-(3.33) with respect to t, we have:

$$\begin{pmatrix} \frac{\partial CA_2}{\partial w} & \frac{\partial CA_2}{\partial H} \\ \frac{\partial V}{\partial w} & \frac{\partial V}{\partial H} \end{pmatrix} \begin{pmatrix} \frac{dw}{dt} \\ \frac{dH}{dt} \end{pmatrix} = \begin{pmatrix} -\frac{\partial CA_2}{\partial t} \\ -\frac{\partial V}{\partial t} \end{pmatrix}$$

Then, the change in the number of firms is

$$\frac{dH}{dt} = \frac{\left(\frac{\partial CA_2}{\partial t}\frac{\partial V}{\partial w} - \frac{\partial V}{\partial t}\frac{\partial CA_2}{\partial w}\right)}{\left(\frac{\partial CA_2}{\partial w}\frac{\partial V}{\partial H} - \frac{\partial CA_2}{\partial H}\frac{\partial V}{\partial w}\right)}$$

Operating with these expressions, we arrive at

$$\frac{dH}{dt} = -\frac{\frac{\partial V}{\partial t} + \frac{\partial V}{\partial w}\left(-\frac{\partial CA_2/\partial t}{\partial CA_2/\partial w}\right)}{\frac{\partial V}{\partial H} + \frac{\partial V}{\partial w}\left(-\frac{\partial CA_2/\partial H}{\partial CA_2/\partial w}\right)} \tag{3.74}$$

The denominator is equal to the stability condition (3.54) in Proposition 5, while the numerator is the effect of a change in the rate of transfers (t) over the ratio of indirect utilities (V_1/V_2). Additionally, making use of (3.16) and (3.32), we can rewrite the numerator of (3.74) as

$$\frac{dV}{dt} = \frac{V_1}{V_2}\left\{\left[\frac{\frac{dL_{E_1}}{dt}}{L_{E_1}} - \frac{\frac{dL_{E_2}}{dt}}{L_{E_2}}\right] + \left[\frac{\frac{dw}{dt}\big|_{CA_2=0}}{w}\right] - \left[\frac{\mu_2}{w} + \mu_1\frac{\frac{\partial(P_1/P_2)}{\partial w}}{P_1/P_2}\right]\frac{dw}{dt}\bigg|_{CA_2=0}\right\}$$

which is equal to expression (3.35). Evaluating at the symmetric equilibrium,

$$\frac{dV}{dt}\bigg|_{sym} = \frac{2}{Z(\phi)}\left[\sigma U(\phi) - J(\phi)\right] \gtrless 0 \tag{3.75}$$

where

$$J(\phi) \equiv (1-\mu_2+\mu_1)\left[\mu_2\sigma-\mu_1(\sigma-1)\right]\phi^2 + 2\left[\mu_2(1-\mu_2\sigma)+\mu_1^2(\sigma-1)\right]+(1-\mu)\left[\mu_2\sigma+\mu_1(\sigma-1)\right] \tag{3.76}$$

$U(\phi)$ and $Z(\phi)$ are defined in (3.49) and (3.50), and $J(\phi) > 0$. Thus, the sign is determined by the numerator. After some manipulations we have that

$$\sigma U(\phi) - J(\phi) = a\phi^2 + b\phi + c \gtrless 0 \tag{3.77}$$

where

$$\begin{aligned} a &\equiv 2\mu_2\sigma - (1-\mu_2+\mu_1)\left[\mu_2\sigma-\mu_1(\sigma-1)\right] + \sigma^2(1-\mu) > 0 \\ b &\equiv 2\left[2\mu_2\sigma(\sigma-1)+\mu_2^2\sigma-\mu_1^2(\sigma-1)\right] \gtrless 0 \\ c &\equiv -(1-\mu)\left[\sigma^2+\mu_2\sigma+\mu_1(\sigma-1)\right] < 0 \end{aligned}$$

Additionally, evaluating (3.75) at the extreme cases $\phi = 0$ and $\phi = 1$,

$$\left.\frac{dV}{dt}(\phi=0)\right|_{sym} = -2\frac{\mu_1(\sigma-1)+\sigma(\sigma+\mu_2)}{\sigma(\sigma-1)} < 0 \tag{3.78}$$

$$\left.\frac{dV}{dt}(\phi=1)\right|_{sym} = 2\mu_2\frac{\sigma-1+\mu_2}{(\sigma-\mu_1)(1-\mu_2)} > 0 \tag{3.79}$$

Thus, the polynomial (3.77) has only one positive root,

$$\phi^{lr} = \frac{-b+\sqrt{b^2-4ac}}{2a} \in (0,1) \tag{3.80}$$

Furthermore, because $J(\phi) > 0$ for all $\phi \geq 0$, then the following relation must hold:

$$0 < \phi^{sr} < \phi^{lr} < 1 \quad \text{when} \quad \mu_2 \in (0, 1-\mu_1) \tag{3.81}$$

$$\phi^{sr} = \phi^{lr} \quad \text{when} \quad \mu_2 = 0, 1-\mu_1 \tag{3.82}$$

Combining these results with those from Proposition 5 the four cases stated in Proposition 6 are obtained. Moreover, using expressions (3.55), (3.56), (3.78) and (3.79) properties *i)* and *ii)* of Proposition 6 are derived.

Derivation of the Figures 3.4 (a) - (e): We focus first on ϕ^{lr}, which presents the same shape for all values of d. Then, we turn to analyze ϕ^b and ϕ^r, considering the different cases ($d < 1$, $d = 1$ and $d > 1$).

By differentiating of the polynomial (3.77) with respect to μ_2 is

$$\frac{\partial(\sigma U(\phi)-J(\phi))}{\partial\mu_2} = \sigma\left\{2\mu_2\phi^2 + \left(\mu\text{-}\mu_1\phi^2\right) + (\sigma\text{-}1)\,\phi\,(4\text{-}\phi) + 4\mu_2\phi + \sigma\text{-}1 + \mu_2\right\} + \mu_1(\sigma\text{-}1) > 0$$

And the differential with respect to ϕ is

$$\frac{\partial\left(\sigma U\left(\phi\right)-J\left(\phi\right)\right)}{\partial\phi}=2a\phi+b>0$$

which it is positive because $\phi^{lr}>\frac{-b}{2a}$ (see expression (3.80)). Then, the implicit differentiation gives,

$$\frac{\partial\phi^{lr}}{\partial\mu_2}=-\frac{\partial\left(\sigma U\left(\phi\right)-J\left(\phi\right)\right)/\partial\mu_2}{\partial\left(\sigma U\left(\phi\right)-J\left(\phi\right)\right)/\partial\phi}<0$$

Additionally, evaluating the polynomial (3.77) at $\mu_2=0$ and $\mu_2=1-\mu_1$,

$$\phi^{lr}\left(\mu_2=0\right)=1 \text{ and } \phi^{lr}\left(\mu_2=1-\mu_1\right)=0$$

Turning to ϕ^b and ϕ^r we begin with the simplest case, $d=1$ $(\sigma-1=\mu_1)$. In this special case we have that

$$\phi^b\left(\sigma-1=\mu_1\right)=0 \text{ and } \phi^r\left(\sigma-1=\mu_1\right)=\frac{1-\mu_2-\mu_1\left[4\mu_1^2+\mu_1(6\mu_2-1)+2\mu_2^2+\mu_2-2\right]}{1-\mu_2-\mu_1\left[2\mu_1^2+\mu_1(2\mu_2-1)+\mu_2-2\right]}$$

Thus, we focus only on ϕ^r. Differentiating $\phi^r\left(\sigma-1=\mu_1\right)$ with respect to μ_2,

$$\frac{\partial\phi^r(\sigma-1=\mu_1)}{\partial\mu_2}=\frac{\mu_1^2\left(5\text{-}2\mu_1^2\right)+\mu_2\left(2\text{-}\mu_2\text{-}\mu_1^3\right)+3\mu_1^3(1\text{-}\mu_2)+2\mu_1[1+\mu_2(2\text{-}\mu_2)]+2\mu_1^2\mu_2(1\text{-}\mu_2)}{-(2\mu_1)^{-1}\left\{1-\mu_2-\mu_1\left[2\mu_1^2+\mu_1(2\mu_2-1)+\mu_2-2\right]\right\}^2}<0$$

Additionally, note that the previous derivative tends to $-\infty$ when $\mu_2=1-\mu_1$. Evaluating $\phi^r(\sigma-1=\mu_1)$ at $\mu_2=0$ and $\mu_2=1-\mu_1$:

$$\phi^r(\sigma-1=\mu_1,\mu_2=0)=\frac{1+2\mu_1+\mu_1^2-4\mu_1^3}{1+2\mu_1+\mu_1^2-2\mu_1^3} \text{ and } \phi^r(\sigma-1=\mu_1,\mu_2=1-\mu_1)=0$$

Bringing these results together, when $d=1$, we have that $\phi^r(\mu_2=0)<\phi^{lr}\left(\mu_2=0\right)$ and $\phi^r(\mu_2=1-\mu_1)=\phi^{lr}\left(\mu_2=1-\mu_1\right)=0$. Both thresholds diminish as μ_2 increases, and they cross at least once within the interval $\mu_2\in(0,1-\mu_1)$.

When $d>1$ $(\sigma-1<\mu_1)$, the BHC case, $\phi^b<0$. Then, again, we only need to focus on ϕ^r. By differentiating expression (3.67) with respect to μ_2,

$$\frac{\partial\phi^r}{\partial\mu_2}=\frac{1}{\sqrt{(Tr)^2-4Det}}\left[\frac{\partial Tr}{\partial\mu_2}\phi^r-\frac{\partial Det}{\partial\mu_2}\right] \tag{3.83}$$

where

$$\begin{aligned}\frac{\partial Det}{\partial\mu_2} &= \frac{-2\mu_1\sigma(\sigma-1-\mu_1)(\sigma-\mu_1)^2}{(\sigma\text{-}1+\mu_1)\left[\sigma\mu_1^2\text{-}\sigma^2(1\text{-}\mu_2)+\mu_1(\sigma\text{-}2)(\sigma\text{-}1+\mu_2)\right]^2}>0 \text{ if } \sigma-1<\mu_1\\ \frac{\partial Tr}{\partial\mu_2}-\frac{\partial Det}{\partial\mu_2} &= \frac{-\left\{\sigma\left(\sigma^2\text{-}\mu_1^2\right)\text{-}\mu_1(1\text{-}\mu_2)+\sigma[(1\text{-}\mu_2)\sigma\text{-}\mu_1(\sigma\text{-}1)]+\mu_1[\sigma(2\text{-}\mu)\text{-}(1\text{-}\mu_2)]\right\}}{[4\mu_1(\sigma\text{-}1)(\sigma\text{-}1+\mu_2)]^{-1}(\sigma\text{-}1+\mu_1)\left[\mu_1^2\sigma\text{-}\sigma^2(1\text{-}\mu_2)+\mu_1(\sigma\text{-}2)(\sigma\text{-}1+\mu_2)\right]^2}<0\end{aligned}$$

Then, expression (3.83) must be negative whenever $d > 1$. Now, evaluating ϕ^r at $\mu_2 = 0$ and $\mu_2 = 1 - \mu_1$, we have that $\phi^r \in (0,1)$. Thus, when the BHC holds with inequality $(d > 1)$, $\phi^r(\mu_2 = 0) < \phi^{lr}(\mu_2 = 0)$ and $\phi^r(\mu_2 = 1 - \mu_1) > \phi^{lr}(\mu_2 = 1 - \mu_1)$. As in the previous case, both thresholds diminish as μ_2 increases, and they cross at least once within the interval $\mu_2 \in (0, 1 - \mu_1)$.

When $d < 1$ $(\sigma - 1 > \mu_1)$, we are interested only in the case when the thresholds are real numbers $(0 < \phi^b \leq \phi^r < 1)$, that is, when $\bar{d} \leq d < 1$. From Proposition 5 we can define a value $\mu_2 = \mu_{2_0}$ (implicitly defined by $(Tr)^2 - 4Det = 0$) such that $\phi_0 \equiv \phi^b = \phi^r$. Then, by differentiating the polynomial $\mathcal{O}_{(\phi,\mu_2)} \equiv \phi^2 - (Tr)\,\phi + Det = 0$ (see the polynomial (3.65)), and evaluating at (μ_{2_0}, ϕ_0)

$$\begin{aligned}
\frac{\partial \mathcal{O}}{\partial \phi}(\mu_{2_0}, \phi_0) &= 2\phi - Tr|_{\phi_0} = 2\phi_0 - (\phi_0 + \phi_0) = 0 \\
\frac{\partial \mathcal{O}}{\partial \mu_2}(\mu_{2_0}, \phi_0) &> 0 \\
\frac{\partial^2 \mathcal{O}}{\partial \phi^2}(\mu_{2_0}, \phi_0) &= 2
\end{aligned}$$

Thus, we have that for the function $\mu_2(\phi)$ implicitly defined by $\mathcal{O}_{(\phi,\mu_2)} = 0$,

$$\frac{d\mu_2}{d\phi}(\mu_{2_0}, \phi_0) = 0 \quad \text{and} \quad \frac{d^2\mu_2}{d\phi^2}(\mu_{2_0}, \phi_0) < 0$$

Which implies that the function $\mu_2(\phi)$ (implicitly defined by $\mathcal{O}_{(\phi,\mu_2)} = 0$) has a maximum at (μ_{2_0}, ϕ_0). In a close neighborhood of μ_{2_0}, ϕ^b increases, and ϕ^r diminishes as μ_2 increases until $\mu_2 = \mu_{2_0}$. At this point, both thresholds converge to the value ϕ_0.

Conclusions

The New Economic Geography (NEG) literature explains the geographical distribution of the economic activity in the space as the progression of the interaction of two types of opposing forces: dispersion and agglomeration. This literature gives strong microeconomics foundations for the existence of these forces. The main elements are increasing returns to scale, transport costs and input mobility, combined in a general equilibrium model. In recent decades the popularity of NEG models has increased rapidly, influencing other economic fields, like international trade, economic growth and innovation, economic policy, and environmental economics, to name a few.

In this thesis we have shown that NEG models can provide a fresh and novel vision when applied to these latter fields, and that the NEG literature can benefit from the interaction with these other economic fields by expanding its tools, forces and its economic intuition. To do this we developed an extension of the CP model that incorporates notions of the environmental economics, and an extension of the FE model to evaluate the impact of income transfers.

In Chapter 1 we present an extension of the original Core-Periphery (CP) model, which provides a more comprehensive modeling of the primary sector, usually treated as residual. Our model incorporates two key features of a primary sector: the dynamics of the renewable natural resources, and the possibility of using primary goods also as inputs for industrial production.

In addition to the standard NEG effects (market size, price index and competition effects), a new dispersion force arises as a consequence of the natural resource dynamics, which we have called “the resource effect”. When agglomeration forces attract firms and population to one of the regions, the demands for primary goods and raw materials increase, forcing a higher extraction of the natural resource. Once the dynamics of the resource is taken into account, the higher extraction diminishes the sustainable long-run level of the resource, making the primary good expensive, and increasing the industrial production costs. The trade deficit experienced by the most populated region tends to bring down nominal and real wages, so triggering the dispersion of population.

When the primary good is non-tradable, we find that the stability pattern of the original CP model is reversed. For high transport costs agglomeration is a stable solution, while for low transport costs agglomeration equilibria become unstable and the symmetric equilibrium, stable. The extraction productivity of the primary sector becomes an important parameter that defines the strength of the resource effect and also gives insights into the transition between agglomeration and dispersion equilibria, which can be sudden or smooth. Furthermore, for sufficiently large values of the extraction productivity, cyclical behavior arises. If the primary goods are tradable at the same transport cost as industrial goods, any reduction of the transport costs weakens the dispersion force associated to the resource. Then, for low values of transport cost the dispersion equilibrium is unstable. Moreover, in most cases we find that the symmetric equilibrium goes from stable to unstable as the openness of trade increases.

Chapter 2 provides a broader understanding of the interaction between population migration, trade, the distribution of the economic activity and natural resource exploitation. The model presented in Chapter 1 is extended by allowing for specific transport costs in the primary and industrial sectors. We focus on the dispersion equilibrium and the leading forces that encourage and discourage its stability.

We find that although the difference in transport costs between the two sectors affects the resource effect, this effect remains an important determinant of the distribution of the economic activity. Additionally we have been able to distinguish three channels through which the resource effect affects the distribution of the economic activity: the primary productivity channel, the wage channel and the firms channel. When the stock of the natural resource decreases in one of the regions, the primary labor productivity falls and primary price rises. The wage diminishes due to the trade imbalance generated by the change in primary price, and the number of firms increases because of the lower wage.

When the primary good is non-tradable, the labor mobility between sectors makes the market size effect overcome the competition effect. In contrast, if industrial goods are non-tradable, the competition effect overcomes the market size effect. Moreover, if industrial goods are freely traded, all the traditional NEG effects vanish. In this last case, the symmetric equilibrium is always stable because of the dispersive force of the resource effect. Finally, when each sector has its specific transport costs we find that the dispersion force of the resource effect is stronger, the higher the extractive productivity is and the higher both transport costs are.

In the two first chapters of the thesis, the NEG concepts contribute to the environmental and the natural resource economics by explaining some of the factors that lead to the expansion of the economic activity and, thus, to increasing the pressure on the harvesting and extraction of natural resources. On the other hand, the incorporation of some notions of the environmental economics into the CP model gives rise to a new effect: “the resource effect”, which acts mainly as a dispersion force. This effect is not present in the NEG literature but according to many empirical studies is a major cause of migration in developing and resource-based economies.

In Chapter 3 we present an extension of the footloose entrepreneurs (FE) model in order to study the effects of income transfers on the spatial distribution of the economic activity, and at the same time reconcile the contradictory results from the NEG and the

Dutch disease (DD) literatures. The proposed FE model incorporates some key features of the DD literature: a non-tradable sector and sectorial labor mobility. We avoid wage equalization by introducing a slightly differentiated agricultural good. We also let one region be a net contributor, while the other is a net recipient of income transfers.

In the short-run we find that high levels of foreign competition (low transport costs) can lead to de-industrialization. The expansion of the demand as a consequence of the income transfers is distributed among all firms in both regions, so reducing the beneficial effects on the companies of the recipient region. Meanwhile, the competition between the industrial and the non-tradable sectors raises production costs only in the recipient region. In the long run, changes in the prices (wages) and in the cost of living always favor the recipient region by increasing its industrial nominal and real operating profits. Thus, only when there is de-industrialization in the short run, may the recipient region also suffer from DD in the long-run. This scenario takes place when the competition is very high (low transport costs). If this is the case, transfers create or even exacerbate regional disparities instead of reducing them. Thus, short-run results, which are associated with the DD literature, condition the long-run results, which are associated with the NEG literature.

Our results point out that a de-industrialization scenario, predicted by the DD literature, can be reversed once the mechanisms proposed by the NEG literature are taken into consideration. However, they also show that the wage adjustment explained by the DD compromises the long-run results, and may even reverse the conclusions given by the NEG literature.