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Tesis Doctoral

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Doctoranda: Lucía Bolea Marcén

Directores: Dra. Rosa Duarte Pac y Dr. Julio Sánchez Chóliz

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A mis padres, a mis abuelos y a Adrián.

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"Todos los triunfos nacen cuando nos atrevemos a comenzar"

Eugene Fitch Ware.

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"All glory comes from daring to begin"

Eugene Fitch Ware.

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Introducción

1. *Motivación y revisión general de literatura.*

Esta tesis está escrita en un contexto de un periodo de tiempo marcado por grandes desajustes económicos con periodos de aceleración y desaceleración de la economía global. En este contexto de creciente incertidumbre, así como en sus efectos sobre la renta, el empleo y los factores medioambientales, marcados por el crecimiento del comercio internacional y las interdependencias de los países, es donde se sitúa el objetivo principal de esta tesis doctoral. El reciente proceso de globalización, el cambio tecnológico y el aumento del comercio internacional han provocado que los procesos productivos sean cada vez más globales, lo que implica estructuras interdependientes que vinculan bienes, procesos y países (ver Kaplisnky, 2006). Los bloques económicos tradicionales y los vínculos sectoriales dentro del país coexisten con el aumento de las dependencias mundiales. Por otra parte, el comercio ha sido considerado tradicionalmente como un elemento clave en el impulso del progreso económico de un país, así como la competitividad y la especialización (Barro, 1991). Dicho impacto del comercio internacional sobre el crecimiento económico ha sido ampliamente estudiado en la literatura, tanto desde el punto de vista teórico como empírico (Frankel y Romer, 1999; Grossman y Helpman, 1997; Keller, 2002).

Recientemente, el papel del comercio internacional como factor intrínseco impulsor de las tecnologías nacionales y movilización de recursos endógenos ha sido revisado vinculado al fenómeno de la globalización (Yu *et al.*, 2013). Varios son los trabajos que han estudiado este proceso y sus consecuencias en el comercio y la producción desde una perspectiva multisectorial. Por ejemplo, Rueda-Cantuche *et al.* (2013) mostraron cómo la globalización no solo provocó una distribución en los procesos de producción de bienes, sino que también generó una serie de vínculos comerciales que impulsaron la generación de empleo a través de este comercio. Los *et al.* (2013) encontraron un claro aumento de la fragmentación en la producción de la mayoría de bienes manufacturados en Europa, de 1995 a 2008 debido a la globalización, con una reducción temporal de este fenómeno después de la crisis internacional. Arto *et al.* (2014) evaluaron la renta y el empleo incorporados al comercio internacional, destacando la importante contribución del comercio fuera de la UE que apoya el empleo y la renta en los países de la UE. En la misma línea, Duarte *et al.*, (2016) cuantificaron estas magnitudes plasmadas en los flujos comerciales intracomunitarios y extracomunitarios, encontrando evidencia de un comercio predominante de inputs intermedios para ambos, así como un cierto proceso de especialización intracomunitaria, con una transferencia de sectores manufactureros a los países del Este, y un predominio de los servicios intensivos en conocimiento (KIS) y el resto de servicios en los países de Europa Central.

Además, en esta misma línea, otros trabajos han destacado también el importante papel que juega el comercio internacional, no solo como motor del crecimiento económico, sino como impulsor de intercambios de bienes, tecnologías e ideas que actúan como incentivos para la adquisición y difusión del conocimiento, ofreciendo también mayores oportunidades potenciales de mercado y afectando a los precios internacionales (Grossman y Helpman, 2015). Tal y como reconoce la Comisión Europea, "los flujos de comercio e inversión difunden nuevas ideas e innovación, nuevas tecnologías y una mejor investigación, lo que lleva a mejoras en los productos y servicios que utilizan las personas y las empresas" (Comisión Europea, 2012).

De acuerdo a este contexto, la tesis profundiza en el papel que juega el comercio internacional, el cambio tecnológico y estructural, y la composición de la demanda interna de los diferentes países en su evolución e incorporación a las cadenas globales de valor desde una perspectiva económica, histórica y medioambiental. La perspectiva económica permite entender estos procesos como inputs necesarios para lograr el desarrollo y avance de los países. La perspectiva histórica nos ayudará a conocer el pasado más reciente para comprender el presente y construir posibles escenarios de evolución futura. Finalmente, la perspectiva medioambiental es necesaria dada la transcendencia actual de asuntos como el cambio climático y sus consecuencias - desastres naturales, temperaturas extremas, inundaciones, etc.; su conexión con la actividad económica y los procesos de globalización, así como la necesaria y urgente necesidad de cooperación internacional para combatir estos problemas.

Los trabajos sobre la importancia de la desigualdad y convergencia de rentas entre países, y el papel desempeñado por fenómenos recientes como la globalización o el progreso tecnológico en el crecimiento, han experimentado un fuerte auge en los últimos años. La mayoría de ellos reconocen a la globalización y al cambio tecnológico como dos de los principales impulsores del reciente crecimiento económico de los países. La reducción de las barreras de entrada a los mercados y el aumento de la internacionalización han permitido a los países emergentes reducir las brechas de ingresos, lo que debería llevar a la convergencia económica. La globalización también está afectando al lado del consumidor, con una convergencia en estilos de vida y gustos. Los consumidores en diferentes países, de diferentes orígenes culturales, están desarrollando preferencias por los mismos productos, mostrando signos crecientes de convergencia en torno a las identidades globales del producto (Kjeldgaard y Askegaard, 2006; Smith, 2009).

La investigación aborda, por tanto, cuestiones relacionadas con la economía internacional, la economía regional y la economía ambiental, y se basa en herramientas comúnmente usadas en el análisis económico como la metodología input-output, para estudiar la evolución de los flujos comerciales intercambiados entre países y sectores, así como en técnicas tradicionales para medir la desigualdad a nivel económico, social y ambiental. Estas herramientas e indicadores serán extendidas, en la presente investigación, para el estudio de nuevas cuestiones relacionadas con la desigualdad intrarregional e intersectorial, la desigualdad a lo largo de las cadenas globales de valor y sus impactos sobre el medio ambiente.

2. *Objetivos*

En línea con las ideas previamente establecidas, la literatura económica destaca la necesidad creciente de reconocer la naturaleza multisectorial y multirregional de las economías, y su participación en las llamadas cadenas de valores mundiales y regionales. Por tanto, en este contexto, los modelos input-output multirregionales y multisectoriales (MRIO) se han convertido en poderosas herramientas para cuantificar el papel de las relaciones intersectoriales e interregionales, a diferentes escalas, en la evolución del crecimiento económico (ver una explicación detallada en Miller y Blair, 2009). Estos modelos serán clave para llevar a cabo el desarrollo de la presente tesis doctoral, no solo por su poder para captar las ligazones entre las diferentes regiones, países y sectores, sino también por su capacidad para medir los efectos directos e indirectos de grandes fenómenos económicos como la globalización, la internacionalización o el cambio tecnológico. Su capacidad para trazar el mapa completo de importaciones y exportaciones directas e indirectas a lo largo de las distintas etapas productivas, permite además conectar las perspectivas del consumo y la producción en las cadenas productivas globales, permitiendo identificar de forma precisa el origen y destino de la producción y los factores productivos y ambientales asociados. Es importante destacar también, que los modelos multirregionales pueden ser aplicados a los diferentes ámbitos espaciales, ya sean las regiones dentro de un país o unidades que abarquen más territorio, ya sea por ejemplo la Unión Europea o la economía global. En esta tesis doctoral se estudia el desarrollo metodológico de estos modelos, así como su aplicación empírica sobre varios aspectos como el económico, medioambiental y tecnológico.

Para el desarrollo empírico de lo descrito anteriormente, utilizaremos la base de datos World Input-Output Database (WIOD) (Timmer *et al.* 2015) como la principal base informativa, así como sus cuentas sociales asociadas (Timmer *et al.* 2015). Dicha base de datos proporciona tablas input-output multirregionales y multisectoriales para un periodo de tiempo que abarca los años pre y post crisis, de manera que nos permitirá un análisis detallado de este fenómeno económico y otros desde una perspectiva global. La primera versión (Release 2013) incorpora tablas input-output para el periodo desde 1995 hasta 2011, mientras que la segunda (Release 2016) abarca el periodo 2000-2014. En la presente tesis doctoral haremos uso de ambas. En el capítulo introductorio (Capítulo 1) y en el penúltimo (Capítulo 4) se utilizará la primera versión de WIOD (Release 2013), en este último caso se tendrán en cuenta las dos para analizar en profundidad la evolución de las variables objeto de estudio. En el resto de capítulos trabajaremos con la versión más actualizada (Release 2016). Además en el Capítulo 4 de la tesis doctoral también se hará uso de la base de datos EORA (Lenzen *et al*. 2012, 2013) para ampliar el periodo económico de análisis y obtener un mayor detalle regional.

En esta línea y marco, la tesis doctoral tiene como objetivo fundamental profundizar de forma sistemática en el estudio de los factores que han liderado el crecimiento económico en las últimas décadas desde una perspectiva europea, y en particular, sobre el papel que el comercio intra y extra europeo, el cambio tecnológico y el cambio estructural han jugado como motores del crecimiento.

Dado que el reciente proceso de globalización, unido al cambio tecnológico y al aumento del comercio internacional, ha dado lugar a un mundo económico y social cada vez más internacionalizado, analizaremos qué factores han liderado el crecimiento económico en los últimos años. Primero estudiaremos la evolución de las tendencias tanto de la renta como del empleo dentro del contexto de la Unión Europea. Para ello se desarrolla un modelo multirregional y multisectorial de la Unión Europea, distinguiendo entre tecnologías domésticas y tecnologías externas, y dentro de las tecnologías domésticas de la UE distinguiremos las de cada país. Con este instrumental se estudian los flujos de renta y empleo intra y extra europeos, así como los flujos internos de la UE. Ello permite una primera aproximación a las cadenas globales de valor y a la relevancia de la Unión Europea en estas. Además, permitirá detectar las principales tendencias en los cambios estructurales que se han manifestado durante el proceso de integración europea.

Una vez estudiada la evolución de la renta y el empleo en el contexto europeo en los últimos años, el objetivo siguiente es el estudio del papel que ha desempeñado la evolución de las estructuras económicas en la convergencia reciente en Europa, ampliando las medidas tradicionales de convergencia económica a un marco multirregional input-output. Desde los trabajos fundamentales de Abramovitz (1986) y Barro y Sala-i-Martin (1992), la hipótesis de convergencia, es decir, el hecho de que las economías rezagadas avancen y reduzcan las disparidades con las economías más avanzadas, ha sido un tema recurrente en la literatura sobre crecimiento económico. Siguiendo esta línea, estudiaremos el papel potencial que el cambio estructural, la especialización tecnológica de los países, el comercio y la creciente fragmentación de la producción tienen en el desempeño económico de los países y, en consecuencia, en la convergencia. En particular, desde el punto de vista de la convergencia de las estructuras económicas, profundizaremos en el papel que ciertos sectores económicos, como los sectores de alta tecnología y tecnología intensiva, han desempeñado como motores del crecimiento económico en algunos países. Todo ello nos llevará a revisar el concepto de convergencia económica en el Capítulo 2, prestando especial atención a los factores estructurales y comerciales subyacentes. La revisión se hará tanto desde una perspectiva de la producción como de la demanda.

Los cambios en la estructura económica de los países, así como las consecuencias de los procesos de globalización e internacionalización, tienen un impacto significativo en el medio ambiente. En este contexto, es importante analizar si la evolución de la convergencia económica está conduciendo a presiones ambientales más limpias y menos desiguales entre los países, regiones y sectores (es decir, si la internacionalización está actuando como una fuerza impulsora para la descarbonización de las economías mundiales) o, por el contrario, está llevando a un proceso creciente de desigualdad en las emisiones mundiales. En los últimos años, los estudios sobre la desigualdad internacional en las emisiones ambientales han crecido. El principal objetivo de este tipo de trabajos es tratar de informar del diseño de políticas globales contra el cambio climático y determinar los criterios para la distribución de los esfuerzos de mitigación en todo el mundo (ver por ejemplo Duro *et al.* 2016 o Teixidó-Figueras, 2016). Por tanto, siguiendo esta misma línea, en el Capítulo 3 se lleva a cabo un análisis de la convergencia a nivel medioambiental en el contexto europeo y en el contexto global. Se extiende así el análisis de convergencia al análisis de emisiones, estudiando especialmente la relación entre clústeres regionales y generación de emisiones. Se hará también un análisis de la distribución mundial de emisiones y del papel de ciertos países y de ciertos sectores en ella.

La segunda línea de esta tesis doctoral se centra en el estudio de los recientes procesos de integración, como es el caso de la formación de la Unión Europea y sus links con la evolución de las cadenas globales de producción en los últimos años. Así, tras el estudio de la evolución de los procesos de convergencia desde el punto de vista económico y medioambiental, el Capítulo 4 se centra en el análisis de la evolución de los recientes procesos de integración, estudiando qué información sobre los mismos nos pueden aportar los indicadores derivados de los modelos multirregionales. Se procede para ello al análisis de diferentes escenarios hipotéticos o contrafactuales, donde se plantean diferentes situaciones para analizar las consecuencias que supondría para la economía europea y global. Como caso guía del estudio, en dicho capítulo consideramos la Unión Europea y en concreto, los procesos de adhesión de los países del Este. Por último, el capítulo 5 extiende el análisis al ámbito espacial, estudiando cómo impactan los cambios en la composición de las cadenas productivas globales en la escala regional. En concreto, haciendo uso de técnicas de econometría espacial, se estudiará el tipo de influencia que tienen, sobre la participación y posición de una región en la cadena de valor, las participaciones y posiciones de sus vecinos más cercanos y su especialización productiva. Se analizarán globalmente, por países y por sectores, las diferentes pautas de influencia que pueden suponerse para sectores manufactureros, agrícolas o sectores de servicios. Dicho análisis se realizará también para las regiones europeas.

3. *Estructura de la tesis*

La presente tesis estará formada de cinco capítulos centrales y un capítulo final de conclusiones. En el Capítulo 1 se ofrece una valoración general del comportamiento de la economía en las últimas décadas, así como del comercio internacional desde el punto de vista de la generación de renta y empleo. De esta forma, será un capítulo introductorio a los siguientes que vendrán. Con la información obtenida de la base de datos WIOD y sus correspondientes cuentas sociales, haremos un análisis analítico-descriptivo, en un marco global, de estas dos macro magnitudes básicas que describen una economía. Para ello, tal y como se ha establecido anteriormente, se desarrolla un modelo multirregional y multisectorial de la Unión Europea, distinguiendo entre tecnologías domésticas y tecnologías externas, y dentro de las tecnologías domésticas de la EU distinguiremos las de cada país de esta.

El Capítulo 2 profundizará en los procesos de generación de renta desde el punto de vista de la convergencia. Para llevar a cabo este estudio, analizamos el comportamiento del valor añadido en los últimos años en un contexto europeo y su relación con los flujos de producción de los países. En otras palabras, nos centraremos en el estudio del papel que ha desempeñado la evolución de las estructuras económicas en la convergencia reciente en Europa, ampliando las medidas tradicionales de convergencia económica a un marco multirregional input-output. Además, como novedad, además de las medidas tradicionales de convergencia, centradas en la comparación del valor añadido generado en cada país, nuestro trabajo también analiza la evolución de la convergencia *sigma* en el valor añadido global (lo que llamaremos valor añadido embodied/incorporado), es decir, el valor añadido incorporado por cada uno de los países de la Unión Europea a lo largo de la cadena de valor global de los productos de la UE. De esta manera, se pretende proporcionar una perspectiva más amplia sobre los problemas derivados de la convergencia económica, teniendo en cuenta sus consecuencias sobre las ganancias de productividad transmitidas a través de la cadena de valor europea basándonos en la base tecnológica y estructural de cada uno de los países.

El Capítulo 3 se centra específicamente en el análisis de la convergencia a nivel medioambiental en el contexto europeo y en el contexto global. En concreto, y siguiendo la misma línea del capítulo anterior, este capítulo ofrece un nuevo enfoque en el análisis de la evolución de las emisiones de CO2, teniendo en cuenta la heterogeneidad en la estructura de la industria, la tecnología, la población y la composición de la producción y la demanda de los países. El objetivo es estudiar algunas medidas de desigualdad en las emisiones de dióxido de carbono incorporadas tanto en la demanda interna de los países como en el comercio internacional entre los mismos, es decir, analizando la evolución de la convergencia o divergencia desde un punto de medioambiental para poder estudiar la evolución de la globalización.

El Capítulo 4, una vez estudiados los principales impulsores del progreso económico de los países, así como la evolución de los procesos de convergencia y divergencia en un contexto económico y medioambiental, se centra en el análisis de la evolución de los recientes procesos de integración, estudiando qué información sobre los mismos nos pueden aportar los indicadores derivados de los modelos multirregionales. Para ello, se plantean diferentes escenarios hipotéticos, donde se aplican ciertos cambios para ver sus efectos sobre las economías de los diferentes países. Como caso guía del estudio, en este capítulo consideramos la Unión Europea y en concreto, los procesos de adhesión de los países del Este. Además, el uso de modelos input-output multirregionales (MRIO) nos permiten estudiar el papel de los enlaces intersectoriales e interregionales en el valor añadido incorporado en las transacciones comerciales internacionales entre países, ya sean estos los países del Este de Europa, del resto de la Unión Europea, del resto de Europa y del resto del mundo.

El capítulo 5 extiende el análisis al ámbito espacial, estudiando cómo impactan los cambios en la composición de las cadenas productivas globales en la escala regional. En concreto, haciendo uso de técnicas de econometría espacial, se estudiará el tipo de influencia que tienen, sobre la participación y posición de una región en la cadena de valor, las participaciones y posiciones de sus vecinos más cercanos y su especialización productiva. Se analizará, por regiones y por sectores, dadas las diferentes pautas de influencia que pueden suponerse para sectores manufactureros, agrícolas o sectores de servicios. Para ello, se hará uso de la tabla input-output multirregional y multisectorial input-output EUREGIO recientemente publicada a nivel regional y correspondiente al año 2010 (ver Thissen *et al.* 2018). Dicho análisis se realizará exclusivamente para las regiones europeas.

El último capítulo resumirá los principales resultados de cada capítulo y las conclusiones generales de esta tesis. Finalizaremos avanzando posibles líneas de investigación futura que pueden ser abiertas a partir de los temas que aquí se han tratado.

Introduction

1. Motivation and general literature review

This dissertation is written in a context of a period of time marked by major economic imbalances with periods of acceleration and deceleration in the global economy. This context of raising uncertainty, as well as the effects on income, employment and environmental factors, marked by the growth of international trade and the interdependencies of the countries, is where the main objective of this thesis is located. The recent globalization process, technological change and the increase in international trade have caused production processes to become increasingly global, which implies interdependent structures that link goods, processes and countries (see Kaplisnky, 2006). Traditional economic blocs and sectoral ties within the country coexist with increasing global dependencies. However, trade has traditionally been considered a key element in driving a country's economic progress, as well as competitiveness and specialization (Barro, 1991). This positive impact of international trade on economic growth has been widely studied in the literature, both theoretically and empirically (Frankel and Romer, 1999; Grossman and Helpman, 1997; Keller, 2002).

More recently, the role of international trade as intrinsic factor boosting domestic technologies and mobilizing endogenous resources has been revisited linked to the phenomenon of globalization (Yu *et al.*, 2013). Several works study this process and its consequences on trade and production from a multisectoral perspective. For instance, Rueda-Cantuche *et al.* (2013) showed how globalization not only caused a distribution in the processes of production of goods, but also generated a series of commercial links that boosted the generation of employment through this trade. Los *et al.* (2013) found a clear increase of fragmentation in the production of most manufacturing goods in Europe, from 1995 to 2008 due to globalization, with a temporary reduction in this phenomenon after the international crisis. Arto *et al.* (2014) evaluated the income and employment embodied in international trade, highlighting the important contribution of extra-EU trade supporting employment and income in EU countries. In the same line, Duarte *et al.* (2016) quantified these magnitudes embodied in the intra-EU and extra-EU trade flows, finding evidence of a predominant trade in intermediate inputs for both, as well as a certain process of intra-EU specialization, with a transfer of manufacturing sectors to Eastern countries, and a dominance of knowledge intensive services (KIS) and the rest of services in Central European countries.

In addition, other works have also highlighted the important role that international trade plays, not only as an engine of economic growth, but as a driver of exchanges of goods, technologies and ideas that act as incentives for the acquisition and dissemination of knowledge, also offering greater potential market opportunities and affecting international prices (Grossman and Helpman, 2015). As recognized by the European Commission, "trade and investment flows spread new ideas and innovation, new technologies and the best research, leading to improvements in the products and services used by people and companies" (European Commission, 2012).

According to this context, the dissertation deepens into the role played by international trade, technological and structural change, and the composition of domestic demand of then different countries in their evolution and incorporation into global value chains from an economic, historical and environmental perspective. The economic perspective allows us to understand these processes as necessary inputs to achieve the development and advancement of the countries. The historical perspective will help us to know the most recent past to understand the present and build possible scenarios for future evolution. Finally, the environmental perspective is necessary given the current significance of issues such as climate change and its consequences - natural disasters, extreme temperatures, floods, etc.; its connection with economic activity and globalization processes, as well as the urgent and necessary need for international cooperation to combat these problems.

Several works on the importance of income inequality between countries, and the role played by recent phenomena such as globalization or technological progress in growth, have experienced a strong increased interest in recent years. Most of them recognize globalization and technological change as two of the main drivers of the recent economic growth of countries. Lowering market entry barriers and increasing internationalization have enabled emerging countries to narrow income gaps, which should lead to economic convergence. Globalization is also affecting the consumer side, with a convergence in lifestyles and tastes. Consumers in different countries, from different cultural backgrounds, are developing preferences for the same products, showing increasing signs of convergence around global product identities (Kjeldgaard and Askegaard, 2006; Mitry and Smith, 2009).

Therefore, the dissertation addresses issues related to the international economy, the regional economy and the environmental economy, and is based on tools commonly used in economic analysis such as the input-output methodology, to study the evolution of trade flows exchanged between countries and sectors, as well as traditional techniques to measure inequality at the economic, social and environmental levels. These tools and indicators will be extended, in the present investigation, to the multiregional and multisectoral framework for the study of new issues related to intraregional and intersectoral inequality, inequality along global value chains and their impacts on the environment.

2. *Objectives*

In line with previously established ideas, the economic literature establishes the growing need to recognize the multisectoral and multiregional nature of economies, and their participation in the so-called global and regional value chains. Therefore, in this context, multiregional and multisectoral input-output models (MRIO) have become powerful tools to quantify the role of intersectoral and interregional relationships at different scales in the evolution of economic growth (see a detailed explanation in Miller and Blair, 2009). These models will be key to carrying out the development of this dissertation, not only because of its capacity to capture the links between different regions, countries and sectors, but also because of its ability to measure the direct and indirect effects of economic phenomena such as globalization, internationalization or technological change. Their ability to draw the complete map of direct and indirect imports and exports throughout the different production stages, also allows connecting the perspectives of consumption and production in global supply chains, allowing to precisely identifying the origin and destination of the production and associated productive and environmental factors. It is important to note that multiregional models can be applied to different spatial areas, that is, the regions within a country or units that cover more territory, for example the European Union or the global economy. In this dissertation, the methodological development of these models is studied, as well as their empirical application on various aspects such as economic, environmental and technological.

For the empirical development of the previously described analysis, we use the World Input-Output Database (WIOD) (Timmer *et al.* 2015) as the main informative base, as well as its associated social accounts (Timmer *et al.* 2015). This database provides multiregional and multisectoral input-output tables for a time period that covers the pre and post crisis years, so it allow us a detailed analysis of this economic phenomenon and others from a global perspective. The first version (Release 2013) incorporates input-output tables for the period from 1995 to 2011, while the second one (Release 2016) covers the period 2000-2014. In this dissertation we will make use of both. In the initial chapter (Chapter 1) and in Chapter 4, the first version of WIOD (Release 2013) will be used, in the latter case both will be taken into account to analyze in depth the evolution of the variables under study. In the rest of the dissertation we will work with the most updated version (Release 2016). Furthermore, in Chapter 4 of the dissertation, the EORA database (Lenzen *et al.* 2012, 2013) will also be used to extend the economic period of analysis, and to get more regional detail.

Consequently, the main objective of the dissertation is the systematic study of the factors that have led economic growth in recent decades from a European perspective, and in particular, on the role that intra and extra-European trade, technological and structural change have played a role as engines of growth and as drivers of environmental policies applied in the European and global context in recent years.

Given that the recent globalization process, along with technological change and increased international trade, has given rise to an increasingly internationalized economic and social world, we will analyze what factors have led economic growth in recent years. We first study the evolution of trends in both income and employment within the context of the European Union. For this, a multiregional and multisectoral model of the European Union is developed, distinguishing between domestic and external technologies, and within the domestic technologies of the EU, we distinguish those of each country in this. With this tool, intra and extra European income and employment flows are studied, as well as the internal flows of the EU. This allows a first approximation to global value chains and the relevance of the European Union in these. In addition, it detects the main trends in the structural changes that have manifested themselves during the European integration process.

Once we study the evolution of income and employment in the European context in recent years, the next objective is to study the role that the evolution of economic structures has played in recent convergence process in Europe, expanding traditional measures of economic convergence to a multiregional input-output framework. From the fundamental works of Abramovitz (1986) and Barro and Sala-i-Martin (1992), the convergence hypothesis, that is, the fact that lagging economies advance and reduce disparities with more advanced economies has been a recurring topic in the literature on economic growth. In this context, we study the potential role that structural change, the technological specialization of countries, trade and the increasing fragmentation of production have on the economic performance of countries and, consequently, on convergence. In particular, from the point of view of the convergence of economic structures, we focus on the role that certain economic sectors, such as high technology and technological intensive sectors, have played as drivers of economic growth in some countries. Therefore, all this lead us to review the concept of economic convergence in Chapter 2, paying special attention to the underlying structural and trade factors. The review is done from both a production and a demand perspective.

Changes in the economic structure of countries, as well as the consequences of globalization and internationalization processes, have a significant impact on the environment. In this context, it is important to analyze whether the evolution of economic convergence is leading to cleaner and less unequal environmental pressures between countries, regions and sectors (that is, internationalization is acting as a driving force for the decarbonization of world economies) or, conversely, is leading to a growing process of inequality in global emissions. In recent years, studies on international inequality in environmental emissions have grown. The main objective of them is to try to inform the design of global policies against climate change and determine the criteria for the distribution of mitigation efforts around the world (see for example Duro *et al.* 2016 or Teixidó-Figueras, 2016). Therefore, following the same line, Chapter 3 develops an analysis of convergence at the environmental level in the European and global context.

Thus, the convergence analysis is extended to the analysis of emissions, especially studying the relationship between regional clusters and emission generation. An analysis is also made of the global distribution of emissions and the role of certain countries and certain sectors in it.

The second line of this dissertation focuses on the study of recent integration processes, such as the formation of the European Union and its links with the evolution of global value chains in recent years. Thus, after studying the evolution of convergence processes from an economic and environmental point of view, Chapter 4 focuses on the analysis of the evolution of recent integration processes, studying what information about them can provide us indicators derived from multiregional models. To do this, we analyze different hypothetical scenarios or counterfactuals where different situations arise to study the consequences it would have for the European and global economy. As a case study guide, in this chapter we consider the European Union and specifically, the adhesion process of Eastern European countries. Finally, Chapter 5 extends the analysis to the spatial level, studying how changes in the composition of global value chains impact on the regional scale. Specifically, using spatial econometric techniques, the type of influence on the participation and position of a region in the value chain, the participations and positions of its closest neighbors and its productive specialization are studied. It is analyzed globally, by country and by sector, given the different patterns of influence that can be assumed for manufacturing, agricultural or service sectors. This analysis is also carried out for the European regions.

3. <u>Outline</u>

The current dissertation consists of five central chapters and a final chapter of conclusions. Chapter 1 provides a general assessment of the behavior of the economy in recent decades, as well as of international trade from the point of view of income and employment generation. In this way, it will be an introductory chapter to the following ones that will come. With the information obtained from the WIOD database, we will make an analytical-descriptive analysis, in a global framework, of two of the basic macro magnitudes that describes an economy. For this, a multiregional and multisectoral model of the European Union is developed, distinguishing between domestic technologies and external technologies, and within the domestic technologies of the EU we will distinguish those of each country of this. With this tool, intra and extra European income flows are studied, as well as the internal flows of the EU. This allows a first approximation to global value chains and the relevance of the EU in these. Furthermore, it will detect the main trends in the structural changes that have manifested themselves during the European integration process.

Chapter 2 analyzes the processes of income generation from the point of view of convergence. To carry out this study, we study the behavior of value added in recent years in a European context and its relationship with the production flows of the countries. In other words, we focus on studying the role that the evolution of economic structures has played in recent convergence process in Europe, expanding traditional measures of economic convergence to a multiregional input-output framework. Furthermore, as a novelty, in addition to traditional convergence measures, focused on comparing the value added generated in each country, our work also analyzes the evolution of *sigma* convergence in global value added (what we call value added embodied), that is, the value added incorporated by each of the European countries along the global value chain of EU products. In this way, we try to provide a much broader perspective on the problems derived from economic convergence, taking into account its consequences on productivity gains transmitted through the European value chain based on the technological and structural base of each of the countries.

Chapter 3 focuses on the analysis of convergence at the environmental level in the European context and in the global context. Specifically, and following the same line of the previous chapter, this chapter offers a new approach in the analysis of the evolution of CO2 emissions, taking into account the heterogeneity in the structure of the industry, technology, population and composition of the production and demand of the countries. The objective is to study some measures of inequality in carbon dioxide emissions incorporated both in the domestic demand of the countries and in international trade between them, that is, analyzing the evolution of convergence or divergence from an environmental point of view to study the evolution of globalization.

Chapter 4, after studying the main drivers of the economic progress of the countries, as well as the evolution of the convergence and divergence processes in an economic and environmental context, focuses on the analysis of the evolution of recent integration processes, studying what information about them can provide us with the indicators derived from the multiregional models. For this, different hypothetical scenarios/counterfactuals are proposed where certain changes are applied to see their effects on the economies of the different countries. As a case study guide, in this chapter we consider the European Union and specifically, the adhesion processes of Eastern European countries. Furthermore, the use of multiregional input-output models (MRIO) allow us to study the role of intersectoral and interregional links to measure the value added embodied in international trade transactions between countries depending on the situation (real or hypothetical) of the countries of the Eastern Europe, the rest of the European Union, the rest of Europe and the Rest of the World.

Chapter 5 extends the analysis to the spatial field, studying how changes in the composition of global production chains impact on the regional scale. Specifically, using spatial econometric techniques, the type of influence they have on the participation and position of a region in the value chain, the participations and positions of its closest neighbors and its productive specialization are studied. It is analyzed, by region and by sector, given the different patterns of influence that can be assumed for manufacturing, agricultural or service sectors. To do this, we make use of the multiregional and multisectoral input-output EUREGIO table recently published at the regional level and corresponding to the year 2010 (see Thissen *et al.* 2018). This analysis will be carried out exclusively for the European regions.

The last chapter will summarize the main results of each chapter and the general conclusions of this dissertation. We will finish by advancing possible future research lines that can be opened based on the topics that have been discussed here.

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Chapter 1. Europeanization vs. Globalization? A deeper look into income and employment embodied in intra-European trade[1]

1. Introduction

Trade has been traditionally considered a key factor for the growth of economies, encouraging country specialization and competitiveness. The positive impact of international trade on economic growth has been widely documented in economic literature from both the theoretical and the empirical points of view (Barro, 1991; Frankel and Romer, 1999; Grossman and Helpman, 1997; Keller, 2002). Recent papers highlight the important links between economic integration and growth as a result of the increasing exchanges of goods, technologies, and ideas which act as incentives for knowledge acquisition and diffusion, also offering greater potential market opportunities and affecting international prices (Grossman and Helpman, 2015). The role of trade as an active driver of economic growth in an increasingly globalized economy has been acknowledged by public institutions and citizens worldwide. As the European Commission recognizes, "trade and investment flows spread new ideas and innovation, new technologies and the best research, leading to improvements in the products and services that people and companies use" (European Commission, 2012).

Production processes are nowadays characterized by an important international fragmentation, which implies an increasingly interdependent structure linking products, goods, processes and countries (see Yu *et al.*, 2013). This increasing globalization of production, often involving large geographical and sectoral distances between the production and the consumption, has brought to the fore the need for accounting and analyzing production structures and international links in this complex framework. Traditional economic blocks and strong intra-regional links coexist with increasing world dependencies, this having associated impacts on the location and distribution of employment and income. In this line, Los *et al.* (2013) show evidence in this phenomenon

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using a new distribution index of value added, which they call the international production fragmentation (IPF). They find a clear increase of fragmentation in the production of most manufacturing goods in Europe, from 1995 to 2008, with a temporary reduction in this index after the international crisis. In addition, Timmer *et al.* (2014) conduct a study of global value chains by different factors for the period 1995 to 2008 with 560 final products from 14 manufacturing industries of 40 countries around the world. They show an evidence of increasing international fragmentation due to the increase in the foreign value added share in the total value added of studied countries and demonstrate that global value chains started with the advance of emerging economies as major suppliers of intermediate inputs. In the same way, Los *et al.* (2015) carry out an analysis of global production chains to show if international fragmentation occurs between countries within the same region or is really a global process that includes all countries and they find that it is a globalized process since 1995, however it has been weakly interrupted by the financial crisis of 2008.

In this context, recent literature supports the concept of a new globalization centered in large regions (see Fernández Núñez *et al*., 2017), which are acquiring technological knowledge of the production processes that in the past they began to carry out only because of their competitive advantage in the form of low wages. In this way, there would be a consolidation of increasingly competitive macro-regions at a global level, within which there would be a growing specialization of countries. Thus, high-income countries would benefit from the production and trade of final and/or high-value-added goods while other countries operate as input suppliers to the former or as factories of low-value-added goods (Los *et al.*, 2015; Baldwin, 2016; Frigant and Zumpe, 2017). Moreover, this new globalization is causing very different and unpredictable impacts within the economic sectors. For instance, a worker with the same training and experience as another can be affected by the unexpected changes in globalization, simply because his occupation or the production phase in which he works ends up moving to another country (Baldwin, 2016).

Our work builds on this literature and proposes a multiregional input-output (MRIO) model of the European Union (EU) to analyze whether the generation of employment and income in Europe in the recent past can be defined as a process that is mainly regional or global (involving countries within the region versus countries outside Europe), what patterns have characterized this process, and which European countries have benefitted from this process of integration (and how). We are also interested in the economic effects associated with the evolution of vertical trade in Europe, (defined as the trade in intermediate goods that are part of an international production network, Hummels *et al.*, 2001) in comparison to the trade in final goods. In this line, this chapter aims to contribute to the current debate on trade patterns and the evolution of trade relations between European countries and non-European countries, as well as, providing an integrated approach to study the similarities and differences that exist within the European block.

The European Union as a whole is the largest economy in the world and the largest trading block (WTO Statistics, 2016). With its highs and lows, the European Union experience has been seen by other world areas (African Union, ASEAN, Mercosur, etc.) as probably the most successful process of regional integration, with positive effects on the employment, income and wellbeing of its citizens. In this regard, it seems relevant to evaluate the strength of its trade and the associated impacts on employment and income.

Recent improvements in calculating the income and employment associated with EU exports, like the use of multiregional frameworks empirically supported by extensive world databases (WIOD, OECD, GTAP, EORA), have become critical when analyzing the impact of trade policies (Rueda-Cantuche *et al.*, 2013). The impact of extra-EU exports on income and employment has recently received attention in the literature (Rueda-Cantuche *et al.*, 2013; Arto *et al.*, 2015). However, there are no previous studies on the European employment and value added embodied in intra-EU trade. For these reasons, this first chapter focuses on this latter point, particularly on the analysis of the different country patterns found over a long period of economic growth in Europe and the first years of the international crisis.

The period chosen, 1995-2011, is a period of exceptional historical interest, as it represents the consolidation of the EU common market, the monetary union, and the first decades after the accession to the EU of eastern European economies.

Our results suggest that intra-EU trade has been an important factor contributing to the income and employment growth in the EU, extra-EU trade has turned out to be a key driver for the whole EU, and different country patterns regarding the orientation of trade can be identified. Additionally, trade within the EU is more oriented to intermediate inputs like in the extra-EU trade, however in this last case, there are some countries more specialized in final goods.

The rest of the chapter is structured as follows. In Section 2, we describe the methodology used for quantifying the employment and value added (VA) embodied in intra-EU exports over the years 1995 to 2011. In Section 3, we describe the data used in this chapter. In Section 4, we present and discuss the main results of the analysis, with a focus on the different country patterns observed. Section 5 closes the chapter with a review of the main conclusions.

2. Methodology

As already mentioned, the main objective of our work is to analyze the income and employment generated in Europe and embodied in intra-EU trade, paying special attention to the temporal evolution of this intra-EU trade and the different country patterns observed. The starting point is a MRIO model, following a multi-sectoral and multiregional analysis, which enables us to study changes in intra-European trade patterns between 1995 and 2011. Basic references for this framework are Isard (1951) and Miller and Blair (2009). Empirically we make use of the World Input-Output Database (WIOD) (Timmer *et al*., 2015). This database covers 27 EU Member States, 13 other major countries and the Rest of the World as an aggregated region. The WIOD has a breakdown of 35 industries for each country, which covers the overall economy, including agriculture, mining, construction, utilities, 14 manufacturing industries and 17 services industries.

Below we present the main features of the methodological approach adopted. For an easier understanding, we start by considering the world economy divided into two blocks; countries 1 and 2 belong to the EU block and countries 3 and 4 are non-EU countries.

$$\mathbf{Z} = \begin{pmatrix} \mathbf{Z}^{11} & \mathbf{Z}^{12} & \mathbf{Z}^{13} & \mathbf{Z}^{14} \\ \mathbf{Z}^{21} & \mathbf{Z}^{22} & \mathbf{Z}^{23} & \mathbf{Z}^{24} \\ \mathbf{Z}^{31} & \mathbf{Z}^{32} & \mathbf{Z}^{33} & \mathbf{Z}^{34} \\ \mathbf{Z}^{41} & \mathbf{Z}^{42} & \mathbf{Z}^{43} & \mathbf{Z}^{44} \end{pmatrix};\ \mathbf{f} = \begin{pmatrix} \mathbf{f}^{11} & \mathbf{f}^{12} & \mathbf{f}^{13} & \mathbf{f}^{14} \\ \mathbf{f}^{21} & \mathbf{f}^{22} & \mathbf{f}^{23} & \mathbf{f}^{24} \\ \mathbf{f}^{31} & \mathbf{f}^{32} & \mathbf{f}^{33} & \mathbf{f}^{34} \\ \mathbf{f}^{41} & \mathbf{f}^{42} & \mathbf{f}^{43} & \mathbf{f}^{44} \end{pmatrix};\ \mathbf{x} = \begin{pmatrix} \mathbf{x}^{1} \\ \mathbf{x}^{2} \\ \mathbf{x}^{3} \\ \mathbf{x}^{4} \end{pmatrix}; \mathbf{w} = \begin{pmatrix} \mathbf{w}^{1} \\ \mathbf{w}^{2} \\ \mathbf{w}^{3} \\ \mathbf{w}^{4} \end{pmatrix}$$

As usual in a MRIO model, the relationship between $\mathbf{x}$, $\mathbf{Z}$ and $\mathbf{f}$ is defined by $\mathbf{x} = \mathbf{Zi} + \mathbf{f}$, i being a column vector of ones of the appropriate dimension. We denote by $\mathbf{w}$ a generic vector of inputs (labour, value added, etc.). The input-output equation of the global economy in a multiregional context can be expressed as:

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{f} \qquad (1.1)$$

where $\mathbf{x}$ represents the total output of each country and sector, $\mathbf{A}$ is the multiregional matrix of technical coefficients and $\mathbf{f}$ is the total final demand by sector and country. In terms of the Leontief inverse, the solution of the model will be given by:

$$\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1} \quad \text{so that} \quad \mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} = \mathbf{L}\mathbf{f} \qquad (1.2)$$

Let us now focus on the EU block. We denote it by $\mathbf{x}^{\mathbf{EU}} = \begin{bmatrix} \mathbf{x}^1 \\ \mathbf{x}^2 \end{bmatrix}$. Similarly, we can define: $\mathbf{w}^{\mathbf{EU}} = \begin{bmatrix} \mathbf{w}^1 \\ \mathbf{w}^2 \end{bmatrix}$, $\mathbf{F}^{\mathbf{EU,EU}} = \begin{bmatrix} \mathbf{f}^{11} & \mathbf{f}^{12} \\ \mathbf{f}^{21} & \mathbf{f}^{22} \end{bmatrix}$ and

$$\mathbf{E}^{\mathbf{EU,noEU}} = \begin{bmatrix} \mathbf{e}^{13} & \mathbf{e}^{14} \\ \mathbf{e}^{23} & \mathbf{e}^{24} \end{bmatrix} = \begin{bmatrix} \mathbf{f}^{13} + \mathbf{Z}^{13}\mathbf{i} & \mathbf{f}^{14} + \mathbf{Z}^{14}\mathbf{i} \\ \mathbf{f}^{23} + \mathbf{Z}^{23}\mathbf{i} & \mathbf{f}^{24} + \mathbf{Z}^{24}\mathbf{i} \end{bmatrix}$$

where $\mathbf{F}^{\mathbf{EU,EU}}$ represents the final demand of European countries and $\mathbf{E}^{\mathbf{EU,noEU}}$ includes the final demand made by European countries to no European countries. This subdivision of the final demand is necessary to continue in the analysis by parts of the European trade.

The matrix of EU intermediate inputs will be $\mathbf{Z}^{\mathbf{EU}} = \begin{bmatrix} \mathbf{Z}^{11} & \mathbf{Z}^{12} \\ \mathbf{Z}^{21} & \mathbf{Z}^{22} \end{bmatrix}$.

Based on these matrices, we can derive the corresponding $\mathbf{A}^{\mathbf{EU}}$ matrix,

$$\mathbf{A}^{\mathbf{EU}} = \mathbf{Z}^{\mathbf{EU}}(\hat{\mathbf{x}}^{\mathbf{EU}})^{-1} = \begin{bmatrix} \mathbf{A}^{11} & \mathbf{A}^{12} \\ \mathbf{A}^{21} & \mathbf{A}^{22} \end{bmatrix}$$

This matrix represents the domestic technology of the EU (considering the EU countries and their relationships as internal components). The choice of this representation of the world economies in two blocks (EU countries and non-EU countries) is due to the fact that using alternatively national country tables would not account for EU spillover effects and otherwise, using the global IO table would incur in double counting of the value added embodied in the goods crossing the border more than twice (Arto *et al.* 2015).

Thus, for a certain final demand:

$$\mathbf{f}^{\mathbf{EU}} = \begin{bmatrix} \mathbf{f}^{11} + \mathbf{f}^{12} + \mathbf{e}^{13} + \mathbf{e}^{14} \\ \mathbf{f}^{21} + \mathbf{f}^{22} + \mathbf{e}^{23} + \mathbf{e}^{24} \end{bmatrix} = \begin{bmatrix} \mathbf{f}^{11} + \mathbf{f}^{12} + (\mathbf{Z}^{13}\mathbf{i} + \mathbf{f}^{13}) + (\mathbf{Z}^{14}\mathbf{i} + \mathbf{f}^{14}) \\ \mathbf{f}^{21} + \mathbf{f}^{22} + (\mathbf{Z}^{23}\mathbf{i} + \mathbf{f}^{23}) + (\mathbf{Z}^{24}\mathbf{i} + \mathbf{f}^{24}) \end{bmatrix}$$

$$= \mathbf{F}^{\mathbf{EU,EU}}\mathbf{i} + \mathbf{E}^{\mathbf{EU,noEU}}\mathbf{i} = \mathbf{f}^{\mathbf{EU,EU}} + \mathbf{e}^{\mathbf{EU,noEU}}$$

it holds that

$$\mathbf{x}^{\mathbf{EU}} = \mathbf{A}^{\mathbf{EU}}\mathbf{x}^{\mathbf{EU}} + \mathbf{f}^{\mathbf{EU}} \tag{1.3}$$

In terms of the Leontief inverse, the solution of the model will be given by:

$$\mathbf{x}^{\mathbf{EU}} = (\mathbf{I} - \mathbf{A}^{\mathbf{EU}})^{-1}\mathbf{f}^{\mathbf{EU}} = \mathbf{L}^{\mathbf{EU}}\mathbf{f}^{\mathbf{EU}} = \begin{pmatrix} \mathbf{L}^{11} & \mathbf{L}^{12} \\ \mathbf{L}^{21} & \mathbf{L}^{22} \end{pmatrix} \mathbf{f}^{\mathbf{EU}} \tag{1.4}$$

Thus, if **w** represents a vector of value added (the same holds for employment), considering the value added directly generated in the EU, we can define the following coefficients:

$$\mathbf{v}^{\mathbf{EU}'} = \mathbf{w}^{\boldsymbol{EU}'}(\hat{\mathbf{x}}^{\mathbf{EU}})^{-1} \text{ and their corresponding diagonalized form } \hat{\mathbf{v}}^{\mathbf{EU}} = \begin{pmatrix} \hat{\mathbf{v}}^{1} & \mathbf{0} \\ \mathbf{0} & \hat{\mathbf{v}}^{2} \end{pmatrix} \tag{1.5}$$

Thus, we can obtain the embodied and the direct value added in the EU generated by the intra-EU final demand and the extra-EU exports to non-EU countries as follows.

Let us define the following flow matrices which contain, in a disaggregated way, the value added (or employment) generated in the EU and incorporated into all the EU goods (domestically consumed, traded within the EU, and exported to non-EU countries).

$$\begin{aligned} &\hat{\mathbf{v}}^{\mathbf{EU}}\mathbf{L}^{\mathbf{EU}}\hat{\mathbf{f}}^{\mathbf{EU}} = \\ &\begin{pmatrix} \hat{\mathbf{v}}^{1} & \mathbf{0} \\ \mathbf{0} & \hat{\mathbf{v}}^{2} \end{pmatrix} \begin{pmatrix} \mathbf{L}^{11} & \mathbf{L}^{12} \\ \mathbf{L}^{21} & \mathbf{L}^{22} \end{pmatrix} \begin{pmatrix} \mathbf{f}^{11} + \mathbf{f}^{12} & \mathbf{0} \\ \mathbf{0} & \mathbf{f}^{21} + \mathbf{f}^{22} \end{pmatrix} + \\ &\begin{pmatrix} \hat{\mathbf{v}}^{1} & \mathbf{0} \\ \mathbf{0} & \hat{\mathbf{v}}^{2} \end{pmatrix} \begin{pmatrix} \mathbf{L}^{11} & \mathbf{L}^{12} \\ \mathbf{L}^{21} & \mathbf{L}^{22} \end{pmatrix} \begin{pmatrix} \mathbf{e}^{13} + \mathbf{e}^{14} & \mathbf{0} \\ \mathbf{0} & \mathbf{e}^{23} + \mathbf{e}^{24} \end{pmatrix} = \boldsymbol{\Omega}^{\mathbf{EU,EU}} + \boldsymbol{\Omega}^{\mathbf{EU,noEU}} \end{aligned} \tag{1.6}$$

We can view these matrices from two different perspectives, the "consumer" and the "producer" perspectives. In the consumption perspective, the column sums over the rows of each $\boldsymbol{\Omega}$ matrix show the embodied value added (or employment) by exporting country independently of where the value added (or employment) is generated (or located). This is the type of measure useful for footprint analysis where, for instance, exports of one specific country lead to the generation of value added across other countries. On the other hand, in the production perspective, the row sums over the columns of each $\boldsymbol{\Omega}$ matrix can be interpreted as the embodied value added (or employment) in a country due to its intra-European final exports and its extra-European total exports, independently of the user.

Below we derive the corresponding mathematical expressions for each one of the two perspectives shown above.

Consumption perspective

Equations (1.7) and (1.8) provide the detailed mathematical expressions of the column sums of the $\boldsymbol{\Omega}$ matrices for intra-European trade ($\boldsymbol{\Omega}^{\mathbf{EU,EU}}$) and for extra- European trade. Let us denote them as $\boldsymbol{\omega}^{\mathbf{EU,EU}'}$ and $\boldsymbol{\omega}^{\mathbf{EU,noEU}'}$, respectively.

$$\boldsymbol{\omega}^{\mathbf{EU,EU}'} = \mathbf{i}'\boldsymbol{\Omega}^{\mathbf{EU,EU}} = \begin{pmatrix}\mathbf{v}^{1'} & \mathbf{v}^{2'}\end{pmatrix}\begin{pmatrix}\mathbf{L}^{11} & \mathbf{L}^{12}\\ \mathbf{L}^{21} & \mathbf{L}^{22}\end{pmatrix}\begin{pmatrix}\mathbf{f}^{11}+\mathbf{f}^{12} & \mathbf{0}\\ \mathbf{0} & \mathbf{f}^{21}+\mathbf{f}^{22}\end{pmatrix}$$

$$= \begin{pmatrix}\mathbf{v}^{1'}\mathbf{L}^{11}+\mathbf{v}^{2'}\mathbf{L}^{21} & \mathbf{v}^{1'}\mathbf{L}^{12}+\mathbf{v}^{2'}\mathbf{L}^{22}\end{pmatrix}\begin{pmatrix}\mathbf{f}^{11}+\mathbf{f}^{12} & \mathbf{0}\\ \mathbf{0} & \mathbf{f}^{21}+\mathbf{f}^{22}\end{pmatrix} =$$

$$\left(\mathbf{v}^{1'}\mathbf{L}^{11}\mathbf{f}^{11}+\mathbf{v}^{2'}\mathbf{L}^{21}\mathbf{f}^{11}+\mathbf{v}^{1'}\mathbf{L}^{11}\mathbf{f}^{12}+\mathbf{v}^{2'}\mathbf{L}^{21}\mathbf{f}^{12} \quad \mathbf{v}^{1'}\mathbf{L}^{12}\mathbf{f}^{21}+\mathbf{v}^{2'}\mathbf{L}^{22}\mathbf{f}^{21}+\mathbf{v}^{1'}\mathbf{L}^{12}\mathbf{f}^{22}+\mathbf{v}^{2'}\mathbf{L}^{22}\mathbf{f}^{22}\right) \tag{1.7}$$

$$\boldsymbol{\omega}^{\mathbf{EU,noEU}'} = \mathbf{i}'\boldsymbol{\Omega}^{\mathbf{EU,noEU}} = \begin{pmatrix}\mathbf{v}^{1'} & \mathbf{v}^{2'}\end{pmatrix}\begin{pmatrix}\mathbf{L}^{11} & \mathbf{L}^{12}\\ \mathbf{L}^{21} & \mathbf{L}^{22}\end{pmatrix}\begin{pmatrix}\mathbf{e}^{13}+\mathbf{e}^{14} & \mathbf{0}\\ \mathbf{0} & \mathbf{e}^{23}+\mathbf{e}^{24}\end{pmatrix} =$$

$$\left(\mathbf{v}^{1'}\mathbf{L}^{11}\mathbf{e}^{13}+\mathbf{v}^{2'}\mathbf{L}^{21}\mathbf{e}^{13}+\mathbf{v}^{1'}\mathbf{L}^{11}\mathbf{e}^{14}+\mathbf{v}^{2'}\mathbf{L}^{21}\mathbf{e}^{14} \quad \mathbf{v}^{1'}\mathbf{L}^{12}\mathbf{e}^{23}+\mathbf{v}^{2'}\mathbf{L}^{22}\mathbf{e}^{23}+\mathbf{v}^{1'}\mathbf{L}^{12}\mathbf{e}^{24}+\mathbf{v}^{2'}\mathbf{L}^{22}\mathbf{e}^{24}\right) \tag{1.8}$$

The outcome of (1.7) can be split into three main parts for the first component:

a) Value added embodied in country 1 (EU country) due to its sales to the domestic market (not to be included as intra-European trade): $\mathbf{v}^{1'}\mathbf{L}^{11}\mathbf{f}^{11}$
b) Value added embodied in country 2 (EU country) due to its intermediate exports to country 1 (EU country): $\mathbf{v}^{2'}\mathbf{L}^{21}\mathbf{f}^{11}+\mathbf{v}^{2'}\mathbf{L}^{21}\mathbf{f}^{12}$
c) Value added embodied in country 1 (EU country) due to its exports of final goods to country 2 (EU country): $\mathbf{v}^{1'}\mathbf{L}^{11}\mathbf{f}^{12}$

And similarly, for the second component: $\mathbf{v}^{2'}\mathbf{L}^{22}\mathbf{f}^{22}$, $\mathbf{v}^{1'}\mathbf{L}^{12}\mathbf{f}^{22}+\mathbf{v}^{1'}\mathbf{L}^{12}\mathbf{f}^{21}$ and $\mathbf{v}^{2'}\mathbf{L}^{22}\mathbf{f}^{21}$, respectively. Hence, we can decompose the embodied value added generated over all countries due to the final use of a specific EU country (i.e. column sums of the $\boldsymbol{\Omega}$ matrix) into four components: embodied value added in an EU country due to its sales to its domestic economy ($\boldsymbol{\omega}^{\mathbf{EU,EU}'}_{dom}$); embodied value added in other EU countries due to their intermediate exports to an EU country ($\boldsymbol{\omega}^{\mathbf{EU,EU}'}_{int}$); embodied value added in an EU country due to its exports of final goods to other EU countries ($\boldsymbol{\omega}^{\mathbf{EU,EU}'}_{fin}$); embodied value added in an EU country due to its exports of final and intermediate goods to non-EU countries ($\boldsymbol{\omega}^{\mathbf{EU,noEU}'}$).

In matrix form, equations (1.7) and (1.8) can be combined in this way:

$$\mathbf{i}'\boldsymbol{\Omega} = \boldsymbol{\omega}^{\mathbf{EU,EU}'} + \boldsymbol{\omega}^{\mathbf{EU,noEU}'} = \boldsymbol{\omega}_{dom}^{\mathbf{EU,EU}'} + \boldsymbol{\omega}_{int}^{\mathbf{EU,EU}'} + \boldsymbol{\omega}_{fin}^{\mathbf{EU,EU}'} + \boldsymbol{\omega}^{\mathbf{EU,noEU}'}$$

$$= \begin{pmatrix}\mathbf{v}^{1'} & \mathbf{v}^{2'}\end{pmatrix}\begin{pmatrix}\mathbf{L}^{11} & \mathbf{0}\\ \mathbf{0} & \mathbf{L}^{22}\end{pmatrix}\begin{pmatrix}\mathbf{f}^{11} & \mathbf{0}\\ \mathbf{0} & \mathbf{f}^{22}\end{pmatrix} + \begin{pmatrix}\mathbf{v}^{1'} & \mathbf{v}^{2'}\end{pmatrix}\begin{pmatrix}\mathbf{0} & \mathbf{L}^{12}\\ \mathbf{L}^{21} & \mathbf{0}\end{pmatrix}\begin{pmatrix}\mathbf{f}^{11}+\mathbf{f}^{12} & \mathbf{0}\\ \mathbf{0} & \mathbf{f}^{21}+\mathbf{f}^{22}\end{pmatrix}$$
$$+ \begin{pmatrix}\mathbf{v}^{1'} & \mathbf{v}^{2'}\end{pmatrix}\begin{pmatrix}\mathbf{L}^{11} & \mathbf{0}\\ \mathbf{0} & \mathbf{L}^{22}\end{pmatrix}\begin{pmatrix}\mathbf{f}^{12} & \mathbf{0}\\ \mathbf{0} & \mathbf{f}^{21}\end{pmatrix} + \boldsymbol{\omega}^{\mathbf{EU,noEU}'}$$

from which we will focus on $\boldsymbol{\omega}_{int}^{\mathbf{EU,EU}'}$, $\boldsymbol{\omega}_{fin}^{\mathbf{EU,EU}'}$ and $\boldsymbol{\omega}^{\mathbf{EU,noEU}'}$ since the first component is not considered as export-driven by definition.

Production perspective

Equations (1.10) and (1.11) yield the detailed mathematical expressions of the row sums of the $\boldsymbol{\Omega}$ matrices for intra-European trade ($\boldsymbol{\Omega}^{\mathbf{EU,EU}}$) and for extra-European trade ($\boldsymbol{\Omega}^{\mathbf{EU,noEU}}$). Let us denote them as $\mathbf{w}^{\mathbf{EU,EU}}$ and $\mathbf{w}^{\mathbf{EU,noEU}}$, respectively, such that:

$$\boldsymbol{\Omega}\mathbf{i} = \boldsymbol{\Omega}^{\mathbf{EU,EU}}\mathbf{i} + \boldsymbol{\Omega}^{\mathbf{EU,noEU}}\mathbf{i} = \mathbf{w}^{\mathbf{EU,EU}} + \mathbf{w}^{\mathbf{EU,noEU}} \quad (1.9)$$

Then,

$$\mathbf{w}^{\mathbf{EU,EU}} = \begin{pmatrix}\hat{\mathbf{v}}^1\mathbf{L}^{11} & \hat{\mathbf{v}}^1\mathbf{L}^{12}\\ \hat{\mathbf{v}}^2\mathbf{L}^{21} & \hat{\mathbf{v}}^2\mathbf{L}^{22}\end{pmatrix}\begin{pmatrix}\mathbf{f}^{11}+\mathbf{f}^{12} & \mathbf{0}\\ \mathbf{0} & \mathbf{f}^{21}+\mathbf{f}^{22}\end{pmatrix}\begin{pmatrix}\mathbf{1}\\ \mathbf{1}\end{pmatrix}$$

$$= \begin{pmatrix}\hat{\mathbf{v}}^1\mathbf{L}^{11}\mathbf{f}^{11} + \hat{\mathbf{v}}^1\mathbf{L}^{11}\mathbf{f}^{12} + \hat{\mathbf{v}}^1\mathbf{L}^{12}\mathbf{f}^{21} + \hat{\mathbf{v}}^1\mathbf{L}^{12}\mathbf{f}^{22}\\ \hat{\mathbf{v}}^2\mathbf{L}^{21}\mathbf{f}^{11} + \hat{\mathbf{v}}^2\mathbf{L}^{21}\mathbf{f}^{12} + \hat{\mathbf{v}}^2\mathbf{L}^{22}\mathbf{f}^{21} + \hat{\mathbf{v}}^2\mathbf{L}^{22}\mathbf{f}^{22}\end{pmatrix} \quad (1.10)$$

$$\mathbf{w}^{\mathbf{EU,noEU}} = \begin{pmatrix}\hat{\mathbf{v}}^1\mathbf{L}^{11} & \hat{\mathbf{v}}^1\mathbf{L}^{12}\\ \hat{\mathbf{v}}^2\mathbf{L}^{21} & \hat{\mathbf{v}}^2\mathbf{L}^{22}\end{pmatrix}\begin{pmatrix}\mathbf{e}^{13}+\mathbf{e}^{14} & \mathbf{0}\\ \mathbf{0} & \mathbf{e}^{23}+\mathbf{e}^{24}\end{pmatrix}\begin{pmatrix}\mathbf{1}\\ \mathbf{1}\end{pmatrix}$$

$$= \begin{pmatrix}\hat{\mathbf{v}}^1\mathbf{L}^{11}\mathbf{e}^{13} + \hat{\mathbf{v}}^1\mathbf{L}^{11}\mathbf{e}^{14} + \hat{\mathbf{v}}^1\mathbf{L}^{12}\mathbf{e}^{23} + \hat{\mathbf{v}}^1\mathbf{L}^{12}\mathbf{e}^{24}\\ \hat{\mathbf{v}}^2\mathbf{L}^{21}\mathbf{e}^{13} + \hat{\mathbf{v}}^2\mathbf{L}^{21}\mathbf{e}^{14} + \hat{\mathbf{v}}^2\mathbf{L}^{22}\mathbf{e}^{23} + \hat{\mathbf{v}}^2\mathbf{L}^{22}\mathbf{e}^{24}\end{pmatrix} \quad (1.11)$$

The outcome of (1.10) can then be decomposed into three components as for (1.7):

a) Value added embodied in country 1 (EU country) due to its sales to the domestic market (not to be included as intra-European trade): $\hat{\mathbf{v}}^1\mathbf{L}^{11}\mathbf{f}^{11}$
b) Value added embodied in country 1 (EU country) due to its intermediate exports to country 2 (EU country): $\hat{\mathbf{v}}^1\mathbf{L}^{12}\mathbf{f}^{21} + \hat{\mathbf{v}}^1\mathbf{L}^{12}\mathbf{f}^{22}$

c) Value added embodied in country 1 (EU country) due to its exports of final goods to country 2 (EU country): $\mathbf{\hat{v}^1 L^{11} f^{12}}$

And analogously for country 2 (EU country): $\mathbf{\hat{v}^2 L^{22} f^{22}}$, $\mathbf{\hat{v}^2 L^{21} f^{11}} + \mathbf{\hat{v}^2 L^{21} f^{12}}$ and $\mathbf{\hat{v}^2 L^{22} f^{21}}$, respectively. Therefore, we can decompose the embodied value added in EU countries (i.e. row sums of the $\mathbf{\Omega}$ matrix) into the four components: embodied value added in EU countries to satisfy domestic final use; embodied value added in EU countries due to their intermediate exports to EU countries; embodied value added in EU countries due to their exports of final goods to EU countries; embodied value added in EU countries due to their exports of final and intermediate goods to non-EU countries.

In matrix form, equations (1.10) and (1.11) can be combined in this way:

$$\mathbf{\Omega i} = \mathbf{\Omega^{EU,EU} i} + \mathbf{\Omega^{EU,noEU} i} = \mathbf{w^{EU,EU}} + \mathbf{w^{EU,noEU}} = \mathbf{w}_{dom}^{\mathbf{EU,EU}} + \mathbf{w}_{int}^{\mathbf{EU,EU}} + \mathbf{w}_{fin}^{\mathbf{EU,EU}} + \mathbf{w^{EU,noEU}}$$

$$= \begin{pmatrix} \mathbf{\hat{v}^1} & \mathbf{0} \\ \mathbf{0} & \mathbf{\hat{v}^2} \end{pmatrix} \begin{pmatrix} \mathbf{L^{11}} & \mathbf{0} \\ \mathbf{0} & \mathbf{L^{22}} \end{pmatrix} \begin{pmatrix} \mathbf{f^{11}} \\ \mathbf{f^{22}} \end{pmatrix} + \begin{pmatrix} \mathbf{0} & \mathbf{\hat{v}^1} \\ \mathbf{\hat{v}^2} & \mathbf{0} \end{pmatrix} \begin{pmatrix} \mathbf{0} & \mathbf{L^{12}} \\ \mathbf{L^{21}} & \mathbf{0} \end{pmatrix} \begin{pmatrix} \mathbf{f^{11}} + \mathbf{f^{12}} \\ \mathbf{f^{21}} + \mathbf{f^{22}} \end{pmatrix}$$
$$+ \begin{pmatrix} \mathbf{\hat{v}^1} & \mathbf{0} \\ \mathbf{0} & \mathbf{\hat{v}^2} \end{pmatrix} \begin{pmatrix} \mathbf{L^{11}} & \mathbf{0} \\ \mathbf{0} & \mathbf{L^{22}} \end{pmatrix} \begin{pmatrix} \mathbf{f^{12}} \\ \mathbf{f^{21}} \end{pmatrix} + \mathbf{w^{EU,noEU}}$$

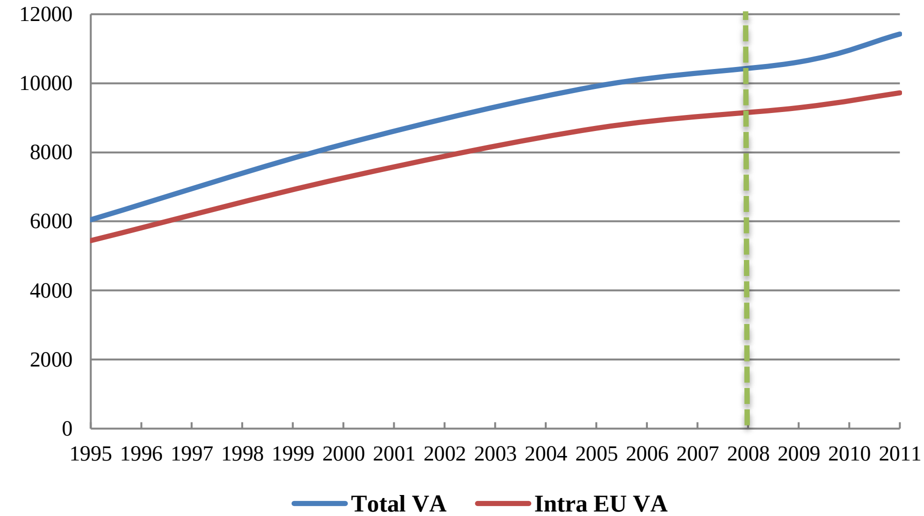
from which we will focus on the embodied value added in EU countries due to their intermediate and final exports to other EU countries ($\mathbf{w}_{int}^{\mathbf{EU,EU}}$, $\mathbf{w}_{fin}^{\mathbf{EU,EU}}$) and extra-EU countries ($\mathbf{w^{EU,noEU}}$). In summary, our methodology allows the representation of the full income generated in Europe. A similar analysis is done for employment.

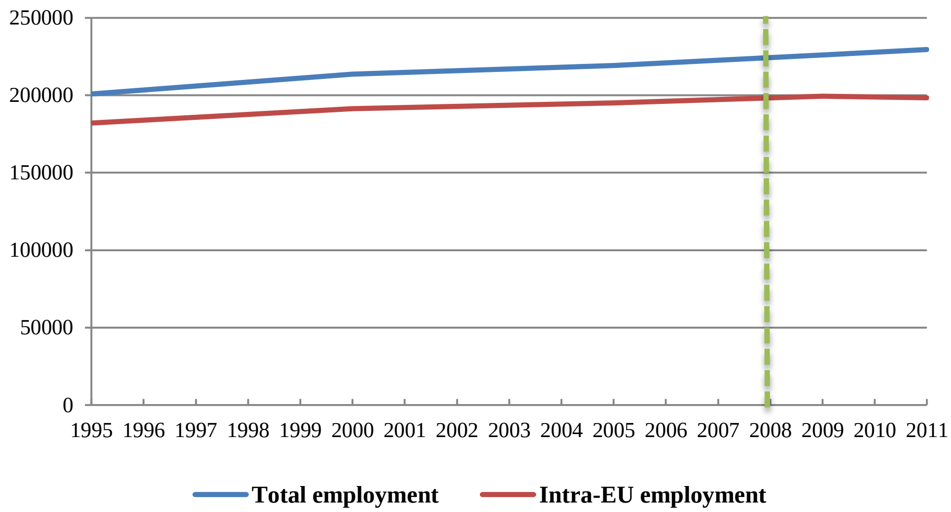
Our main source of data is WIOD, World Input-Output Database, Release 2013, which is freely available at http://www.wiod.org. It provides world input-output tables since 1995 covering 27 European countries and 13 other major countries (Australia, Brazil, Canada, China, India, Indonesia, Japan, Mexico, Russia, South Korea, Taiwan, Turkey and United States). In addition, it includes data for 35 industries, which cover all economic sectors (agriculture, mining, construction, utilities, manufacturing and services). Information on employment has been obtained from the socioeconomic accounts of WIOD, considering national employment of each country and they are expressed in thousands of jobs. The analysis is carried out for the period 1995-2011.

3. Results

In this section, we present the general results obtained from the analysis of value added and employment embodied in EU trade flows, with a particular focus on intra-EU trade.

Figure 1. Evolution of income (billion EUR) and employment (thousands of jobs) in Europe





Source: Own elaboration

A first look at Figure 1 shows the close relationship between the evolution of value added (VA) embodied in intra-EU production (i.e. production generated in European countries that is also destined for Europe) and the general evolution of VA, mainly explained by the important weight of the domestic demand for all the EU countries. This same behavior is repeated for the magnitude of employment. The parallel evolution in both cases seems to decouple by the end of the period studied (from 2005 onwards), mainly due to the expansive effect of extra-EU trade for EU countries and the beginning of the impact of the economic crisis on the domestic demands.

These general trends can be qualified with a closer look at the changes in intra-EU and extra-EU trade in Europe and their share in income generation. Table 1 shows these results.

Table 1: Embodied value added and its components in the EU-27 and the 6 top contributors (current prices in EUR)

	1995				2011				
	VA	**VA embodied in intra-EU demand**	**VA embodied in extra-EU exports**	**VA embodied in intra-EU trade**		**VA**	**VA embodied in intra-EU demand**	**VA embodied in extra-EU exports**	**Traded within EU**
DE	1671.7	1514.2	157.5	163.7	**DE**	2357.6	1909.3	448.3	297.7
ES	403.1	380.6	22.5	36.9	**ES**	989.1	903	86.1	92.4
FR	1028.5	937.9	90.5	91.3	**FR**	1817	1632.9	184.2	131.9
IT	743.1	669.9	73.1	71.8	**IT**	1421.7	1250.7	171	113.2
NL	277.2	239.2	38	61.9	**NL**	542.5	449.5	93	114.8
UK	766.7	673.5	93.2	72.8	**UK**	1584.2	1353.4	230.8	134.8
EU-27	**6047.5**	**5443.3**	**604.1**	**685.7**	**EU-27**	**11423.7**	**9721.1**	**1702.5**	**1270.8**
6 top contributors (%)	**80.9**	**81.1**	**78.6**	**72.7**		**76.3**	**77.1**	**71.3**	**69.6**

Source: Own elaboration

As can be observed, in 1995, the EU-27 countries generated a total income of EUR 6047.5 billion, most of which ended up in the EU (EUR 5443 billion), with this appearing for all the countries, magnitudes and years analyzed[2]. Germany, Spain, France, Italy, Netherlands and the UK accounted for 80.9% of the total income generated in the European Union, also explaining 81.1% of all the income generated in Europe due to EU's final uses of products. The participation of this group of countries is slightly lower for the VA embodied in extra-EU trade and, particularly, for the VA embodied in intra-EU trade. For the EU as a whole, at the beginning of the period, the value added embodied in trade accounted for a 21.33%

[2] Data for the years between 1995 and 2011 are available upon request.

of the total, with a slightly higher share of the intra-EU trade over the extra-EU trade (EUR 685.7 billion vs EUR 604.1 billion).

From 1995 to 2011, three general features can be observed. First, for the EU as a whole, value added embodied in trade increased its share by 5 percentage points (up to 26.03% of the total income generated in Europe in 2011), showing the trade expansion of European countries and its positive effect in terms of income (rise in the value added associated to traded goods). Second, while intra-EU trade almost maintains its share in income generation (11.12% versus 11.34% in 1995), the value added incorporated into extra-EU goods goes up to 14.9% (9.99% in 1995)[3]. In other words, the results suggest that trade and particularly extra-EU trade have been driving factors of income generation in Europe. Third, the group of the six top income contributors (Germany, Spain, France, Italy, Netherlands and the United Kingdom) loses share in all the magnitudes and particularly in extra-EU exports, showing a higher dispersion in income generation among EU countries. In any case, the share of these countries in intra-EU trade is not seriously affected (reduction of 3 percentage points in 15 years). Behind these general figures, however, we can find important disparities in the behaviour of countries. Table 2 shows the share of trade components in the income generation of the EU-27 countries and the EU as a whole.

Table 2: Trade share in income generation in Europe (in italics the 6 top contributors)

	1995								**2011**						
		Intra-EU trade			**Extra-EU trade**					**Intra-EU trade**			**Extra-EU trade**		
	Total trade/ Total magnitude	**Interm/Total intra trade**	**Final/ Total intra trade**	**Total Intra-EU trade/ Total trade**	**Interm/Total extra trade**	**Final/ Total extra trade**	**Total Extra-EU/Total trade**		**Total trade/ Total magnitude**	**Interm/Total intra trade**	**Final/ Total intra trade**	**Total Intra-EU trade/ Total trade**	**Interm/Total extra trade**	**Final/ Total extra trade**	**Total Extra-EU/Total trade**
AT	23.4	66.4	33.7	57.5	62.2	37.8	42.5	**AT**	33.8	59.4	40.7	43.8	64.1	35.9	56.2
BE	38.3	57.3	42.8	71.1	64.3	35.7	28.9	**BE**	38.4	58.1	41.9	53.2	68.7	31.3	46.8
BG	28.9	60	40	38.5	48.0	52.0	61.5	**BG**	32.3	61.9	38.1	42	60.5	39.5	58
CY	16.1	25	75	40	54.9	45.1	60	**CY**	14.9	50	50	29.2	61.8	38.2	70.8
CZ	32.5	65.8	34.2	66.4	62.4	37.6	33.6	**CZ**	41.2	56.5	43.5	59	58.9	41.1	41
DE	***19.2***	***54.7***	***45.3***	***51***	***54.4***	***45.6***	***49***	**DE**	***31.6***	***51.8***	***48.2***	***39.9***	***58.8***	***41.2***	***60.1***

[3] Comparing the values of 2011 and 1995 for all the general magnitudes, and assigning an index=100 to the change in value added, we can deduce that the intra-EU trade embodied in the EU demand had a relative change of 94% (the least dynamic growth factor), while the VA embodied in intra-EU trade relatively changed by 98% and the VA embodied in extra-EU trade changed by 149% (the most dynamic factor).

DK	27.2	40.9	59.2	52.6	52.0	48.0	47.5	**DK**	31.1	52.3	47.7	41.4	60.6	41.2	58.6
EE	37.5	60	40	55.6	53.6	46.4	44.4	**EE**	36.7	60	40	49	68.1	31.9	51
EL	6.2	40.7	59.3	50	64.5	35.5	50	**EL**	11.3	47.2	52.8	16.8	72.1	27.9	83.2
ES	***14.7***	***45.5***	***54.5***	***62.1***	***56.0***	***44.0***	***37.9***	***ES***	***18.1***	***48.7***	***51.3***	***51.8***	***61.8***	***38.2***	***48.2***
FI	28.6	73.7	26.3	47.7	61.9	38.1	52.3	**FI**	26.9	74.5	25.5	33.2	67.7	32.3	66.8
FR	***17.7***	***53***	***47***	***50.2***	57.6	42.4	***49.8***	**FR**	***17.4***	***52***	***48***	***41.7***	***57.9***	***42.1***	***58.3***
HU	26.8	61	39	54	55.0	45.0	46.1	**HU**	44.8	58.1	41.9	50.4	56.4	43.6	49.6
IE	47.6	39.7	60.3	63.2	57.6	42.4	36.8	**IE**	56.5	49.2	50.8	31.5	70.6	29.4	68.5
IT	***19.5***	***46.2***	***53.8***	***49.6***	***50.6***	***49.4***	***50.5***	**IT**	***20***	***49.1***	***50.9***	***39.8***	***49.8***	***50.2***	***60.2***
LT	29.6	60	40	46.2	58.8	41.2	53.9	**LT**	33.3	53.1	46.9	34.8	68.5	31.5	65.2
LU	54	76.5	23.5	68.9	75.1	24.9	31.1	**LU**	59.4	71.4	28.6	30.3	79.3	20.7	69.7
LV	31.3	75	25	40	66.6	33.4	60	**LV**	29	61.1	38.9	34	64.9	35.1	66
MT	30.4	60	40	71.4	62.4	37.6	28.6	**MT**	39.3	55.6	44.4	45.5	74.6	25.4	54.6
NL	***36***	***52.7***	***47.3***	***62***	***63.7***	***36.3***	***38***	**NL**	***38.3***	***57.6***	***42.4***	***55.3***	***67.2***	***32.8***	***44.8***
PL	19.7	57.6	42.4	66.7	52.1	47.9	33.3	**PL**	29.5	51.5	48.5	55	56.0	44.0	45
PT	18.2	43.3	56.7	68.2	61.6	38.4	31.8	**PT**	17.8	56	44	53	61.5	38.5	47
RO	18.6	50	50	49	70.1	29.9	51	**RO**	22.6	56.3	43.7	43.1	64.2	35.8	56.9
SE	29.5	64.3	35.8	46.3	57.7	42.3	53.7	**SE**	32.5	59.2	40.8	33.4	67.8	32.2	66.6
SI	30.8	50	50	60	52.8	47.2	40	**SI**	33.4	54.7	45.3	51.4	52.6	47.4	48.6
SK	35.7	70.6	29.4	71.7	67.0	33.0	28.3	**SK**	36.6	60.7	39.3	62.3	52.8	47.2	37.7
UK	***21.7***	***55.3***	***44.7***	***43.9***	***62.6***	***37.4***	***56.1***	**UK**	***23.1***	***62.2***	***37.8***	***36.9***	***67.5***	***32.5***	***63.1***
EU-27	21.3	53.8	46.2	53.2	57.4	42.6	46.8	**EU-27**	26	54.6	45.4	42.7	61.4	38.6	57.3

NB: The shares of intra-EU plus extra-EU trade sum 100%, as well as the sum of shares of intra-EU intermediates and final goods

Source: Own elaboration.

Again, three important additional features can be deduced from this table. At the aggregate level, we can confirm the increasing role of trade, the clear shift between intra-EU trade and extra-EU trade, and the predominance of the intra-EU trade of intermediate inputs explaining income embodied over the trade of final goods. The trade share for the EU-27 was 21.3% in 1995 and 26% in 2011. Focusing on extra-EU trade, the extra-EU share (of total trade) was 46.8% and 57.3% in 1995 and 2011 respectively. If we focus on the subdivision of extra-EU trade, it is remarkable the dominance of extra European trade in intermediate inputs, as in the inter-EU trade. However, in this case, in many European countries, the extra-EU trade of inputs and final products is less uneven, for instance Czech Republic, Italy, Latvia, Romania and Slovakia. Moreover, 21 out of 27 EU countries increased the trade share in this period and 26 countries also increased the share of extra-EU trade from 1995 to 2011. Notably, 16 of these 26 countries increased these shares by more than 10 percentage points, and Belgium, Greece, Ireland, Luxembourg, Malta and Portugal by more than 15 percentage points.

Focusing on the six top income contributors, all save France (from 17.74% to 17.40%) increased their trade share, and all of them increased the extra-EU share by more than 6 percentage points. The highest increment in the trade share corresponds to Germany, which went from 19.21% in 1995 to 31.64% in 2011. This is mainly due to the strong orientation towards non-EU exports, which in 1995 represented 49.03% of all its value added embodied in trade and 60.09% in 2011.

If we focus on the composition of intra-EU trade, on average this is more oriented towards intermediate inputs, 53.8% in 1995 and 54.58% in 2011. Greece, Spain, Ireland and Italy were the countries which showed the strongest orientation of intra-EU trade towards final goods in 2011, while Finland, Luxembourg, Slovakia and Sweden were the most specialized in intermediate inputs.

An interesting analysis refers to the income effects of the relationships between EU countries, which can be seen in Table 3. We present here the data for 2011; the other years analyzed are available upon request.

<u>Table 3:</u> Income embodied in intra-EU trade (2011, billion EUR)

	AT	BE	BG	CY	CZ	DE	DK	EE	EL	ES	FI	FR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK	EU-27 (direct)
AT	0.0	1.1	0.4	0.0	1.8	15.9	0.3	0.0	0.4	1.6	0.3	2.7	1.8	0.2	4.8	0.1	0.2	0.1	0.0	1.0	1.4	0.2	1.2	0.8	0.6	0.6	2.6	**40.1**
BE	1.2	0.0	0.2	0.1	0.9	13.1	1.1	0.1	0.9	4.5	0.9	12.3	0.7	0.7	5.8	0.1	1.7	0.1	0.0	8.9	1.6	0.8	0.5	2.1	0.2	0.2	8.7	**67.4**
BG	0.2	0.3	0.0	0.0	0.1	0.8	0.0	0.0	0.5	0.2	0.0	0.4	0.1	0.0	0.6	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.5	0.0	0.0	0.0	0.2	**4.2**
CY	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	**0.7**
CZ	2.7	1.1	0.2	0.0	0.0	11.2	0.3	0.0	0.2	1.2	0.3	2.5	1.0	0.2	2.0	0.1	0.1	0.0	0.0	1.2	2.2	0.2	0.6	0.6	0.2	2.6	2.5	**32.9**
DE	25.1	17.2	1.5	0.4	12.0	0.0	7.3	0.4	4.6	22.2	4.6	50.3	7.6	2.9	36.0	0.8	2.1	0.5	0.2	21.5	17.4	4.1	4.8	11.6	1.5	3.5	37.6	**297.7**
DK	0.3	0.6	0.1	0.0	0.4	5.6	0.0	0.1	0.3	1.2	1.1	1.8	0.2	0.3	1.3	0.2	0.0	0.1	0.0	1.6	1.0	0.2	0.2	4.8	0.0	0.1	4.9	**26.4**
EE	0.0	0.1	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.0	0.7	0.1	0.0	0.0	0.1	0.2	0.0	0.2	0.0	0.1	0.1	0.0	0.0	0.4	0.0	0.0	0.1	**2.5**
EL	0.1	0.1	0.3	0.4	0.0	0.7	0.0	0.0	0.0	0.2	0.0	0.2	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.2	0.1	0.0	0.0	0.4	**3.7**
ES	1.5	3.6	0.3	0.2	1.5	16.0	1.2	0.1	1.4	0.0	0.6	21.0	0.6	0.9	12.6	0.1	0.2	0.1	0.1	3.9	2.6	10.7	1.1	1.5	0.2	0.3	10.1	**92.4**
FI	0.3	0.6	0.0	0.0	0.2	2.9	0.5	0.3	0.1	0.9	0.0	1.2	0.1	0.1	0.8	0.1	0.0	0.1	0.0	0.9	0.7	0.1	0.1	2.7	0.0	0.1	1.7	**14.5**
FR	2.1	11.8	0.5	0.2	1.9	32.3	1.3	0.1	1.9	19.5	1.0	0.0	1.3	1.4	18.6	0.2	1.4	0.1	0.1	6.3	3.9	2.4	1.6	3.2	0.4	0.8	17.6	**131.9**
HU	1.5	0.4	0.3	0.0	0.7	5.7	0.2	0.0	0.2	1.7	0.1	1.5	0.0	0.1	1.7	0.0	0.1	0.0	0.0	0.5	1.0	0.1	1.5	0.3	0.2	0.6	1.4	**19.8**
IE	0.3	1.4	0.0	0.0	0.4	4.3	0.4	0.0	0.1	2.2	0.2	2.6	0.2	0.0	2.1	0.0	0.1	0.0	0.0	1.2	0.4	0.3	0.2	0.6	0.0	0.1	8.1	**25.4**
IT	4.6	4.3	0.8	0.4	2.3	27.0	1.3	0.1	3.8	12.5	1.0	22.5	1.6	1.0	0.0	0.3	0.3	0.2	0.4	3.3	4.8	1.9	3.2	2.1	1.3	0.8	11.5	**113.2**
LT	0.1	0.1	0.0	0.0	0.0	0.6	0.2	0.1	0.0	0.1	0.1	0.3	0.0	0.0	0.2	0.0	0.0	0.4	0.0	0.2	0.3	0.0	0.0	0.2	0.0	0.0	0.2	**3.2**
LU	0.2	1.4	0.0	0.0	0.2	1.7	0.1	0.0	0.0	0.2	0.1	1.4	0.1	0.1	0.6	0.0	0.0	0.0	0.0	0.3	0.2	0.1	0.0	0.1	0.0	0.0	0.3	**7.1**
LV	0.1	0.0	0.0	0.0	0.0	0.3	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.2	0.0	0.0	0.1	**1.8**
MT	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	**1.0**
NL	1.8	14.6	0.3	0.2	1.4	28.0	3.2	0.1	1.6	7.9	1.8	11.2	1.5	1.5	11.4	0.3	0.6	0.1	0.1	0.0	2.9	1.3	0.8	3.0	0.2	0.5	18.6	**114.8**
PL	1.5	1.6	0.3	0.0	3.1	16.6	1.1	0.2	0.3	2.3	0.6	4.9	1.5	0.4	4.3	0.9	0.1	0.4	0.0	2.2	0.0	0.3	1.1	1.9	0.2	0.9	5.8	**52.5**
PT	0.2	0.5	0.0	0.0	0.1	2.0	0.1	0.0	0.1	4.8	0.1	2.4	0.1	0.2	1.0	0.0	0.0	0.0	0.0	0.5	0.2	0.0	0.1	0.3	0.0	0.0	1.4	**14.1**
RO	0.7	0.4	0.5	0.0	0.3	2.7	0.1	0.0	0.2	0.8	0.1	1.2	0.6	0.1	2.2	0.0	0.0	0.0	0.0	0.4	0.4	0.1	0.0	0.2	0.1	0.1	0.7	**11.9**
SE	0.7	2.2	0.1	0.0	0.6	6.7	4.1	0.2	0.3	1.9	3.9	3.4	0.4	0.3	2.2	0.2	0.1	0.2	0.0	2.4	1.5	0.4	0.2	0.0	0.1	0.1	4.7	**37.0**
SI	0.5	0.1	0.1	0.0	0.2	1.6	0.1	0.0	0.1	0.1	0.0	0.5	0.2	0.0	0.9	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.1	0.1	0.0	0.1	0.2	**5.4**
SK	1.1	0.3	0.1	0.0	2.0	3.4	0.1	0.0	0.1	0.7	0.1	1.1	1.0	0.0	1.1	0.0	0.1	0.0	0.0	0.5	1.0	0.1	0.3	0.3	0.1	0.0	0.9	**14.4**
UK	2.4	8.3	0.3	0.5	1.8	32.6	3.7	0.2	1.3	8.4	1.9	17.9	1.4	13.9	10.7	0.2	0.5	0.2	0.4	15.6	4.2	1.7	1.3	4.9	0.3	0.6	0.0	**134.8**
EU-27 (emb)	**49.1**	**71.9**	**6.2**	**2.6**	**31.9**	**232.0**	**26.9**	**2.1**	**18.7**	**95.2**	**19.6**	**163.4**	**22.1**	**24.5**	**121.7**	**4.4**	**7.9**	**3.0**	**1.5**	**72.8**	**48.4**	**24.8**	**19.7**	**41.9**	**5.7**	**12.2**	**140.6**	**1270.8**

Source: Own elaboration

Table 3 provides a quantification of the income embodied in the trade flows across EU countries. Considering one of the countries, Spain, as an example, the reading of the table is as follows. Looking by row, in 2011, Spain generated EUR 92 billion of value added in the production of goods (intermediate and final goods) traded with the other EU countries. This income was mainly generated in the production of goods exported to France (EUR 21 billion), Germany (EUR 16 billion), Italy (EUR 13 billion), Portugal (EUR 11 billion) and the UK (EUR 10 billion). Looking by column, the final demand of Spain incorporates (or induces the generation of) EUR 95 billion across the other EU countries. Germany, in the production of goods imported by Spain, generates EUR 22 billion, France EUR 19 billion and Italy EUR 12 billion. Net balances between countries can be obtained by comparing different row and column sum elements in Table 3.

On the basis of the income embodied in intra-EU trade, we can obtain additional information about the patterns of export and import and the effect on income associated to intra-EU trade.

Figure 2 shows the shares of the different countries in embodied income (by rows and columns) for 1995 and 2011. We present only those percentages above the simple average of the EU-27 countries (also shown, as the standard deviation, at the bottom of each table).

Figure 2: Intra-EU main patterns and income shares

Shares by row, 1995

	AT	BE	BG	CY	CZ	DE	DK	EE	EL	ES	FI	FR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK	
AT		5			5	38				5		5	5		10					5							10	
BE						25				4		20			10					14							12	
BG																												
CY																												
CZ	13					38																				13		
DE	9	9					4			7		16			13					10				4			15	
DK		6				31				6	6	6			6					6				13			13	
EE																												
EL						33									33													
ES	3	3				22			3			24			14					5		11		3			11	
FI						18	9			9		9			9					9				18			18	
FR		11				26				11					16					5							14	
HU	25					25																						
IE		8				23				8		15			8					8							31	
IT	4	4				29			4	8		21								4							11	
LT																												
LU		20				20						20			20													
LV																												
MT																												
NL		16				29	3			5		11			8									3			15	
PL						50						8			8					8							8	
PT						22				22		22			11												11	
RO						50									50													
SE		9				18	14			5	5	9			5					9							14	
SI						50																						
SK					33	33																						
UK	3	7				25	3			7		16		7	11					10				4				
nun	*6*	*11*	*0*	*0*	*2*	*20*	*5*	*0*	*2*	*12*	*2*	*14*	*1*	*1*	*16*	*0*	*0*	*0*	*0*	*12*	*0*	*1*	*0*	*6*	*0*	*1*	*13*	
Average	2.5																										6	11
Desvest	11																											

Shares by row, 2011

	AT	BE	BG	CY	CZ	DE	DK	EE	EL	ES	FI	FR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK
AT					5	40				5		8	5		13												8
BE						19				7		18			9		3			13	3			3			13
BG						25									25								25				
CY																											
CZ	9	3				33				3		6	3		6					3	6		3	3		9	9
DE	8	6			4					7		17			12					7	6			4			13
DK		4				23				4	4	8			4					8	4			19			19
EE											33																
EL						25									25												
ES		4				17						23			14					4	3	12					11
FI		7				20	7			7		7			7					7	7			20			13
FR		9				24				14					14					5	3						14
HU	10				5	30				10		5			10					5	5		5			5	5
IE		4				16				8		12			8					4				4			32
IT	4	4				24			4	11		19									4						10
LT						33																					
LU		14				29						14			14												
LV																											
MT																											
NL		13				24				7		10			10												17
PL		4			6	33				4		10			8					4				4			12
PT						14				36		14			7												7
RO	8		8			25				8		8	8		17												8
SE		5				19	11			5	11	8			5					5	5						14
SI	20					40						20			20												
SK	7				14	21				7		7	7		7						7						7
UK		6				24	3			6		13		10	8					12	3			4			
nun	*7*	*13*	*1*	*0*	*5*	*22*	*3*	*0*	*1*	*17*	*3*	*19*	*4*	*1*	*21*	*0*	*1*	*0*	*0*	*12*	*12*	*1*	*3*	*8*	*0*	*2*	*17*
Average	2.9																										
Desvest	8.3																										

Shares by column, 1995

	AT	BE	BG	CY	CZ	DE	DK	EE	EL	ES	FI	FR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK	num
AT					10	6							17		3													**4**
BE	4					9	6		9	5	10	11			7		25			15		7		5			7	**13**
BG																												**0**
CY																												**0**
CZ	4																									33		**2**
DE	52	29			40		33		27	25	20	29	33	10	31		25			35	40	21	33	27	33	33	30	**20**
DK						3					10													9				**3**
EE																												**0**
EL																												**0**
ES	4					6			9			10			7					4		29		5			5	**9**
FI							6																	9				**2**
FR	7	20			10	17	6		9	23	10			10	21		25			10	10	14		9			16	**16**
HU	4																											**1**
IE																											5	**1**
IT	11	6			10	15	6		27	14	10	16	17							6	10	7	33	5	33		10	**17**
LT																												**0**
LU																												**0**
LV																												**0**
MT																												**0**
NL	4	20				13	11		9	7	10	7			7						10	7		9			11	**13**
PL						4																						**1**
PT										5																		**1**
RO																												**0**
SE		4				3	17				10									4							4	**6**
SI																												**0**
SK					10																							**1**
UK	7	10			10	13	11		9	11	10	13		50	11					15	10	7		14				**15**
Average	2.5																										10	11
Desvest	11																											

Shares by column, 2011

	AT	BE	BG	CY	CZ	DE	DK	EE	EL	ES	FI	FR	HU	IE	IT	LT	LU	LV	MT	NL	PL	PT	RO	SE	SI	SK	UK	num
AT					6	7							9		4								5		17	8		**7**
BE					3	6	4		5	5	5	7	5	4	5		25			12	4	4	5	5			6	**17**
BG																							5					**1**
CY																												**0**
CZ	6					5							5								4		5			25		**6**
DE	51	24	33		38		26		26	23	25	31	36	12	30	25	25	33		29	35	16	25	29	33	33	27	**23**
DK											5													12			4	**3**
EE											5																	**1**
EL																												**0**
ES	4	6			6	7	4		5		5	13	5	4	11					5	6	44	5				7	**16**
FI							4																	7				**2**
FR	4	17	17		6	14	4		11	20	5		5	4	16		13			8	8	8	10	7		8	13	**20**
HU	4				3																		5			8		**4**
IE																											6	**1**
IT	10	6	17		6	12	4		21	13	5	13	9	4						4	10	8	15	5	17	8	8	**20**
LT																												**0**
LU																												**0**
LV																												**0**
MT																												**0**
NL	4	21			3	12	11		11	8	10	7	9	8	9		13				6	4	5	7		8	13	**19**
PL					9	7	4				5	3	5		3	25							5	5		8	4	**12**
PT										5																		**1**
RO			17										5															**2**
SE					3	3	15				20										4						4	**6**
SI																												**0**
SK					6								5															**2**
UK	4	11			6	14	15		5	8	10	11	5	56	9		13			22	8	8	5	12		8		**19**
Average	3.0																										11	9.4
Desvest	10																											

Source: Own elaboration

The first interesting result is the decrease from 1995 to 2011 in the standard deviation of the shares, both in columns and rows, showing higher diffusion (diversification) in the intra-EU export destination from 1995 to 2011. This change is more marked in exports (first two pictures, shares by row) than in imports.

Regarding the income embodied in exports, in 1995, the final demand of Germany was a significant driver for income (above the EU-27 average) for 20 of the 26 EU countries. For 14 of them, the German market represented at least the 25% of the income generated in the intra-EU trade, with the cases of Poland, Romania and Slovenia, for which the German destination represented around 50% of the income embodied in their intra-EU trade, being especially significant. Italy, France, Spain, Netherlands, Belgium and the UK were also important drivers of income embodied for a significant number of countries. In 2011, these countries were also featured destinations, for even more countries, with slightly reduced shares (in general). The emergence of Poland as a significant destination for 12 countries is also significant. In 2011, Germany's demand drove at least 30% of the VA generated in Austria, Czech Republic, Hungary, Lithuania, Poland and Slovenia for intra-EU trade. Spanish demand crystalized 36% of the Portuguese income associated to intra-EU trade, Finnish demand 33% of the Estonian income and UK demand 32% of the Irish income. These data confirm the leading role of German final demand, particularly for eastern economies, and the importance of neighboring countries (shorter distances), explaining trade.

Regarding the income embodied in imports, in Figure 2 we also observe an increase in the interconnections between EU countries from 1995 to 2011. The average share increase, the standard deviation decrease, and the top six income contributors (Germany, the UK, France, Italy, Spain and Netherlands) together with Belgium also appear as the main providers of inputs (generating domestic income) to the production of final goods of other countries. The increasing integration of Poland in intra-EU trade is worthy of note, appearing as relevant for the production of 12 countries in 2011 (versus only 1 in 1995), as is the intensification of the Spanish links in this period, significantly contributing to the production of 16 EU countries, compared to 9 in 1995.

As well as for income, we now present the results obtained regarding the employment embodied in exports of intermediate inputs and final products among European countries. The general evolution of employment can be seen in Figure 1. The main general data are summarized in Table 4.

Table 4: Embodied employment and its components in the EU-27

										Employment embodied growth (%) between 1995 and 2011				
1995 EMP	Total employment	Total intra EU	Total extra EU	Traded within EU	2011 EMP	Total employment	Total intra EU	Total extra EU	Traded within EU		Total employment	Total intra EU	Total extra EU	Traded within EU
AT	3718	3373	345	477	AT	4295	3534	761	630	AT	15.5	4.8	120.8	32.0
BE	3867	3463	404	1012	BE	4530	3763	767	886	BE	17.1	8.7	89.8	-12.4
BG	3519	2954	564	364	BG	3463	2820	644	514	BG	-1.6	-4.6	14.0	41.4
CY	296	265	32	27	CY	394	350	44	22	CY	33.2	32.4	39.2	-18.1
CZ	5148	4570	578	1155	CZ	5147	4262	886	1297	CZ	0.0	-6.7	53.1	12.3
DE	37601	34276	3325	3544	DE	41987	34927	7060	4840	DE	11.7	1.9	112.3	36.6
DK	2553	2235	318	373	DK	2739	2294	445	333	DK	7.3	2.6	39.9	-10.6
EE	633	536	98	155	EE	617	515	102	114	EE	-2.6	-3.9	4.7	-26.8
EL	4131	3978	154	170	EL	5183	4837	347	122	EL	25.5	21.6	125.9	-28.1
ES	13569	12862	707	1207	ES	18247	16650	1597	1814	ES	34.5	29.4	125.9	50.3
FI	2053	1774	279	252	FI	2493	2066	427	210	FI	21.4	16.4	53.3	-16.4
FR	22694	20691	2003	2087	FR	25566	22983	2583	1942	FR	12.7	11.1	28.9	-6.9
HU	4026	3531	495	600	HU	4022	3170	852	828	HU	-0.1	-10.2	72.0	38.0
IE	1285	1113	172	334	IE	1895	1402	494	276	IE	47.5	25.9	186.9	-17.4
IT	21841	19771	2070	2131	IT	25096	21962	3134	2160	IT	14.9	11.1	51.4	1.4
LT	1480	1239	241	207	LT	1416	1162	254	150	LT	-4.4	-6.3	5.4	-27.8
LU	216	187	29	69	LU	375	260	115	74	LU	73.8	39.3	296.5	6.9
LV	968	803	165	113	LV	855	715	140	78	LV	-11.7	-11.0	-15.2	-30.5
MT	139	124	15	27	MT	174	136	37	30	MT	25.0	10.2	148.0	10.9
NL	7155	6251	904	1439	NL	8816	7441	1375	1637	NL	23.2	19.0	52.1	13.8
PL	14735	13779	956	2035	PL	15748	13778	1970	2576	PL	6.9	0.0	106.1	26.6
PT	4531	4289	242	631	PT	5021	4609	413	529	PT	10.8	7.5	70.4	-16.2
RO	9503	8637	866	942	RO	10673	9257	1415	1058	RO	12.3	7.2	63.4	12.3
SE	4129	3547	582	493	SE	4600	3728	872	433	SE	11.4	5.1	49.8	-12.2
SI	918	794	124	201	SI	934	782	152	162	SI	1.7	-1.5	22.3	-19.4
SK	2107	1923	185	509	SK	2251	1941	310	531	SK	6.8	1.0	67.8	4.3
UK	27913	25145	2768	2212	UK	32888	28919	3970	2242	UK	17.8	15.0	43.4	1.4
EU-27	200728	182108	18621	22763	EU-27	229424	198262	31163	25488	EU-27	14.3	8.9	67.4	12.0
top 6 income contributors(%)	65.1	65.3	63.2	55.4	top 6 income contributors(%)	66.5	67.0	63.3	57.4					
PL+RO (%)	12.1	12.3	9.8	13.1	PL+RO (%)	11.5	11.6	10.9	14.3					

Source: Own elaboration

From 1995 to 2011, the EU employment increased by 29 million additional jobs, which means a yearly growth rate of almost 2%, and 14.3% throughout the whole period. This positive growth is mainly explained by the long positive economic period experienced by the EU countries. Of these 29 million jobs, more than 50% can be associated to trade, and, particularly, to extra-EU trade (12.5 million jobs). As can be seen, intra-EU demand (domestic country components and intra-EU trade) supported more than 16 million jobs (2.7 million associated to intra-EU trade), while extra-EU trade supported 12.5 million jobs from 1995 to 2011. Moreover, we can see in Table 1 that while the six top income contributors represented 76.3% of the EU-27 income in 2011, 71.3% of the VA embodied in extra-EU trade and 69.6% of the VA embodied in intra-EU, these percentages fall to 66.5%, 63.3% and 57.4%, respectively, regarding employment. This unequal relationship tells us about the character of the goods traded (with a high value added per unit of employment), confirming that the trade of these countries is ruled by a certain competitive advantage, which is more intense in the extra-EU trade. Moreover, two other countries, Poland and Romania, gain relevance regarding employment, generating in 2011, 11.5% of the total EU-27 employment, 10.9% of the jobs resulting in extra-EU exports, and up to 14.3% of the jobs associated to intra-EU trade (Table 4). In other words, these countries are acting as important employment factories in Europe. In addition, if we focus on the last part of Table 4, in total employment, they follow the six top main contributors with growth rates of 6.9% and 12.3% from 1995 to 2011, allowing a rapid increase in their income.

Note that during the analyzed period, for countries such as Bulgaria, Estonia, Hungary, Lithuania and Latvia, the total number of jobs decreased. However, for Bulgaria and Hungary, trade represented a clear source of employment, particularly the intra-EU trade in Bulgaria and the extra-EU trade in Hungary.

Given the space restrictions, we cannot show here more detailed results for employment. These are available upon request. In any case, the same analysis for employment shows the significant increase in the role of trade. The percentage of the total EU-27 employment supported by trade went from 20.6% to 24.7%, with an increase in most of the countries. In addition, there has been a significant shift from intra-EU to extra-EU markets, which have practically interchanged shares (intra-EU trade represented 55% of the total employment embodied in trade, and 45% for extra-EU, and, in 2011, intra-EU trade represented 45% of total employment embodied in trade, and 55% for extra-EU trade). Moreover, the share of intermediate inputs and final products, and the associated employment is relatively balanced and constant over time.

4. Conclusions

Globalization has changed the traditional perspective of economic growth of countries. International supply chains, involving trade among countries in the different stages of the production processes, have affected the generation and distribution of income and employment worldwide. Recent literature supports the concept of a new globalization based on the consolidation of macro-regions with different specialization patterns. In this context, we wonder if there has been a certain phenomenon of "Europeanization" as opposed to "globalization" and if, in this process, some EU countries have been more globally competitive in final goods while other EU countries have acted as input suppliers to the former.

To address these questions, we have analyzed the role that trade, and particularly intra-EU trade, has played as a driver of income and employment in the EU countries. On the basis of a multiregional input-output model focused on the EU production structure, we quantify the employment and value added embodied in trade by importing and destination countries for the period 1995-2011, a relevant period in the recent past of the EU.

Our results suggest that trade in European countries represents a very relevant proportion in the generation of income and employment in the European Union as a whole. The results strongly support the importance of intra-EU trade as well as the irruption of extra-EU trade as a central driver of employment and income in the EU.

When comparing the distribution of total trade between European countries, the study shows a certain trend towards the trade of intermediate inputs, which means that European countries trade more in the intermediate steps of the production chain than in the last step with final products. This is the case of countries like Austria, Czech Republic, Finland, Luxembourg and Slovakia.

For all the indicators and years analyzed in this study, we can conclude that there is a higher homogeneity in embodied variables but there is a higher dispersion in direct variables. This would suggest the existence of important similarities in consumption patterns, leading to a similar distribution of embodied values. Our results also provide evidence of two different specialization patterns among European countries. On the one hand, eastern countries have experienced an important increase in income and employment linked to intra-EU trade in the period analyzed, revealing their dynamism since their incorporation into the European Union. On the other hand, although the countries of central Europe have also experienced an increase in intra-EU trade, these countries show a clear shift towards extra-EU trade, not forgetting the great relevance of the domestic component.

Finally, regarding the two magnitudes analyzed, value added and employment, we can obtain a first approximation to the terms of trade in Europe. Our results show a somewhat unequal relationship between regions, with most central EU countries trading goods with a high VA/employment ratio and importing labour-intensive goods from eastern and peripheral regions. Although this characteristic clearly persists over time, these latter economies show a rapid increase in their productivities (related to the EU average), suggesting a positive effect of the EU integration and the intensification of trade on the income of these countries as well as a general convergence in productivity and income in Europe.

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Chapter 2. From convergence to divergence? Some new insights into the evolution of the European Union[4]

1. Introduction

Since its origins, the European Union has had as its main objectives the economic growth and social progress of Member States, promoting economic, social, and territorial cohesion and solidarity among them. To this end, the single market and the creation of the common currency have been two fundamental pillars. European policies have resolutely sought economic growth and the reduction of economic and social differences between countries. In this sense, the concept of convergence has been a central element in Europe and its evaluation continues to be a topic of great social and academic interest (European Commission, 2007; 2015).

At the global EU level, this economic convergence has been seen as one of the major attractions for potential EU candidate countries, who see in adherence to the EU a way to catch up to EU living standards. At the regional level, within the EU countries, the secular differences in GDP across regions have always been regarded as undesirable and some of the most important EU policies have focused on the objectives of reducing income disparities, increasing territorial competitiveness, and fostering employment creation in the EU[5].

This general objective has coexisted, however, with a quite different evolution of EU countries at the technological, economic, and social levels. As Fagerberg and Verspagen (2014) recognize, the capitalist world economy consists of countries with very different levels of economic and technological development. The European Union, as a part of this world, has also shown different country dynamics and capacities for adapting to changes and impacts in the global economic context. One of the most recent impacts has been the

[4] A reduced version of this chapter was published in *Structural Change and Economic Dynamics*, Nº 47, pags. 82-9. This extended version includes new figures, as well as the associated comments, which were not available in the original published version due to limits on article length in the Journal.

[5] Convergence can be evaluated at different levels, e.g., cross-country convergence or regional convergence (territorial cohesion). Although undoubtedly related, the relationship between them is mediated by different political, social and demographic factors and policies.

arrival of the international financial crisis, which caused serious imbalances in the real economy and affected the EU countries in very different ways. During a long period before the crisis, the European economy exhibited a relatively calm behavior, known as the "Great Moderation" (Pancrazi, 2015), which favored the positive and stable behavior exhibited by the main economic indicators. However, the abrupt and uneven effects of the international crisis on the macro- and micro-economic indicators, and the significant and various impacts on the European citizens' income, employment, and welfare, raised doubts about the soundness of the convergence process, broadening the gaps among and between different areas of Europe. In this general context, the main objective of our work is to analyze the convergence in income experienced by European countries over the last several years, offering insights from a different perspective. More specifically, we base our analysis on the structural and technological factors underlying convergence processes in the EU, and we take into account the multi-regional and multi-sectoral perspective of income generation. To do this, we make use of an MRIO approach and its associated indicators.

From the seminal papers of Abramovitz (1986) and Barro and Sala-i-Martin (1992) the hypothesis of convergence, i.e., lagging economies catching-up and reducing disparities, has been a recurrent issue in the economic growth literature. As noted in Aghion and Jaravel (2015), convergence can be explained because of decreasing returns in physical or human capital accumulation but also as resulting from cross-country knowledge spillovers. In this sense, productivity in one sector or in one country often benefits from knowledge, innovations and productivity improvements in other sectors or countries. In consequence, the processes of diffusion, technology spillovers and, increasingly, the acquisition of knowledge embodied in goods and services appear as vehicles explaining the processes of cross-country convergence (see for instance Prescott, 1998; Howitt *et al.*, 2002 and Feyrer, 2001).

In the empirical literature, the most common practice has been evaluating convergence considering the countries as homogeneous units, without considering the specific structural characteristics, country specialization and the links between them. In this context, the results for Europe have been mixed. As example, Sala-i-Martin (1994, 1996) suggest the existence of conditional convergence in the period 1950-1990 within the European Union. Hein *et al.* (2005) conclude the absence of real convergence between the countries either before or after the adoption of the euro, and Lein *et al.* (2007) evaluate convergence for the last European Member States, taking into account the productivity growth and the increased trade openness. Despite its potential relevance, the effects of structural change on the processes of convergence has received far less attention, as well as the role of the increasing production fragmentation and the irruption of global supply chains trade in the paths of growth of sectors and countries. In this line, Palan *et al.* (2010) test structural convergence on the sectoral and industry-sectoral level for Western European countries finding an intersectoral convergence process due to a general tertiarization trend in all the analyzed countries, particularly in lagging countries. However, they obtain a slight inter-industry divergence process within each sector, highlighting the behavior of technology-intensive manufacturing and services industries. Gluger *et al.* (2004) investigate the impact of convergence in productivity on economic structures for European industries over the period 1985-1988. Other authors such as Fabergerg (2000), Gluger and Pfaffermayr (2004), study the relationship between convergence in industrial structure and in productivity levels, finding that this relationship is mediated by agglomeration and path-dependence of economic growth.

In this framework, this chapter acknowledges the potential role that structural change, technological specialization of countries, trade and the increasing fragmentation of production have on the economic performance of countries and, in consequence, on convergence. In particular, with the focus on the convergence of economic structures, we delve into the role that certain economic sectors, such as the high-tech and intensive-technology sectors have played as drivers of economic growth in some countries. Moreover, through the decomposition of the domestic European Global Value Added chain in their main components (domestic demand, intra-EU trade, and extra-EU trade), we analyze for each country and group of sectors whether the income and the embodied income in the various transactions among European countries has tended to converge in the period studied.

As a novelty, in addition to the usual measures of convergence, focused on the comparison of the value added generated in each country, the chapter also analyzes the evolution of *sigma* convergence on global value added (value added embodied), i.e., on the value added incorporated by each of the European Union countries throughout the global value chain of EU products. In our view, this second approach provides an interesting perspective on convergence issues, as it takes into account the effects on convergence of the productivity gains transmitted through the European supply chain and is informative of the technological and structural bases of that convergence.

Global supply chains and their relationship to income generation across countries have recently received a renewed interest in the literature, boosted by the construction of new international input-output databases[6] which serve as empirical basis for multiregional input-output models and related analysis (see as example Johnson and Noguera, 2012; Baldwin and Lopez Gonzalez, 2015; Los *et al.* 2015; Suder *et al.*, 2015; Pomfret and Sourdin, 2018). In this context, however, the study of convergence in the input-output framework is a non-standard issue, seldom considered in the literature. One of the few references is Dietzenbacher *et al.* (2009) who perform an analysis of *sigma* convergence throughout the variance on the matrix of technical coefficients to study similarities in the input structures of countries. Also Fagerberg *et al.* (2014) carry out a *beta* convergence analysis and an input-output analysis of the contributions to GDP growth of different components (what they call traded GDP and domestic GDP).

In summary, our work builds on the literature of value chains, multiregional input-output models and convergence, to analyze how European Union countries have evolved in recent decades and what has been the role of structural and technological factors in the convergence processes in the EU.

We use data from the World Input-Output Database (2016 release) in current prices, for 28 countries over the period 2000-2014 to compute the convergence indicators for the EU. The choice of the period is mainly conditioned by the availability of comparable data, but it is of notable economic interest itself, insofar as it includes the expansive period of the early 2000s, as well as the subsequent period of international economic crisis starting in 2008.

The rest of the chapter is organized as follows. Section 2 presents the methodology used, based on a multi-regional input-output model of the European Union from 2000 to

[6] World Input-Output Database, EORA, OECD, GTAP, among others. For a complete reference and a comparative study of them can be seen Inomata and Owen (2014).

2014. Section 3 addresses the results obtained in this work related to the convergence process and the behaviors observed for different components, regions, countries and sectors. We close the chapter with some final comments in Section 4.

2. Methodology

In order to take into account the internal structure of countries and the sectoral within and cross-country linkages, we make use of a multiregional input-output framework. Input-output models are powerful tools to analyze the full map of direct and indirect economic interrelations worldwide, being increasingly used to study global supply chains. Basic references for this framework are Isard (1951) and Miller and Blair (2009).

As it has been explained in the previous chapter, let us begin by representing the equilibrium equation for the world economy formed of *m* countries and *n* sectors as in (2.1). Our starting point is the representation of the world economy in this multiregional context, where $\mathbf{x}$ denotes the total output, $\mathbf{Z} = \left[\mathbf{Z}_{\mathbf{ij}}^{\mathbf{rs}}\right]$ is the matrix of multiregional intermediate flows, $\mathbf{f}$ is the vector of total final demand of countries and $\mathbf{i}$ a unitary vector of the adequate dimension.

$$\mathbf{x} = \mathbf{Zi} + \mathbf{f} \tag{2.1}$$

Let us denote by $\mathbf{A} = \left[\mathbf{A}_{\mathbf{ij}}^{\mathbf{rs}}\right]$ the matrix of technical coefficients in the multiregional framework. Each representative element shows the volume of intermediate input *i* of a country *r* that is needed to produce a unit of output *j* in country *s*. As it mentioned in the previous chapter, equation (2.1) can be expressed on the basis of $\mathbf{A}$ and in terms of the Leontief inverse $\mathbf{L}$ for the whole multiregional economy.

$$\mathbf{x} = \mathbf{Ax} + \mathbf{f} \rightarrow \mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} = \mathbf{Lf} \tag{2.2}$$

In this case, each element in $\mathbf{L} = \left[\mathbf{L}_{\mathbf{ij}}^{\mathbf{rs}}\right]$ shows all the production generated in sector *i* and country *r* to fulfill the demands of inputs incorporated in all the steps of the production chain and ending in the final demand of sector *j* in country *s*. In this regard, the elements in $\mathbf{L}$ capture the production embodied in all the economic flows linking sectors *i* and *j*, and countries *r* and *s* through the international supply chains.

As in the previous chapter, we work within this multisectoral and multiregional input-output model, and we focus on domestic EU production. This enables us to study how changes in domestic demands, intra-EU traded goods, and extra-European trade patterns may condition the EU convergence process between 2000 and 2014. To approach this issue, we pay attention to the value added generated within the EU countries and incorporated through the EU value chains (see Duarte *et al.*, 2016). In other words, we study the EU convergence in the value added (income) generated in EU countries and in the EU value added embodied in EU final demands, showing in this way the transmission of income through the different countries and sectors involved in EU value chains.

Following the previous methodology, we can define the value added coefficients as in equation (1.5). Therefore, we define the matrix $\mathbf{\Omega}^{\mathbf{EU}}$ as in equation (1.6), which contains the value added generated in the EU and incorporated in all the EU goods (domestically consumed, traded within the EU, and exported to non-EU countries). Moreover, matrix $\mathbf{\Omega}^{\mathbf{EU}}$ can be broken down into the EU income ending within the EU ($\mathbf{\Omega}^{\mathbf{EU,EU}}$) and the EU income ending abroad, through EU exports to non-EU countries ($\mathbf{\Omega}^{\mathbf{EU,noEU}}$).

As it mentioned in Chapter 1, the reading by column and rows of the matrices above gives us significant information on the process of income generation and distribution across EU countries. We have two different perspectives, consumption and production, as in equations (1.7), (1.8), (1.10) and (1.11).

Finally, note that $\mathbf{\Omega}^{\mathbf{EU,EU}}$ includes both the income generated within each country and devoted to its domestic final demand, and the income generated obtaining the goods traded within the EU and used to produce EU final demand.

$$\begin{aligned}
\mathbf{\Omega}^{domestic\mathbf{EU,EU}} &= \begin{pmatrix} \hat{\mathbf{v}}^{\mathbf{1}} & \mathbf{0} \\ \mathbf{0} & \hat{\mathbf{v}}^{2} \end{pmatrix} \begin{pmatrix} \mathbf{L}^{\mathbf{11}} & \mathbf{0} \\ \mathbf{0} & \mathbf{L}^{\mathbf{22}} \end{pmatrix} \begin{pmatrix} \mathbf{f}^{\mathbf{11}} & 0 \\ 0 & \mathbf{f}^{22} \end{pmatrix} \\
\mathbf{\Omega}^{trade\mathbf{EU,EU}} &= \begin{pmatrix} \hat{\mathbf{v}}^{\mathbf{1}} & \mathbf{0} \\ \mathbf{0} & \hat{\mathbf{v}}^{2} \end{pmatrix} \begin{pmatrix} 0 & \mathbf{L}^{\mathbf{12}} \\ \mathbf{L}^{\mathbf{21}} & 0 \end{pmatrix} \begin{pmatrix} \mathbf{f}^{\mathbf{11}} + \mathbf{f}^{\mathbf{12}} & 0 \\ 0 & \mathbf{f}^{21} + \mathbf{f}^{22} \end{pmatrix} + \begin{pmatrix} \hat{\mathbf{v}}^{\mathbf{1}} & \mathbf{0} \\ \mathbf{0} & \hat{\mathbf{v}}^{2} \end{pmatrix} \begin{pmatrix} \mathbf{L}^{\mathbf{11}} & 0 \\ 0 & \mathbf{L}^{\mathbf{22}} \end{pmatrix} \begin{pmatrix} \mathbf{f}^{\mathbf{12}} & 0 \\ 0 & \mathbf{f}^{\mathbf{21}} \end{pmatrix}
\end{aligned} \tag{2.3}$$

Again, the reading by columns (and rows) of these matrices gives us information on the distribution on the process of VA generation (and distribution) across EU countries.

The decomposition of income flows described above, based on the MRIO structure, allows us a more complete view of the (complex) process of income growth and convergence in Europe, as far as it is possible to analyze the contribution both by generation and distribution of the different variables (domestic demands, intra-EU trade, extra-EU trade) and sectors, and the cross-country relationships.

On these bases, in order to analyze the convergence and the level of inter-country inequality in the EU between 2000 and 2014, we study the standard deviation of the log of value added, as follows:

$$\sigma_t = \left[\frac{\sum_{i=1}^{n} (\log(VA_{i,t}) - u_t)^2}{N} \right]^{\frac{1}{2}} \tag{2.4}$$

where σ_t is the dispersion measure of a set of VA amounts generated in the production activities of the 28 EU Member States in a specific year *t*; u_t is the average of the logarithms of the VA analyzed, and *N* represents the number of observations in each study.

The analysis is complemented in two ways in this work, taking advantage of our MRIO framework. First, the multisectoral nature of the MRIO information allows for a more detailed study of the economic sectors involved in the European process of *sigma* convergence. In this regard, we compare the results obtained at the more aggregated country level and those appearing when sectoral disaggregation is used.

Moreover, we study convergence through the EU value chain (i.e., in the value added generated in the EU and embodied in the final demand of countries) and analyze the evolution of convergence in their different components (intra-EU and extra-EU trade and domestic components). While the traditional measures of convergence based on direct VA (GDP) are interpreted from a supply-side perspective (convergence is expected as a result of changes in country-production structures), the study of convergence in global value chains approximates us to the driver role of final demand patterns (consumption and investment patterns) as sources of income convergence or divergence.

Finally, we complete our analysis with the *sigma* convergence in per capita income, using the population data of the range of European countries obtained from EUROSTAT (see Annex I).

Empirically, we make use of the World Input-Output Database WIOD (Timmer *et al.*, 2015). This database covers 28 EU Member States and 14 other major countries, and the Rest of the World as an aggregated region, for the period 2000-2014. The WIOD database has a breakdown of 56 industries for each country.

3. Results

This section shows the results of the empirical analysis over the analyzed period (2000-2014). All the data regarding the monetary magnitudes (value added) are expressed in €billion[7].

As a first approximation to the differences in the evolution of income in the EU countries, Table 5 shows a descriptive analysis including VA shares by sectors in the EU countries in 2000 as well as their contribution to country growth over the period, 2000-2014. This allows us to observe different specialization pattern of the EU countries at the beginning of the period studied as well as different sector contributions to growth over the period. In order to better present the data, the 56 economic sectors have been aggregated into 8 sectoral blocks according to their technological level, namely: primary sector, energy sector, high and medium-high technology industrial sectors, medium-low technology industrial sectors, low technology industrial sectors, construction sector, knowledge intensive services and rest of services[8].

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[7] These have been calculated using the exchange rates provided by WIOD, taking Germany as reference.

[8] Sectors have been grouped in these blocks attending to their technology intensity definition (following OECD Directorate for Science, Technology and Industry, 2011, and Knowledge intensive services (KIS) classification. The specific grouping of sectors and their correspondence with the sectors in WIOD can be seen in the Annex II, Table II.1.

Table 5: Evolution of income by sectors in the EU countries, 2000–2014

	Share of sectoral blocks in VA in 2000 (%)								**Sectoral contribution to VA growth (%) for 2000-2014**								
	B1:Primary sector	Block 2: Energy sector	Block 3: HTS&MHT	Block 4: MLT	Block 5:LT	Block 6: Construction	Block 7: KIS	Block 8: Rest of services	Block 1: Primary sector	Block 2: Energy sector	Block 3: HTS&MHT	Block 4: MLT	Block 5:LT	Block 6: Construction	Block 7: KIS	Block 8: Rest of services	GDP changes (%)
AUT	1.85	3.59	7.71	5.77	7.05	7.54	35.92	30.58	0.58	2.50	8.95	3.14	2.54	4.27	41.41	36.60	54.23
BEL	1.31	3.12	9.03	5.01	5.52	5.12	42.75	28.13	-0.39	1.96	2.07	-0.18	1.45	6.65	59.90	28.55	55.50
BGR	12.58	7.12	3.09	4.60	6.08	4.96	30.13	31.45	1.53	7.72	4.74	2.77	8.44	4.18	40.02	30.60	195.93
CYP	3.58	2.33	0.95	2.10	5.89	8.09	43.29	33.78	0.21	4.15	0.59	-0.05	-2.20	-6.32	60.33	43.29	58.87
CZE	3.42	4.90	9.67	7.62	8.62	6.37	29.91	29.49	2.15	6.49	15.70	7.03	4.37	4.98	35.57	23.72	129.33
DEU	1.06	2.82	12.52	5.14	5.31	5.11	41.24	26.80	-0.32	3.84	16.30	3.60	1.79	3.24	46.25	25.29	37.39
DNK	2.50	5.57	7.08	3.33	6.02	5.46	42.80	27.25	-0.38	2.98	9.44	-0.85	-1.21	2.65	58.02	29.35	46.98
ESP	4.12	2.80	5.94	5.46	6.45	10.09	34.87	30.27	-0.07	5.29	3.00	-1.23	4.03	-2.15	44.01	47.14	61.74
EST	4.84	4.58	2.79	2.99	11.48	5.92	32.12	35.29	2.81	6.42	4.49	4.23	6.52	6.83	37.59	31.10	220.95
FIN	3.38	2.35	12.63	4.73	10.29	6.16	35.47	24.99	1.71	6.10	-1.63	0.85	-5.06	6.34	57.75	33.96	48.23
FRA	2.34	2.70	6.06	3.51	6.16	4.91	44.86	29.46	0.13	2.28	-0.02	-0.50	1.22	7.44	57.45	32.00	43.30
GBR	0.92	5.02	6.60	3.39	5.68	6.37	44.12	27.90	-0.02	1.45	-1.73	-0.81	-1.87	5.76	65.25	31.96	33.60
GRC	6.08	3.35	1.99	3.50	5.13	7.01	37.68	35.25	-6.02	4.05	-0.99	1.57	3.23	-15.03	58.09	55.11	22.78
HRV	6.41	6.58	5.61	3.42	8.75	4.97	35.31	28.96	1.88	6.82	1.50	3.08	6.06	5.19	41.57	33.90	84.63
HUN	5.74	4.21	9.84	5.44	7.14	5.14	36.34	26.15	3.20	2.41	16.39	5.24	2.96	3.58	40.80	25.43	100.71
IRL	2.83	2.25	16.22	2.25	7.51	7.14	38.12	23.67	-0.07	3.91	2.53	-0.43	9.54	-2.51	67.52	19.51	77.58
ITA	2.85	2.78	7.00	5.08	7.47	4.82	37.39	32.63	-0.02	4.28	2.37	-0.06	-0.38	5.27	44.06	44.47	30.48
LTU	6.28	4.75	3.29	3.75	11.83	5.99	31.20	32.93	2.00	3.26	4.12	4.01	11.36	8.29	25.68	41.29	196.43
LUX	0.70	1.80	2.08	6.09	2.61	6.07	54.55	26.10	-0.07	0.62	0.81	-1.64	0.35	5.42	66.61	27.89	113.78
LVA	5.12	4.22	1.64	1.85	11.87	11.87	6.95	35.55	2.19	4.46	2.70	2.83	4.78	4.78	6.75	35.81	110.14
MLT	2.20	2.53	8.10	2.91	9.93	5.77	35.36	33.20	0.42	0.07	-4.37	0.05	-0.19	1.93	6.03	23.20	21.86
NLD	2.50	4.03	6.29	2.98	5.98	5.42	45.37	27.43	0.47	5.81	2.36	1.20	2.00	2.60	65.17	20.39	48.42
POL	3.30	6.13	4.65	5.06	8.34	8.62	31.56	32.35	2.76	6.68	6.60	6.97	7.40	5.97	33.50	30.12	120.57
PRT	3.55	3.09	4.03	4.09	9.05	7.64	38.24	30.31	-1.19	5.77	-0.59	0.55	2.11	-4.59	39.64	58.30	34.74
ROU	12.02	5.66	4.84	4.68	12.56	5.78	26.28	28.19	2.78	6.03	6.53	5.72	10.02	8.98	35.00	24.93	262.13
SVK	4.42	4.96	7.05	7.89	8.96	7.20	28.94	30.58	4.39	4.09	8.84	6.69	4.16	8.84	34.94	28.05	243.60
SVN	3.31	3.56	8.85	6.51	9.57	6.51	35.62	26.06	1.10	5.33	12.74	7.02	0.54	4.51	40.52	28.24	68.29
SWE	1.90	2.72	12.37	4.15	6.46	4.66	41.49	26.24	0.39	5.26	3.55	1.53	-1.20	8.60	55.77	26.10	53.05
EU sample average	**3.97**	**3.91**	**6.71**	**4.40**	**7.78**	**6.45**	**36.35**	**29.68**	**0.79**	**4.29**	**4.54**	**2.23**	**2.96**	**3.42**	**45.19**	**32.72**	**91.97**

As can be seen, the services economy, that is, blocks 7 and 8 represent the most significant part of the economies, with a sample average of 66.03% of the total VA generated in EU countries in 2000. Moreover, for most EU countries, the sectors included in the group of KIS (block 7) had a higher share in VA than the traditional services included in block 8. However, notable exceptions are Bulgaria, Czech Republic, Estonia, Lithuania, Latvia, Poland, and Romania having a higher participation of block 8.

More specifically, the different specialization of EU countries in this relevant group of knowledge intensive sectors is one of the most remarkable characteristics of structural composition of EU countries. In 2000, almost all the Western economies had a higher share of the KIS block than the sample average, most of them above 40% and being relevant the case of Luxembourg (54.55%). One the contrary, none of the Eastern economies has a share above the sample average in this relevant group of sectors.

Regarding the role in the value added of the group Rest of Services, we can see the highest shares in Cyprus, Estonia, Greece and Latvia (over 35%), being also relevant the share of this block in other Mediterranean countries such as Spain, Italy, Malta and Portugal, as well as in Poland.

A significant feature is that a group of Eastern economies appeared in 2000 as the most specialized in the Primary sector. This is the case of countries such as Bulgaria, and Romania which more than tripled the EU sample average, and to a lesser extent Greece, Croatia and Lithuania, all clearly specialized in the primary sector, with a VA share higher than 5% in all the cases. Bulgaria, Croatia and Romania, also stand out, together with Denmark and Poland, regarding the contribution of the energy sector to the economy.

Important differences among countries can be seen regarding industry specialization. Germany, Ireland and Sweden appeared in 2000 as the EU countries more specialized in the HT and MHT industry, for which these sectors contributed more than 10% of their VA. This share is also significant in Belgium, Finland and a group of Eastern economies such as Czech Republic (9.67%), Hungary (9.84%) and Slovenia (8.82%)

Moreover, Czech Republic, Slovakia and Slovenia clearly stand out by their specialization in medium-low technology industries, contributing more than 6.5% to their VA (40% more than the sample average). Similarly, other EU Eastern economies appeared as the most specialized countries in low-technology industries; this is the case of Estonia, Lithuania, and Romania with shares above 11% (40% above the sample average for this industry block).

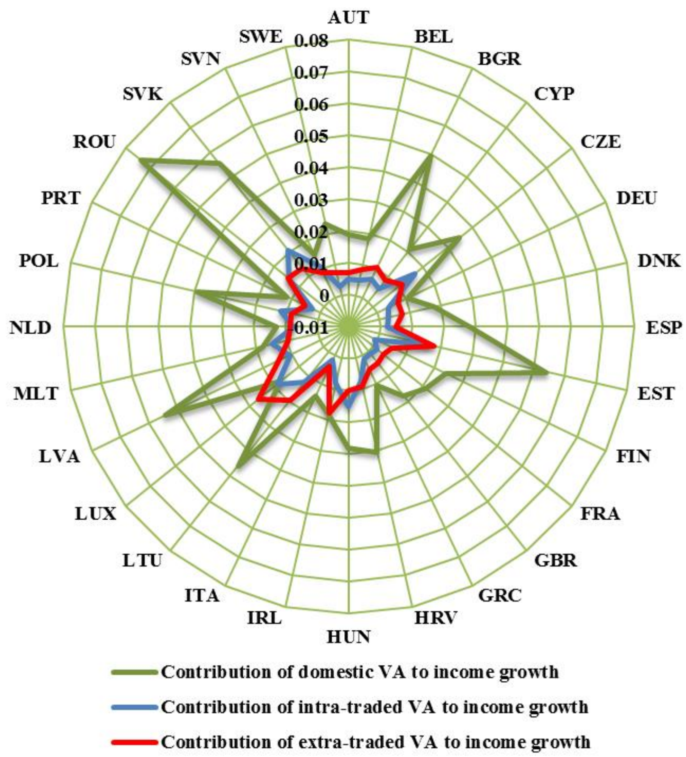
Table 5 also shows the contribution of the different productive blocks to income growth by country. As can be seen, different patterns of growth can be deduced for the different countries.

In general terms, economic growth over the period for the whole of the EU was mainly explained by growth in the services economy (blocks 7 and 8). However, the pattern of growth shows several differences by groups of countries. The most dynamic countries in the whole period were the Eastern economies and particularly (Bulgaria, Czech Republic, Estonia, Lithuania, Romania and Slovakia). In these countries, the growth of services explains around 70% of their total growth in Bulgaria, Estonia and Lithuania and around 60% in Czech Republic, Romania and Slovakia. The contribution to growth of KIS was in general higher than the rest of services safe for the case of Lithuania. However, it can be noted that despite this positive behavior, these countries were below the sample average in terms of the contribution to growth of the services sectors. These countries have also based an important part of their economic growth in a positive evolution of the manufacturing sectors, mainly driven by the evolution of their domestic demands and the increasing intra-EU trade. Thus, the contribution of HT&MHT industry was significantly important in Czech Republic and Slovakia, doubling the average of the EU countries, being also very important in Hungary and Slovenia. Moreover, in contrast with very reduced or even negative contributions to growth of low and medium-low technology in most Western EU countries, the contribution of these blocks in Easter Europe has been important. Note for instance the contribution of low technology in Lithuania (11.36%), Romania (10.02%) and Bulgaria (8.44%) as well as the contribution of medium-low technology in Czech Republic (7.03%), Romania (5.72%), Slovakia (6.69%) and Slovenia (7.02%), more than doubling the average. Given the size of Poland, it is also notable the contribution to income growth of all the manufacturing sectors. The expansion of these economies is also behind the significant contribution to growth of the construction and energy sectors. In summary, Eastern European economies are characterized by an important dynamism of the services sectors as well as the manufacturing industry. This is mainly related to the new domestic demands (associated to increasing per capita income of their citizens), and the production of medium and low technology sectors, more focused on basic and intermediate goods to fulfill domestic demands as well as supplying western economies and, increasingly, extra-EU markets.

When we focus on the growth patterns of the largest EU economies (in 2000 these economies were Germany, France, Italy, UK, Netherlands and Spain), their growth rates were in average significantly lower than in the case of the Eastern Europe economies, and this scarce growth mainly relied on the evolution of KIS sectors. As example, these sectors represented 65.25% of VA growth in UK, 57.45% in France, being 65.17% in the Netherlands, being much more moderated the contribution of this block in Spain and Italy (around 44%). In these latter two countries, the rest of services contributed to growth by 45%, clearly above the average. Regarding the manufacturing sectors, the contribution of these sectors to economic growth was reduced and even negative in some cases, especially the medium and low technology. Block 3, HT&MHT represented a significant contribution in Austria (accounting for 8.95% of the country growth rate), Germany (16.30%) and Denmark (9.44%).

This pattern of growth is also reflected in the contribution of domestic and intra-EU trade components to EU income growth. Following Fagerberg and Verspagen (2014), in Figure 3 we present the contributions of the three categories of VA to overall income growth for the 28 European countries included in the WIOD database, which have been ordered according to their contribution of domestic demand to income growth, because it is the most remarkable variable.

Figure 3. Contributions of domestic demand, intra-EU trade, and extra-EU trade to average income growth, by country, 2000-2014

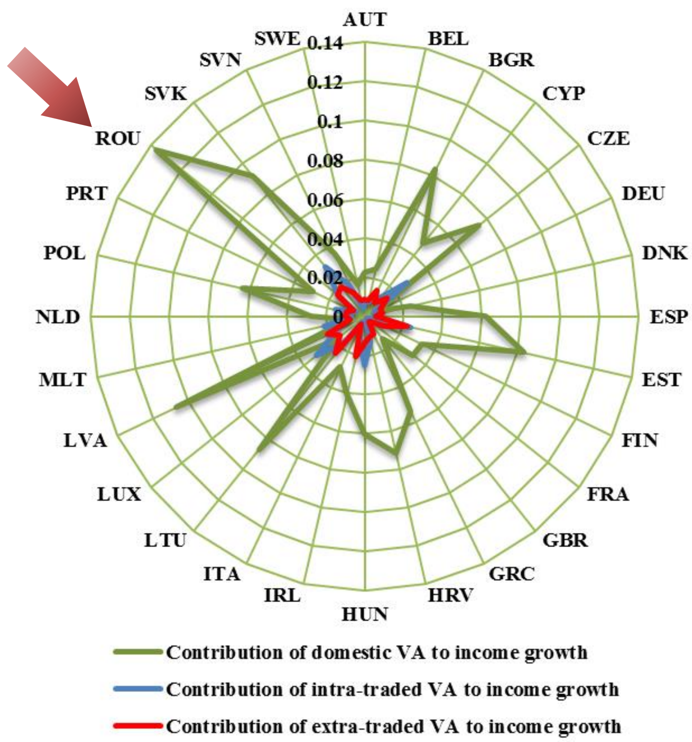


Source: Own elaboration

In this radial graph, we can see that the domestic demand (household consumption, public expenditure, and investment) of the 28 member countries of the European Union has been the main contributor to EU income growth. We can appreciate that Eastern European countries are those that, on average, have most of their income growth due to the dynamism of their internal demand. This is the case of Romania, Estonia, Slovakia, and Latvia. On the other hand, Central and Southern European countries, present a relatively lower contribution of domestic sources. The case of Luxembourg is quite different, mainly due to its traditional internationalization, and it is the only country presenting a similar contribution of domestic and intra-EU traded sources and a significant contribution of extra-EU trade.

The average behaviour shown in Figure 3, however, can hide the different situation of countries before and after the international crisis of 2008 in terms of these magnitudes. To illustrate this, Figures 4 and 5 show the contribution of the same variables, now in two different sub-periods, 2000-2008 and 2008-2014.

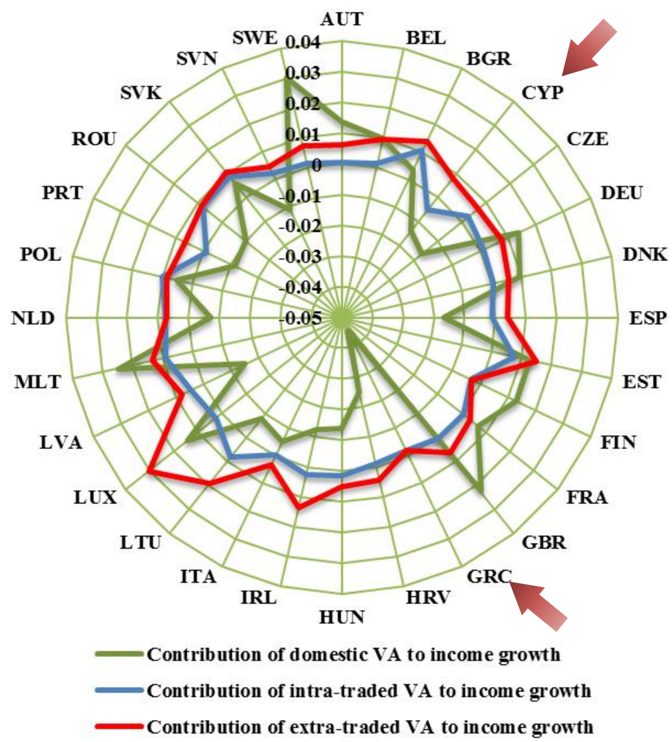
<u>Figure 4.</u> Contributions of domestic demand, intra-EU trade, and extra-EU trade to average income growth by country, 2000-2008



Source: Own elaboration

As can be seen, the period 2000 to 2008 (the expansive period) is characterized by an economic growth rate highly dependent on country-domestic demands. The weight of the VA traded with the other countries of the European Union and with non-European countries is very low compared to the internal sources. The most notable case is Romania, with a contribution of internal demand to income growth of 13.61%. Again, the Eastern European countries (Romania, Bulgaria, Estonia, Lithuania, Latvia, and Slovakia) are the ones with the largest contribution of domestic demand to income growth, compared to other member states.

Figure 5. Contributions of domestic demand, intra-EU trade, and extra-EU trade to average income growth, by country, 2009-2014



Source: Own elaboration

As can be seen in Figure 5, the onset of the international crisis seriously affects the generation of income in EU countries, with certain very clear features. First, a sharp decline in average growth rates (close to zero). Second, important changes in the role of intra-EU and extra-EU trade as sources of growth. Basically, trade, and particularly extra-EU trade, drove the weak income generation in many countries, compensating to some extent for the collapse of internal demand. Looking by country, Luxembourg again stands out as the most internationalized country in Europe, from this perspective. From 2009 to 2014, certain European countries, such as Cyprus and Greece, experienced negative income growth, caused mainly by the fall of their domestic production. From the graph, we can also see how the crisis caused the old member countries of the European Union to reduce their contributions to income growth, especially in the cases of Greece and Cyprus. Some Central and North-European economies, as in the cases of Sweden and the United Kingdom, increased their income, with the three magnitudes, domestic demand and total trade boosting this growth.

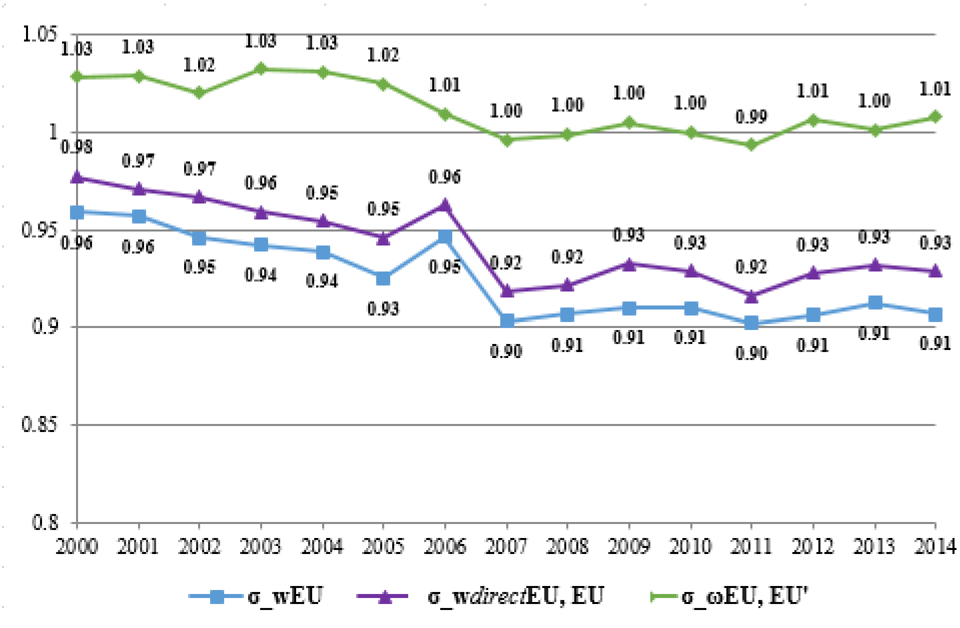
This first analysis offers a scenario of several behaviors in Europe regarding recent economic growth and leading factors and evidence that there may have been a real structural rupture around the beginning of the crisis, in 2008, which will be tested later. The following questions are, in consequence, whether these differential behaviors resulted in an increasing convergence or divergence in the European countries, which have been the contributing factors and how can we evaluate the results from an integrated European perspective.

3.1. Sigma-convergence at the country-industry level

Figure 6 shows the evolution of *sigma* over the period 2000-2014, calculated as described in (2.3), taking as measure of income a range of variables: first, the "Direct VA", that is, the total income generated in each European country (internally and traded with other EU countries and non-EU countries; that is, *sigma* convergence on the components of vector). Second, we use the "Total Intra direct VA", taking into account only intra EU-trade and domestic production (*sigma* convergence on the components of vector $\mathbf{w}^{direct\text{EU,EU}} = \mathbf{\Omega^{EU,EU}i}$). Third, we compute the *sigma* convergence on the "EU embodied VA", that is, the convergence in the total income generated in the European Union and incorporated into the final products of each country ($\boldsymbol{\omega}^{\mathbf{EU,EU}'} = \mathbf{i}'\mathbf{\Omega^{EU,EU}}$). The first two variables refer to the generation of income in each EU country that is driven by its domestic demand, and its trade, both EU internal and external. Our third variable captures the value-added embodied in the final production of a given country and generated in other European countries. This embodied value-added reflects the productivity transfers from one EU-country to another.

For each year, our sample consist of 1,568 observations, corresponding to the 28 European countries and 56 industry sectors classified according to the International Standard Industrial Classification in the World Input-Output database.

Figure 6. *Sigma* convergence in income (total direct VA, total intra-EU direct VA, and total embodied VA), 2000-2014

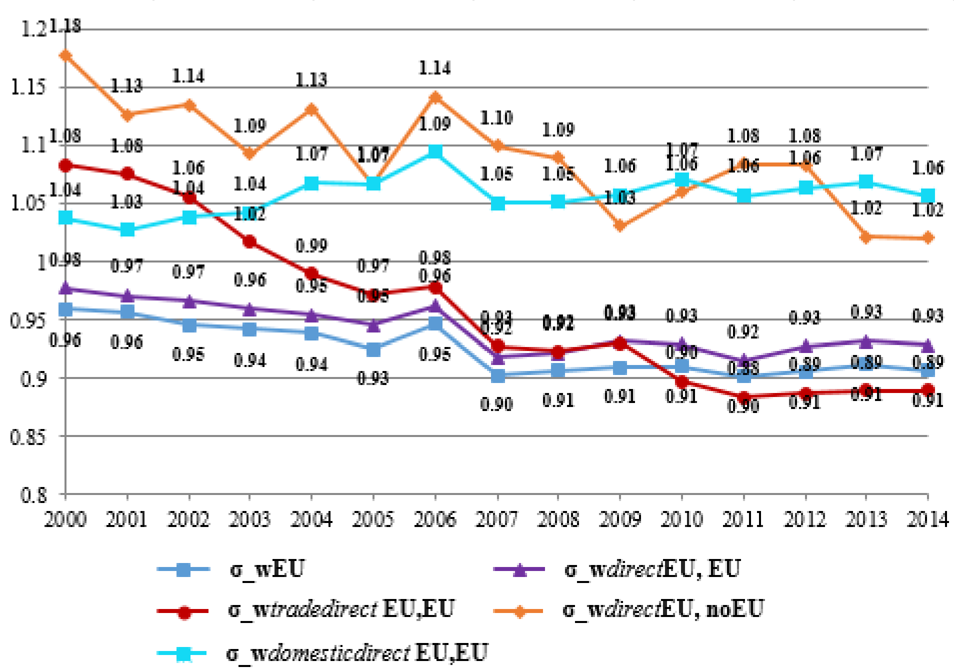


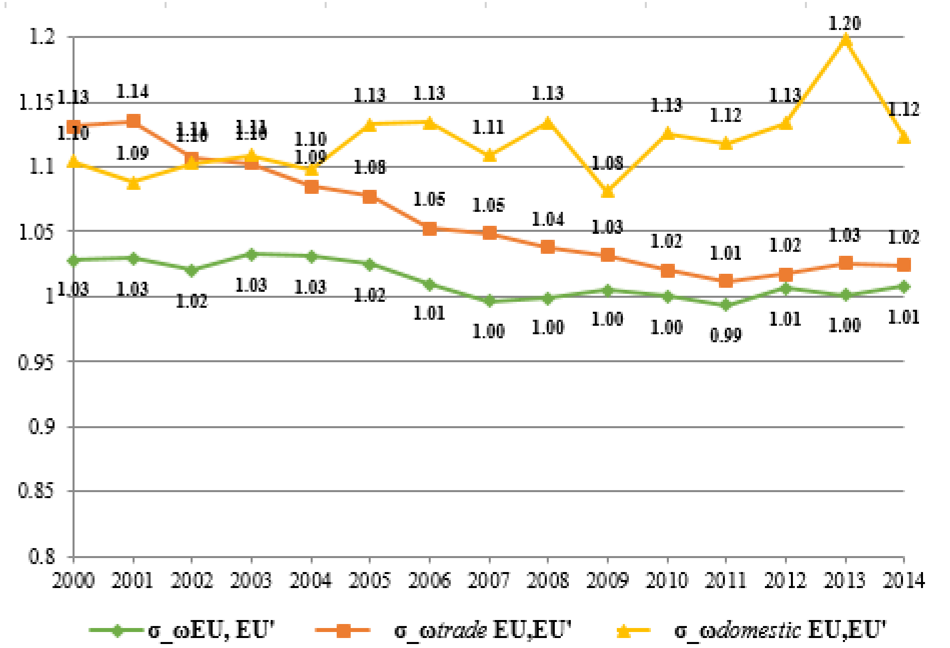
Source: Own elaboration

Figure 6 shows in the blue line the *sigma* convergence calculated as a measure of dispersion in the value-added generated by each country ("$\mathbf{w}^{EU}$ = total direct VA"). It also shows the evolution of *sigma* calculated over the total income generated in the European Union and embodied in the final products of the different countries in green, and the *sigma* over the total intra direct VA in violet. We can see a clear convergence until 2008 (reduction in *sigma* in the three cases), followed by a period of instability, combining stages of convergence and divergence, from that year until the end of the analysed period. In other words, the three magnitudes show a clear process of convergence in Europe that abruptly ended in 2008.

While the evolution of traditional $\boldsymbol{\sigma}\_{wEU}$ reflects the convergence or reduction in production disparities across countries, the decline in $\boldsymbol{\sigma}\_{\omega EU,EU}$ shows a convergence of countries to a similar composition in their final products in terms of net values, that is, a convergence of countries in technologically-integrated productivity. This last convergence is a key factor for the process detected via classical *sigma* convergence and shown in the blue line. Moreover, when we focus on the intra-EU figures, we obtain, as expected, similar values to the total direct VA, mainly due to the significance of country-domestic demands as drivers of production in the EU, particularly in the first part of the period. Once the evolution of *sigma* convergence has been analysed for the three variables, we go deeper into the behaviour of the different components, that is, the “trade” and “domestic” components of $\mathbf{w}^{\mathbf{EU}}$= total direct VA, and $\boldsymbol{\omega}^{\mathbf{EU,EU'}}$= total embodied VA. The three σ from Figure 6 and the four new σ are shown in Figure 7.

Figure 7. *Sigma* convergence in the different components of direct and embodied VA, 2000-2014





Source: Own elaboration

When we focus on the trajectory that follows the magnitudes in both graphs, we can appreciate that European countries present the greater convergence rate for the VA incorporated in intra-EU trade, suggesting that the common market has been a strong source of convergence in Europe. Moreover, when we compare the direct and embodied magnitudes, the European Union converges much more in the direct values, that is, more in direct than in technologically integrated productivity.

If we focus on the trade with non-EU countries, we also discover a clear convergence during the period, before and after 2008, confirming that trade, intra and extra trade, has been an important factor of convergence in the EU.

By contrast, when we focus on the two comparable magnitudes (total intra-EU direct VA = $\mathbf{w}^{direct\text{EU,EU}}$ in violet, and total embodied VA = $\boldsymbol{\omega}^{\mathbf{EU,EU'}}$ in green), both evolutions have small ups and downs until reaching a level of convergence at the end of the period that is very similar to that of the beginning. However, in both cases, we can see a slight convergence from 2000 to 2014, higher in direct VA.

Undoubtedly, the most remarkable behavior in both graphs from Figure 7 is the one that presents the domestic VA, given that the bulk of the income generated in European countries is driven by domestic demand. These components clearly show a negative convergence (increasing trends), revealing than the domestic European demands (private and public consumption and investment demands) are not fostering economic structures in the direction of generating higher convergence in income, and again confirming the role of trade as driver of convergence. Surprisingly, the domestic productive conditions of each EU country do not seem to tend clearly to converge.

In order to better understand the meaning of these results, and taking advantage of the multiregional-multisectoral nature of our data, in what follows we perform a decomposition analysis of the standard deviation **σ_wEU** previously obtained. With this study, we want to verify which part of the total variation of convergence or divergence **σ_wEU** is due to the variation or dispersion between European countries (σ_{INTER}) and which part is due to the variation or dispersion within each country (σ_{INTRA}). Therefore, we have the following decomposition of the standard deviation:

$$\boldsymbol{\sigma}_{\_\mathbf{wEU}}{}^{\mathbf{2}} = \sigma_{INTER}{}^{2} + \sigma_{INTRA}{}^{2}$$

The above formulation can be expressed as:

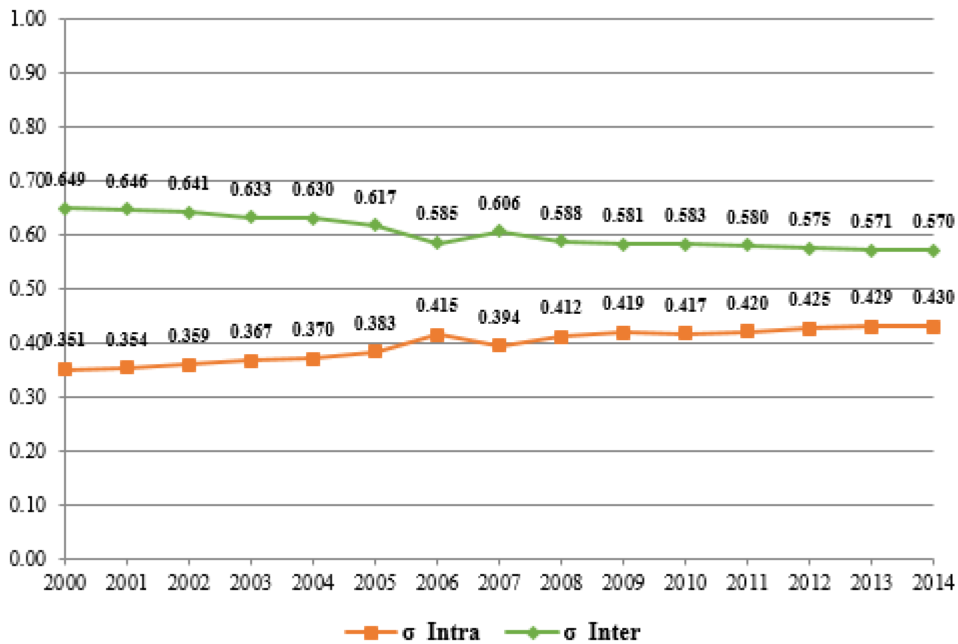
$$\frac{\sum_{j=1}^{g}\sum_{i=1}^{n_j}(\log(VA_{ij}) - \overline{\mu}_{\bullet\bullet})^2}{N} = \frac{\sum_{j=1}^{g} n_j(\overline{\mu}_{\bullet j} - \overline{\mu}_{\bullet\bullet})^2}{N} + \frac{\sum_{j=1}^{g}\sum_{i=1}^{n_j}(\log(VA_{ij}) - \overline{\mu}_{\bullet j})^2}{N}$$

where $\overline{\mu}_{\bullet\bullet}$ is the total average and $\overline{\mu}_{\bullet j}$ is the average of each European country.

Through this decomposition analysis of the total standard deviation in its two components, we want to check if possible similarities or differences within the European Union are due to differences across countries or differences within each country, i.e. among their sectors.

In Figure 8, we present the evolution of the share of each component. As can be appreciated, the initial share of inter-country deviation is higher than the share of intra-country deviation for all the analyzed periods, but it is also decreasing showing a clear convergence trend. By contrast, the intra-country share grows from 2000 to 2014, showing a slight trend to a higher productive difference between domestic sectoral structures, in line with the results obtained before for the convergence of domestic components. In this regards, our results suggest that EU countries have tended to be more similar among themselves in productivity and growth rate (given the different growth rates observed in the period in the different areas of Europe), but tend to be more diverse regarding their sectorial composition. The economic crisis meant a certain disruption in this process. However, from 2009 to the end of the period analyzed, European countries seem to confirm the trends observed again. Undoubtedly, the different behaviors observed in the inter-country and intra-country components demands a more in depth analysis of the evolution of main magnitudes at these two different scales.

Figure 8. Evolution of the deviation components (inter and intra), 2000-2014



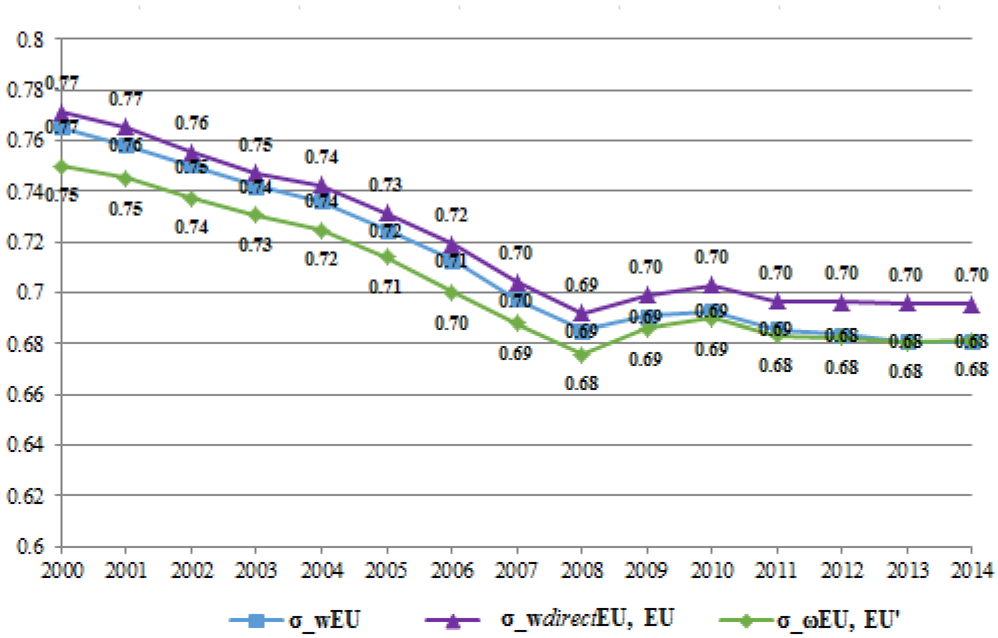
Source: Own elaboration

3.2. Country-convergence

Once the hypothesis of convergence has been studied at a disaggregated level, we perform a similar analysis aggregating the information by country, i.e. eliminating the sectoral variability within the countries. This means working with only 28 observations (corresponding to the 28 EU countries) and according to the previous results we should expect a strong convergence.

As a general result, the dispersion values are smaller than in the previous section, but confirm the general trends obtained at the disaggregated level, suggesting a more similar growth behaviour of countries in Europe in the expansive period, with a reduction in the *sigma* coefficient over 0.5 pp, as can be seen in Table 6.

<u>Figure 9.</u> *Sigma* convergence in income (total direct VA, total intra-EU direct VA, and total embodied VA). Aggregated data by country



Source: Own elaboration

The data presented in this Figure 9 confirm the general results obtained at the disaggregated level (see Figure 6). That is, the convergence trend is also observed for the three magnitudes until 2008, there is a structural breakdown that year, and a loss of convergence until the last year of the analyzed period. To appreciate this more fully, we analyze in Table 6 the values of the coefficients of the regression equations.

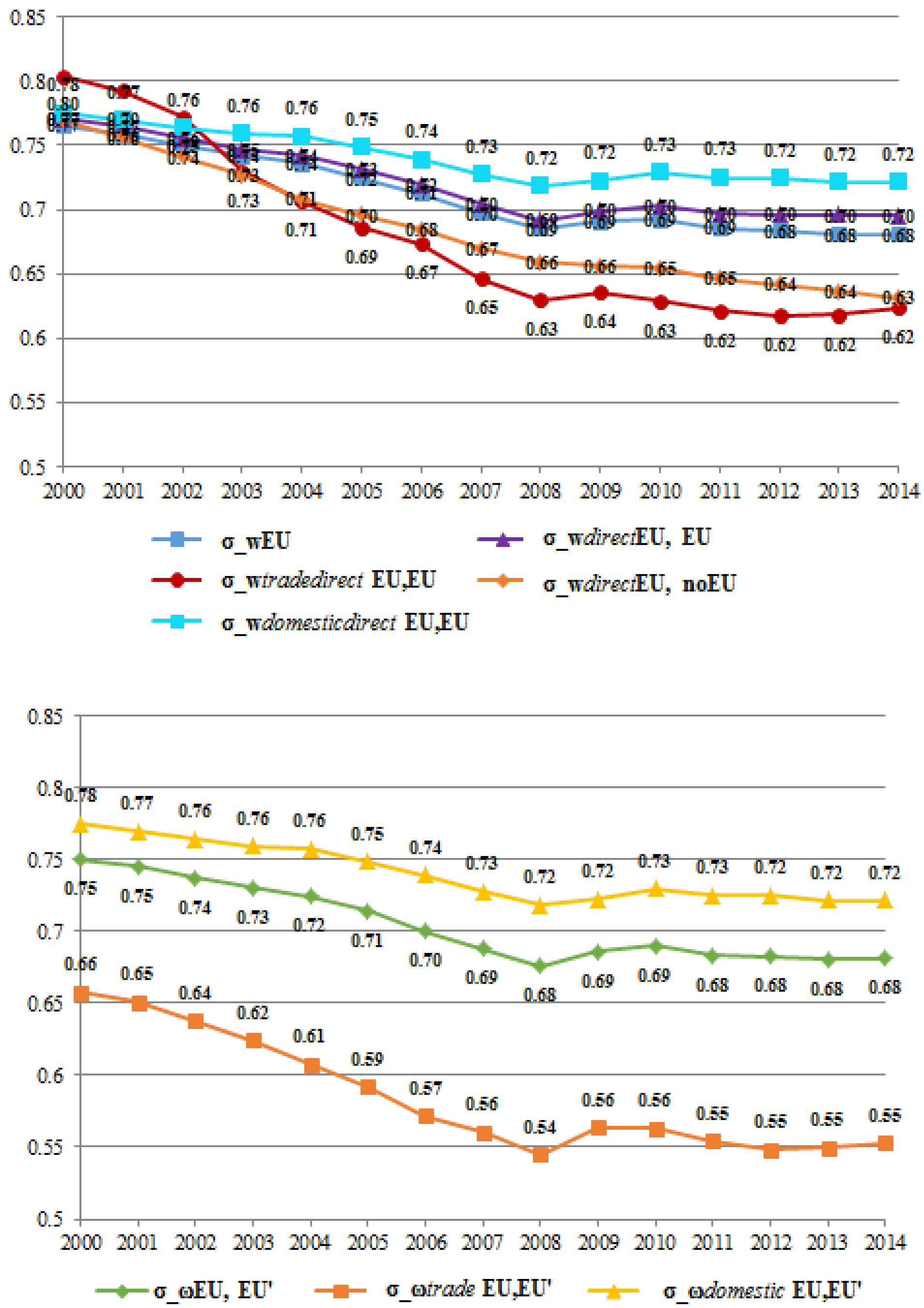
Table 6. Results of regression equations

	σ_{wEU}	$\sigma_{wdirect\ EU,EU}$	$\sigma_{\omega EU,EU}$
	2000-2014		
α	0.7649	0.7681	0.7479
β	-0.006	-0.0059	-0.0054
p-value	3.61e-08 ***	5.86e-07 ***	1.15e-06 ***
	2000-2008		
α	0.7798	0.7854	0.7650
β	-0.0099	-0.0098	-0.0093
p-value	3.51e-07 ***	3.81e-07 ***	9.02e-07 ***
	2009-2014		
α	0.6944	0.7016	0.6889
β	-0.0025	-0.0012	-0.0015
p-value	0.0073 **	0.0862 *	0.0559 *

Source: Own elaboration

We can see that both the estimations of the constant and the estimations of the time coefficients variable are similar. For the full period, in the three cases, the trend is negative, showing the increase of convergence between European countries, except for the last years of uncertainty. However, when we observe the period after the crisis, the values for trend in the three magnitudes are smaller than in the period 2000-2008. Moreover, it is clear that the trends are not significant (as can be seen in Figure 9) in the second sub-period, suggesting that after the onset of the economic crisis, European countries seem to be in a period of uncertainty about the evolution of convergence.

Figure 10. *Sigma* convergence in the different components of direct and embodied VA, by country, 2000-2014



Source: Own elaboration

As we have done in the previous, more disaggregated analysis (see Figure 7), Figure 10 presents the convergence behavior of the subdivisions of the total direct and embodied income. Again, the dispersion when taking as income the intra-traded VA presents the greatest decline in both charts. We also have a strong declining result for the extra-traded VA. That is to say, the general trend is a rising productive integration within the EU region driven by both the intra-EU trade and extra-EU trade; this regional integration generates reductions in income disparities among countries and contributes to homogenize the contribution of the EU as a whole to the economic growth of countries.

Note now that the domestic components are also declining in both cases, with a softer trend than those of trade components. We have here different results from those in Figure 7; there the domestic components did not converge due mainly to increasing differences between domestic sectoral structures, which are not captured in Figure 10 because we are only focusing on the countries, not on sectors.

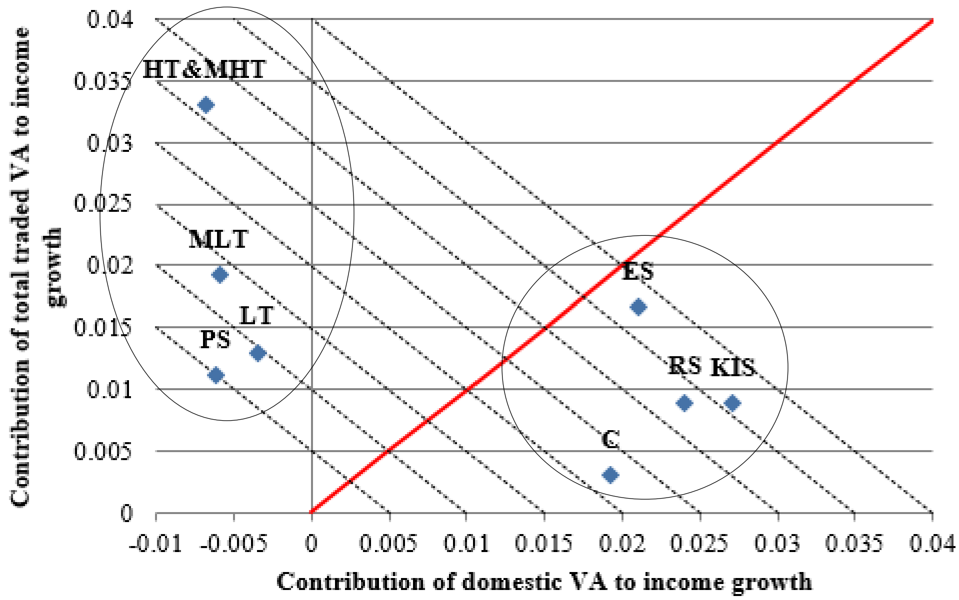
3.3. Convergence by industry-blocks

Our final analysis refers to the convergence in the generation of income by sector in the EU. According to the results obtained in Table 5, block 7 and 8, corresponding to knowledge intensive services (KIS) and the rest of services (RS) have been the most dynamic sectors for the total EU. Nevertheless, the group of Eastern European countries, the most dynamic over the period studied, have notably based their growth on the positive behaviour of medium and low technology manufacturing sectors (MLT and LT), together with a positive reliance of the primary sectors. In this context, it is interesting to analyse the role that the different components of VA (domestic, intra-EU and extra-EU) which have also a different sectoral character, has played driving sectoral growth in EU countries.

As has been done before, the 56 economic sectors have been aggregated into 8 sectoral blocks according to their technological level. We want to check whether the convergence-divergence phenomenon observed in Europe is due in particular to some specific sectors, or whether it is a common feature affecting all the sectors. Thus, we are looking at the industry character of convergence, an important aspect usually neglected in the literature.

Before analyzing the behavior of *sigma* convergence for the different sectoral blocks, Figure 11 shows the sectoral contribution by domestic demand and trade (intra-EU and extra-EU trade) to income growth in Europe.

Figure 11. Average contributions of domestic demand and trade to income growth in Europe, by sectoral blocks, 2000-2014

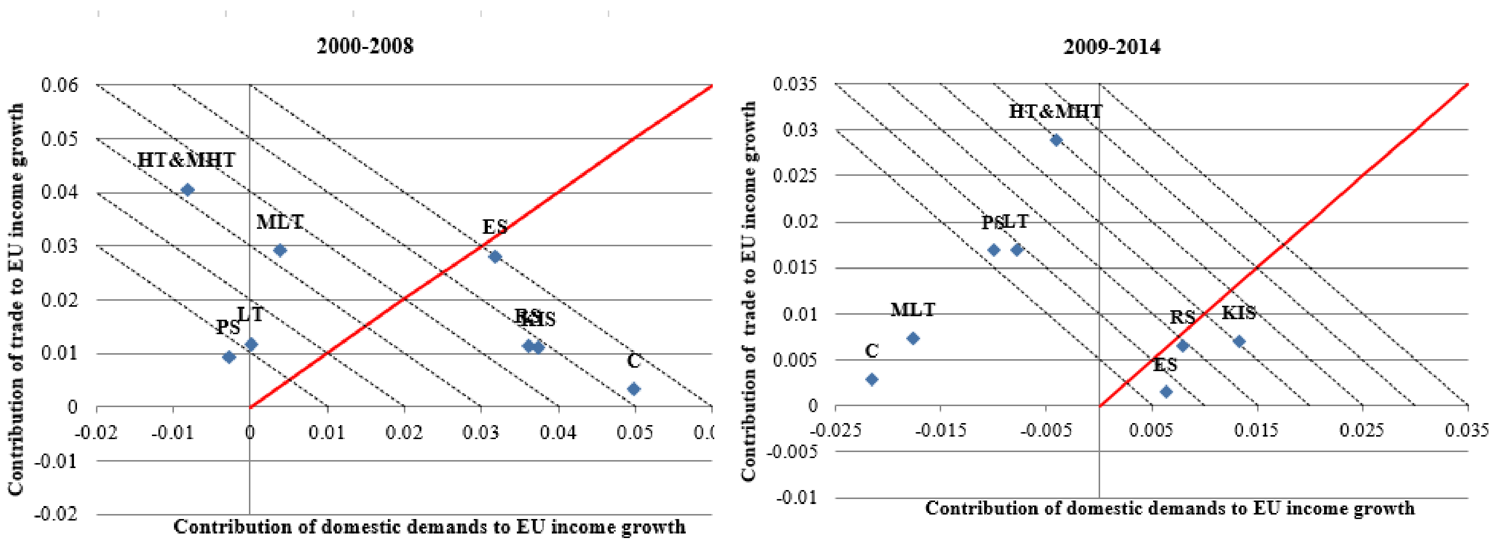


Source: Own elaboration. PS: Primary sector; ES: Energy sector; HT&MHT: High and medium-high technology industry, MLT: Medium-low technology industry, LT: Low technology industry, C: Construction, KIS: Knowledge intensive services, RS: Rest of services

In Figure 11, there are two groups of sectors. The services, energy and construction sectors play a significant role in domestic demand and drive income generation; in Energy sector we observe a quite similar participation of domestic and foreign demands as sources of growth in Europe. The second group is the primary sector and manufacturing (particularly the HT&MHT industries) for which trade is the main (and significant) source of income generation, even compensating for declines in country domestic demands. The differential behaviour of the technology-intensive sectors in Europe is notable. It is clear that KIS in Europe has been a dynamic sector and has based its growth on serving country-domestic demands. On the contrary, the technological industry sectors, and particularly the HT&MHT, have had as main source of income generation the increasing international demand, boosted by both intra-EU expansions of markets and extra-EU world demands. In addition, when we add the contributions of the domestic and commercial parts, it is clear that KIS and ES are the ones that contribute most to the growth of the European Union's income, while LT and PS have the lowest but positive contributions.

These results are also in line with those presented in Table 5, which highlighted the dynamism of manufacturing in Eastern European countries (see Table 5) but also the importance that the new domestic and intra-EU demands of services in these economies (and also in the whole EU) have had explaining income growth.

Figure 12. Contributions of domestic demand and trade to income growth in Europe, by sectoral blocks and sub-periods

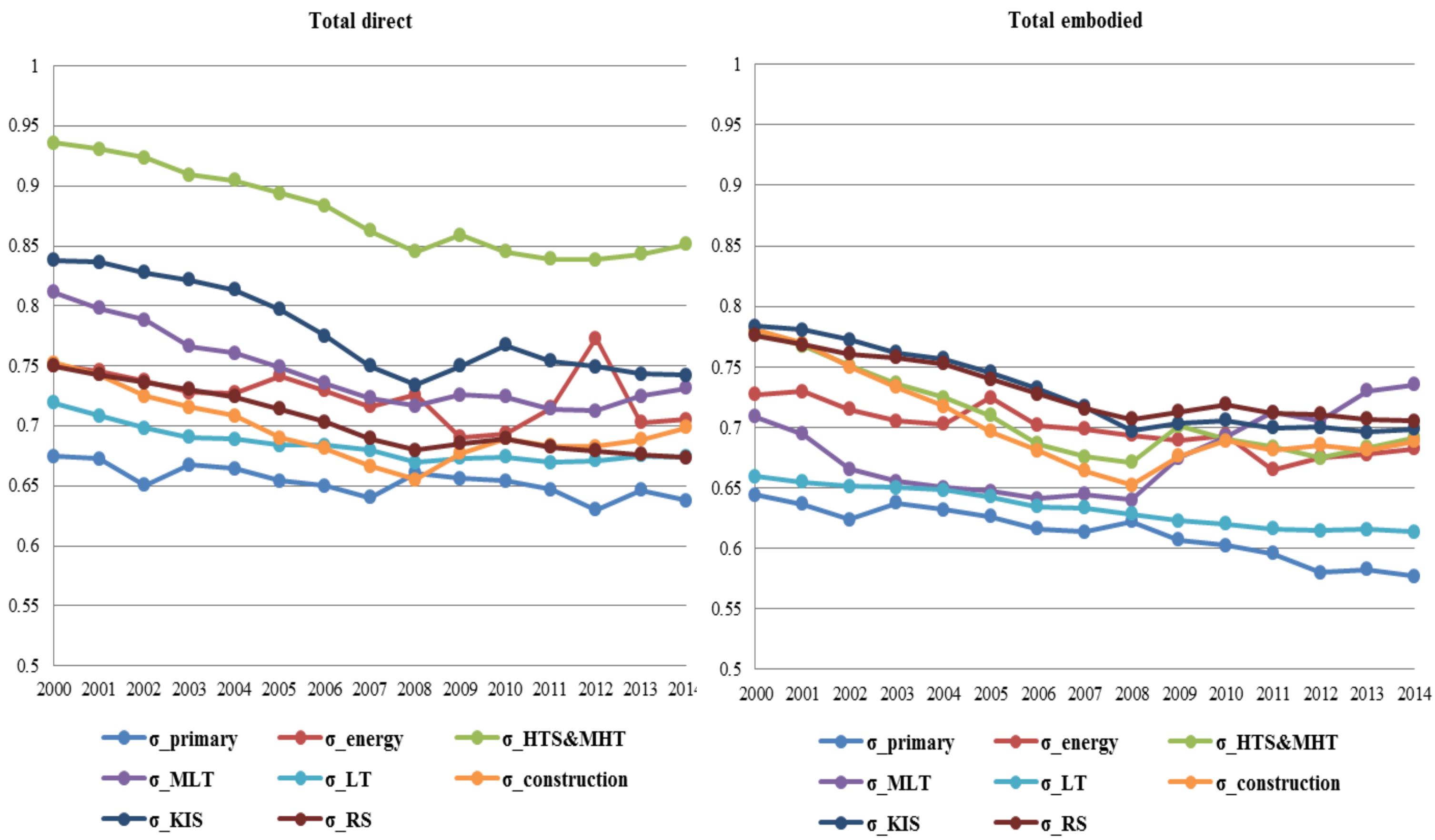


Source: Own elaboration. PS: Primary sector; ES: Energy sector; HT&MHT: High and medium-high technology industry, MLT: Medium-low technology industry, LT: Low technology industry, C: Construction, KIS: Knowledge intensive services, RS: Rest of services

The analysis by sub-periods also offers interesting insights into industry behaviours. In the expansion period, services and construction were the most dynamic sectors, followed by HT&MHT and MLT, with LT and PS achieving the last positions. In the post-crisis period, HT&MHT and KIS are the growth leaders, followed by rest of services (RS), getting the last positions MLT and C, both with negative growth rate.

It should be noted that construction is the sector that has experienced the greatest change as a result of the crisis, having gone from being one of the most dynamic sectors for growth (the second), to being the most backward. Moreover, there are two different growth profiles from 2000 to 2014: sectors focused on domestic demand before the 2008 crisis; and high technology sectors after the 2008 crisis, mainly oriented to intra-EU and extra-EU trade. Note that both changes are compatible with non-convergence of domestic components of VA previously detected. Additionally, the study of *sigma* convergence by sectoral blocks provides the results seen in Figure 13.

Figure 13. *Sigma* convergence in total direct and embodied VA, by block sector, 2000-2014



Source: Own elaboration

Figure 13 shows the evolution of *sigma* convergence, taking as income the total VA direct (first graph) and total VA embodied (second graph) generated by the 8 blocks of sectors. As we can see, when we take into account direct values, the high- and medium-high-technology industrial sectors are the most divergent over the period, followed by knowledge-intensive services (KIS). Thus, European countries present the greatest differences in the income generated by the most technology-intensive sectors. However, these are also the sectors (together with the Energy sector) showing the highest convergence rate in the period before the crisis. Their convergences end when the crisis arrives.

By contrast, the primary and low-technology sectors are the most homogenous over the whole period showing a very weak or null convergence before and after 2008 crisis. In sum, our results suggest that the convergence in income observed in Europe, especially before the crisis, is the mixed result of a certain homogeneity in specialization in basic and non-technological sectors, and important but decreasing differences in high-technology sectors (predominant in the Western European countries). After the crisis, a new trend in sectoral convergence is not clearly delineated.

When we look at the second graph, with embodied values, we obtain a different picture. First, figures for HT&MHT and KIS are less marked in terms of embodied income than in direct income, suggesting that products consumed by European citizens have more similar technology-intensity content, no matter the country of origin. In other words, trade within Europe has allowed the diffusion of technology among EU countries. EU products in different countries tend to incorporate similar technology components, although technology production tends to be more geographically concentrated.

Another important feature obtained from the embodied data is that the impact of the crisis in the different sectors varies widely in terms of convergence. The primary sector and the low-technology industry are barely affected by the crisis in terms of convergence and both continue increasing slowly their convergence after 2008. In both cases, we observe a reduction in the discrepancies among countries, which take place in parallel to the progressive and generalized loss of importance of these sectors in the economy. On the contrary, Construction and the Medium-low-technology sectors are those in which the economic crisis generated larger disparities among countries regarding embodied income. Due to the importance of these blocks (in terms of share of the total economy), a significant part of the current disparities in the domestic (internal) income component can be understood as stemming from their evolution. Additionally, the structure of these sectors, with a clear country-demand focus in the first case, and with a significant export orientation in the second (to compensate for the strong reduction of domestic demands), provides some idea of the directions in which the EU economy moves and converges.

4. *Conclusions*

Economic growth and convergence have always been seen as among the most important objectives in the EU, as a way to achieve high levels of welfare for all European citizens. The international economic crisis has involved profound and rapid changes, not only in the path of growth but also in the structural and technological characteristics of EU countries. These elements affect economic outcomes and convergence.

Our objective in this second chapter is to study the recent evolution of the *sigma* convergence in Europe from a new perspective, paying attention to the multi-sectoral and increasingly multi-regional nature of income generation. Thus, traditional measures of economic convergence have been extended to a multi-regional input-output framework, which allows us to study how productivity is translated to convergence through the European supply chains, and to identify the technological and structural bases of the convergence.

Our results show a clear breakpoint in the process of EU convergence, around 2008, an increasing role of trade in explaining the domestic and total evolution of income in Europe, and a differential contribution of sectors according to their technological nature.

More specifically, our study of the value-added generated in Europe and its distribution among countries for the period 2000-2014 shows that the role of trade (intra-EU and extra-EU) has widely expanded and strengthened, particularly in certain countries and sectors, while other regions have based their incipient recovery on the strength of internal demands.

The economic analysis confirms the structural break in the convergence process in 2008, and this holds in general for all the magnitudes analysed, which suggests an impact on the structural relationships contributing to increase inequality in Europe in recent years.

The analysis by industry-blocks also reveals significant differences in Europe. Our results have shown of the significant share of services in income growth in Europe as well as its role as driver of domestic demands in all the countries. EU countries mostly differ in the generation of income through high-technology and KIS, although a certain convergence is observed before the crisis, which is driven by trade (intra-EU and extra-EU) and technological sectors. After the crisis, the convergence process stops, but trade continues pushing in the same direction but with less force. The convergence in non-technological sectors appears less affected by the international crisis than technological ones. Moreover, the evolution of the construction and energy sectors has been an important source of instability and divergence in the last few years.

In the same way, the analysis shows a higher convergence in embodied values than in direct values, which suggests a real convergence in the consumption patterns of European citizens, and the evidence of a significant role of intra-EU trade in fulfilling their demands. This process has contributed to economic growth in Europe that has been unequal, primarily due to the initial situation of countries and their different capacities to generate income linked to the high-technology sectors and the KIS.

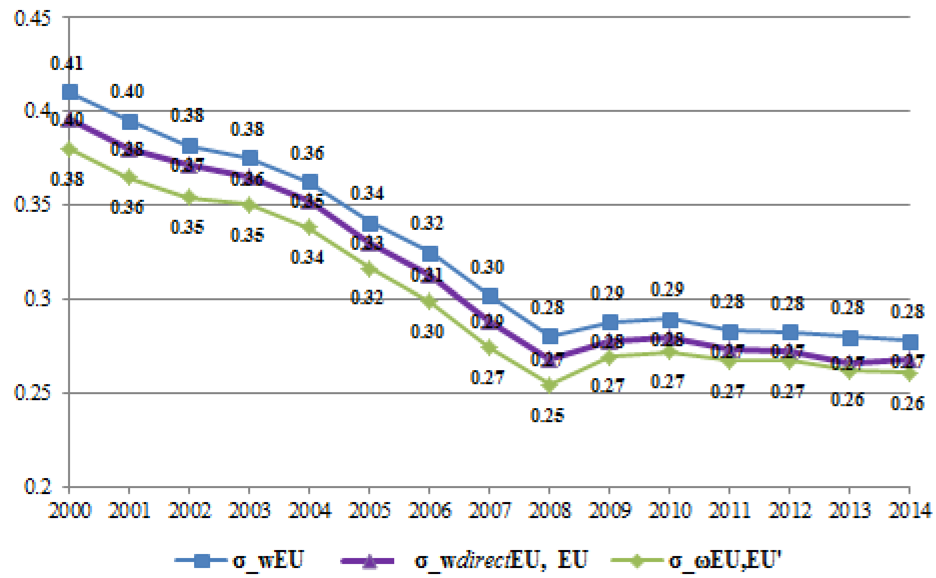
Our results point out the need of including the productive structure and structural change in the analysis of global processes such as convergence. Income generation in countries cannot be understood without acknowledging the complex interaction of sectors, countries and institutions worldwide. In this regard, the analysis shows the capacity of multisectoral and multiregional models to link income growth with the peculiarities of structural and technological change in countries, and trade relations among them, providing new perspectives for the analysis.

The findings from this work also raise new questions. For instance, the consideration of the analysis worldwide is a natural extension of this work, allowing us to study areas of geographical convergence and its behavior since the international crisis. Similarly, in this increasingly global world, certain sectors have attracted our attention, as is the case of the HT&MTH and the KIS. The study of the capacity of these sectors to reduce or increase world income disparities (and the role of trade) is a clear challenge to address in future research.

5. *Appendix A. Country-convergence per capita*

As we have carried out the analysis with total values, taking the population data from the EUROSTAT database, we can obtain the per-capita values. Thus, following the same procedure, the results obtained for each of the 28 European countries with the per capita data, are presented in this graph.

Figure A.1. *Sigma* convergence in income per capita (total direct VA, total intra-EU direct VA and total embodied VA). Aggregated data by country



Source: Own elaboration

As with total income values, the three magnitudes present a clear convergence until 2008, followed by an uncertainty period with some convergence and divergence stages.

Therefore, it must be noted that, despite the treatment of per-capita income data, the structural rupture caused by the international economic crisis is clearly seen again in 2008. European countries show similarities in their production up to 2008 (measured by traditional convergence: **Ω**_wEU), and also show a similar composition of their final products in net terms, i.e. convergence in technologically-integrated productivity (measured by convergence embodied: **Ω**_ωEU,EU').

6. *Appendix B. Correspondence among WIOD sectors and blocks of sectors*

Table B.1. Correspondence among WIOD sectors and blocks of sectors

WIOD sectors	Correspondence
Crop and animal production, hunting and related service activities	Block 1: PS
Forestry and logging	Block 1: PS
Fishing and aquaculture	Block 1: PS
Mining and quarrying	Block 2: ES
Manufacture of food products, beverages and tobacco products	Block 5: LTS
Manufacture of textiles, wearing apparel and leather products	Block 5: LTS
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	Block 5: LTS
Manufacture of paper and paper products	Block 5: LTS
Printing and reproduction of recorded media	Block 5: LTS
Manufacture of coke and refined petroleum products	Block 4: MTS
Manufacture of chemicals and chemical products	Block 3: HT&MTS
Manufacture of basic pharmaceutical products and pharmaceutical preparations	Block 3: HT&MTS
Manufacture of rubber and plastic products	Block 4: MTS
Manufacture of other non-metallic mineral products	Block 4: MTS
Manufacture of basic metals	Block 4: MTS
Manufacture of fabricated metal products, except machinery and equipment	Block 4: MTS
Manufacture of computer, electronic and optical products	Block 3: HT&MTS
Manufacture of electrical equipment	Block 3: HT&MTS
Manufacture of machinery and equipment n.e.c.	Block 3: HT&MTS
Manufacture of motor vehicles, trailers and semi-trailers	Block 3: HT&MTS
Manufacture of other transport equipment	Block 3: HT&MTS
Manufacture of furniture; other manufacturing	Block 5: LTS
Repair and installation of machinery and equipment	Block 5: LTS
Electricity, gas, steam and air conditioning supply	Block 2: ES
Water collection, treatment and supply	Block 2: ES
Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services	Block 2: ES
Construction	Block 6: Construction
Wholesale and retail trade and repair of motor vehicles and motorcycles	Block 7: KIS
Wholesale trade, except of motor vehicles and motorcycles	Block 7: KIS

Retail trade, except of motor vehicles and motorcycles Land transport and transport via pipelines	
Water transport Air transport	**Block 8: Rest of services**
Warehousing and support activities for transportation Postal and courier activities Accommodation and food service activities	**Block 7: KIS**
Publishing activities Motion picture, video and television programme production, sound recording and music publishing activities; programming and broadcasting activities Telecommunications Computer programming, consultancy and related activities; information service activities Financial service activities, except insurance and pension funding Insurance, reinsurance and pension funding, except compulsory social security Activities auxiliary to financial services and insurance activities	**Block 8: Rest of services**
Real estate activities	**Block 7: KIS**
Legal and accounting activities; activities of head offices; management consultancy activities Architectural and engineering activities; technical testing and analysis Scientific research and development Advertising and market research Other professional, scientific and technical activities; veterinary activities Administrative and support service activities Public administration and defence; compulsory social security Education Human health and social work activities Other service activities	**Block 8: Rest of services**
Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use Activities of extraterritorial organizations and bodies	**Block 7: KIS**

Source: Own elaboration

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Chapter 3: Exploring carbon emissions and international inequality in a globalized world: a multiregional-multisectoral perspective[9]

1. *Introduction*

Climate change is increasingly affecting every country worldwide, disrupting national economies and affecting lives and communities. As a consequence, taking urgent action to combat climate change and its impacts has been included as one of 17 Sustainable Development Goals by the United Nations, which also calls for international cooperation and coordinated actions in the path towards a low-carbon economy. In this context, the recent Paris Agreement (COP21 in Paris, December 2015) represented an important step forward in the international awareness of the need to take urgent action and boost national policies to combat climate change. The Paris Agreement aims to strengthen the global response to climate change and the ability of countries to deal with the negative impacts of climate change (see the United Nations Framework Convention on Climate Change, UNFCC, 2015). In order to achieve the objective of keeping the global temperature rise below 2°C by 2100, the Paris Agreement needs to be developed and incorporated in national policies, technological changes and financing, to ensure the progressive de-carbonization of economies.

In this context, the need for informative instruments and methodologies to assess the opportunities and bottlenecks of current world production becomes relevant and complex, given the fast processes of globalization and production fragmentation, and the increasing internationalization of markets and consumers.

Technological progress, population growth, and international trade have been recognized as important drivers of recent economic growth (Barro, 1991; Frankel and Romer, 1999; Grossman and Helpman, 1997; Keller, 2002). The lowering of barriers to entry into markets, and increasing internationalization has allowed emerging countries to reduce secular production and income gaps, leading to economic convergence.

[9] This is an extension of a paper published in *Resources, Conservation & Recycling*, Nº 152, 104516. We have included new tables, as well as the associated comments, which were not available in the original published version due to limits on article length in the Journal.

Globalization is also affecting the consumer side, with a convergence in lifestyles and tastes. Consumers in different countries, from different cultural origins, are developing preferences for the same products, showing increasing signs of convergence around global product identities (Kjeldgaard and Askegaard, 2006; Mitry and Smith, 2009).

These changes in economic structures, however, may have a significant impact on environments. In this context, it is important to analyze whether the signs of economic convergence resulting from world globalization are leading to cleaner and less unequal environmental pressures among countries (that is, is globalization acting as a driving force for the de-carbonization of world economies) or, on the contrary, an increasing process of inequality in world emissions resulting from the delocalization of carbon-intensive industries.

The analysis international inequality in environmental emissions has received renewed attention in the literature, to identify the main driving forces, to inform the design of global policies against climate change, and to determine the criteria for the distribution of mitigation efforts worldwide (see for instance Duro *et al.* (2016) or Teixidó-Figueras, (2016)) for a review and a comprehensive evaluation of indicators). Most of the studies focus on aggregate data by country or region, as well as on production (direct emissions), considering countries as homogenous units, without paying attention to the heterogeneity of economic sectors. This is the case of Aldy (2006), who studies whether convergence in income is sufficient for per capita CO2 emissions convergence, by focusing on certain advanced economies. Li and Lin (2013) analyze the absolute and conditional convergence in CO2 emissions for the period 1971-2008 and find evidence of absolute convergence and different income-emissions relationships, depending on the income level of countries. Westerlund and Basher (2008) perform an analysis of convergence in the 20th century[10], finding clear evidence of the existence of convergence at the international level. Romero-Ávila (2008) examines the stochastic and deterministic convergence of CO2 emissions in 23 countries over the period 1960–2002, finding evidence of this convergence. Other studies, such as Ozcan and Gultekin (2016) and El-Montasser *et al.* (2015) explicitly test the hypothesis in cross-country CO2 emissions for OECD countries, finding mixed results.

[10] They use an initial sample of 28 developed countries for the period 1870-2002, adding 12 developing countries during the period 1901-2002 for the complete sample.

Despite wide research on cross-country convergence of emissions, and recognition of the technological and structural composition of economies as factors driving emissions, there are very few studies that investigate the convergence process from a sectoral perspective.

Notable exceptions are Oliveira *et al.* (2017), who test the hypothesis of per capita convergence in direct greenhouse gas emissions, estimating dynamic multi-sectoral panel data, and the evolution of convergence GHG in 27 EU countries and the 13 largest economies around the world, finding evidence of convergence for some GHGs and for the majority of sectors. Similarly, Mulder and de Groot (2012) perform a convergence analysis, for 18 OECD countries and 50 sectors, of energy-intensity growth, finding that only after 1995 cross-country variations in energy intensity levels tend to decrease, driven by the evolution of manufacturing and services sectors.

This sectoral nature of CO2 emissions underlies input-output studies, aiming to explore the role that technological and structural change, along with demand size and composition, have played in the evolution of direct and total emissions.

In parallel, input-output techniques have been increasingly used to analyze the role of domestic demand and international trade in driving current emissions (see Wiedmann *et al.* 2007, Wiedmann, 2009 for a review), acknowledging the multiregional and multi sectoral nature of economic flows, their associated environmental impacts, and bringing to the forefront the need to link the supply side and the demand side perspectives for a deeper understanding of environmental responsibilities (Lenzen *et al.* 2012, Serrano and Dietzenbacher, 2010, Duarte *et al.* 2018). The increasing availability of comprehensive multiregional input-output databases has allowed better accounting to be performed of the contribution of trade flows to global CO2 emissions trends (see Lenzen *et al.* 2012 and Lenzen *et al*. 2013; Wiedmann, 2009; Dietzenbacher *et al.* 2009 and Xu and Dietzenbacher, 2014, among others).

This chapter builds on this literature to offer a new approach in the analysis of the evolution in CO2 emissions, which takes into account the heterogeneity in industry structure, technology, population, and composition of production and demand of countries. More specifically, this is, to the best of our knowledge, the first work to explicitly study some inequality measures in CO_2 emissions embodied in domestic demand, and international trade, i.e. studying the convergence or divergence of emissions to accomplish globalization trends.

Our work makes use of a multiregional input-output model (MRIO) for the global economy that serves as a basis for the formulation and evaluation of convergence in emissions[11]. This allows us to base our analysis on the structural and technological factors underlying convergence processes, taking into account the multi-regional and multi-sectoral perspective of production, and environmental impact generation.

We are also interested in the analysis of how this has been affected by the onset of the international economic crisis of 2008.

We use data from the World Input-Output Database (WIOD, 2016 Release). Regarding the environmental database, our main source is the recent database published by the Joint Research Centre of the European Commission[12], which contains data on energy use and carbon dioxide emissions by industry and country for 2000-2016, fully consistent with the Release 2016 of WIOD.

The rest of the chapter is organized as follows. Section 2 presents the methodology used based on an MRIO model, from 2000 to 2014. Section 3 addresses the results obtained as they relate to the convergence process and the behaviors observed for different countries and sectors. Finally, Section 4 closes the chapter with a review of our main conclusions.

2. *Methodology*

Following the same line as in the previous chapters, our starting point is a multi-regional input-output (MRIO) model, with the basic references being Isard (1951) and Miller and Blair (2009). As mentioned before, the use of an MRIO model allows us to study trade patterns that may condition the evolution of CO_2 emissions and the process of disparity over time. Our interest is in analyzing the evolution of CO_2 emissions in a global context from the convergence perspective. In that follows we present the main features of the methodological approach adopted.

[11] We focus on CO_2 emissions as the most representative GHG.
[12] See https://ec.europa.eu/jrc/en/research-topic/economic-environmental-and-social-effects-of-globalisation

To do this, we study some indicators of inequality applied to two ways of measuring emissions: emissions directly generated by sectors and countries, and “embodied” emissions, i.e., the emissions generated across countries and incorporated in the final products of each country, showing the transmission of emissions through global value chains.

Starting from the equation 1.1, equation 3.1 represents the equilibrium equation in a multiregional model context, with *m* countries and *n* sectors, where **x** $((m \times n) \times 1)$ denotes the total output, $\mathbf{A}((m \times n) \times (m \times n))$ is the matrix of multiregional technical coefficients. The representative element $\mathrm{a}_{\mathrm{ij}}^{\mathrm{rs}}$ shows the intermediate input *i* of a country *r* necessary to produce a unit of output *j* in country *s*, and **f** $((m \times n) \times 1)$ is the of final demand of countries, where if each representative element f_{i}^{rs} is the final demand of good i produced in country *r* and consumed in country *s*, with $\mathbf{f} = (\mathrm{f}_i^{r})$ and $\mathbf{f}_{\mathbf{i}}^{\mathbf{r}} = \sum_{s=1}^{m} f_i^{rs} = f_i^{rr} + \sum_{s \neq r} f_i^{rs}$ **.** As in the previous chapters, this equation can be also represented in terms of the well-known Leontief inverse **L** $((m \times n) \times (m \times n))$ defined for the whole economy.

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{f} \rightarrow \mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{f} = \mathbf{L}\mathbf{f} \tag{3.1}$$

In this case, let’s consider the vector of emissions directly generated by the countries and sectors **e** $((m \times n) \times 1)$. As in the previous chapters we have worked with value added, we can define the following direct emission coefficients $\mathbf{c} = \mathbf{e}' \left(\hat{\mathbf{x}}\right)^{\mathbf{-1}}$ showing the direct emissions per unit of production (emission intensity).

Pre-multiplying equation 3.1 by the diagonalized vector of direct emissions intensities and allocating final demands to the different productive countries and sectors, we obtain the following matrix.

$$\mathbf{\Omega} = \hat{\mathbf{c}}\ \mathbf{L}\hat{\mathbf{f}} \tag{3.2}$$

where each element $\mathbf{\Omega}_{ij}^{rs}$ depicts the CO_2 emissions generated in sector *i* of region *r* to meet the final demand of sector *j* in region *s*.

The reading by columns and rows of the matrix above gives us significant information on the origins and destination of emissions through the global production chains.

Thus, the sums of the elements by rows reproduce the direct emissions (production-based emissions) by sectors and countries, that is to say, $\mathbf{w}^{\mathbf{emi}} = \boldsymbol{\Omega}\,\mathbf{i} = \hat{\mathbf{c}}\mathbf{L}\hat{\mathbf{f}}\mathbf{i} = \mathbf{e}$ being $\mathbf{i}$ a unitary vector of appropriate dimension. In consequence, the different elements of each row in $\boldsymbol{\Omega}$ show how the direct emissions of a country and sector are incorporated in its sales to other sectors and countries though the global production chain.

The reading by columns shows the embodied emissions, that is, $\boldsymbol{\omega}^{emi} = \mathbf{i}'\boldsymbol{\Omega}$ depicts, for each sector and country, the emissions generated across the world and crystalized in the final demand of each country and sector. That is to say, this is the description of the world emissions from a "consumption-based approach". Obviously, the total amount of world emissions under both approaches is the same, that is to say, $\mathbf{i}'\mathbf{w}^{\mathbf{emi}} = \boldsymbol{\omega}^{\mathbf{emi}}\mathbf{i} = \mathbf{i}'\boldsymbol{\Omega}\;\mathbf{i} = \mathbf{i}'\mathbf{e}$.

Moreover, as we are studying a global scenario, we can distinguish between the emissions generated in each country and ending in the final demand consumed in the own country, and the emissions generated and embodied in the goods and services traded with other countries and consumed in a foreign country. That is to say, we can distinguish two parts in $\mathbf{L} = \left(L_{ij}^{rs}\right) = \mathbf{L}^{\mathbf{d}} + \mathbf{L}^{\mathbf{m}}$ with $\mathbf{L}^{\mathbf{d}} = \left(L_{ij}^{rs}\right)$ if r=s and 0 if r≠s, $\mathbf{L}^{m} = \left(L_{ij}^{rs}\right)$ if r≠s and 0 if if r=s. Similarly, the final demand **f**, can be divided into $\mathbf{f} = \mathbf{f}^{\mathbf{d}} + \mathbf{f}^{\mathbf{z}}$, with $\mathbf{f}^{d} = \left(f_i^{rr}\right)$being the interior consumption and $\mathbf{f}^{z} = \sum_{s \neq r}^{m} f_i^{rs}$ the foreign demand for final consumption.

In consequence, we can extend equation 3.2 as follows:

$$\boldsymbol{\Omega} = \hat{\mathbf{c}}\,\mathbf{L}\hat{\mathbf{f}} = \hat{\mathbf{c}}\,\mathbf{L}^{\mathbf{d}}\hat{\mathbf{f}}^{\mathbf{d}} + (\hat{\mathbf{c}}\,\mathbf{L}^{\mathbf{m}}\hat{\mathbf{f}}^{\mathbf{d}} + \hat{\mathbf{c}}\mathbf{L}\hat{\mathbf{f}}^{z}) = \boldsymbol{\Omega}^{\mathbf{domestic}} + \boldsymbol{\Omega}^{\mathbf{trade}} \qquad (3.3)$$

Note that other different breakdowns can be considered, depending on the definition of domestic production, both in the case of intermediate inputs and finals demands. In our case, we consider as domestic production the goods and services produced in the country and that are finally consumed in the country (for simplicity we also include as domestic a small spillover effect as $\mathbf{L}^{\mathbf{d}} > (\mathbf{I}-\mathbf{A}^{\mathbf{d}})^{-1}$).

As in the case of value added, looking at (3.3), the evolution of matrix $\boldsymbol{\Omega}^{\mathbf{domestic}}$ will be marked by the evolution of domestic emissions associated with the internal production and consumption of own products in each country (intermediate and final demand); while the evolution of the second, $\mathbf{\Omega}^{\mathbf{trade}}$,will be strongly linked to the evolution of international trade of emissions, including the emissions of a country embodied in products traded as intermediate inputs or final products, with other countries. Again, the reading by columns (and rows) of these matrices gives us information on the distribution of the process of emissions generation (and distribution) across countries.

The decomposition of flows described above, based on the MRIO structure, allows us a more complete view of the (complex) process of convergence in emissions, and, as far as possible, an analysis of the contribution, by both generation and distribution, of the different variables (domestic demand and trade) and sectors, and the cross-country relationships.

In other words, these flows by country, sector, and year, can be highly informative for the evaluation of convergence in world emissions. In this regard, although it is not common in the literature, the MRIO models and indicators presented also provide the basis to evaluating to what extent countries and/or sectors are walking towards a common path or, on the contrary, tend to be more unequal over time. Given the role that structure, final demands and international trade play in these models, we can offer a novel structural view of the convergence issue. Moreover, MRIO models also allow analyzing this question combining the perspectives of production and consumption, and their relationship through international trade.

The evolution of global world regions has attracted attention in the literature in recent decades. On the basis of the seminal works of Sala-i-Martin (1992, 1994, 1996) in the economic literature, numerous papers have emerged that focus on studying the inequality in emissions using the well-known the *sigma* or *beta* convergence indexes (see for instance Brock and Taylor, 2010; Ordás Criado *et al.*, 2011). Economic convergence has traditionally been evaluated on the basis of *sigma* convergence, making use of a range of dispersion measures (see for instance Sala-i-Martin, 1994; Lein *et al.* 2007; Dietzenbacher *et al.* 2009, Fagerberg *et al.* 2014). In our case, in order to analyze the level of inter-country imbalance between 2000 and 2014, we study the standard deviation of the log emissions as an indicator of inequality. On the basis of the indicators presented in the previous equations, we can define the following dispersion indexes for the direct (production-based approach) and the embodied (consumption-based) emissions as follows:

$$\sigma^e{}_t = \left[\frac{\sum_r (\log(\sum_{i,j,s} \Omega_{ij,t}^{rs}) - u^e{}_t)^2}{m} \right]^{\frac{1}{2}}$$

$$\sigma^\omega{}_t = \left[\frac{\sum_s (\log(\sum_{i,j,s} \Omega_{ij,t}^{rs}) - u^\omega{}_t)^2}{m} \right]^{\frac{1}{2}} \qquad (3.4)$$

where σ_t^e and σ_t^ω are, respectively, the dispersion measures of country direct and embodied emissions in a specific year t; and are the corresponding average of the logarithms of the emissions data analyzed. Note that we can estimate these dispersion indexes at different aggregation levels (country, sector-country, country or regional blocks) and for different components in $\mathbf{\Omega}$, being of interest the above presented $\mathbf{\Omega^{domestic}}$ and $\mathbf{\Omega^{trade}}$. Additionally, we perform *beta*-convergence analysis, in this case looking at the relationship between direct or embodied emissions and their associated growth rate. The hypothesis of *beta* convergence relates emissions growth over a period with the initial emissions levels. If *beta* convergence exists, a direct association with negative slope would be expected.

As can be seen, the multi-sectoral nature of the MRIO information allows us a more detailed study of the economic sectors involved in the process of *sigma* convergence around the world. In this regard, we can compare the results obtained at the more aggregated country level and those appearing when sectoral disaggregation is used. We study the convergence through the global value chains (i.e., in the emissions generated in the world and embodied in the final demand of countries) and analyze the evolution of convergence in its different components (domestic and trade), which is the main contribution of the study and a novel approach to convergence and inequality issues.

While the traditional measures of convergence are based on direct emissions, the study of convergence in global value chains directs us to the driver role of final demand patterns (consumption and investment patterns) as sources of income convergence or divergence.

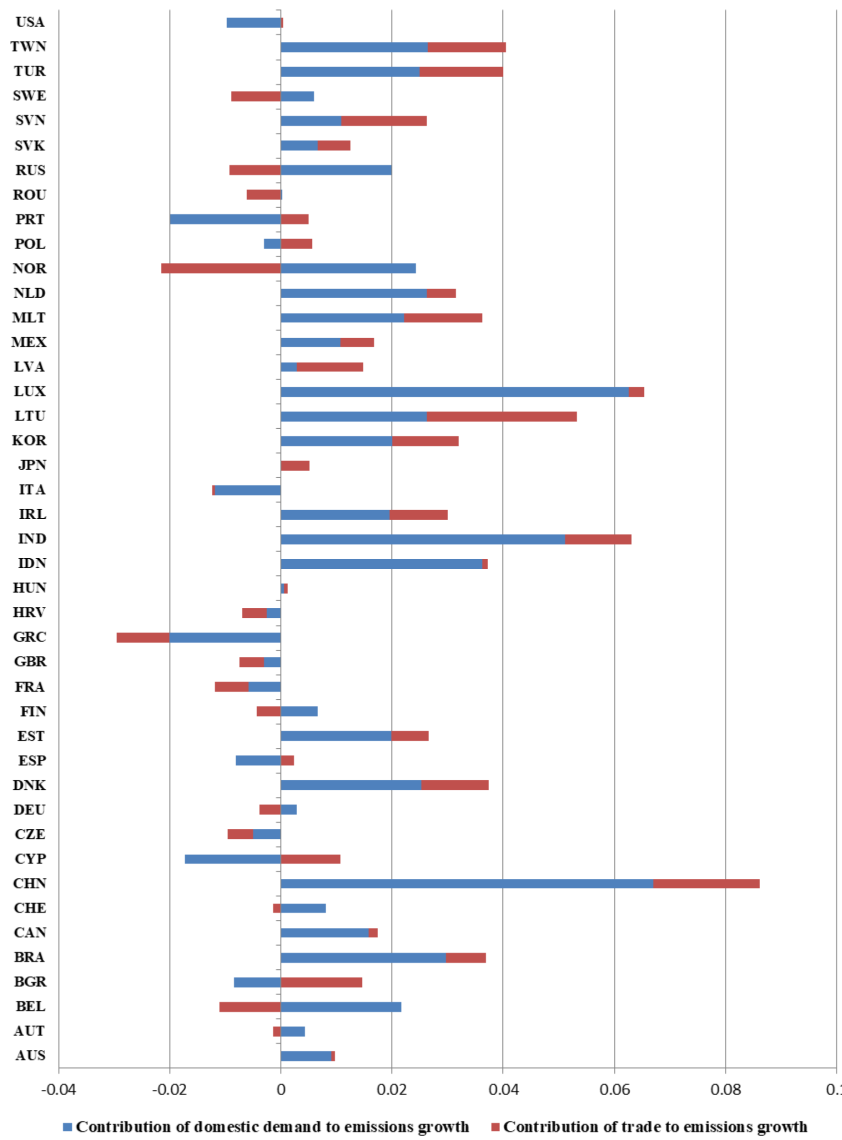
Empirically, we make use of the World Input-Output Database WIOD (see Timmer *et al.* 2015), which covers 28 EU Member States and 15 other major countries in the world for the period 2000-2014, our period of analysis. The WIOD database has a breakdown of 56 industries in the Release of 2016 for each country, covering all economic sectors: agriculture, mining, construction, utilities, manufacturing, and services. As it was mentioned above, we make use of the new emissions data published recently by the Joint Research Centre of the European Commission (WIOD Environmental Accounts 2019), which are completely consistent with the WIOD Release 2016. Therefore, this database provides information for 44 countries (including the Rest of the World) and 56 industries by country.

3. Results

3.1. Trends in CO2 emissions and main components

In order to better understand the trends observed in CO2 emissions and the role of domestic and foreign demand, Figure 14 illustrates the contribution of domestic and trade components to emission growth for the 43 countries included in the WIOD database.

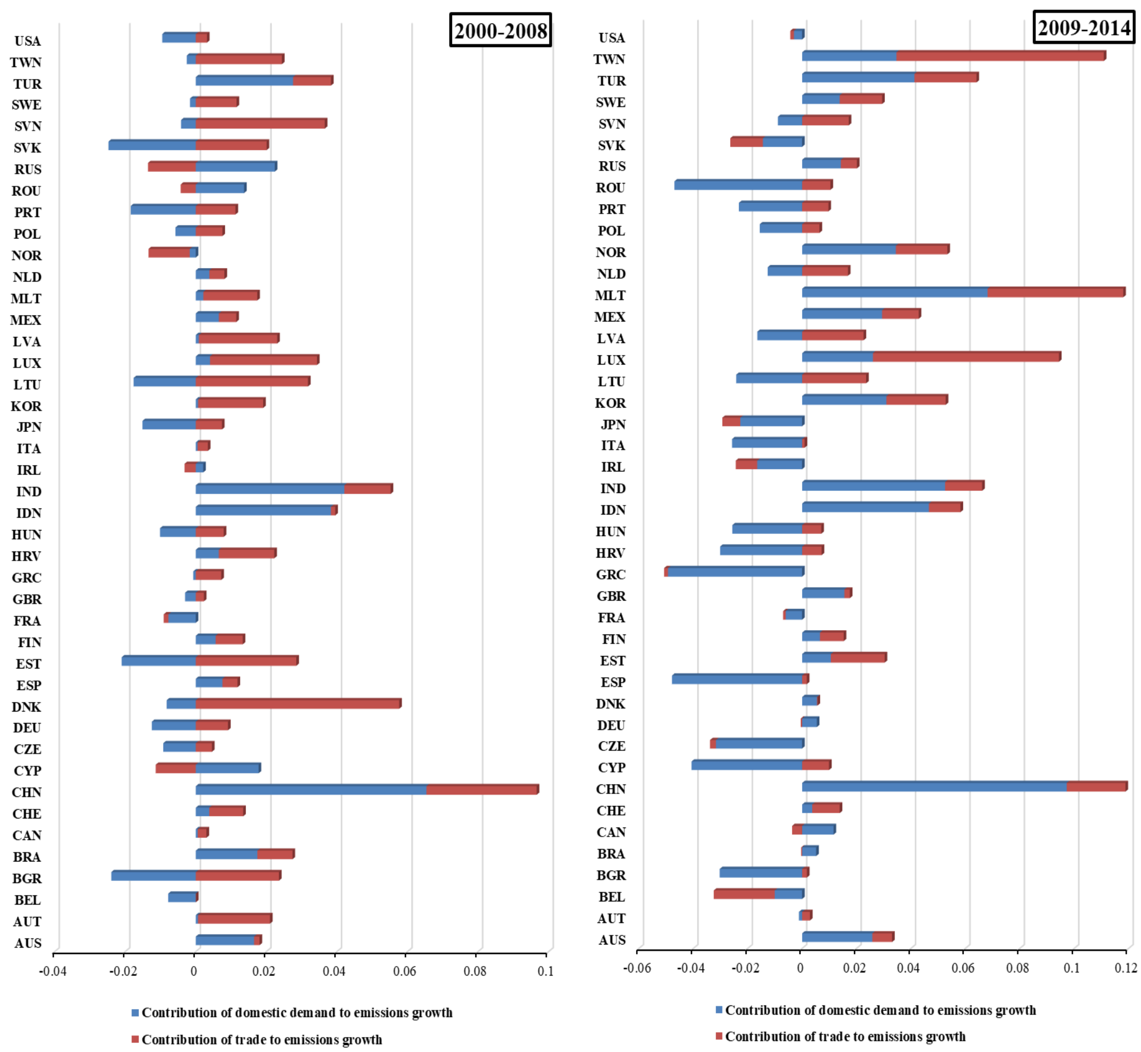
Figure 14. Contributions of domestic demand and trade to average emissions growth, by country, 2000-2014



Source: Own elaboration

As can be seen, China, India and Luxembourg stand out as the countries with the highest rates of emissions growth, and are also main contributors to current global CO2 emissions. Both show a high contribution of their domestic demand to emissions growth. Economic expansion in these economies is reflected in vigorous domestic production and in increasing trade with the rest of the world, thus contributing to the expansion of CO2 emissions. Trade has been the main contributor to global emissions for most of the countries, and we can see that Central and Eastern Europe and Asian countries are the ones with higher rates of emissions growth associated with the dynamism of their trade. This is the case, for instance, of Denmark, and Estonia. The lowest growth rates in CO2 emissions over the period can be found for the US and the Mediterranean Europe countries. Nevertheless, when we look at the two sub-periods, before and after the 2008 economic crisis, we can appreciate different characteristics regarding CO2 emissions and the contributions of domestic demand and trade.

Figure 15. Contributions of domestic demand and trade to average emissions growth, before and after the crisis



Source: Own elaboration

As can be seen in Figure 15, in the period 2000 to 2008 (the expansive period), international trade between countries caused a large increase in air emissions, leading to an increase in global pollution, especially in the case of some Central European countries such as Denmark, Lithuania, and Luxembourg. In addition, some Asian countries, such as Japan, and some Eastern European countries had negative emissions growth rates associated with domestic demand. When we focus on the second graph, the onset of the international crisis affected the generation of emissions, with certain clear features. First, the growth rate of CO2 associated with exports is reduced, but the decrease of domestic demand is much greater. After the crisis, some major EU countries, such as Greece, Italy, and Spain, are those that show the most negative contributions of domestic demand to emissions growth, while the emissions associated with exports are maintained.

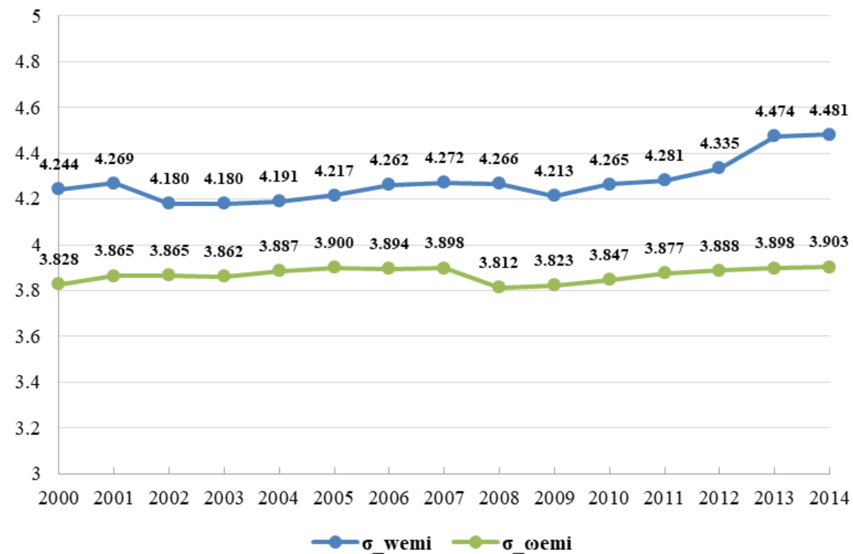
The questions are, in consequence, whether these differential behaviors resulted in an increasing convergence or divergence between countries, in terms of carbon emissions, which have been the contributing factors, and how can we evaluate the results from an integrated global perspective.

3.2. Environmental inequality analysis

As it mentioned above, there are many indicators of inequality that have been used in the literature. In this work, we make use of the measure of *sigma*-convergence process on the basis of the estimations described in (3.4) during the period 2000-2014, and taking two types of variables as measures of emissions: first, the “Direct emissions”, that is, the total emissions generated in each country and sector, both internally and traded with other countries. That is, *sigma*-convergence on the components of **e**. Second, we compute the process of *sigma*-convergence on “Embodied emissions”, that is, the convergence in the total emissions generated and incorporated in the final products of each sector and country. Thus, in this first analysis, our sample has, for each year, 1,462 observations (43 countries, with 34 sectors for each[13]).

[13] The sectors have been grouped according to the International Standard Industrial Classification in the World Input-Output database, Release 2013.

Figure 16. Evolution of inequality in total emissions (total direct and embodied), 2000-2014



Source: Own elaboration

Figure 16 shows in the blue line the environmental inequality calculated as a measure of dispersion in the direct emissions ("$\mathbf{w}^{\mathbf{emi}}$ = total direct magnitude") and in the green line, calculated over the total global emissions and embodied in the final products. We can see a period of stability in the convergence index until 2008, followed by a period of a marked divergence in emissions[14].

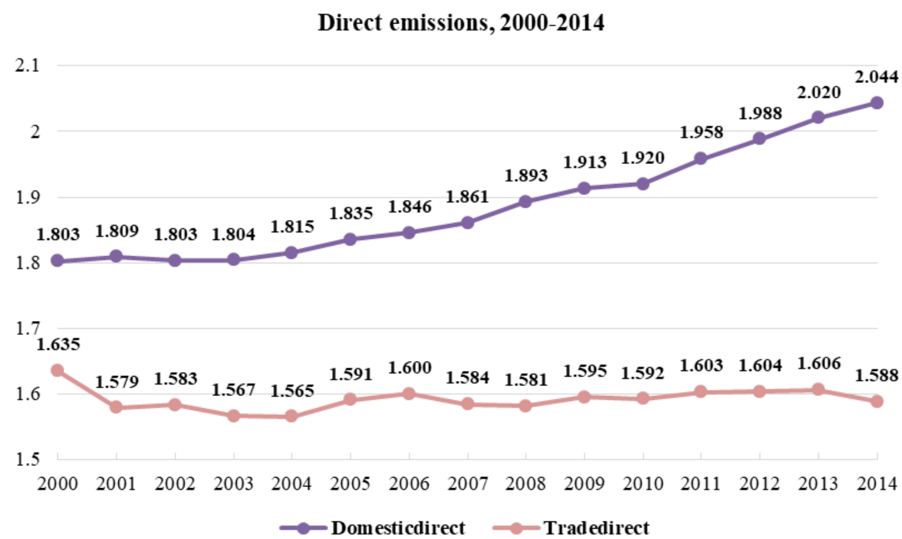
While the evolution of traditional *sigma*-convergence reflects a period of rapprochement or distancing of countries in the direct emissions generated in production, the evolution of the "embodied magnitudes" indicates an approach or distancing of countries to a similar composition in their final products, that is, certain similarity of countries in technologically-integrated productivity.

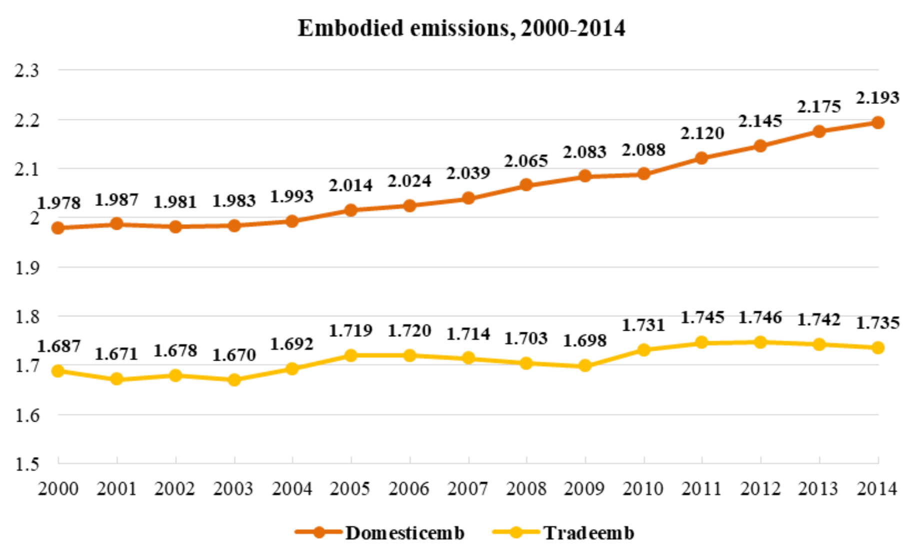
Our results show a continuous process of inequality in direct CO2 emissions from the early 2000s, which increases from 2008 and onwards. Moreover, values of *sigma* are lower for the embodied emissions, and it is possible to identify two trends. A period of convergence and stability until 2007, and an increasing estrangement in embodied emissions from then on. In order to go deeper into the behavior of the different structural

[14] The analysis with EORA database is available upon request.

components regarding the trend observed in convergence, we analyse the same indicator in the "trade" and "domestic" components of direct and embodied emissions. Equations (3.2) and (3.3) show the significance of these components.

Figure 17. Evolution of inequality in the different components of direct and embodied emissions, 2000-2014





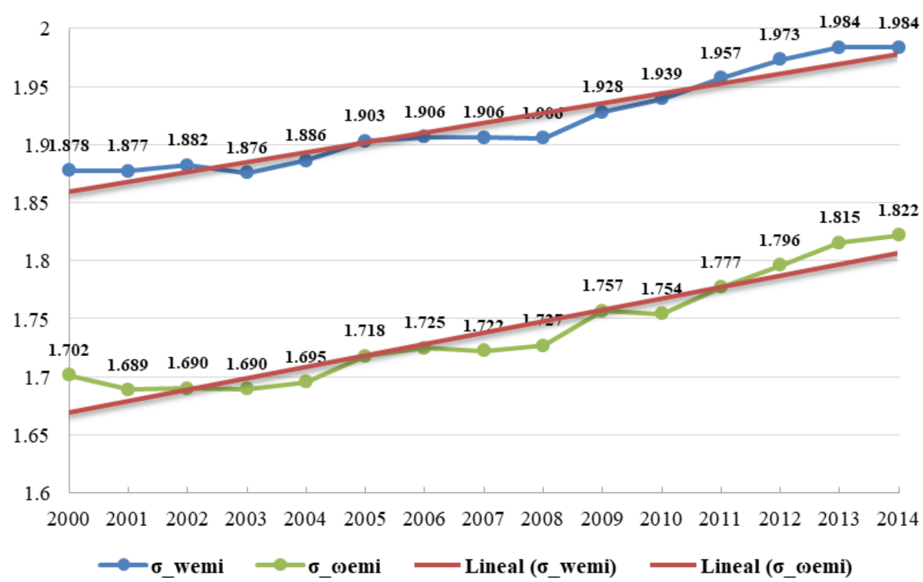
Source: Own elaboration

As can be seen, both in direct and embodied emissions, the main contributor to the rising disparity in emissions is the domestic component. The 2008 economic crisis also seems to inaugurate a period of rising inequity in the emissions associated with trade, also contributing to increasing inequality in world emissions.

Once the hypothesis of convergence has been studied at the most disaggregated level, we perform a similar analysis aggregating the data by country that is, eliminating the sectoral variability within countries. For this reason, we have only 43 observations per year, corresponding to the 43 countries of the study (not including the Rest of the World). As a general result, the values confirm the trends obtained at the disaggregated level.

As in the previous case, the magnitudes present a clear rising gap throughout the period, but more marked in the second half.

<u>Figure 18</u>. Evolution of inequality in total emissions (total direct and total embodied), 2000-2014. Aggregated data by country



Source: Own elaboration

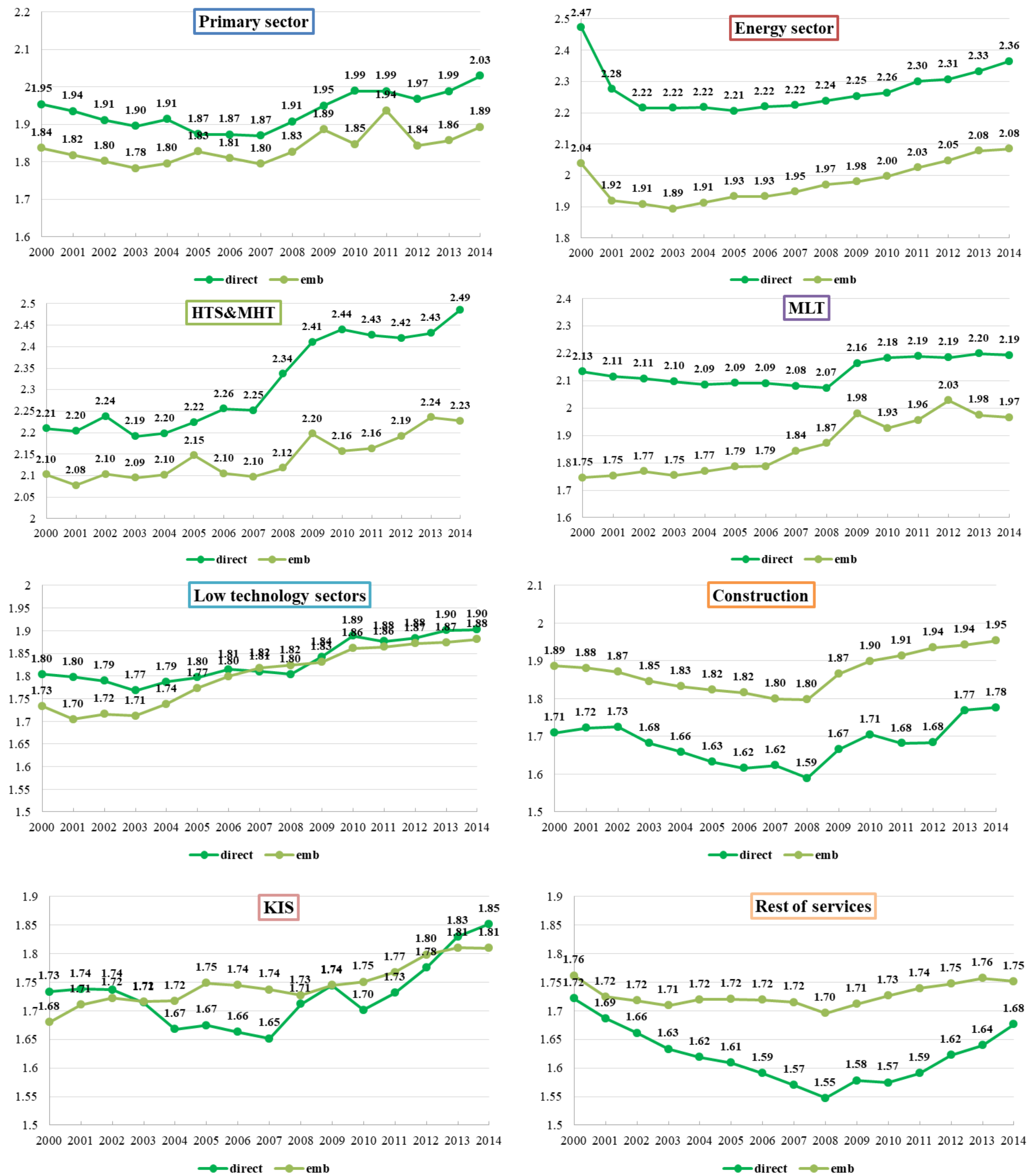
These results show that countries tended to diverge over the period in the production of emissions and embodied emissions. As can be seen, the trend lines of both variables present an increasing evolution of the indicator, that is, an increase of the divergence in generated and embodied emissions. However, comparing these results with those obtained at the most disaggregated level, the stability period observed in embodied emissions is not so clearly appreciable when data are aggregated by country, nor is the significant role played by the domestic component in explaining the rising inequality in emissions from the economic crisis. This suggests the importance of structural components and sectoral specialization in countries, in explaining emissions trends.

Thus, in order to have a clearer insight into the role that specific sectors or groups of sectors can play in the evolution of a country's emissions, and in convergence, in what follows we show the evolution of the inequality indicators by sectoral blocks, grouped according to their technological levels.

The final analysis refers to convergence in the generation of pollution by sectoral groups. The economic sectors have been aggregated into 8 sectoral blocks, according to their technological level namely: primary sector, energy sector, high and medium-high technology industrial sectors, medium-low technology industrial sectors, low technology industrial sectors, construction sector, knowledge-intensive services and the rest of services[15]. Our interest here is to see if this divergence process over time is due to the extreme behavior of some sectors in particular, or is mainly due to a trend observed in most of them. In figure 19, we show the evolution of inequality for the sectoral groups, having now 43 observations for each sectoral block and year, corresponding to the 43 countries of the sample.

[15] The sectors have been grouped in these blocks according to their technology intensity definition (following the OECD Directorate for Science, Technology and Industry, 2011, and Knowledge intensive services (KIS) classification. In this way, the sectors are grouped as follows: primary (crop and animal production, forestry and fishing), energy (mining, electricity, gas, water collection and sewage), HTS&MHT (manufacture of chemicals, pharmaceutical products, computer, electronic and optical products, electrical equipment, motor vehicles and other transport equipment), MLT (manufacture of coke and petroleum, rubber and plastic products and non-metallic mineral products), LT (manufacture of food, beverages, tobacco, textiles, wood and paper products), Construction, KIS (water and air transport, publishing activities, telecommunications, information services, financial service activities and insurance, reinsurance and pension funding) and RS (wholesale and retail trade, land transport, warehousing, support and real estate activities). Tourism is not classified independently, which is strange given its importance and impact on the Spanish economy, for instance, on specific areas like Venice, areas around airports, islands with high contamination, etc.

<u>Figure 19</u>. Evolution of inequality in total direct and embodied emissions, by block sector, 2000-2014



Source: Own elaboration

Figure 19 shows the evolution of inequality (*sigma*) on direct emissions generated by each block, as well as inequality (*sigma*) in emissions generated by total production and incorporated into the final products of each block (embodied emissions). Significant differences can be observed, breaking the smooth trend toward increasing divergence observed in the previous results.

On the one hand, when we take into account direct values (dark green lines), the high and medium-high-technology industrial sectors are the most divergent over the period. Thus, countries present the greatest differences in the emissions generated by the most technology-intensive sectors. Medium-low technology sectors exhibit the clearest tendency towards convergence over the whole period, showing that they are the sectors where the generated emissions have been distributed globally. The Rest of Services and construction show the most marked change in the trend, due to the 2008 economic crisis, with a clear tendency towards convergence in the expansive period pre-crisis and a marked movement towards divergence afterward.

On the other hand, when we look at the embodied values (light green lines), we obtain a different picture. When we observe the embodied values, we can appreciate that for the majority of blocks, their values are smaller than in the case of direct magnitudes, and moreover they present a clear divergence process since the beginning of the analyzed period. The behavior of high and medium-high-technology industrial sectors is clearer than others, suggesting that products consumed by world citizens have more different technology-intensity content, no matter the country where this is generated. In other words, it seems that world trade has not allowed technological diffusion between countries, but has contributed to a progressive specialization of countries, which causes significant divergence in the generation and incorporation of emissions in production.

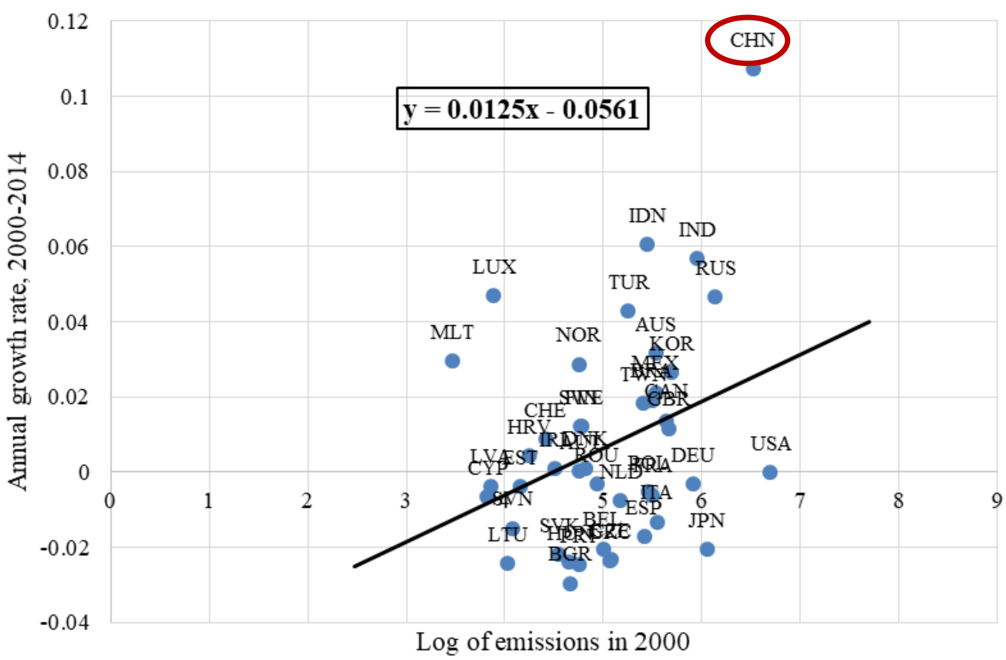
The results above tell us that the general trend in CO2 emissions is toward an increasing inequality in CO2 emissions of countries, also implying a certain specialization of countries in production, and with global values strongly driven by the evolution of the domestic demand of countries.

At this point, several questions arise. First, the existence of *sigma* divergence implies more inequality in world emissions: to what extent do initial conditions of countries affect this inequality (which implies an analysis of the so-called *beta* convergence in emissions)? Second, different clusters can be identified, and to what extent do these clusters refer to geographical areas and/or to different economic conditions? Finally, we go further into the link between per capita income growth and per capita emissions, to test how convergence in per capita income, technology, and population affects convergence in emissions.

3.3. Beta convergence analysis

The problem we now face is whether the observed *sigma* divergence in emissions is mainly due to the smaller growth rate of emissions in less polluting countries, or to the increasing rate of the most polluting countries. As has been stated, the hypothesis of *beta* convergence relates emissions growth over a period with the initial emissions levels. A direct association with negative slope should be expected in presence of *beta*-convergence.

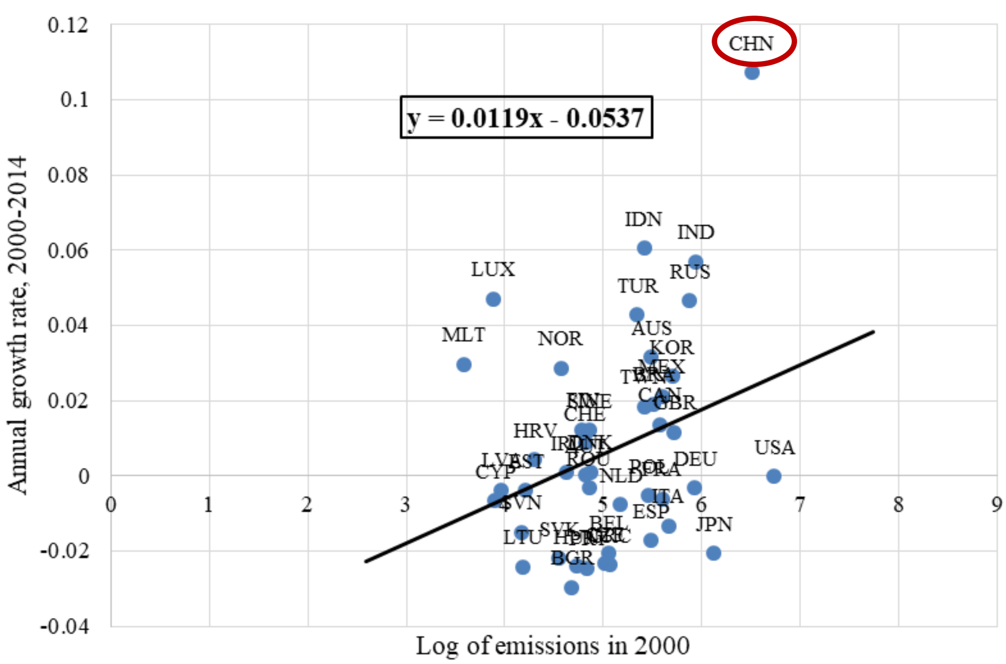
<u>Figure 20</u>. *Beta* convergence in direct emissions, 2000-2014



Source: Own elaboration

As can be seen in Figure 20, the analyzed countries present a clear *beta* divergence in emissions, which is fully compatible with the results on *sigma*. The graph shows that the countries with the highest level of emissions at the beginning of the analyzed period are the ones that increased their pollution levels the most during the analyzed period, and in the same way, those countries with the lowest levels of pollution are those ones that increased their emissions the least. Therefore, *beta* divergence is telling us that *sigma* divergence is associated with a significant increase in the pollution rate of those countries that had levels of pollution above the average at the beginning of the analyzed period. The case of China stands out in the sample; it presents the highest annual emissions growth rate over the period, related not only to its initial pollution levels but also with the consistently high level of economic growth experienced over the period. In addition, we can observe that the *beta* divergence is caused by the behavior of the most industrialized countries that have been those that increased their pollution levels the most.

<u>Figure 21</u>. *Beta* convergence in embodied emissions, 2000-2014



Source: Own elaboration

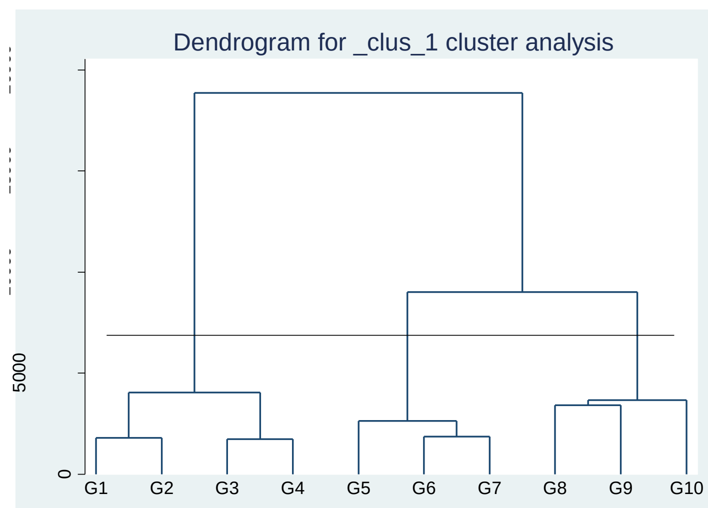
Figure 21 shows a similar picture for the relationship to embodied (global) emissions. Again, we can confirm the existence of *beta* divergence and see that the positive relationship between the emissions growth rate and the initial pollution levels is due to the rapid growth of the most polluting countries, such as India, Indonesia, Turkey, and, notably, China[16]. In order to go deeper into the behavior of countries and the existence of common trends by group of countries, these results are complemented with a cluster analysis and the subsequent convergence analysis in the following section.

3.4. Cluster analysis

The trends observed for the full sample of countries can be analyzed by cluster analysis, to identify common and differential behaviors among countries following some geographical and/or economic criteria. We have developed a cluster analysis applying the Ward criterion that uses the variance as a dissimilarity metric (see Ward, 1963). The study has been carried out in Stata for a total sample of 645 observations, corresponding to the 43 countries in the sample and to 15 years. In addition, this study has been carried out for total emissions data, so that we can know the clusters by size (larger, more polluting economies).

Applying Ward's method, the following dendogram is obtained, showing three groups across the countries and the years of the analyzed period:

<u>Figure 22</u>. Dendogram for cluster analysis, total emissions data, 2000-2014



Source: Own elaboration from the Ward clustering method in Stata

These groups correspond to the countries (from most to least CO2 emitters):

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[16] Given the exceptional impact of China, the analysis has also been developed for the full sample, omitting China, and confirming a positive and significant relationship between growth rate in emissions and emissions in 2000.

- Cluster 1: Australia, Brazil, China, Germany, France, UK, Indonesia, India, Italy, Japan, Korea, Mexico, Poland, Russia, Turkey, Taiwan, USA.
- Cluster 2: Austria, Belgium, Bulgaria, Switzerland, Czech Republic, Denmark, Spain, Finland, Greece, Hungary, Ireland, Netherlands, Portugal, Romania, Slovakia, Sweden.
- Cluster 3: Cyprus, Estonia, Croatia, Lithuania, Luxembourg, Latvia, Malta, Norway, Slovenia.

When we look at the three groups of countries, we can see that the first group includes the leading countries in economic growth and therefore in emissions. In the second group, most of the countries of Central and Mediterranean Europe, and in the third cluster, we mainly find the Eastern European countries, with the exception of Norway.

Table 7. Convergence in emissions by clusters, total emissions, 2000-2014

	Cluster 1	**Cluster 2**	**Cluster 3**
α	0.867128	0.526696	0.905428
β	0.00703412	0.00121914	-0.00891384
p-value	4.61e-09 ***	0.0301 **	2.61e-09 ***

Source: Own elaboration

When we focus on the results of this table, we can see that the time trend coefficient of cluster 1 and cluster 2 is positive, indicating divergence in emissions (not being so significant in the second case), while in cluster 3 the coefficient is positive, which means that Eastern European countries show convergence in the generation of emissions. Thus, although the countries belonging to cluster 1 and 2 are generating the global divergence, there are also differences among them. However, those countries with lower levels of emissions are the ones with the greatest similarities and, therefore, the greater convergence among them.

Finally, we have checked the consistency of our results with other international databases. More specifically we have compared these results with those obtained using the EORA database for the same period (we have used the reduced version with 190 countries and 26 productive sectors per country). Because of the differences between WIOD and

EORA databases, and the different country and sector aggregations, the values of *sigma* are bigger than in the case of WIOD. However, its trend/evolution, which is what really informs us about convergence, follows the same path in both cases (direct and embodied) with a convergence period until 2008 followed by a divergence process until 2014. More detailed results are available upon request.

4. *Conclusions*

The phenomenon of economic convergence has been analyzed from several perspectives, taking into account the effects of population, economic growth, and the stage of development, and providing diverse results. The objectives in the literature have been to study whether economies move toward a common growth path, or tend to diverge over time, and to determine the consequences of this on economic cohesion. However, the analysis of global convergence of CO2 emissions and the implications in terms of pollution and the income-dependence of emissions has received little attention in the literature of convergence.

The main objective of this third chapter is to study the evolution of inequality in the emissions generated and embodied around the world. We make use of traditional measures of economic convergence as inequity indicators, and we extend them to a multi-regional input-output framework to check whether the phenomenon of convergence or divergence is due to a specific region, a country, or a particular productive structure.

Our results show a general process of growth in emissions accompanied by a continuous process of divergence worldwide. Regarding the evolution of world emissions, the temporal reduction in emissions observed in some economies was only due to the contraction of the economies during the first years of the economic crisis, and not to an improvement in the production conditions (technological improvement that reduces unit emissions). These general and global results, however, can be better qualified when sectoral and regional characteristics of countries are taken into account. First, the analysis by industry-blocks reveals that countries are specialized in specific economic structures, conditioning the evolution of emissions. Direct emissions and embodied emissions present a greater divergence in those sectors that are more technology-intensive. So, it seems that the general trend in emissions is towards an increasing inequality in the CO2 emissions of countries, which also implies a certain specialization of countries in production, with global values strongly driven by the growth in domestic demand of countries.

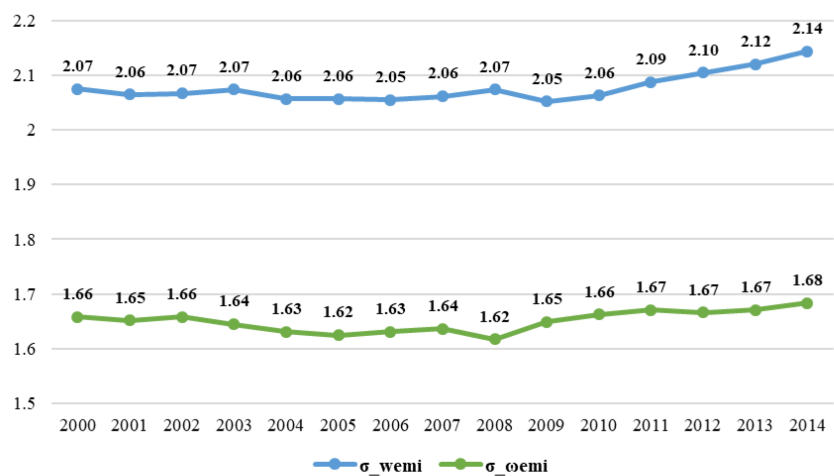
The study of *beta* convergence offers other interesting insights. Our results show that the observed sigma divergence is the result of a clear process of *beta* divergence, marked by the fact that the largest polluters at the beginning of the period have continued to increase emissions over the period, and at the highest rate. This suggests the existence of different country behaviors related to productive and developmental characteristics. To approach the role of country features, a cluster analysis has been carried out, finding significant regional clusters. On the one hand, developed countries such as China, the US, Central and Mediterranean European countries, presented a divergence process in emissions, showing that there are significant differences between them. On the other hand, Eastern European countries exhibited a clear process of convergence in emissions. In the Appendix, all the results have been checked at the per capita level, confirming the previous findings.

Finally, our findings contribute new dimensions to the issue of international inequality in terms of environmental pressures, and open new debates on the relocation of environmental damage, comparative advantage, and environmental footprints.

5. Appendix C. Per capita emissions analysis

All the previous analysis has been calculated on the basis of the total emissions generated and embodied in country production, confirming the roles of domestic growth, international trade, and sector specialization in the trends observed in global emissions and convergence measures. In order to better capture the relationship between the level of development and the growth in emissions, as well as the consequences of convergence trends, we replicate the analysis above but now referring to the *sigma* and *beta* convergence among countries in per capita emissions.

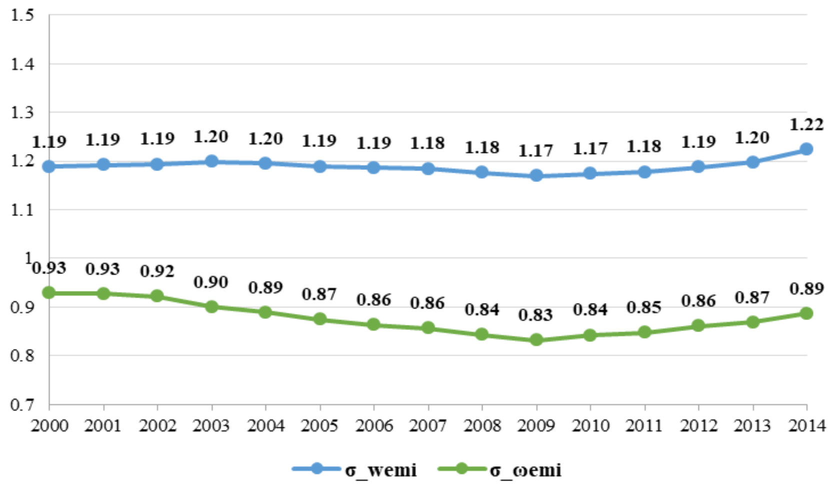
Figure C.1. Evolution of inequality in per capita emissions (total direct and embodied), 2000-2014



Source: Own elaboration

Figure C.1 shows the same analysis as Figure 16. In this case, the evolution of convergence in direct and embodied per capita emissions is similar to the earlier figure. Two main magnitudes present a certain period of stability in the convergence index, followed by some instability in the last years of the analyzed period. On the one hand, we can appreciate that the per capita emissions generated directly by each country (blue line) show certain divergence at the end of the period. On the other hand, the green line, corresponding to the embodied emissions, tells us that from the beginning to the end of the period, the countries have not tended to incorporate the same amount of emissions in their final products, and they have differed in terms of the composition of their products.

Figure C.2. Evolution of inequality in per capita emissions (total direct and total embodied), 2000-2014. Aggregated data by country

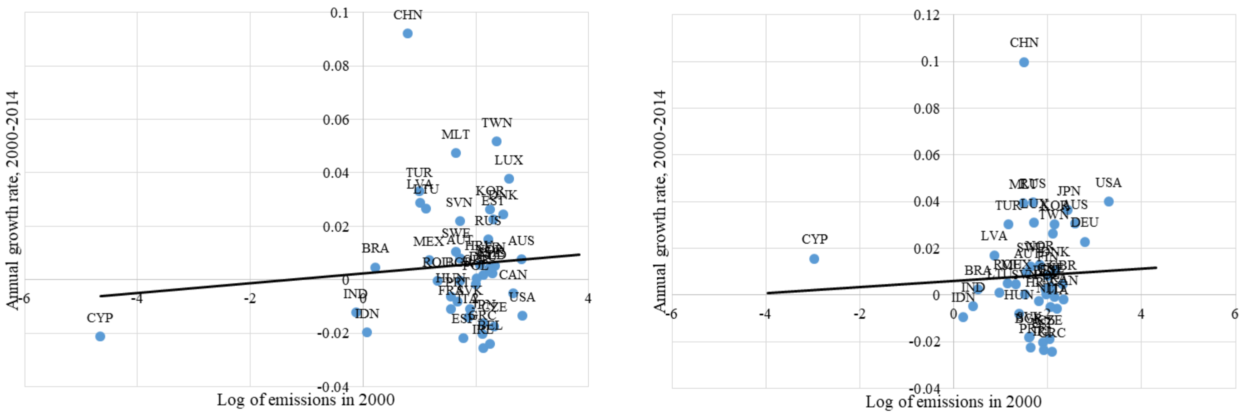


Source: Own elaboration

This graph shows the same analysis as Figure 18. In this case, we have aggregated the information by country, but the evolution is somewhat different from before. It is true that the effects of population soften the results obtained previously, although the two magnitudes show the same trend, with a slight convergence process until 2009, followed by a certain divergence until the end of the analyzed period. Again, in this case, the values are smaller when we compact the information by country and eliminate the sectoral variability.

Once the tendency of the countries to present divergence towards the end of the period is verified, it is necessary to know if this divergence is due to the fact that the most developed countries move away, or that the developing countries are lagging behind in terms of emissions. This study is carried out through the *beta* convergence analysis shown in the following figures.

Figure C.3. *Beta* convergence in direct and embodied per capita emissions, 2000-2014



Source: Own elaboration

Figure C.3 shows the evolution of *beta* convergence in direct and embodied per capita emissions, respectively. As the logic shows, if there is *sigma* divergence, there must be *beta* divergence, but not necessarily the contrary. As shown in the two graphs above, the countries present *beta* divergence in per capita emissions, because those that issued a large amount of emissions at the beginning of the period, are those that present a higher rate of growth of per capita emissions throughout the analyzed period. The case of China stands out as an outlier, since it is the country that generates the largest amount of emissions globally, and the one that generates the most emissions in the elaboration of its final products.

A cluster analysis is carried out to check if there is a common tendency in groups of countries. When we carry out this study for per capita emissions data to determine the clusters by pollution intensity, the countries are grouped as follows[17]:

- Cluster 1: Australia, Bulgaria, Brazil, Canada, China, Indonesia, India, Korea, Latvia, Mexico, Poland, Russia, Slovakia, Turkey, Taiwan.
- Cluster 2: Austria, Switzerland, Czech Republic, Denmark, Spain, Estonia, Greece, Croatia, Hungary, Ireland, Lithuania, Luxembourg, Malta, Portugal, Slovenia and Romania.

[17] Cyprus has been eliminated from the analysis because it does not belong to any cluster.

- Cluster 3: Belgium, Germany, Finland, France, United Kingdom, Italy, Japan, Netherlands, Norway, Sweden and USA.

When we look at the three groups of countries, we can see that the classification has changed in terms of total emissions. In the first group are countries with higher pollution intensity, while in the last group there are countries with the lowest emissions intensity. Thus, in the same way as before, a convergence analysis is carried out within each of the clusters formed after applying the cluster methodology. Table C.1 shows a summary of the results.

Table C.1. Convergence in emissions by clusters, per capita emissions, 2000-2014

	Cluster 1	**Cluster 2**	**Cluster 3**
α	0.930718	0.373607	0.327609
β	-0.00745014	0.00736691	0.000480688
p-value	3.75e-06 ***	2.28e-06 ***	0.3321

Source: Own elaboration

When we observe the results, the time trend coefficient presents a negative sign for cluster 1, indicating the existence of convergence, while that same coefficient for clusters 2 and 3 is positive (being not significant in the latter case), which in itself indicates the presence of a divergence process.

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Chapter 4: Exploring scenarios for the disintegration in the European Union: a case study for Eastern Europe economies[18]

1. *Introduction*

The phenomenon of economic integration, which promotes the benefits of greater trade by the reduction in tariffs and administrative barriers, has been the dominant development mantra for many decades. Since the mid twentieth century, several economic areas have been formed with the European Union perhaps exemplifying integration that extends beyond just economic to include political decisions. However, there are clear differences between associate and full membership (the first one is only an economic integration and the second one is economic and political integration) generating the possibility of there being two Europes moving at different speeds (see Fagerberg and Verspagen, 2014). In addition, the effects of the international economic crisis in 2008 triggered a clear divergence between European countries (see Bolea *et al.* 2018). In this sense, the phenomenon of integration and its consequences for the social, political, and economic characteristics of countries has been a central topic in the literature, and its evaluation continues to attract great academic interest (European Commission, 2007; 2015).

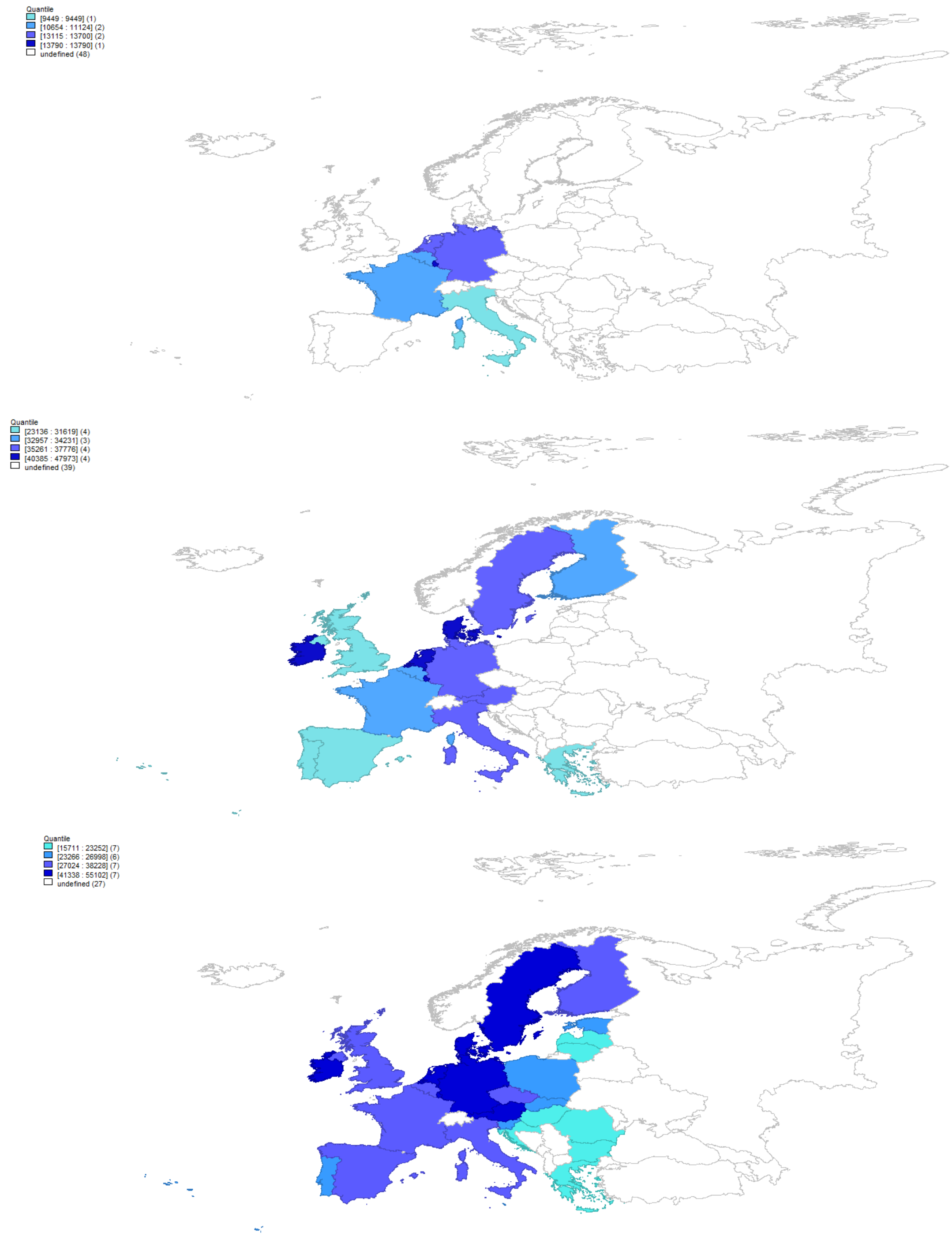
The creation of the European Union and its subsequent enlargements have been well studied in the literature. The economic outcomes from these enlargements have not been monotonically positive. In 2004, a group of Eastern countries became part of the European Union (with the exception of Bulgaria and Romania, which would enter in 2007). From that moment, the EU had become a bloc of much more heterogeneous countries, and it was not clear whether the benefits of development would be equally spread across all countries. The process of the EU's enlargement actually began in 1993, however, when the so-called "European agreements" with the Czech Republic, Slovakia, Hungary, Poland, Bulgaria, and Romania were enacted. These trade agreements established the path to accession to the EU as the final objective. Therefore, from that date until the beginning of the twenty-first century, the Eastern bloc was awaiting entry into the EU. In 2004, the "extension to the

[18] A preliminary version of this chapter was presented at the 27th International Input-Output Conference, and 59th ERSA Conference.

East" meant a change not only political, but also economic; eight of the 10 new states that entered the EU had belonged to the Soviet bloc, which meant allowing entry to a group of countries whose economies and cultures differed significant from those of other EU countries.

In addition, as a consequence of the 2008 global financial crisis, individual EU countries responded in very different ways, which caused serious imbalances in the real economies. A first insight into the development of GDP in Europe can be gained by analyzing the evolution of GDP from 1957 (foundation of the European Coal and Steel Community) to the last year of our study, 2014. Figure 23 shows the GDP per capita in European Union countries over that period.

<u>Figure 23</u>. Changes in GDP per capita generated in Europe (1957, 2000 and 2014)



Source: Elaborated with GEODA (data from Maddison Historical Statistics). GDP per capita is expressed in 2011US$ per inhabitant. The EU countries have been divided into 4 quartiles: low, medium-low, medium-high and high income, corresponding colours from least to highest intensity.

There has been a clear increase in the heterogeneity among the Member States of the European Union over the last decades and an increase in the levels of GDP per capita. In 1957, we can see that the founding countries, Belgium, France, Germany, Italy, Luxembourg and the Netherlands, presented very similar levels of income per inhabitant (the differences between quartiles are minimum) being Luxembourg the country with the highest levels. At the beginning of the 21th century, 2000, with the incorporation of some Central European countries and the Mediterranean countries, a small increase in heterogeneity can be observed. In the last year of our analysis 2014, there would appear to be two distinct groups within the current European Union, Western and Eastern countries due to these are countries with very divergent routes, which leads to the differences in income levels. Despite the process of income convergence over time, high income differences still hold among EU members (a detailed analysis of the income convergence can be seen in Bolea *et al.* (2018)).

Figure 23 shows, as demonstrated in the literature, the divergence between countries that were initially part of the EU (Belgium, France, Germany, Italy, Luxemburg, and the Netherlands) and those countries that joined in recent years (see Sonis *et al.*, 1993). This is also the case for Eastern European countries that became members in 2004 (the Czech Republic, Estonia, Hungary, Lithuania, Latvia, Poland, Slovakia, and Slovenia). These countries shared certain economic characteristics and political interests with other EU countries, but also differed in many respects in terms of economic structure, production and trade specialization, and income inequality. In this general context, it seems relevant to employ methodologies that allow us to assess how the process of economic integration has strengthened the productive structures, and advanced structural and technological change. Estimating the contribution is not trivial, because diverse concurrent economic, political, historical, and social factors underlie the economic trajectories of countries.

Nowadays, economic growth needs the recognition of the multisectoral and multiregional nature of economies, and their involvement in the so-called global and regional value chains (see Escaith and Inomata, 2013). In this global context, multiregional input-output models (MRIO) have revealed as powerful instruments to quantify the role of intersectoral and interregional links at different scales on economic evolution (see for instance Bolea *et al.* 2020 and Zhang *et al.* 2017).

More specifically, on the basis of a MRIO model developed for the world economy, this chapter analyzes the effects of a possible no-adhesion of the Eastern bloc of countries in the European Union. To do this, we also inspire in the synthetic indicators methodology and the hypothetical extraction methods to develop some scenarios/counterfactuals that will be tested using a MRIO model, to calculate the effects on themselves, on the rest of the EU, on the rest of Europe and on the rest of the world comparing current trajectories and those projected under the "contrafactual" paths.

In this context, to the best of our knowledge, there is lack of studies focused on the analysis of the hypothetical scenarios/counterfactuals with a multiregional and multisectoral perspective to analyze the dependence of countries on intra-EU trade flows and the exposure of long term economic growth in different EU areas to these processes. Multiregional input-output models (MRIO) have proven to be powerful instruments to quantify the role of intersectoral and interregional links in the evolution of economic growth of countries. More specifically, by way of a scenario analysis, this chapter explores the effects of hypothetical scenarios of no-adhesion of Eastern European countries in the European Union globally, taking advantage of the full map of intersectoral and interregional relationships along the full supply chain that MRIO models capture. This analysis allows us to obtain some relevant insights on the interdependence of the EU economies and their potential exposure to changes in demands from other EU countries.

The chapter is organized as follows. Section 2 provides a brief literature review in this framework. Section 3 presents an elaboration of the methodology used, based on a multi-regional input-output model from 1995 to 2014, and explaining in detail each of the scenarios that will be considered. Section 4 addresses the results obtained in this work related to each of those hypothetical situations and to the behaviors observed for different countries and sectors. We close the chapter with some conclusions in Section 5.

2. *Literature review*

In the literature, several studies focused on the role played by the European Union in recent years to boost overall EU growth. Some of them analyzed these economic phenomena through building counterfactuals with the synthetic control methodology, others with econometric techniques and a few also with a multiregional perspective.

Input-output multiregional and multisectoral (MRIO) models have been increasingly used to study the effects of economic growth and trade expansion. The MRIO models allow us to analyze both direct and indirect effects of these phenomena, studying the interlinked trade patterns among regions and countries, allowing a comprehensive evaluation of the so-called global value chains (see for instance Hummels *et al.* 2001, Los *et al.* 2015). This approach has been recently extending to capture related phenomena as is the case of Amendolagine *et al.* (2019), who use a MRIO input-output model to study how the effect of the participation and position in the global value chains (GVCs) of host countries is associated with local sourcing by foreign investors. Bahar *et al.* (2019) make use of input-output related indexes to explore the degree to which export take-offs are more likely to occur in sectors that are upstream to already competitive export industries in the developing world. More recently, Fan and Liu (2020), using a multiregional input-output table, present a model of global supply chain to capture the macro production relationships among major world economies in the first decades of this century.

However, despite the power of these models to quantify, not only direct, but also indirect interrelationships and dependences among countries and regions, few papers have used this methodology to analyze the consequences of integration or disintegration processes. Some exceptions are Chen *et al.* (2017) who explored the degree to which EU regions and countries are exposed to negative trade-related consequences of BREXIT using an MRIO; the results from this model are transformed into an index that summarizes the effects of this phenomenon. In similar fashion, Los *et al.* (2016) carry out a hypothetical extraction method to assess the impacts of the exposure of EU regions to BREXIT. Bailey and De Propris (2017) analyze the effect of BREXIT through global value chains, taking into account both domestic and international input-output relationships between countries, finding that the UK exposure to BREXIT is four times higher than the other EU countries exposure, with the exception of Ireland.

In this chapter, we aim to approximate a complementary perspective will be provided that provides a longer-term view of these effects. In order to do this, and inspired in the synthetic control methodology, we extend this multiregional and multisectoral framework to propose counterfactuals or different scenarios to analyze the effect of certain shocks on economies that originate from the process of cohesion or disruption engendered by the Global Recession.

Note that since the synthetic control methods were implemented in the literature (see for instance Abadie and Gardeazabal, 2003), they have become a relevant tool for policy evaluation and for analyzing the effect of the implementation of some economic policies as well as the impact of certain economic shocks. Campos *et al.* (2015) apply synthetic control methods with regional data to study if the European economic and political integration is much better than only economic integration. In this same line, Abadie and Gardeazabal (2003) perform a synthetic control method to study the economic effects of terrorism in Basque Country, building counterfactuals with other similar Spanish regions before the outset of Basque political terrorism in the 1960s. In addition, Badinger (2005) or Crespo *et al.* (2008), using the synthetic counterfactual methods, estimate the evolution of the GDP per capita in the European Union over the last years, paying special attention to intra-EU trade flows, finding that the GDP per capita generated in the EU would be lower today if integration had not taken place. Finally, Garrett-Peltier (2017) uses the input-output information to create "synthetic" industries in the US context, to evaluate whether the public and private spending in clean energy sectors is more efficient than spending on fossil fuels.

This methodology, as well as the hypothetical extraction method, inspires our scenario analysis. Scenario analysis is a usual exercise in input-output modelling used to explore how counterfactual changes in demand composition and trade, holding other things constant, alter the values in input-output tables, thereby affecting equilibrium values and participation of countries in the global and European production chains. Although the scenarios can be seen as extreme in nature, they are useful for understanding some distinctive features of the framework. In consequence, our approach should be seen as an accounting exercise, providing quantitative information of the extent to which GDP in EU countries are exposed to changes in demands from other EU and non-EU countries (see for instance Antràs and de Gortari, (2020), Costinot and Rodríguez-Clare, (2015); or Chen *et al.* (2017) for other applications of scenario analysis and input-output to different research topics).

Finally, in the last years, new literature has highlighted the role of governance and European funding explaining part of the divergent economic paths observed in EU countries (Da Cruz and Marques, 2017 and Caldas *et al.* (2018a, 2018b)) and the effectivity of the European Cohesion Policy and the associated economic funds, which without doubts has been central explaining the recent evolution of all EU countries, also being central for the industry transformation of East-EU economies.

Therefore, in line with previous literature and acknowledging the multisectoral and multiregional character of global production flows, the objective is to focus on the possibility of defining a type of synthetic indicators, building "counterfactuals" and alternative scenarios to evaluate the impact of the "non-integration" of Eastern European countries in the European Union (we will it call "the EE-EXIT") from a multiregional and a multisectoral perspective.

3. *Methodology*

From the empirical point of view, we make use of the IO tables from the World Input Output Database (WIOD, Release 2013, and Release 2016[19]) in current prices, denoted in current millions of United States dollars and data from EORA database to complete our work. The choice of the period is mainly conditioned by the availability of comparable data, but it is of notable economic interest itself, insofar as it includes a 13-year period with positive growth (it includes the years of the Great Moderation), as well as the subsequent period of international economic crisis starting in 2008.

As it mentioned above, the IO methodology is a potential instrument to evaluate the role of interregional links on the evolution of economic growth. Using the MRIO tables from the World Input-Output Database[20] (WIOD, Release 2013, 2016) for the world economy, and using the methodology for the development of MRIO in Isard (1951, 1953) and Miller and Blair (2009), we study the political and economic effects of the hypothetical case of non-integration of Eastern European countries in EU in three different scenarios. Taking into account the information provided by WIOD, our sample contains 41 countries: 27 European countries and 14 non-European countries (including the Rest of World) from

[19] See Timmer *et al.* (2015)
[20] The WIOD's WIOTs are expressed in current millions of United States dollars.

1995 to 2014[21]. We are going to study the effects on changes in GDP embodied in trade flows as well as in the domestic production of East Europe to themselves, to the rest of Europe and to the rest of the world. In addition, we make use of certain information from EORA database to be explained in detail later.

In what follows, we present the main features of the methodological approach adopted. First, in Table 8, the structure of the MRIO model used in this work is presented. The distribution of the table is totally logical with the study because we order the MRIO table of WIOD according to the importance of countries in our analysis.

<u>Table 8</u>. Economic structure of the MRIO table

<table>
<tr><th></th><th>East</th><th>Rest of EU</th><th>Rest of Europe</th><th>Rest of World</th><th colspan="4">Final demand</th><th>X</th></tr>
<tr><td>East</td><td>$Z_{ij}^{E,E}$</td><td>$Z_{ij}^{E,RoEU}$</td><td>$Z_{ij}^{E,RoE}$</td><td>$Z_{ij}^{E,RoW}$</td><td rowspan="4">Y_1^{E}
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Y_j^{E}</td><td rowspan="4">Y_1^{RoEU}
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Y_j^{RoE}</td><td rowspan="4">Y_1^{RoW}
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Y_j^{RoW}</td><td>X^{E}</td></tr>
<tr><td>Rest of EU</td><td>$Z_{ij}^{RoEU,E}$</td><td>$Z_{ij}^{RoEU,RoEU}$</td><td>$Z_{ij}^{RoEU,RoE}$</td><td>$Z_{ij}^{RoEU,RoW}$</td><td>X^{RoEU}</td></tr>
<tr><td>Rest of Europe</td><td>$Z_{ij}^{RoE,E}$</td><td>$Z_{ij}^{RoE,RoEU}$</td><td>$Z_{ij}^{RoE,RoE}$</td><td>$Z_{ij}^{RoE,RoW}$</td><td>X^{RoE}</td></tr>
<tr><td>Rest of World</td><td>$Z_{ij}^{RoW,E}$</td><td>$Z_{ij}^{RoW,RoEU}$</td><td>$Z_{ij}^{RoW,RoE}$</td><td>$Z_{ij}^{RoW,RoW}$</td><td>X^{RoW}</td></tr>
<tr><td>VA</td><td>$VA^{E'}$</td><td>$VA^{RoEU'}$</td><td>$VA^{RoE'}$</td><td>$VA^{RoW'}$</td><td colspan="5"></td></tr>
<tr><td>X</td><td>$X^{E'}$</td><td>$X^{RoEU'}$</td><td>$X^{RoE'}$</td><td>$X^{RoW'}$</td><td colspan="5"></td></tr>
</table>

Source: Own elaboration

where the terms Z_{ij}^{RS} represent interindustry sales by sector i of region *R* to all sectors *j* of region *S* (including itself, when *j*=*i* and *R*=*S*). Y_i represents the final demand by sector and country, being the super index the origin of that final demand ("E" represents countries of the East bloc, "RoEU" the countries of the rest of European Union, "RoE" the countries of the rest of Europe, and "RoW" the countries of the Rest of World). X is the total output by sector and country; and VA is the vector of value added generated by sector and country of

[21] The WIOD Release 2013 is taken into account for the analysis of the period prior to integration and WIOD Release 2016 to extend the post-crisis period.

the sample. As can be seen in the table, we develop a multiregional accounting system divided into four clear different regions, including the Eastern European countries, the Rest of European Union, the Rest of Europe (Russia and Turkey) and the Rest of World (RoW) that incorporates the 14 non-European regions that WIOD contains.

In line with the methodology of the previous chapters, an extended MRIO model can be estimated on the basis of this information following the procedure of the input-output framework. Starting from equation (1.1), and as established in the previous chapter, this equation (1.1) can be also represented in terms of the well-known Leontief inverse **L**, an ($r \times n$) × ($r \times n$) matrix, defined for the whole multiregional economy.

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} = \mathbf{L}\mathbf{y} \qquad (4.1)$$

If we pre-multiply (4.1) by a diagonalized vector of direct value added unitary coefficients, we obtain (4.2) that shows all VA flows in the global economy associated with the production of goods traded among countries, as well as for each country's domestic production.

$$\mathbf{GDP} = \boldsymbol{\Omega} = \left(\omega_{ij}^{rs}\right) = \hat{\mathbf{v}}\boldsymbol{L}\hat{\mathbf{y}} = \begin{pmatrix} \boldsymbol{\omega}^{11} & \boldsymbol{\omega}^{12} & \cdots & \boldsymbol{\omega}^{1r} \\ \boldsymbol{\omega}^{21} & \boldsymbol{\omega}^{22} & \dots & \boldsymbol{\omega}^{2r} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{\omega}^{r1} & \dots & \dots & \boldsymbol{\omega}^{rr} \end{pmatrix} =$$

$$\begin{pmatrix} \hat{\mathbf{v}}^{11} & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \hat{\mathbf{v}}^{22} & \dots & \mathbf{0} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{0} & \dots & \dots & \hat{\mathbf{v}}^{rr} \end{pmatrix} \begin{pmatrix} \mathbf{L}^{11} & \mathbf{L}^{12} & \cdots & \mathbf{L}^{1r} \\ \mathbf{L}^{21} & \mathbf{L}^{22} & \dots & \mathbf{L}^{2r} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{L}^{r1} & \dots & \dots & \mathbf{L}^{rr} \end{pmatrix} \begin{pmatrix} \hat{\mathbf{y}}^{11} & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \hat{\mathbf{y}}^{22} & \dots & \mathbf{0} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{0} & \dots & \dots & \hat{\mathbf{y}}^{rr} \end{pmatrix} \qquad (4.2)$$

As it has been mentioned above, $\boldsymbol{\Omega}$ represents all VA flows in the global economy associated with the production of commodities among countries as well as with the domestic production of each country. Each element of matrix $\boldsymbol{\Omega}$ is a block (n x n) and represents the VA generated in any sector of a country r to meet the final demand of a country s. Summing by columns in $\boldsymbol{\Omega}$ and defining $\mathbf{b}$ as a 1 x n vector of ones to aggregate the information by country, we obtain the total VA generated in the total economy and incorporated through the full supply chain to obtain the final demand of country s as follows:

$$\mathrm{GDP}_{\boldsymbol{s}} = \sum\nolimits_{\mathbf{r}} \mathbf{b}'\boldsymbol{\Omega}\mathbf{b} \qquad (4.3)$$

In this study, we are interested in measuring the potential effect that Eastern European countries would have had on the EU countries' GDP if they had not accepted to be members of the EU in 2004. For that reason, and because we apply the changes in the matrix by columns, we only take into account the vertically integrated value added for each of the countries in the sample.

We assume that from the year 2002 (two years before their entry into the EU), there is the beginning of significant effects over all countries. Since 1993 and as a consequence of "European agreements", Eastern Europe had already been informed that its membership in the EU had been accepted and knowing that the integration of these economies had begun earlier. We assume that since 2002 to 2011, the Eastern countries are going to experienced several changes in their GDP evolution.

As a consequence of this, three different hypothetical scenarios are proposed to study which part of GDP of regions is exposed to EE-EXIT and to compare the effects on GDP under different assumptions.

Scenario 1

In the first scenario, which is our base scenario, we consider that there are no exports between Eastern European countries and the rest of the EU; this becomes the baseline against which the others are contrasted. As Chen *et al*. (2017) assume, it addresses the impact of the total elimination of exports EU countries to Eastern countries, the hypothetical situation in which none of the rest of the EU countries export products to Eastern European regions and therefore, Eastern European countries do not import any product from the EU either (both intermediate inputs and final goods). In essence, it is assume all this bilateral trade is lost and not recovered.[22]

To accomplish this, and following the structure of Table 8, we apply the hypothetical extraction method on the matrix of intermediate inputs $\mathbf{Z} = \mathbf{A}\hat{\mathbf{x}}$ and on the matrix of final demand $\mathbf{Y}$, taking into account direct and indirect effects of the trade generated between these two regions. So, the part of the matrix $\mathbf{Z}$ and final demand $\mathbf{Y}$ that corresponds to the

[22] We assume that it is an unrealistic scenario since the lost trade is not recovered by any of the countries, and therefore it is like "building a wall" between them.

exports from European countries to Eastern countries is set to zero, as shown in equations (4.4) and (4.5):

$$\mathbf{Z^1} = \begin{pmatrix} \mathbf{Z^{E,E}} & \mathbf{Z^{E,RoEU}} & \mathbf{Z^{E,RoE}} & \mathbf{Z^{E,RoW}} \\ \mathbf{0} & \mathbf{Z^{RoEU,RoEU}} & \mathbf{Z^{RoEU,RoE}} & \mathbf{Z^{RoEU,RoW}} \\ \mathbf{Z^{RoE,E}} & \mathbf{Z^{RoE,RoEU}} & \mathbf{Z^{RoE,RoE}} & \mathbf{Z^{RoE,RoW}} \\ \mathbf{Z^{RoW,E}} & \mathbf{Z^{RoW,RoEU}} & \mathbf{Z^{RoW,RoE}} & \mathbf{Z^{RoW,RoW}} \end{pmatrix} \tag{4.4}$$

$$\mathbf{Y^1} = \begin{pmatrix} \mathbf{Y^{E,E}} & \mathbf{Y^{E,RoEU}} & \mathbf{Y^{E,RoE}} & \mathbf{Y^{E,RoW}} \\ \mathbf{0} & \mathbf{Y^{RoEU,RoEU}} & \mathbf{Y^{RoEU,RoE}} & \mathbf{Y^{RoEU,RoW}} \\ \mathbf{Y^{RoE,E}} & \mathbf{Y^{RoE,RoEU}} & \mathbf{Y^{RoE,RoE}} & \mathbf{Y^{RoE,RoW}} \\ \mathbf{Y^{RoW,E}} & \mathbf{Y^{RoW,RoEU}} & \mathbf{Y^{RoW,RoE}} & \mathbf{Y^{RoW,RoW}} \end{pmatrix} \tag{4.5}$$

where $\mathbf{Z^{RoEU,E}}$ and $\mathbf{Y^{RoEU,E}}$ are equal to zero since they represent the part of exports (imports) from European Union (East) to the Eastern European countries (EU) both of intermediate inputs and final goods. As noted earlier, the first scenario is taken as the most extreme alternative to compare with the rest of scenarios. Once the changes in the matrices have been made, the new GDP is calculated as follows on the basis of the following matrix:

$$\mathbf{GDP^1} = \mathbf{\Omega_1} = (\omega_1^{rs}) = \hat{\mathbf{v}}\,\mathbf{L^1}\hat{\mathbf{y}}^{\mathbf{1}} \tag{4.6}$$

In consequence, value added generated in the total economy and incorporated to obtain the final demand of country *s* as:

$$GDP_s^{\mathbf{1}} = \sum\nolimits_{\mathbf{r}} \mathbf{b}'\mathbf{\Omega_1}\mathbf{b} \tag{4.6bis}$$

To quantify the part of GDP exposed to this hypothetical situation in country *r* on final demand and intermediate inputs (as Los *et al*., 2017 and Chen *et al*., 2017), we apply the index described in (4.7):

$$IE^1 = \frac{(\mathrm{GDP_s^1} - \mathrm{GDP_s^0})}{\mathrm{GDP_s^0}} * 100 \tag{4.7}$$

where the superscripts "0" and "1" represent the real and first hypothetical situations, respectively.

Scenario 2

In the second scenario, and with the purpose of being more realistic than the previous one, we again assume that European Union countries do not export anything to Eastern

European countries, but in this case, those exports are reallocated to other countries. As a consequence of this situation, we propose two different cases related with the second scenario. First, we assume that, as a consequence of the non-entry into the EU, the Eastern bloc decides to relocate all that trade in the Rest of World, that is, decide to make a *substitution of imports*. And in the second case, as a consequence of the non-entry into the EU and knowing that Eastern economies can also decide to increase their domestic production, we assume that EU-East trade is *gradually distributed* between non-EU production and domestic production. This means that it will be assumed that each year (since 2003[23]) the Eastern bloc increases gradually[24] its domestic production of its trade with the Rest of World. That is, due to the elimination of EU-East trade, Eastern countries increase their domestic production and non-European trade gradually according to these proportions. To an easier understanding, the following table shows the distribution of the East-EU trade after the "no-adhesion" process.

Table 9. Distribution of EU trade according to the "gradually distributed" scenario

a_z	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
EU trade_Domestic production	0%	2%	4%	6%	8%	10%	12%	14%	16%	18%	20%	22%	24%
EU trade_Trade with EU	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
EU trade_Trade with non-EU	100%	98%	96%	94%	92%	90%	88%	86%	84%	82%	80%	78%	76%

Source: Own elaboration

In this scenario, it is assumed that the EU-East trade is reallocated to each part (domestic production and trade with RoW) according to the weight of each sector within each country with respect to the total of that sector in the EU-East bloc. So, equations (4.8) and (4.9) show the procedure to share the EU-East trade in the different scenarios.

[23] In 2002 it is assumed that 100% is imported from the rest of the world.
[24] We consider that East bloc increases their domestic production by 2% each year of their trade with the European Union that now is eliminated.

$$Z_{ij}^{RS*} = Z_{ij}^{RS} + \left[\frac{Z_{ij}^{RS}}{\sum_{j=1}^{n} Z_{ij}^{RS} + \sum_{j=1}^{n} Z_{ij}^{TS}} * b_j\right] * a_Z \tag{4.8}$$

$$Z_{ij}^{AS*} = Z_{ij}^{AS} + \left[\frac{Z_{ij}^{AS}}{\sum_{j=1}^{n} Z_{ij}^{AS} + \sum_{j=1}^{n} Z_{ij}^{BS}} * b_j\right] * (1 - a_Z) \tag{4.9}$$

being $b_j = Z_{ij}^{CS} + Z_{ij}^{DS}$ and a_Z the parameter that indicates the proportion that is assigned to each part (see table 9). In those equations, *S* represents a country from East; *R* and *T* are non-EU countries (belong to RoE or RoW); *A* and *B* represent other Eastern countries; *C* and *D* represent EU countries outside the East bloc. In this way, we can see as the EU-East trade is divided between imports from the rest of the world and domestic production according to the weight of each sector of each country with respect to the total weight of each sector in the corresponding bloc.

Therefore, following the earlier procedure, we have the following matrices:

$$\mathbf{Z}^2 = \begin{pmatrix} \mathbf{Z}^{\mathbf{E,E}} & \mathbf{Z}^{\mathbf{E,RoEU}} & \mathbf{Z}^{\mathbf{E,RoE}} & \mathbf{Z}^{\mathbf{E,NoEU}} \\ \mathbf{0} & \mathbf{Z}^{\mathbf{RoEU,RoEU}} & \mathbf{Z}^{\mathbf{RoEU,RoE}} & \mathbf{Z}^{\mathbf{RoEU,NoEU}} \\ \mathbf{Z}^{\mathbf{RoE,E}} & \mathbf{Z}^{\mathbf{RoE,RoEU}} & \mathbf{Z}^{\mathbf{RoE,RoE}} & \mathbf{Z}^{\mathbf{RoE,NoEU}} \\ \mathbf{Z}^{\mathbf{NoEU,E}} & \mathbf{Z}^{\mathbf{NoEU,RoEU}} & \mathbf{Z}^{\mathbf{NoEU,RoE}} & \mathbf{Z}^{\mathbf{NoEU,NoEU}} \end{pmatrix} \tag{4.10}$$

$$\mathbf{Y}^2 = \begin{pmatrix} \mathbf{Y}^{\mathbf{E,E}} & \mathbf{Y}^{\mathbf{E,EU}} & \mathbf{Y}^{\mathbf{E,RoE}} & \mathbf{Y}^{\mathbf{E,NoEU}} \\ \mathbf{0} & \mathbf{Y}^{\mathbf{EU,EU}} & \mathbf{Y}^{\mathbf{EU,RoE}} & \mathbf{Y}^{\mathbf{EU,NoEU}} \\ \mathbf{Y}^{\mathbf{RoE,E}} & \mathbf{Y}^{\mathbf{RoE,EU}} & \mathbf{Y}^{\mathbf{RoE,RoE}} & \mathbf{Y}^{\mathbf{RoE,NoEU}} \\ \mathbf{Y}^{\mathbf{NoEU,E}} & \mathbf{Y}^{\mathbf{NoEU,EU}} & \mathbf{Y}^{\mathbf{NoEU,RoE}} & \mathbf{Y}^{\mathbf{NoEU,NoEU}} \end{pmatrix} \tag{4.11}$$

where $\mathbf{Z}^2$ and $\mathbf{Y}^2$ represent the new initial IO matrix and the new final demand, respectively. In the first case (*substitution of imports*), the part assigned to domestic production is multiplied by $(1 - a_Z) = 0$ since all trade is imported from non-EU countries and a_Z is always equal to 1. However, in the second case (*gradual assignment*), each part is multiplied by the corresponding percentage, depending of the year of analysis (see table 9). Once we have the new initial IO matrix, Generalized RAS method (GRAS[25]) is applied (see Junius and Oosterhaven, 2003; Lenzen *et al*., 2007; Temurshoev *et al*., 2013) to match the IO matrix with the resulting from these changes, taking into account that the sum of the columns of final demand is maintained. As noted earlier, we are analyzing the changes in

[25] Following the Matlab programming developed by Andre F.T. Avelino (2017). This procedure is used to adjust a matrix, with a minimum loss of information, to a required sum of columns and rows when positive and negative entries are present.

the GDP generated in the economy and incorporated through the full supply chain to obtain the final demand (all the value-added embodied in a good consumed, i.e. demand perspective). For that reason, and because the lost trade is reallocated throughout the same column of each East country, we calculate the GDP exposed to these EE-EXIT scenarios as in (4.7).

Scenario 3

In the last scenario, probably the most realistic situation, we assume that Eastern countries maintain, both in output and VA, the same trend they had from 1990 to 2001 (the period prior to EU integration) and the average of trend of countries most similar to them within the sample, in terms of output and VA generation. We calculate these trends with simple moving averages (SMA). This means that both the new output vector and the new VA vector are obtained according to the following equations:

$$\mathrm{x}_{2002}^{R} = \mathrm{t\_x}_{1990-2001}^{R} + average\left(\mathrm{t\_x}_{1990-2001}^{S}\right)$$

$$VA_{2002}^{R} = t\_VA_{1990-2001}^{R} + average\left(t\_VA_{1990-2001}^{S}\right) \qquad (4.12)$$

where superscript *R* represent an Eastern European country, and superscript *S* is the group of countries that are similar to *R* in terms of output and VA in the previous years of integration. In (4.12), the calculations are shown for the year 2002, but since it is a structural mobile average (SMA), for the year 2003 the trend will be taken for the period 1991-2002. The EORA database is used to complete this task, from which the output and VA data were obtained from 1990 to 1994 (WIOD has data from 1995 onwards). Therefore, we obtain a new output vector and a new VA vector.[26] Taking into account the new values of these vectors, it is also necessary to apply the GRAS method to balance the initial IO matrix and the corresponding part of final demand year by year. It is well-known that it is necessary to obtain a new column vector *u* [(r x n) x 1] (corresponding to the sum of the columns of each row) and a new row vector *v* [1 x (r x n)] (corresponding to the sum of the rows of each column). The first, vector *u*, is obtained assuming that, maintaining the proportions of each country on its final demand, the total of the new vector of VA is equal to the total of the final demands of the countries ($\sum_{i=1}^{n} VA_{ij}^{RS} = \sum_{j=1}^{n} y_{j}^{RS}$). In this way, the

[26] Note that those vectors only change in the part corresponding to the countries of Eastern Europe, the rest remains the same.

vector u (column vector of the sum by rows of the matrix) is composed of the new output vector plus the total of the new VA vector, and the vector v (row vector of the sum by columns of the matrix) is composed of the new output vector plus the new final demands whose sum is equal to the total of the new VA vector. In addition, and in the same way that the trend of the previous years is applied, it is assumed that the productive structure of the countries, year by year, is maintained according to the balanced matrix of the previous year (except in the case of 2002, where the productive structure of 2001 is maintained).

In this situation, the GDP generated in the total economy and incorporated through the entire global value chain that is calculated as follows:

$$\mathbf{GDP^3} = \mathbf{\Omega_3} = (\boldsymbol{\omega}_3^{rs}) = \hat{\mathbf{v}}^3 \, \mathbf{L}^3 \hat{\mathbf{y}}^3 \qquad (4.13)$$

Similarly, the VA generated in the total economy and incorporated to obtain the final demand of country s as:

$$GDP_s^{\mathbf{3}} = \sum_{\mathbf{r}} \mathbf{b}' \boldsymbol{\omega}_3^{rs} \mathbf{b} \qquad (4.14)$$

Equation (4.14) shows the new GDP generated in the new economy with Eastern European countries outside the EU. Again, to calculate the ratio of GDP exposed to the hypothetical situation of EE-EXIT, (4.7) is used.

4. Results

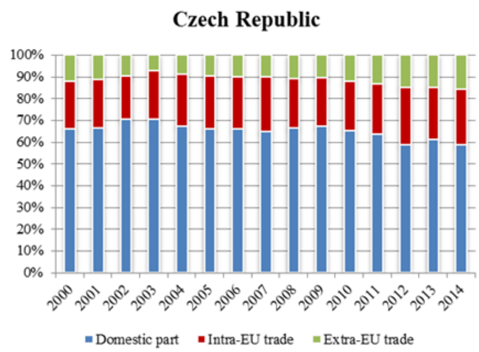
4.1. Factors that explain VA embodied in bilateral trade flows: 2000-2014

From the creation of the integration group of countries to the incorporation, in 2004, of the East bloc, the European Union has gone through many changes in its composition. As mentioned in Figure 23, the heterogeneity between European countries has been growing over the years, causing a more varied Europe.

Therefore, we consider that it is necessary to study which or what are the factors that could be causing these changes. Figure 24 shows for each of the countries of Eastern Europe its evolution with intra-European, extra-European trade and the domestic component. In this way, the aim is to offer, in the first place, a descriptive analysis of the effects of the new integrations in the European Union.

<u>Figure 24</u>. Contribution to the income growth of domestic, intra-EU and extra-EU trade, 2000-2014 for Czech Republic, Estonia, Hungary, Lithuania, Latvia, Poland, Slovakia, and Slovenia.

Figure 24.a. **Figure 24.b.**



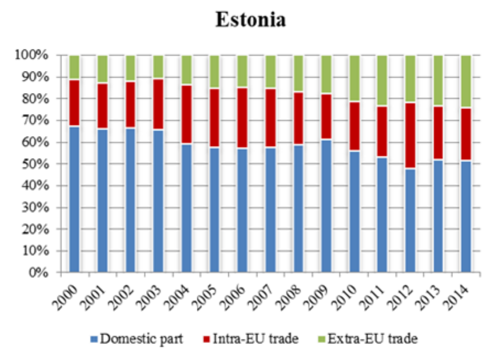
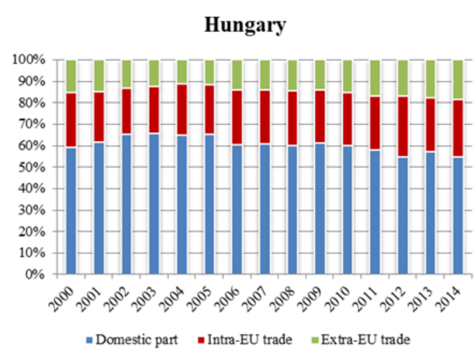


Figure 24.c. **Figure 24.d.**



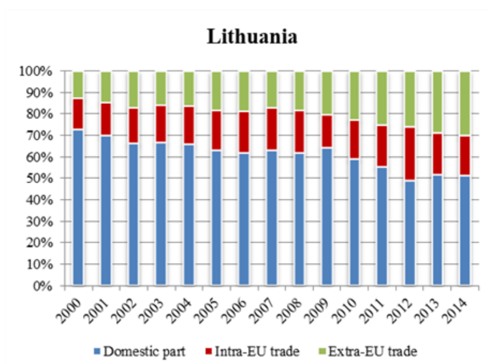
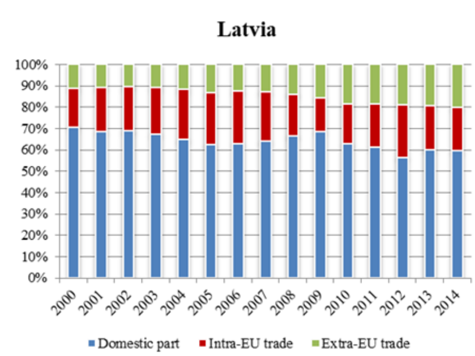


Figure 24.e. **Figure 24.f.**



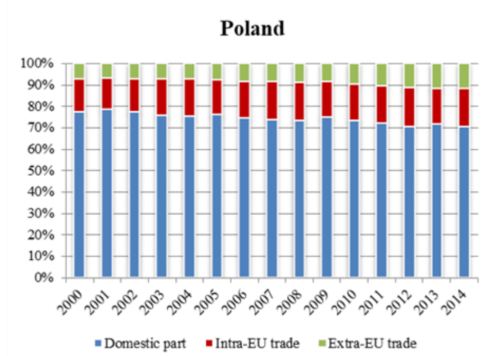
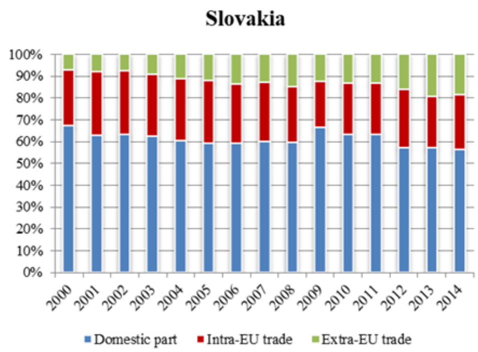


Figure 24.g. **Figure 24.h.**



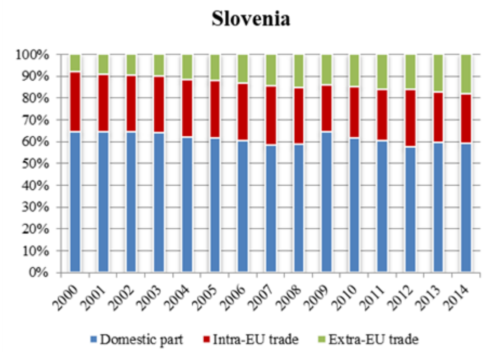
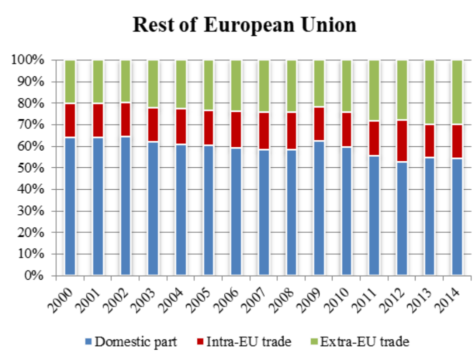
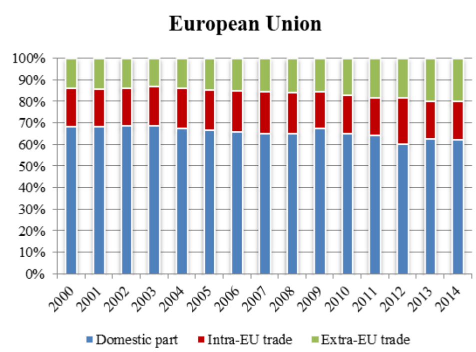


Figure 24.i. **Figure 24.j.**





Source: Own elaboration

In figure 24, we can see that the domestic demand (in blue) of the 8 East countries has been the main contributor to the income growth in the last years although on average its weight shows a slight decreasing trend. However, we can observe how the weight of trade with non-European countries (in green) increases over time, to the detriment of intra-European trade (in red) and the domestic part (in blue), being Estonia and Lithuania the clearest cases of these changes. These last two countries are those that present a greater change with respect to the evolution of their intra-European trade (red part). The results show that Estonia and Lithuania are increasingly dependent on extra-European trade, and this may be due to the fact that they are two countries with great economic opportunities compared to the rest of East bloc and their GDP per capita levels are higher (see Figure 23). For example, in the figure 24.a, which corresponds to Czech Republic, we can observe the evolution of the three main components. The domestic demand represents around 65% over all analyzed period, but it is in 2003 when the domestic production starts to decrease little by little until 60% of the total. If we focus on the pink part (intra-EU trade), we can see that represents around 20% of the total, but from 2003 to the end of the period, this component is gradually increasing. And third, the extra-EU trade component corresponds to the green part and represents around 15%. This is the component with the least weight. However, we can observe its growth as the period progresses. Therefore, if we focus on the individual situation of each of the countries, we can see how Hungary (figure 24.c), Slovakia (figure 24.g), and Slovenia (figure 24.h) are the most dependent countries on intra-EU trade throughout the analyzed period. In addition, as we can see in the figure, the last two graphs show the behavior of these three components (domestic, intra-EU and extra-EU trade) in the EU without Eastern countries (figure 24.i) and in the total European Union (figure 24.j). If we compare the results of these two graphs with the rest of figures, we can observe that the weight of the extra-EU trade component is greater if the Eastern countries are not taken into account (Rest of European Union). However, in the last graph, we can see how by showing the EU average taking into account the Eastern bloc, the component of domestic production and intra-EU trade are higher again. Therefore, from these figures, we can conclude that European countries show a clear trend towards extra-European trade, with the Eastern bloc being the most focused on trade within the European Union.

4.2. Effects on VA embodied by alternative scenarios

Once the main features of the VA embodied have been presented, we now present the effects of the different scenarios that we explain previously, to quantify the impact of each alternative scenario in bilateral trade flows between 2002 and 2014. Table 10 shows the results obtained for the analysis of each of the hypothetical scenarios.

Table 10. Evolution of the IE index. Effects of the non-integration of East in terms of GDP (average 2002-2014, %)

	Scenario 1	Scenario 2		Scenario 3
		Subst. Imports	Gradual assign.	
Czech Republic	-16.36%	6.06%	7.09%	-3.32%
Estonia	-12.34%	5.85%	6.71%	2.68%
Hungary	-17.50%	6.69%	8.23%	-8.98%
Lithuania	-7.71%	4.14%	5.01%	-18.08%
Latvia	-9.23%	5.25%	6.33%	-5.50%
Poland	-10.89%	6.21%	7.06%	-19.03%
Slovakia	-13.78%	6.14%	6.81%	-27.18%
Slovenia	-14.80%	5.97%	9.30%	3.49%
Austria	-2.26%	4.23%	3.92%	3.31%
Belgium	-0.96%	5.40%	5.26%	5.65%
Bulgaria	-1.42%	6.24%	6.11%	-0.24%
Cyprus	-0.54%	2.83%	2.72%	-1.42%
Germnay	-1.57%	4.18%	4.00%	4.33%
Denmark	-0.92%	5.71%	5.61%	3.49%
Spain	-0.46%	4.48%	4.40%	5.03%
Finland	-0.96%	5.94%	5.85%	3.18%
France	-0.45%	4.58%	4.53%	3.48%
Great Britain	-0.36%	5.11%	5.07%	0.43%
Greece	-0.18%	4.25%	4.21%	0.74%
Ireland	-0.75%	4.70%	4.56%	1.31%
Italy	-0.66%	4.58%	4.50%	5.76%
Luxembourg	-0.75%	4.22%	4.12%	-0.15%
Malta	-1.15%	4.32%	4.00%	4.16%
Netherlands	-0.90%	5.07%	4.95%	7.10%
Portugal	-0.26%	6.37%	6.33%	8.48%
Romania	-1.23%	5.38%	5.21%	-1.87%
Sweden	-0.89%	5.80%	5.70%	1.81%
Russia	-0.19%	5.39%	5.34%	-7.46%
Turkey	-0.13%	7.23%	7.27%	-0.82%
Canada	-0.03%	3.04%	3.02%	0.64%
United States	-0.02%	0.87%	0.86%	0.33%
Australia	-0.03%	3.31%	3.31%	-3.41%
China	-0.04%	1.67%	1.67%	-10.97%
Indonesia	-0.03%	1.44%	1.43%	-8.02%
India	-0.03%	4.88%	4.89%	-2.33%
Japan	-0.01%	0.89%	0.87%	3.87%
Korea	-0.04%	5.71%	5.68%	-1.00%
Taiwan	-0.04%	2.82%	2.79%	0.33%
Brazil	-0.03%	8.13%	8.11%	0.07%
Mexico	-0.04%	2.19%	2.19%	-0.73%
Real EU average	-7.00%	1.08%	1.15%	-0.31%
Real average	-2.91%	1.78%	1.86%	1.26%
Standard dev.	0.05	0.02	0.02	0.07

Source: Own elaboration

Table 10 shows that the effects are much greater in the countries of Eastern Europe and these effects are diluted as the countries move away of them, which means that the effects on the countries of the European Union are greater than the effects on the countries of the rest of the world. For instance, it is remarkable the effect of -2.26% on Austria (country belongs to the EU) in the first scenario, and the least effect on Canada (-0.03%).

The first result that we can see is that the effects take different signs depending on the scenario. The results of the three scenarios are compared with the real situation taken as the base. For instance, if we focus on the first row of the table that corresponds to the first country of our analysis, we can observe the different results for Czech Republic. It is clear that the first and third scenario have negative consequences (calculated with (4.7) as the difference between the hypothetical and real situations) on the Czech economy.

Recall that scenario 1 is taken as the extreme alternative; in this scenario for the Eastern European countries, we can see that the changes in the GDP generated in the global economy and that each country incorporates in its final demand, are much greater for the Czech Republic, Hungary, Slovakia, and Slovenia. These are the countries that, as we have seen in figure 24, show greater dependence on intra-EU trade. In addition, it should be noted that the impact in the Eastern European countries would be almost 3 times greater for themselves than for the rest of the European economies. If we look at the RoEU (Rest of EU countries) bloc, we can see how Austria, Bulgaria, and Romania are those that have a more negative effect than the rest. Hence, a shock produced in the Eastern bloc, as is the case of a hypothetical "non-integration", affects its closest neighbors to a greater extent. This could be partially explained both by the proximity of these countries to Eastern Europe and the fact that these three countries have the highest trade with Eastern Europe; clearly there is strong spatial dependence. On the other hand, the effect in the rest of the world is practically zero in this first scenario.

Focusing on the results of the second scenarios, we can see that the effects are completely different than in the previous one. In the first case (substitution of imports) where all the imports that the East made to Europe, are redirected to the non-European bloc, we can observe that, again, the Czech Republic, Hungary, Slovakia, and Slovenia, along with Poland are the countries that show the greatest change. In this scenario, we can observe in table 10 that the effect of import substitution is positive for all of Eastern countries, even for rest of the European countries and for rest of the world. However, these positive effects can be misleading since we are assuming that Eastern countries relocate their trade to the rest of the world, without having any consequences in the rest of the economy of the Eastern bloc. We are assuming that there is a redistribution of trade without any consequences for them (more tariffs, taxes, border problems ...). As is well known, the Eastern countries would have to face a higher payment of tariffs and fees for importing outside the EU. Similar conclusions can be done from the second case (gradual assignment), in which the EU-East trade is gradually assigned between domestic production and imports from the Rest of the World. In this sense, if we look at the column corresponding to "gradual assignment", it is clear that the results are very similar to the previous case of this second scenario. Again, all countries of our sample have a positive effect after the reallocation of the East-EU trade. Therefore, these results want to tell us that, whether we reassign 100% of the trade between the East and the EU or if we assume that this reallocation is done gradually, the consequences for the whole world (inside and outside the Eastern bloc) would be positive. However, as mentioned above, we are assuming that there are no fiscal, administrative or commercial consequences. If these conditions were considered, the results would clearly have a negative sign.

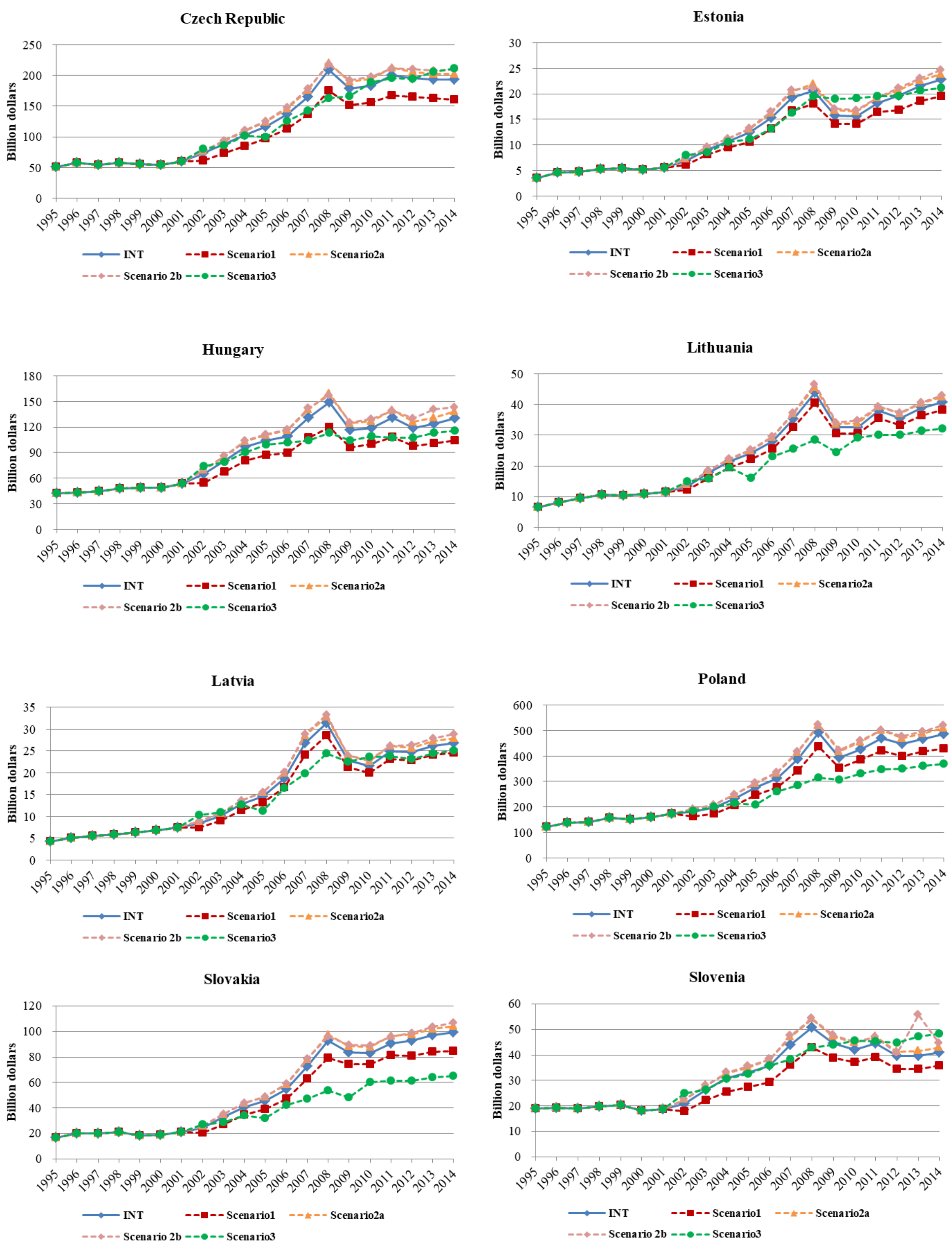
Regarding the third scenario, being the most realistic case of all, we can see how, again, the Eastern European countries would have the greatest declines in GDP as a result of their non-integration in the European Union. The case of Estonia is different due to the great weight of its domestic component, but undoubtedly due to its trade with the rest of the world. Estonia is the country in the Eastern bloc that least depends on intra-European trade. This reason would explain the causes of their different behavior. On the other hand, in this last scenario, it is interesting to see how the consequences for the rest of the EU member countries are very heterogeneous. Austria, Belgium, Germany, Denmark Finland, and the Netherlands are the countries with higher positive effect in the hypothetical scenario of non-integration of Eastern countries. However, Bulgaria, Cyprus, and Romania are the countries with the highest negative effect (-0.24%, -1.42%, and -1.87%, respectively). It is the countries of Central Europe that would recover from this shock before, with Bulgaria and Romania[27] being the most affected. Finally, if we focus on the non-European bloc, some results are surprising. China, Russia, and Indonesia have a higher negative effect than the closest neighbors of the East in the European bloc (-10.97%, -7.46%, and -8.02%, respectively). In the case of China, as is well-known, its entry in November 2001 to the World Trade Organization (WTO) had a positive impact on its global trade position. Since then, Chinese foreign policies started to focus on the direction of expansion towards Europe. Finally, in 2012, it was established the so-called "Cooperation between China and Central and Eastern European countries (CEE)". In the case of Russia, the EU's political and economic relations with it have been based on a bilateral Partnership and Cooperation Agreement (PCA) since 1997. After the conflict in Eastern Ukraine, the bilateral political and commercial dialogue has been affected. However, since Russia joined the WTO, EU-Russia trade relations have increased, focusing on the East bloc of countries as intermediaries of their trade relations with the rest of the EU. Finally, in the case of Indonesia, the relation with the EU has deepened over recent years. Indonesia is a member of the WTO since 1995 and benefits from trade preferences granted by the EU's Generalized Scheme of Preferences (GSP), under which about 30% of total imports from Indonesia enjoy lower duties (see https://ec.europa.eu/trade/policy/countries-and-regions/). Therefore, these results could be showing the significant consequences that the breakdown of the EU would have, not only at a European level but also at a global level due to the strong commercial relations that these non-EU countries have with the European Union bloc as a whole.

In addition, we also present in Table 3, the average (for the European Union and the total sample) and the standard deviation for the different scenarios. First, scenarios 1 and 3 show the greatest dispersion, suggesting more unequal effects among countries. Moreover, both in scenarios 1 and 3 the negative effects on the whole group of Eastern Europe countries are far from the European and global average.

Probing the results more deeply, figure 25 shows the behavior of the GDP in each one of the scenarios and in the real case for some countries of Eastern Europe.

[27] As it mentioned above, these two countries are not considered in this study as the Eastern bloc, for the simple fact that they did not become as EU members in 2004, but they did so in 2007.

<u>Figure 25</u>. GDP evolution in Eastern European countries (real and hypothetical cases), 1995-2014



Source: Own elaboration

For the Eastern countries, the blue line (INT) represents the real evolution of the GDP generated in the total economy and incorporated through the full supply chain to obtain the final demand of each country; the red line corresponds to the first hypothetical scenario; the orange and rose lines shows the evolution of GDP in the two cases of the second scenario; and finally, the green line corresponds to the third scenario. Recall that the effects for Eastern European countries are very different depending on the scenario, as expected, because the modifications made in matrices and vectors are very different in each one of the scenarios, but also due to the weakness and vulnerability of the Eastern economies to changes and shocks of this type.

It is important to highlight the clear negative effect that the fact of not belonging to the European Union would have for the countries of the East in Scenario 1 (red line). It can be observed how the GDP growth would be much lower over the last few years, showing the weakness of these countries in case of moving alone and not receiving certain aid from the union. However, it is important to highlight the behavior of GDP in the Czech Republic, Estonia, Latvia, and Slovenia in the third scenario (green line). At the beginning, the effects of a possible "non-integration" in the EU would be negative for all of them. However, it can be observed as from the year 2008/2009, the effects for them would begin to be positive. This result may be due to the fact that the consequences of the economic crisis of 2008 would not have been so strong for the Eastern countries in the hypothetical case that the Eastern bloc would not have European membership. On the other hand, the effects of a possible disintegration of European Union in the third scenario cause clear negative effects in Hungary, Lithuania, Poland and Slovakia. These results show that these four Eastern countries are those that present the greatest trade links with the rest of the countries of the European Union and after the 2008 crisis they would be the most affected by not belonging to the Union. As shown in figure 2, Hungary and Slovakia are two of the countries that present a large percentage of trade within the European Union, which could explain their negative results in this third hypothetical scenario. In addition, the case of Poland is similar because a large amount of its trade is with Germany, France and the United Kingdom, and around 30% is from intermediate inputs[28]. Finally, Lithuania is one of the main trading partners of Poland, but also of the United Kingdom and Germany. Its trade is based on the

[28] Data obtained from WITS (World Integrated Trade Solution) and from data of Figure 24.

production and export of final products rather than intermediate inputs, but its great dependence on Poland and intra-EU trade would explain its negative effects of a possible disintegration of the EU.

5. *Conclusions*

The phenomenon of integration and its consequences on the economic structure of countries and regions has been a subject that has been analyzed in the literature. The objective in this chapter is to focus on the possibility of defining a type of synthetic indicators, building "counterfactuals" and alternative scenarios to evaluate the impact of the "non-integration" of Eastern European countries in the European Union from a multiregional and a multisectoral perspective. Thus, traditional measures of building alternative scenarios, such as hypothetical extraction methods, have been extended to a multiregional input-output framework that allows us to explore how productivity is translated through the global value chains, as well as the effects in the technological and structural bases of the countries.

The results obtained with the three scenarios analyzed allow us to reach some conclusions. It is clear that the countries of Eastern Europe are very vulnerable to the effects of trade that comes from the rest of European Union. The effects of global value chains are heterogeneous and the results can change with the different scenarios proposed. However, it should be noted that the impact of a possible EXIT of Eastern European countries would be almost 3 times greater for themselves than for the rest of the economies of Europe (similar results are obtained in Chen *et al.* (2017) where they obtained the BREXIT impact is 4.6 times greater for British regions than for the rest of Europe). In addition, the results showed that it would be the countries closest geographically to the Eastern bloc that are the most affected after the shock of non-integration, not only for geographical reasons but also because they are the ones that maintain a stronger trade with the Eastern European countries.

As mentioned above, the case of BREXIT is a clear example of the significant consequences that these shocks would have for the EU as a whole. The empirical evidence of many recent papers suggests BREXIT shows how leaving the EU single market is likely to be very challenging for most of the Britain regions and for the rest of the European countries, not only because of the legal and procedural complexity of the trade agreement, but also because the Brexit phenomenon is likely to lead to greater inequalities between countries than already exist. In our case, "the EE-EXIT case," the consequences for the Eastern countries are higher due to the well-known weakness of these economies in social, political and economic terms.

Based on the empirical findings of this study, we can draw some policy implications as follows. First, as we previously commented, we find that the impact of a hypothetical disintegration of the European Union could have even three times greater negative effects for Eastern European countries than for the rest of the countries of the sample, being the effects more diluted as countries are far from the East bloc. Therefore, Eastern EU countries are highly dependent on the evolution of trade structures and policies within the EU. In addition, our results also suggest that the countries closer geographically to the Eastern bloc are the most affected after the shock of a possible non-integration of those countries. Therefore, geographical proximity continues to be a key factor in the configuration of the GVCs. In this sense, and as pointed out in Johnson and Noguera (2012), geographical proximity, as a reflection not only of transport costs but also as a proxy for other unobservable variables (language, culture, ...), determines in an important way the configuration of interregional trade in the world. This fact is even more important in countries such as those studied where the weight of the intermediate inputs is highly relevant. In this way, the reduction of physical barriers, the improvement of communication infrastructures, continues to be an important channel for boosting trade integration in the European Union.

Despite the potential relevance of the results obtained, some cautions have to be made on the limitations of the analysis. A first limitation of the chapter is the sample that we consider as the database we use is constituted by 41 countries with sectoral data but without regional data detail. After the results obtained in this study and due to the heterogeneity between European countries, it could be interesting to study what happens at the regional level to analyze some regional patterns, as well as the evolution of clusters in Europe, which have been highlighted as important in the configuration of the GVCs. Therefore, as a future extension we could work with a global input-output regional database (such as

EUREGIO[29]) in order to capture in more geographical detail the effects and consequences of the phenomenon of EE-EXIT. Secondly, the results suggest the importance of the proposed structural changes over time explaining the global impacts on countries. The consideration of structural and technological change, transforming production relations and affecting substitutability between inputs within the region or between inputs of different regions can be better captured on the basis of more flexible models such as CGE models, which is also a natural extension of this chapter. In addition, the hypothetical scenarios presented in this work are first approximations to estimate the level of exposure of countries to possible changes in trade. In consequence, a clear extension is to go deeper into the underlying drivers of these effects (productive, structural, political, technological and social in nature). In this line, although the specific study of how different governance model modulate economic trajectories is beyond the scope of this chapter, the consideration of these political variables and the possibility of formulating different scenarios based on certain taxonomies of countries and regions is a clear extension of the chapter.

All in all, the results show that the disintegration processes would undoubtedly lead to negative effects for the growth of Europe, causing unequal effects for the integrated countries and generating a more heterogeneity between them.

[29] See Thissen *et al.* (2018)

6. *References*

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Chapter 5: The regional character of global value chains: an analysis for the European Union[30]

1. *Introduction*

Economic growth, international trade and production processes are increasingly structured around the so called "global value chains" (GVC), which that have been defined as the "full range of activities that firms and workers do to bring a product from its conception to its end use and beyond" (Gereffi and Fernandez-Stark, 2011).

The spatial fragmentation of the production processes across countries has led production chains and income generation to be seen increasingly characterized as "global". Indeed, "linking into GVCs" has become one of the important new development challenges for many developed and developing economies (Ojala *et al.*, (2008), Barnes *et al.*, (2008), Banga, R. (2015)). The recent (2020) experience with the COVID-19 pandemic has also highlighted the complex degree of dependence that most economies, both national and regional, exhibit and the disruptive effects of bottlenecks/supply shortages in generating negative impacts on growth.

The economic performance of economies regarding their engagement in GVCs has been assessed trough the concepts of *participation* and *position* (Gereffi, 1999; Humphrey *et al.*, 2020). While the participation of countries in GVC, that is, the countries share on value added embodied in global exports yields insights on their gains from the globalization process, their position in GVC, that is, their specialization in relatively upstream versus downstream stages of global value chains, is believed to ensure higher value added shares and increased technological complexity. As a consequence, moving upstream or upgrading country position in GVCs are current policy priorities for many countries (see Hagemejer *et al.*, 2017; Fally, 2012).

Methodologically, multiregional input-output models (MRIO) have revealed as powerful instruments to assess the involvement of countries in global and regional value chains (Escaith and Inomata, 2013), given their capacity to capture intersectoral and

[30] A reduced version of this chapter will be presented in October 2020 at REAL seminars in the University of Illinois at Urbana-Champaign (United States).

interregional links and to approximate the participation and position of economies and sectors in GVCs (Dietzenbacher *et al.* (2007); Antràs *et al.* (2012); Johnson and Noguera (2012a) and Koopman *et al.* (2012)).

However, in the GVCs framework, relatively little attention has been directed so far to the fact that the international fragmentation of production also has an important regional (sub-national) dimension, taking place among groups of neighboring regions. In this regard, the literature suggests that while regions are competing with each other, the processes of fragmentation that have given rise to global value chains that may also be generating increased interregional dependencies. This phenomenon has been advanced as a source of explanation for differences in regional business cycle behavior even between regions that are each other's major trading partners (see Park and Hewings, 2012) as well as the possibility of asymmetry in the signs of spillover effects between any two regions (Chung and Hewings, 2015).

The role of spatial heterogeneity and spatial dependence in regional economic growth, has been extensively studied in the regional economics literature, with a broad consensus that the economic growth of a specific region not only depends on its structural and economic characteristics but also on the economic conditions of its neighbors through spatial spillovers (López-Bazo *et al.* (2004); Ertur and Koch (2006) among many others)

This chapter aims to bridge these literatures to study the involvement of regions in GVCs and the role of the spatial dependences in it. To the best of our knowledge, this is the first work that analyzes the participation and position of regions in GVCs providing systematic evidence of the spatial influence of neighborhood closeness. To illustrate the mechanisms at work in generating the results, we control for the economic, educational, and technological characteristics of regions explaining their performance in GVC. Moreover, the use of spatial econometrics techniques allows us to address the spatial heterogeneity and spatial dependence in the analysis of the production processes, showing the key role of spatial factors in the formation of global production chains.

Empirically, the calculation of the value added embodied in the supply chain at the regional level, requires multiregional input-output tables that cover the full supply chain in the world economy. We use the new regional input-output database EUREGIO for the year

2010 (see Thissen *et al.* 2018). The data provide information at the NUTS2 level and cover 249 European regions and 17 non-European countries at the country level with a disaggregation of 14 economic sectors.

In particular, this chapter tries to address questions such as: Do local factors influence the involvement of regions and sectors in global value chains in terms of their participation and position? Does the behavior of neighboring regions influence these regional outcomes? Is there evidence of spatial dependence in the European global value chains? How upstream or downstream are the different European regions? What are the regions that have a greater participation in global production chains?

The remainder of this chapter is structured as follows. Section 2 provides a review of the relevant literature and highlights some important needs that have yet to be explored. Drawing on this review, section 3 offers an explanation of the methodology and methods, along with a description of the explanatory variables that will be explored in this work. In addition, we introduce our variables of interest related to GVC (*Participation* and *Position*) as well as the corresponding methods to define them within the multiregional input-output framework. In section 4, we show the main results, focusing on the spatial role of neighbors in regional economic growth. Section 5 concludes the chapter and offers some future direction for research.

2. Literature review

In GVCs literature, the measure of "vertical specialization" was usually used as a proxy of the measure of participation of a country in a GVC and to evaluate a country's global competitiveness. For example, Hummels *et al.* 2001 or Chen *et al.* 2005, measure the vertical specialization of products separating intermediate inputs and final goods to quantify the economic growth of the countries due to vertical specialization. Other studies, such as Kaplinsky (1998) or Schmitz (2006), show how the gains from participation in the GVC, calculated using a vertical specialization measure, are not distributed equitably and the developing countries are the most affected negatively. Feenstra *et al.* (1999) show the extent of offshoring of activities by U.S. firms, developing a measure defined as the share of imported intermediate inputs over all intermediate inputs used in a specific sector. More recently, Johnson and Noguera (2012a) and Koopman *et al.* (2012) note that the previous concepts disregard the fact that the production of intermediates requires additional production activities that take place both inside and outside the country. However, while the participation of countries in GVC yields relevant insights on their gains from the globalization process, their position in GVC, that is, their specialization in relatively upstream versus downstream stages of global value chains is believed to ensure higher value added shares and increased technological complexity. As a consequence, moving upstream or upgrading country position in GVCs are current policy priorities for many countries (see for instance Hagemejer *et al.*, 2017 or Fally, 2012).

In this context, the economic literature increasingly acknowledges the need to recognize the multisectoral and multiregional nature of economies, and their involvement in the so-called global and regional value chains (see Escaith and Inomata, 2013). In this context, multiregional input-output models (MRIO) have proven to be powerful instruments to quantify the role of intersectoral and interregional links at different scales on the evolution of economic growth and to measure the concepts of *participation* and *position* for different regions or countries in a multiregional framework. To help with the interpretation, Dietzenbacher *et al.* (2007) proposed the indicator called average propagation length. To illustrate its use, they studied the relations among industries and countries of six European countries using the 1985 intercountry input-output table. Other studies, such as Timmer *et al.* (2013) and Los *et al.* (2015), propose a new measure to calculate GVCs participation indexes in a MRIO, which is afterwards used to analyze the fragmentation of GVCs. Over the next decade, one of the most significant papers in this field is by Antràs *et al.* (2012). They present two different approaches to build a measure of industry “upstreamness” (or average distance from final use), one of them related with the notion of forward linkage in input-output analysis. There have been many studies that use this measure in order to analyze the performance of global networks and their evolution over time, for instance, Carvalho (2014) or Baldwin and López-Gonzalez (2015). In the same way, Fally (2012) proposes two measures of vertical fragmentation of production chains using input-output tables that revealed that production had become less vertically fragmented over the last years. Other studies, such as Koopman *et al.* (2010), establish a new approach that integrates all previous measures but in terms of value added. They study whether a country-sector is likely in the upstream or downstream of global value chains.

However, in the GVCs framework, relatively little attention has been directed to the fact that the international fragmentation of production also has an important regional (sub-national) dimension, taking place among groups of neighboring regions. An important contribution is provided by Dietzenbacher *et al.* (2012) who analyze the role of Brazilian regions in the global value chains and compare those regions with other countries around the world. They find important differences between regions, both in terms of trade volume and relevant industries that account for the generation of value added. A complementary perspective is provided by Krishnan (2018) who shows that there are important positive effects of regional value chains from the participation in global value chains that, in addition, may generate important spillover effects among regions. Sturgeon *et al.* (2008), in a global study of the automotive sector, find that the production process of the final product is usually concentrated among regions or countries that are close to each other, while the production of small automobile parts is usually carried out in certain countries. On the other hand, Johnson and Noguera (2012b), in their study focusing on the value added content of bilateral trade flows, find that the geographical distance between regions and countries is important in bilateral trade even in the context of increasingly globalized supply chains.

While there has been limited focus on the regional character in the GVC literature, the regional economics literature has focused extensively on the role of spatial effects, spatial heterogeneity and spatial dependence in regional economic growth. There is a broad consensus that the economic growth of a specific region not only depends on its structural and economic characteristics but also on the economic conditions of its nearest neighbors. For instance, López-Bazo *et al.* (2004) analyze how the spatial technological conditions between economies can influence in the process of economic growth and convergence of a specific region, finding that the spillover or spatial effects of neighbors are really significant. Ertur and Koch (2006), propose an economic growth model with technological externalities and spatial spillovers, finding that there is a different convergence speed for each economy in the sample and that the speed is influenced by the closest neighbor's speed. Similarly, Márquez *et al.* 2015 study the existence of growth spillover effects for the Spanish regions finding spatiotemporal regional spillovers of growth output among regions.

Despite this literature, to the best of our knowledge, there is an absence of studies focused on the analysis of the concepts of participation and position associated with GVC from a spatial perspective that is, exploring the role of spatial location in the composition of these chains. This is the main objective of this chapter. More specifically, in this study, we provide systematic evidence of the spatial influence of neighborhood closeness on global value chain position and participation from a regional perspective. To illustrate the mechanisms at work in generating the results, we control for the economic, educational, and technological characteristics of regions explaining their performance in GVC. Moreover, the use of spatial econometrics techniques allows us to address the spatial heterogeneity and spatial dependence in the analysis of the production processes, showing the key role of spatial factors in the formation of global production chains.

3. *Materials and methods*

3.1. Participation and position in GVCs in a MRIO framework

In this section we show the methodology used to calculate, both *participation* and *position* in GVCs, and the specification of our regressions. Remember that *participation* and *position* are calculated under a MRIO framework (see Miller and Blair, 2009). In that way, our starting point in this last chapter is the representation of a closed global economy with *n* industries and *m* regions, where **x** denotes the total output, being x^r the total output generated by region *r*, and $\boldsymbol{Z} = \boldsymbol{Z}_{ij}^{rs}$ is the matrix of multiregional intermediate flows. In this context, **y** is the vector of total final demand of regions, where each element y^r represents the final demand of region *r*, and **i** a unitary vector of the appropriate dimension. We denote by $\boldsymbol{A} = \boldsymbol{A}_{ij}^{rs}$ the matrix of technical coefficients in the multiregional framework, where each element a_{ij}^{rs} represents the volume of intermediate input *i* of a region *r* that is needed to produce a unit of output *j* in region *s*. The Leontief inverse matrix ***L*** for the whole economy will be as in equation (3.1). Another way to decompose the Leontief matrix and obtain more information about the decomposition of global value chains is the following:

$$\boldsymbol{x} = \boldsymbol{y} + \boldsymbol{A}\boldsymbol{y} + \boldsymbol{A}^2\boldsymbol{y} + \boldsymbol{A}^3\boldsymbol{y} + \boldsymbol{A}^4\boldsymbol{y} + ... + \boldsymbol{A}^{\boldsymbol{m}}\boldsymbol{y} + ... \Rightarrow \boldsymbol{x} = \boldsymbol{L}\boldsymbol{y} \qquad (5.1)$$

Here, each element of $\boldsymbol{L} = \boldsymbol{L}_{ij}^{rs}$ represents all the production generated in sector *i* in region *r* to fulfil the demands of inputs incorporated in all the steps of the production chain and ending in the final demand of sector *j* in region *s*. Therefore, the elements in ***L*** capture the production embodied in all the economic flows linking sectors *i* and *j*, and regions *r* and *s* through the international supply chains.

As in Chapter 1, making use of a diagonalized vector with value added per unit of gross output, let us define the matrix Ω as in equation (1.6), which contains the value added generated in each region-industry involved in a supply value chain. Therefore, with this formulation, we can decompose the value added of a final product into the different value added contributions of different regions around the world. In addition, the reading by columns and rows of the matrix provides information on the origins and destinations of value added through the global production chains. Since our interest is the study of regions as a unit of analysis and their relationships, we aggregate the sectoral information for each one of them, and we obtain $\boldsymbol{\Phi} = \left(\Phi^{rs}\right) = \mathbf{E\Omega E'}$; where $\mathbf{E}$ is a sectorial aggregation matrix of appropriate dimension.

Note that for each region, we can distinguish between the value added directly and indirectly incorporated in the production of the final demand of the region (domestic component($\bar{w}^r = \Phi^{rr}$) , and the regional value added incorporated in the intermediate inputs sold to other regions and countries to fulfill their final demands, that is, incorporated in the global production chains ($\tilde{w}^r = \sum_{s \neq r} \Phi^{rs}$).

In order to calculate the *participation (PA)* of a region *r* in GVCs, we compute the share of the value added embodied in exports of region *r* to other regions and countries in the total value added embodied in exports across the regions:

$$PA^r = \frac{\tilde{w}^r}{\sum_h \tilde{w}^h} \tag{5.2}$$

We will use this share to measure the *participation (PA)* of each region in international fragmentation of value chains in Section 4. The higher the value of the regional *participation*, the greater their level of globalization, and their *participation* in global production processes.

Regarding the *position (POS)*, we follow the proposal of Antràs *et al.* (2012) to build a measure of regional industry "upstreamness" (or average distance from final use):

$$POS^r = \frac{y^r}{x^r} + 2*\frac{\sum_s a^{rs} y^s}{x^r} + 3*\frac{\sum_s \sum_k a^{rk} a^{ks} y^s}{x^r} + 4*\frac{\sum_s \sum_k \sum_t a^{rk} a^{kt} a^{ts} y^s}{x^r} + 5*\frac{\sum_s \sum_k \sum_t \sum_d a^{rk} a^{kt} a^{td} a^{ds} y^s}{x^r} \qquad (5.3)$$

The interpretation of this regional measure is that larger values of *position* are associated with higher levels of upstreamness of region. That is to say, the higher the value of the *position*, the higher the level of upstreamness; for the highest values, the region is situated in the early stages of the global value chain, being an exporter of intermediate inputs and an importer of final goods. In contrast, the lower the value of the *position* measure, the higher the level of downstreamness of region, being an importer of intermediate inputs and an exporter of final goods.

Once the variables of interest have been defined in this MRIO framework, in the next section we explore their potential determinants and the empirical strategy to capture the main relationship.

3.2. Empirical approach

As has been established in the previous literature, the total population of each region is a key factor to explain the fragmentation process of global value chain (Kaplinsky *et al.*, 2011; Gereffi, 2015). The population is our first independent variable to measure the scale effect of different regions of our sample. Further, the *participation* and *position* in a GVC is mostly affected by the situation of the region in terms of business. To capture this feature, we use the SBS data (structural business statistics) of each region as an index expressed in percentage (see Dunning (1998), Sturgeon (2008)). In particular, it describes the structure, activity, competitiveness and performance of economic activities within the business economy down to the detailed level of several hundred sectors. In other words, the higher the SBS index, the stronger the business structure of each region. In addition, the human capital is another key variable introduced in the previous literature (see Basile *et al.* 2012) as a key factor to explain the fragmentation of global value chains. Two independent variables are used; the first is "Tertiary education" measured as a percentage of the region's population with tertiary education. The second is "People in science and technology" that represents the number of people who work in the high technology sectors; in the analysis this is transformed into a ratio by dividing it by the total active population of each region[31].

In addition, the trade structure and the specialization degree of countries can be driving a large part of regional *participation* and *position* evolution in the GVCs, especially for the agricultural, textile and automotive sectors (see for instance Kaplinsky, 2000). We decided to include these sectors because we try to consider the two sides of the coin, that is to say, the agricultural sector is not quite globalized, and so we can take into account the level of internal specialization of the regions. On the contrary, the textile sector and the automobile sector are highly globalized allowing us to explore the degree of globalization in the production processes of the regions. More specifically, we have considered regional specialization indexes for these sectors[32]. Therefore, the specialization indexes show the degree of importance of each of the sectors included in the regression.

We also include in the model a "Mobility" variable (Agiomirgianakis *et al*., 2001), that measures the percentage of the population in each region that has moved their residence to another region in the same country or another country. In other words, it represents the percentage of new residents over total new comers, between 18 and 59 ages, from another region, in essence, the in-migration into the region. One of the factors that can influence the trade among regions and countries is the type of region or the type of regions that are the closest neighboring regions (Nadvi, 2008; Lüthi *et al.*, 2013). To account for this phenomenon, we decided to include 4 dummy variables (described in table 1; eliminating one to avoid perfect collinearity) to measure whether the degree of urbanization or ruralization of a region influences the level of *participation* or the *position* of the regions in the global value chain. So, with these dummies, we try to capture the distinction among rural and urban areas in their level of globalization.

[31] The explanatory variables considered are derived primarily from EUROSTAT.
[32] The specialization indexes are calculated as the rate between the share of the specific sector in the region and the share of the sector for the full regional sample in Europe.

Finally, to consider the degree of internationalization of each region, we decide to include in our model the "Border" variable as a dummy, taken on the value 1 when the region has a border with a region of other country (Antràs *et al.*, 2013). In this way, with this independent variable, we try to measure whether having an international border is a key to measuring the degree of globalization of the regions. It would be expected that this variable would have a positive and significant influence on the degree of *participation* of the regions in the GVC[33].

In addition, we consider the existence of a spatial dependence between the regions that modifies their behavior depending of the spillover effects of the neighbors. It is expected that the spatial dependence is positive, and that the spillover effects cause, mostly, an increase in the *participation* and *position* of the regions in global value chains.

Therefore, in Table 11, we show the description measurement and expected signs of independent variables, both for direct and indirect effects. An indirect effect can be defined as the effect of the performance of my neighbor over my own performance. In the case of indirect effects is more difficult to know what to expect, as there are many variables involved such as competence, scale economies, etc.

Table 11. Description, measurements and expected direct and indirect signs of variables in the intensity model on *participation* (PA) and *position* (POS)

Variables	Description	Measurement	Expected direct sign (PA/POS)	Expected indirect sign (PA/POS)
POP	Population	Thousands of people	+/+	+/+
SBS	Structural business statistics	Index	+/-	-/+
T_edu	Tertiary education	Percentage of people with advanced education	+/-	+/+
People_ST	People in Science and Technology	Percentage of people who works in science and technology	+/+	+/-
Mobility	Mobility	Amount of population that changes their	+/-	+/+

33 Additionally, we have also initially considered other border variable "Outside-EU Border" to specifically check whether having a border with a region of a country that does not belong to the European Union is significant explaining the selected variables. This variable is not significant with either of the two endogenous variables, therefore it has been removed from the models and we only work with the more general variable "Border".

		residence to another region (in-migration)		
Border	Border	Dummy: 1=if there is a frontier with another country; 0=if there is no	+/+	+/+
SI_AGRI	Specialization index in agriculture sector	Ratio	-/-	-/-
SI_TEX	Specialization index in textile sector	Ratio	-/-	-/-
SI_AUTO	Specialization index in automobile sector	Ratio	+/+	+/+
Rtypology_1	Regional typology 1	Dummy: 1=if the level of urbanization is maximum	+/+	+/+
Rtypology_2	Regional typology 2	Dummy: 1=if the level of urbanization is in the second level	+/+	+/+
Rtypology_3	Regional typology 3	Dummy: 1=if the level of ruralization is in the second level	+/+	+/+
Rtypology_4	Regional typology 4	Dummy: 1=if the level of ruralization is maximum	+/+	+/+

Source: Own elaboration

In table 11 we can observe that the expected sign for the majority of the independent variables are positive with some exceptions. The expected signs of the specialization indexes of the agricultural and textile sector are negative since, as explained below, the first is not a much globalized sector (meaning what – huge volumes of agricultural products are exported and enter important food value chains but they may be simple chains (link with notions of average propagation length)), and the second is not globalized in the European Union either. In addition, as explained above, the dummy of typology 5 has been omitted (the most rural case), which causes the expected signs of all of them to be positive if we compare them with the typology 5 dummy. The expected direct signs are positive for *participation* and *position*, since it is expected that the less urban a region is, the lower its degree of *participation* in the global value chain, and the lower will be the degree of upstreaming. The indirect expected signs (spillover effects from now on) take similar signs to direct ones. It is expected that, as with the direct effects, if the closest neighbors of a region have a high level of specialization in agriculture or textiles, the region under study presents a low level of *participation* and *position*.

Once the main variables of the analysis have been presented, in that follows we discuss the empirical strategy. For each region, the following specifications are proposed.

Let PA^r denote the *participation* in a GVC for region *r*. For each region, the proposed specification is:

$$\begin{aligned} PA^r &= \alpha + \beta_1 TotatPOP^r + \beta_2 SBS^r + \beta_3 Tedu^r + \beta_4 PeopleST^r + \beta_5 Mobility^r + \\ &\beta_6 Border^r + \beta_7 SI_{AGRI}{}^r + \beta_8 SI_{TEX}{}^r + \beta_9 SI_{AUTO}{}^r + \beta_{10} Rtypo\log y1^r + \beta_{11} Rtypo\log y2^r + \\ &\beta_{13} Rtypo\log y3^r + \beta_{14} Rtypo\log y4^r + \varepsilon \end{aligned} \tag{5.4}$$

where PA^r is the *participation* of region r in GVC and ε is the error term of the equation.

The linear expression of the other endogenous variable (*position*) can be expressed as follow:

$$\begin{aligned} \ln(POS^r) &= \alpha + \beta_1 \ln(TotatPOP^r) + \beta_2 SBS^r + \beta_3 Tedu^r + \beta_4 PeopleST^r + \beta_5 Mobility^r + \\ &\beta_6 Border^r + \beta_7 SI_{AGRI}{}^r + \beta_8 SI_{TEX}{}^r + \beta_9 SI_{AUTO}{}^r + \beta_{10} Rtypo\log y1^r + \beta_{11} Rtypo\log y2^r + \\ &\beta_{13} Rtypo\log y3^r + \beta_{14} Rtypo\log y4^r + \varepsilon \end{aligned} \tag{5.5}$$

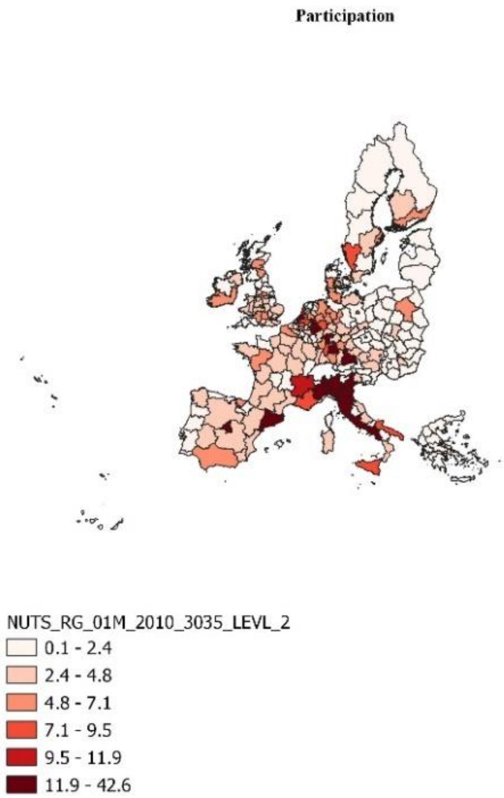
where POS^r is the value of *position* in a GVC for each region *r* and ε is the error term of the equation. In this case, it is a log-log linear equation to smooth the position values.

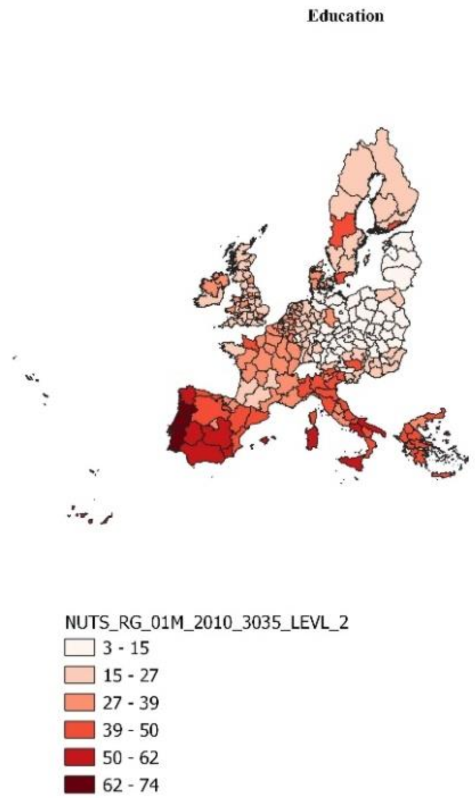
4. <u>Results</u>

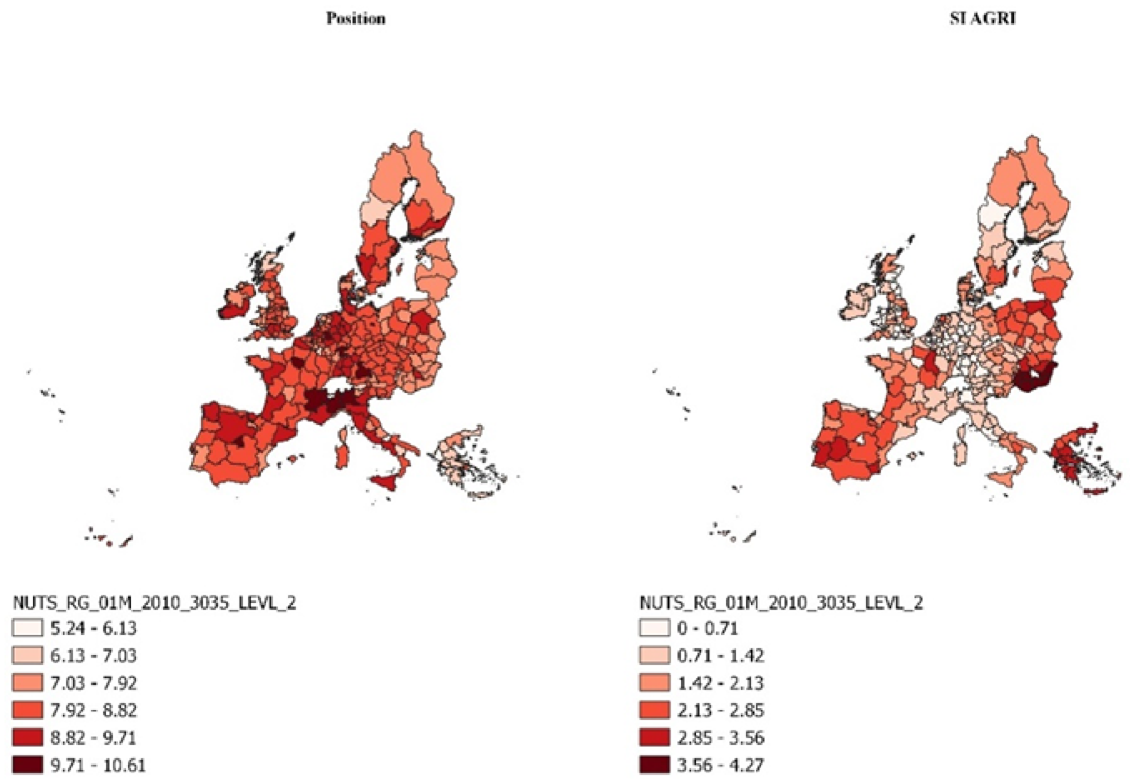
4.1. Initial, sample findings

As a first way of evaluating the behavior of regions with respect to our variables of interest and the potential heterogeneity across Europe, Figure 26 shows the performance EU regions according to different participation and position levels. We also draw the corresponding maps for other explicative variables used in the analysis such as Tertiary education and Agricultural specialization index. The maps for other explicative variables can be seen in the Appendix D.

Figure 26. Mapping of *participation*, *position* and other independent variables







Source: Elaborated with QGis

If we pay attention to figure 26, where we show the mapping of *participation*, *position*, tertiary education and the index of specialization in agriculture, we can observe that all the variables are quite clustered. In the case of *participation* this is especially visible in Germany, Austria, Czech Republic, Netherlands and north Italy. In the case of Tertiary education is clear in all countries, mainly Spain, France, Italy and Poland, among others. Also note the case for *position* in north Italy and the border regions of France or some regions of Germany that share border with Netherlands, showing the significance of the border variable. Indeed, it is in these regions where we find the highest values of *position*, that is, they are upstream regions. By contrast, some regions of Denmark and Sweden are the most downstream, perhaps associated with high levels of human capital. In the case of tertiary education, the cluster pattern is also clear in all countries, mainly Spain, France, Italy and Poland, among others. Turning attention to specialization in agriculture, countries such as Poland or Hungary stand out. To sum up, a first look to the data seem to confirm our statement, regions closeness matters and it should be analyzed.

4.2. Empirical spatial strategy

The behavior of European regions in global value chains depends, as previously stated, on a series of variables that modify or alter the evolution of *participation* and *position* in the GVCs. According to the literature, we first run the OLS model to measure the significance of the explanatory variables and study their behavior. All of the variables appear for 249 European regions of the sample and for the year 2010. So, from now, and as it was mentioned above, the following models contain observations for region *r* (being *r* = 1,…, 249).

In that way, first, we run the equations (5.4) and (5.5) with OLS to check the degree of significance of the explanatory variables. The results appear in Table 12.

Table 12. OLS model for *Participation* and *Position* in the GVC

(OLS)	**PA**	**Ln(POS)**
Total_POP	**0.002*** (0.0002)**	-
lnTotal_POP	-	**0.551*** (0.0002)**
SBS	**0.007** (0.021)**	**0.001*** (0.0009)**
T_education	**0.011** (0.057)**	**-0.002** (0.039)**
People_ST/Active_POP	0.019 (0.982)	-0.025 (0.827)
Mobility	-0.014 (0.538)	-0.003 (0.372)
Border	**0.862** (0.057)**	**0.079** (0.025)**
SI_AGRI	**-1.554*** (2.03e-07)**	**-0.265*** (9.15e-11)**
SI_TEX	0.237 (0.305)	-0.033 (0.289)
SI_AUTO	0.213 (0.512)	**0.117*** (0.008)**
R_typology_1	**2.893*** (0.004)**	**0.610*** (9.71e-06)**
R_typology_2	**0.188*** (0.007)**	**0.419*** (5.06e-05)**
R_typology_3	0.844 (0.297)	**0.386*** (0.0005)**
R_typology_4	0.644 (0.376)	**0.243** (0.015)**
R^2	0.6077	0.7141

$adjR^2$	0.586	0.6983
Observations	249	249

Notes: * imply 10% level of significance; ** imply 5%; *** imply 1%.

Source: Own elaboration

In Table 12, we can observe that the vast majority of explanatory variables are significant but at different levels of significance. If we focus on the second column, the *participation*, note the significance of the POP, the SBS variable, the tertiary education, the international dummy variable "Border," some of the specialization indexes and some of the typology dummies. In particular, the relevance of the population variable stands out, as well as the urbanization dummies. That is to say, the results indicate that the higher population, and the higher urbanization level, the greater level of *participation* in the GVC of the region. The significance of the Border variable indicates the existence of different behaviors of the regions according to the existence or not of an international border (regardless of whether the border is with another European region or non-European region). However, on the other side, the higher the degree of specialization of the region compared to the European average in the agricultural sector, the lower the *participation* in the GVC. This result is expected because the primary sector is not very globalized, so the behavior of this variable is expected as is shown in table 11.

The third column of table 12 presents the results for *position*. Once again, one can see the importance of population, SBS variable, tertiary education, Border variable and some specialization indexes as well as some typology dummies. However, some of the interpretations change. The higher the population, the higher the SBS, the higher the degree of specialization in automobile sector, the higher the urbanization level, the greater the value of *position* in the GVC (level of upstreamness). However, there are two variables that appear with a negative sign, one of them is the percentage of population with tertiary education and the other is the specialization index of agricultural sector. The sign of the first one suggests that if the region has a large percentage of population with tertiary education, the region is more specialized in exporting final goods and importing intermediate inputs, that is to say, the region presents a higher level of downstreamness. The sign of the second variable has the same interpretation as in the *participation*; the higher is the specialization level of region in agricultural sector is associated with a region at the end of the chain, exporting final goods.

Thus far, the analysis has assumed that each region operates independently of other regions; in this section, the analysis will explore the nature and strength of any potential spatial dependence that may exist. To capture this dependence, a queen weight matrix[34] has been used where all the neighbors surrounding each region are considered. Table 13 presents the results for the spatial dependence tests (Anselin *et al.* 1996). Following the previous literature, the following tests have been used to select the preferred specification for spatial dependence.

Table 13. Testing the spatial dependence

Control variables	Model: PA	Model: ln(POS)
Moran's I test	MI = 2.419*** p-value= 0.007	MI = 3.174*** p-value= 0.001
LM spatial lag	LM= 7.563*** p-value=0.006	LM= 0.553 p-value=0.457
LM spatial error	LM= 5.058** p-value= 0.024	LM= 9.588*** p-value= 0.002
Robust LM spatial lag	LM= 2.885 p-value=0.089	LM= 0.032 p-value=0.856
Robust LM spatial error	LM= 5.380*** p-value=0.005	LM= 9.067*** p-value= 0.003

Notes: * imply 10% level of significance; ** imply 5%; *** imply 1%.

Source: Own elaboration

From table 13, we can see that after applying the Moran's *I* test with the queen contiguity weight matrix, we can verify that it is significant, indicating the presence of global spatial autocorrelation. For the case of *participation* (second column of table 13), results suggest strong spatial dependence, and clearly point to the spatial error model (SER[35]) as the preferred specification (the robust version of the Lagrange Multiplier error test rejects its null hypothesis of no spatial dependence, while the test for the spatial lag does not) or the SAC[36] model which is a combination of spatial lag model (SAL[37]) and

[34] A queen weight matrix is a kind of spatial contiguity weight matrices whether spatial units share a boundary or not. The queen criterion determines the neighbors taking into account the common vertices and sides. For instance, for regular grids (square polygons), the queen criterion yields eight neighbors.

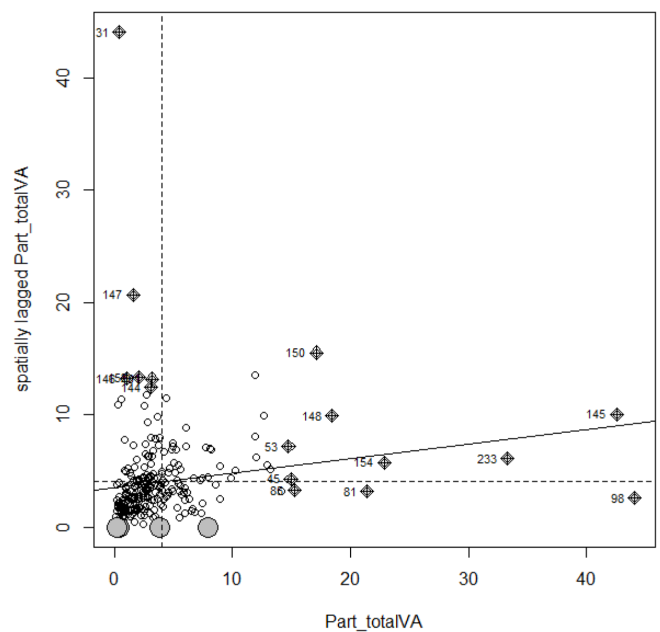
[35] The spatial error model (SER model) is applicable when spatial autocorrelation occurs as a result from misspecification or inadequate delineation of spatial units. It is a model with a spatial autoregressive disturbance.

[36] The Spatial autoregressive combined (SAC) model is a linear model which allows for spatial interactions in the dependent variable and the disturbances.

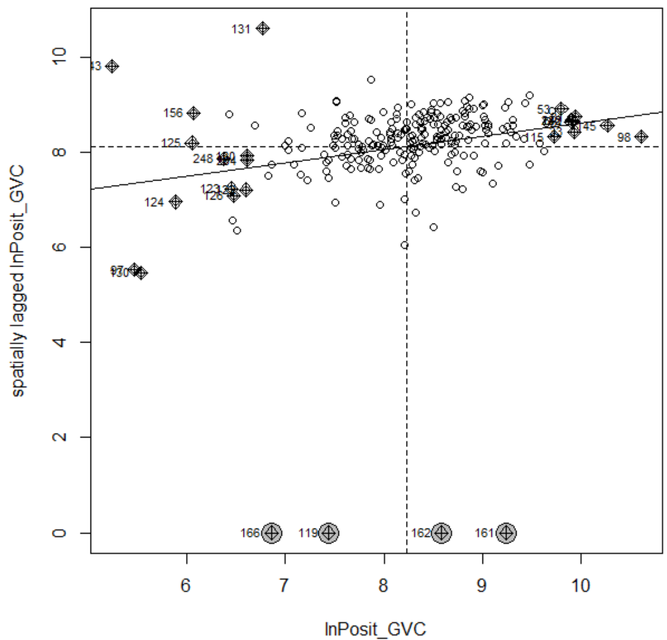
SER. The results change when we focus on the *position* (third column of table 13). In this case, the test for the spatial lag and its robust version do not reject the null hypothesis, so it is clearer than in the previous case that the spatial error model is the most correct specification. Therefore, these results show us that there is a clear spatial dependence between European regions and are consistent with the results obtained with the Moran's *I* test.

Furthermore, to make sure what kind of spatial autocorrelation is involved, we draw the Moran's *I* scatterplot for the two endogenous variables in figure 27.

<u>Figure 27</u>. Moran's I scatterplot: *Participation* and *Position*, respectively



[37] The spatial lag model (SAL) captures substantial spatial dependencies as well as external effects or spatial interactions. It assumes that the spatial dependencies are in the spatial lag of the dependent variable.



Source: Elaborated with R-studio

It can be seen how, in both cases, there is positive spatial autocorrelation, not only for the value of the Moran's *I* test (MI = 4.75; MI = 5.18, respectively), but also for the quadrants where are the observations of the regions in both cases (first and third quadrant: high-high, low-low). Therefore, this means that the *participation* and *position* of the regions in the GVC in Europe presents a significant positive spatial autocorrelation.

4.3. Spatial econometric model and results

In this section, we select the most appropriate spatial econometric model and we present the results obtained among three candidates for *participation* variable. As established in the previous section, and given the results shown in Table 13 by the spatial tests, we show the results for spatial lag (SAL), the combination of spatial error and lag (SAC) and spatial Durbin (SDM)[38]. Table 14 includes the parameters λ[39] and ρ[40] for the

[38] The Spatial Durbin Model (SDM) is a combination of SAL and SLX model (SDM=SAL+SLX). It is used when at least one of the regressors is correlated with the omitted variables. The advantage of the SDM is that its spillover effects are flexible.

[39] λ is the spatial error coefficient.

[40] ρ is the spatial autoregressive parameter that indicates the intensity of interactions between the various observations of the endogenous variables.

corresponding spatial models, and summarizes the results obtained with these three spatial models.

Table 14. Spatial econometric models for *Participation* in European regions, 2010

	SAL model	SAC model	SDM model
λ		**0.111** (0.033)**	-1.203 (0.722)
ρ	**0.135*** (0.010)**	0.091 (0.073)	**0.172** (0.046)**
Total_POP	**0.002*** (2.2e-16)**	**0.002*** (2.2e-16)**	**0.002*** (2.2e-16)**
SBS	**0.007*** (0.009)**	**0.008*** (0.004)**	**0.009*** (0.001)**
T_education	0.002 (0.905)	-0.001 (0.959)	**-0.028* (0.037)**
People_ST/Active_POP	0.149 (0.852)	0.064 (0.936)	0.265 (0.731)
Mobility	-0.015 (0.516)	-0.015 (0.510)	-0.004 (0.873)
Border	**0.808* (0.052)**	**0.868* (0.053)**	**0.823** (0.015)**
SI_AGRI	**-1.466*** (1.39e-07)**	**-1.429*** (7.293e-07)**	**-1.015*** (0.002)**
SI_TEX	0.167 (0.449)	0.178 (0.434)	0.212 (0.376)
SI_AUTO	0.146 (0.637)	**0.154** (0.037)**	**0.192* (0.054)**
R_typology_1	**2.969*** (0.001)**	**2.943*** (0.002)**	**3.318*** (0.0003)**
R_typology_2	0.223 (0.750)	0.246 (0.727)	0.397 (0.573)
R_typology_3	0.751 (0.332)	0.742 (0.340)	0.750 (0.334)
R_typology_4	0.676 (0.332)	0.652 (0.347)	1.231 (0.083)
W*lnTotal_POP	-	-	0.0003 (0.442)
W*SBS	-	-	**-0.014*** (0.001)**
W*T_education	-	-	**0.099*** (0.009)**
W*People_ST	-	-	0.802 (0.681)
W*Mobility	-	-	0.006 (0.882)
W*Border	-	-	**1.040** (0.022)**
W*SI_AGRI	-	-	**-0.984* (0.052)**
W*SI_TEX	-	-	-0.301 (0.443)
W*SI_AUTO	-	-	**0.011*****

			(0.005)
W* R_typology_1	-	-	**2.322**** **(0.014)**
W* R_typology_2	-	-	-1.035 (0.387)
W* R_typology_3	-	-	-0.344 (0.797)
W* R_typology_4	-	-	0.722 (0.567)
R^2	0. 5474	0.5287	0. 4664
Loglikelihood	-653.65	-653.35	-638.90
AIC	1339.3 (for lm: 1343.9)	1340.7 (for lm: 1343.9)	1337.8 (for lm: 1339.8)
Spatial Hausman test	2.58 p-value= 0.027		
LM test for autocorr error	0.386 p-value=0.53		LM=0.58 p-value=0.44
Observations	249	249	249

Notes: * imply 10% level of significance; ** imply 5%; *** imply 1%.

Source: Own elaboration

In all three cases, the coefficient associated with spillover effects across regions, ρ, is statistically significant, positive and very large in magnitude, indicating that there is spatial dependence problems in the data. Thus, results for the sample of EU regions support our thesis regarding the importance of spillovers. Additionally, the LM test for autocorrelation error indicates there is no significant evidence of remaining spatial dependence once we include the spillover effects across European regions in the SAL and SDM models.

If we take a look at the spatial Hausman test (it is used to see if the SAL model is capturing the spatial effect), we can observe that it is significant, so it indicates that we must work with SDM because the SAL model coefficients are inefficient. In addition, the rest of the tests are indicating that the Spatial Durbin Model (SDM) seems to be most appropriate when the endogenous variable is the *participation* of regions in a GVC. So, if we focus in the results of the SDM model (third column of table 14), we observe that the significance of the variables of the OLS model is maintained in the spatial econometric model. In addition, it is noteworthy that the spatial autocorrelation parameter ρ is statistically significant showing that there is spatial dependence in the data. Apart from those variables, by introducing the spillover effects with the weight matrix, it can be seen how most of those variables are significant again. That is to say, the structural business, the tertiary education, the “border” variable, some of the specialization indexes and typology dummies of the closest neighbors, have effects in the region.

However, notwithstanding what the results reflect, it should be noted that the coefficients of the SDM model do not directly reflect the spillovers effects of the corresponding explanatory variables on the dependent variable (LeSage and Pace, 2010). Therefore, it is necessary to calculate the direct, indirect and total effects of the models shown in table 15.

Table 15. Direct, indirect and total effects (SDM) for *Participation*

	Direct effects		**Indirect effects**		**Total effects**	
	Coefficients	p-values	Coefficients	p-values	Coefficients	p-values
	Queen contiguity weight matrix					
TotalPOP	**0.002*** **	**2.22e-16**	0.001	0.096	**0.003*** **	**1.98e-07**
SBS	**0.008*** **	**0.002**	**-0.014*** **	**0.004**	**-0.006** **	**0.029**
T_education	-0.024	0.415	**0.109*** **	**0.007**	**0.085*** **	**0.006**
People_ST/Act_POP	0.301	0.668	0.972	0.634	1.273	0.579
Mobility	-0.004	0.868	0.006	0.884	0.002	0.965
Border	-0.786	0.161	**1.031** **	**0.030**	0.244	0.793
SI_AGRI	**-1.063*** **	**0.001**	**-1.328** **	**0.014**	**-2.391*** **	**7.57e-06**
SI_TEX	0.201	0.419	-0.304	0.485	-0.104	0.822
SI_AUTO	**0.193*** **	**0.006**	**0.050** **	**0.051**	0.243	0.644
R_typology_1	**3.439*** **	**0.0002**	**3.317** **	**0.051**	**6.756*** **	**0.001**
R_typology_2	0.357	0.616	-1.109	0.425	-0.752	0.649
R_typology_3	0.741	0.322	-0.247	0.919	0.494	0.728
R_typology_4	1.271	0.060	1.071	0.419	2.342	0.158

Notes: * imply 10% level of significance; ** imply 5%; *** imply 1%.

Source: Own elaboration

In our study, the direct effect represents an impact, due to changes in the independent variable(s) on *participation* in GVC, at a particular region. The indirect effect represents an impact due to changes in independent variable, in other regions, on the local *participation*. The total effect is simply the sum of the direct and indirect effects.

The coefficients of the direct effects are in line with the results provided in table 13. We can observe that the direct effects of the explanatory variables are different from their coefficient estimates in the previous table. The reason is the spillover or indirect effects that arise as a result of impacts passing through neighboring countries and back to the countries themselves. As we are working with the Spatial Durbin Model, the spillover effects are partly due to the coefficient of the spatially lagged independent variable and partly due to the coefficient of the spatially lagged value of the exogenous variable itself.

Therefore, some interesting interpretations emerge from these results. For the SBS variable, the spillover effect is -0.014, indicating that the higher the business structure observed in the neighboring regions, the lower the value of the *participation* in GVC of the local region. In this case, the negative spillover effect is greater than the positive direct effect, leading to a negative total effect of the SBS variable. In that sense, the business structure variable is indicating that it has a negative influence on the local region due to the weight of the indirect spillover effect that the closest neighboring regions have. In other words, if the neighbors have a strong business structure, the local region is negatively affected in its level of *participation* in the GVC. This can be due to a competitive process, those countries with better business performance will be more trusted and because of that the negative effect over its neighbors. A similar result is found with the specialization index of agricultural sector (SI_AGRI) where the spillover effect amounts to -1.328, which means that if the neighboring regions are more specialized in the agricultural sector than the European average, the local region will have a lower *participation* in the GVC. In other words, being surrounded by regions that are focused on primary sector trade will lead to a lower local *participation* in the GVC, because the neighbor regions will tend to be specialized in agriculture too. We have to note that agriculture is one of the sectors with the lowest *participation* in the globalization process in a European context. On the other hand, there are some explanatory variables that present a positive sign of their spillover effect. This is the case of the tertiary education, the specialization index of the automobile sector, and the dummies that reflect the existence of an international border and a high level of urbanization. Therefore, being surrounded by highly urbanization regions, with an international frontier, with a large percentage of population with tertiary education and very specialized in the automobile sector have positive effects and cause an increase in the level of *participation* of local region (see Sardadvar, 2011). Table 16 shows the results of the spatial econometric models as in table 14, when the endogenous variable is the *position*.

Table 16. Spatial econometric models for *Position* in European regions, 2010

	SER model	SDEM model	SDM model
λ	**0.265*** (0.002)**	**0.188** (0.037)**	**-1.563** (0.043)**
ρ			**0.188** (0.023)**
lnTotal_POP	**0.547*** (2.2e-16)**	**0.528*** (2.2e-16)**	**0.532*** (2.2e-16)**
SBS	**0.001*** (0.002)**	**0.001*** (0.003)**	**0.001*** (0.0003)**
T_education	**-0.005** (0.011)**	**-0.009** (0.027)**	**-0.011** (0.012)**
People_ST/Active_POP	-0.005 (0.964)	0.021 (0.851)	0.035 (0.744)
Mobility	-0.002 (0.453)	-0.002 (0.500)	-0.002 (0.556)
Border	**0.042* (0.055)**	**0.030*** (0.009)**	**0.023** (0.047)**
SI_AGRI	**-0.262*** (5.84e-11)**	**-0.242*** (3.15e-08)**	**-0.242*** (5.81e-08)**
SI_TEX	-0.021 (0.504)	-0.003 (0.926)	0.004 (0.899)
SI_AUTO	**0.086** (0.041)**	**0.067** (0.024)**	**0.050** (0.039)**
R_typology_1	**0.582*** (5.22e-06)**	**0.594*** (6.12e-06)**	**0.587*** (5.95e-06)**
R_typology_2	**0.373*** (0.0001)**	**0.388*** (0.0001)**	**0.381*** (0.0001)**
R_typology_3	**0.334*** (0.001)**	**0.326*** (0.003)**	**0.315*** (0.004)**
R_typology_4	**0.254*** (0.006)**	**0.244** (0.014)**	0.252 (0.105)
W*lnTotal_POP	-	**-0.084** (0.013)**	**-0.120** (0.017)**
W*SBS	-	0.0003 (0.529)	-0.0001 (0.709)
W*T_education	-	**0.009** (0.048)**	**0.012** (0.018)**
W*People_ST	-	-0.099 (0.729)	-0.051 (0.851)
W*Mobility	-	-0.002 (0.764)	0.001 (0.897)
W*Border	-	**0.087** (0.047)**	**0.108** (0.035)**
W*SI_AGRI	-	0.011 (0.861)	**0.067** (0.033)**
W*SI_TEX		-0.061 (0.276)	-0.057 (0.291)
W*SI_AUTO		**0.110** (0.018)**	**0.101** (0.022)**
W* R_typology_1	-	**0.173** (0.043)**	**0.044* (0.054)**
W* R_typology_2	-	0.235	0.136

		(0.191)	(0.439)
W* R_typology_3	-	0.280 (0.151)	0.204 (0.283)
W* R_typology_4	-	-0.102 (0.580)	-0.147 (0.411)
R^2	0.4486	0.4387	0.4365
Loglikelihood	-155.87	-149.22	-147.96
AIC	343.75 (for lm: 351.45)	356.44 (for lm: 358.79)	355.92 (for lm: 359.03)
Spatial Hausman test	20.18 p-value=0.012		
LM test for autocorr error			LM=0.855 p-value=0.075
Observations	249	249	249

Notes: * imply 10% level of significance; ** imply 5%; *** imply 1%.

Source: Own elaboration

In Table 16, we can observe that the coefficient associated with spillover effects across regions is statistically significant in all cases indicating the existence of spatial dependence in our data. The results reinforce the importance of neighboring effects on any given region. In addition, as in the previous case, the LM test for autocorrelation error indicates there is no significant evidence of remaining spatial dependence once we take into account the indirect effects in the SDM model.

According to the results obtained, if we look at the Hausman spatial test (it is used to see if the SER model is capturing the effect of the omitted variables), their significance indicates that the omitted variables are correlated with those included in the model. Therefore, the SER model estimates are biased and it will be preferable to use the SDM. As in the previous case, table 17 shows the direct, indirect and total effects for the SDM model when the endogenous variable is the *position* of regions in a GVC.

Table 17. Direct, indirect and total effects (SDM) for *Position*

	Direct effects		**Indirect effects**		**Total effects**	
	Coefficients	p-values	Coefficients	p-values	Coefficients	p-values
	Queen contiguity matrix					
lnTotalPOP	**0.531*** **	**2.22e-16**	-0.023	0.842	**0.509*** **	**7.05e-07**
SBS	**0.001*** **	**0.004**	-0.0005	0.923	**0.001***	**0.052**
T_education	**-0.011** **	**0.014**	**0.013** **	**0.023**	**0.002** **	**0.027**
People_ST/Act_POP	0.033	0.778	-0.052	0.925	-0.018	0.999
Mobility	-0.002	0.558	0.0003	0.950	-0.002	0.763
Border	0.028	0.705	**0.132** **	**0.029**	0.160	0.174

SI_AGRI	**-0.241*** **	**8.86e-09**	**-0.025*** **	**0.001**	**-0.266*** **	**0.003**
SI_TEX	0.002	0.925	-0.065	0.295	-0.064	0.349
SI_AUTO	0.055	0.362	**0.128** **	**0.013**	**0.184** **	**0.011**
R_typology_1	**0.594*** **	**8.81e-06**	**0.182* **	**0.051**	**0.766** **	**0.017**
R_typology_2	**0.391*** **	**5.02e-05**	0.243	0.241	**0.634*** **	**0.006**
R_typology_3	**0.327*** **	**0.003**	0.308	0.175	**0.634** **	**0.014**
R_typology_4	**0.248** **	**0.014**	-0.116	0.578	-0.132	0.642

Notes: * imply 10% level of significance; ** imply 5%; *** imply 1%.

Source: Own elaboration

Again, we can see how the direct coefficients are not the same as those obtained in table 16, the difference is the feedback or indirect effect. If we take a look at the indirect effects, we can observe several findings. First, we can see how only the spillover effects of the variables "tertiary education", "border", the specialization index of the agricultural and automobile sector, and the dummy variable of more urban typology are significant.

The results show that if the closest neighbors present a high percentage of the population with tertiary education, have a border with another region of another country, are specialized in the production of the automobile sector and are urbanized regions, the value of the *position* in the global value chain of the local region will be higher. That is, if these characteristics are in the closest neighbors, the local region will be more likely to be an exporter of intermediate inputs and an importer of final goods (more basic in the production process) because it is surrounded by regions that are more focused on the final product. On the other hand, whether the closest neighbors are more specialized in the agricultural sector, the value of the *position* in the GVC will be lower, that is to say, the local region will be an exporter of final goods and importer of intermediate inputs because it is surrounded by regions that are more basic in the production process, focused on the production of a less globalized sector.

Following the previous literature (see, for example, You *et al*. 2018), one way to check the robustness of the results obtained with our weight matrix is to check what happens if other weight matrices are used. In this case, we are going to use the Great Circle Distance Matrix with a radio of 200 kilometers and *k*-nearest neighbor matrix considering the 4 closest neighbors of each region of the sample. The results appear in the Appendix. It can be verified that when we use the weight matrix of the Great Circle Distance weight matrix, considering a radio of 200km and the 4-neartest neighbor weight matrix, the results show that the different spatial weight matrices generally provide similar estimates for direct, indirect and total effects. It should be noted that, since in these weight matrices most of the elements are zero, the indirect effects or spillovers and the total effects are less significant.

5. *Conclusions*

Given the importance of globalization and the growth of international trade among countries, in this work attention is directed to the role played by spatial dependence in explaining the *participation* and *position* in GVC of European regions. In order to capture the spatial character of GVCs, we explore and calculate them under a multiregional and multisectoral input-output framework. To analyze the spatial dependence in this context, we make use of spatial econometrics. In this line, one of our main contributions is to explore the role of regional spillovers in *participation* and *position* in GVC, focusing our study on the European regions in 2010. Thereafter, econometric models are proposed to provide explanations for these interrelations among regions.

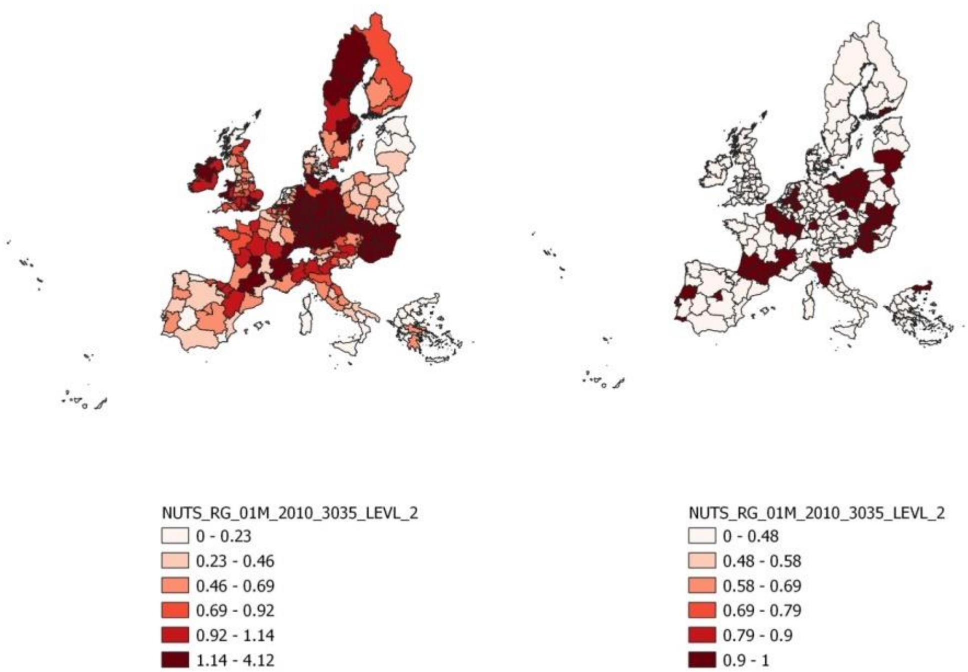
The results indicate that spatial dependence is an important component of the explanation of the determinants of the local *participation* and *position* of a specific region in a global value chain. In fact, the spatial spillover effects are significant, especially for variables that represent human capital; those that represent the degree of urbanization of the regions; those that refer to the sectoral structure of the regions in production processes and those that represent the level of development of the region. In other words, the role of an individual region in the global value chain is affected by the behavior of their closest neighbors, and it seems that the behavior of those neighbors influences the production structure of a specific region as well as its level of globalization in its production processes. Furthermore, according to the results, the globalization process at the regional level seems to be important, the regions tend to behave depending on what their closest neighbors do. Therefore, and contrary to what the previous literature establishes in the GVCs field, it is noteworthy that it is not so much a globalization process in which the countries behave as a block, but rather that there seems to be a globalized *regionalization* process that causes that the regions to behave differently within the same country and according to the behavior of their closest neighbors.

Based on the empirical findings of this study, we can draw some important policy implications as follows. First, as we previously commented, we find that spatial spillover effects of explanatory variables have a significant effect on the local region and its neighbors. Therefore, policies aimed at stimulating the economic growth should focus not only on the effects of the local region but also in its closest neighbors, taking into account the spillover effects with neighboring regions. In that sense, when making decisions of great relevance to the economies, it is not only necessary to take into account the effects on the analyzed regions, but the effects that their closest neighbors have on them. In addition, our results suggest that a region surrounded by prosperous economies could achieve higher economic growth rates. Therefore, policies within the same country might be centered on groups of regions. In this way, spillover effects can be boosted. In other words, countries should take advantage of the regional clusters that have been generated during the globalization process. What is more, these policies should be complementary to the national and international ones, as in a globalized world the different scales matter. In addition, the existence of intraregional spatial dependence could offer options for innovative geographical strategies among certain regions. The regionalization of global value chains could generate an advantage to regions surrounded by large economies. In other words, the phenomenon of regionalization and the existence of clusters within the same country could allow the lagging regions to benefit if they are surrounded by economies with high growth rates. Therefore, is it possible that the regionalization of the global value chain can cause an economy to overcome the "economic gap" that separates it from the rest? The results also suggest that while regions are competing with each other, the processes of fragmentation that have given rise to global value chains may also be generating increased interregional dependencies – as evidenced by the results presented in the previous section. The nature of these dependencies may vary according to *position* in GVCs. This phenomenon has been advanced as a source of explanation for differences in regional business cycle behavior even between regions that are each other's major trading partners (see Park and Hewings, 2012) as well as the possibility of asymmetry in the signs of spillover effects between any two regions (Chung and Hewings, 2015). In addition, as many authors have indicated, trade is becoming increasingly dominated by intra-industry rather than inter-industry trade (Hewings and Parr, 2009); this has important implications for the development of networks of regional economies.

Finally, this work contributes to literature with an explicit consideration of spatial and regional factors in the composition of global value chains, offering an empirical application to the EU regions. In our view, this work opens the door to a new line of research with strong implications in the GVC framework. The methodology proposed can be naturally extended both geographically and temporally to confirm the insights obtained in different world regions and to study the evolution of these trends over time. All in all, the behavior of GVCs has different dimensions and, as we showed here, interactions among regions which may differ in different world areas, could mediate the way in which industries, regions and countries engage in GVC.

6. Appendix D. Mapping other explicative variables

Figure D.1. Mapping of specialization index of textile sector and regional typology 1, respectively



Source: Elaborated with QGIS

7. *Appendix E. Spatial results with other spatial weight matrices*

Table E.1. Direct, indirect and total effects for *Participation* with other weight matrices

Great circle distance weight matrix (200km)						
TotalPOP	0.002***	2.22e-16	-0.0006	0.930	0.002***	0.003
SBS	0.009***	0.002	-0.013**	0.050	-0.004**	0.049
T_education	-0.004	0.967	0.040**	0.043	0.044	0.116
People_ST/Act_POP	-0.337	0.721	1.847	0.398	1.510	0.507
Mobility	-0.017	0.473	0.046	0.547	0.029	0.699
Border	-0.805	0.124	2.203**	0.042	1.397	0.269
SI_AGRI	-0.767**	0.034	-1.401**	0.042	-2.168***	0.001
SI_TEX	0.256	0.251	0.429	0.444	0.685	0.187
SI_AUTO	-0.060	0.887	0.494***	0.005	0.434	0.573
R_typology_1	2.194**	0.025	1.327***	0.001	3.521***	0.009
R_typology_2	-0.382	0.621	-0.641	0.800	-1.022	0.702
R_typology_3	-0.048	0.951	3.008	0.261	2.960	0.295
R_typology_4	0.293	0.711	-2.109	0.403	-1.815	0.516
K nearest weight matrix (4 nearest neighbors)						
TotalPOP	0.002***	2.22e-16	0.0004	0.226	0.002***	1.35e-07
SBS	0.009***	0.001	-0.013***	0.004	-0.004**	0.045
T_education	0.002	0.968	0.040**	0.028	0.042	0.096
People_ST/Act_POP	-0.168	0.865	0.388	0.801	0.220	0.884
Mobility	0.004	0.869	0.046	0.309	0.050	0.250
Border	-0.775	0.138	0.975**	0.028	0.200**	0.048
SI_AGRI	-0.969***	0.003	-0.691	0.199	-1.660***	0.001
SI_TEX	0.258	0.273	0.537	0.192	0.795	0.056
SI_AUTO	-0.037	0.966	0.247**	0.016	0.210	0.603
R_typology_1	3.323***	0.001	2.298**	0.020	5.621***	0.007
R_typology_2	-0.057	0.941	-0.080	0.946	-0.137	0.924
R_typology_3	0.510	0.526	2.114	0.150	2.624	0.133
R_typology_4	0.501	0.471	-0.478	0.686	0.023	0.987

Notes: * imply 10% level of significance; ** imply 5%; *** imply 1%.

Source: Own elaboration

<u>Table E.2</u>. Direct, indirect and total effects for *Position* with other weight matrices

Great circle distance matrix (200km)						
lnTotalPOP	**0.561***	**2.22e-16**	-0.218	0. 288	**0.343***	**0.016**
SBS	**0.001***	**0.004**	0.0003	0.773	**0.001***	**0.028**
T_education	**-0.012***	**0.007**	**0.016***	**0.029**	**0.004***	**0.047**
People_ST/Act_POP	-0.004	0.981	0.610	0.136	0.606	0.170
Mobility	-0.002	0.607	-0.004	0.748	-0.006	0.642
Border	0.004	0.964	**0.582***	**0.009**	**0.586***	**0.007**
SI_AGRI	**-0.118***	**0.009**	**-0.217***	**0.009**	**-0.335***	**0.005**
SI_TEX	0.020	0.492	**-0.180***	**0.046**	**-0.160***	**0.052**
SI_AUTO	0.055	0.238	**0.058***	**0.017**	**0.113**	**0.381**
R_typology_1	**0.508***	**0.0002**	**0.762***	**0.015**	**1.270***	**0.010**
R_typology_2	**0.343***	**0.0007**	0.389	0.408	0.732	0.142
R_typology_3	**0.262***	**0.022**	0.521	0.221	0.783	0.091
R_typology_4	0.164	0.116	-0.101	0.790	0.063	0.893
K-nearest neighbor weight matrix (4 nearest neighbors)						
lnTotalPOP	**0.538***	**2.22e-16**	0.086	0.347	**0.624***	**1.31e-09**
SBS	**0.001***	**0.001**	0.0001	0.777	**0.001***	**0.008**
T_education	-0.004	0.395	**0.007***	**0.019**	**0.003***	**0.041**
People_ST/Act_POP	-0.010	0.381	0.114	0.543	0.014	0.943
Mobility	-0.005	0.205	0.004	0.457	-0.001	0.944
Border	-0.008	0.926	**0.201***	**0.010**	**0.193***	**0.012**
SI_AGRI	**-0.210***	**3.32e-07**	**-0.037***	**0.042**	**-0.247***	**0.0003**
SI_TEX	0.033	0.304	**-0.156***	**0.003**	**-0.123***	**0.021**
SI_AUTO	0.036	0.485	**0.137***	**0.041**	**0.173**	**0.006**
R_typology_1	**0.660***	**1.81e-07**	-0.178	0.477	**0.482***	**0.045**
R_typology_2	**0.373***	**5.06e-05**	0.068	0.687	**0.441***	**0.032**
R_typology_3	**0.325***	**0.002**	0.221	0.239	**0.546***	**0.018**
R_typology_4	**0.257***	**0.007**	-0.136	0.431	0.121	0.545

Notes: * imply 10% level of significance; ** imply 5%; *** imply 1%.

Source: Own elaboration

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Conclusions

This dissertation aimed at deepening on the role played by international trade, globalization and technological progress as main drivers of economic growth of at different scales (countries, regions and sectors) in a globalized world. The phenomenon of globalization has drastically influenced the evolution of countries' economic growth with is increasingly linked to their capability to involve in global value chains.

Recently, some works have defended the idea of a raising "new globalization" that is causing the creation of macro-regions with different patterns of specialization and within which there would be a growing specialization of countries. Thus, high-income countries would benefit from the production and trade of final and/or high-value-added goods while other countries operate as input suppliers to the former or as factories of low-value-added goods. In this way, in Chapter 1 we carry out an in-depth analysis of this phenomenon and, in the European context, whether there has been a certain phenomenon of "Europeanization" in contrast to the previous phenomenon of “Globalization”.

From this analysis we can first conclude that intra-European trade has played a very important role in the generation of income and employment within the European Union in the last decades, accompanied by an increasing share of extra-European trade, mainly in the countries of Central Europe. For example, Italy, France, Spain, the Netherlands, Belgium and the United Kingdom present themselves as the main European recipients of value added and employment embodied in trade for many European countries. In addition, Germany accounted for 30% of the value added generated by intra-European trade in 2011 in Austria, the Czech Republic, Hungary, Lithuania, Poland and Slovenia. With regard to imports, there was a clear increase in interconnections between the countries of the European Union in the analyzed period from 1995 to 2011.

In this same line, through the analysis carried out, we obtain that most European countries show a clear trend towards trade in intermediate inputs, which means that the countries of the European Union would tend to be located in the intermediate steps of global production chains. This is the case of countries such as Austria, the Czech Republic, Finland, Luxembourg and Slovakia. However, despite their homogeneity in terms of the type of trade carried out, there is a clear divergence in the destination of this trade. On the one hand, the Eastern European countries have experienced a significant increase in income and employment linked to intra-European trade in the analyzed period, revealing their dynamism since their accession to the European Union. On the other hand, although the countries of Central Europe have also experienced an increase in intra-European trade, these countries show a clear shift towards extra-European trade, not forgetting the great importance of the domestic component. Therefore, the results of the first chapter strongly support the contribution of intra-EU trade to production expansion, as well as the emergence of extra-EU trade as a central driver of their employment and income.

Then, being observed the main trends on intra-EU and extra-EU trade and their heterogeneous behaviour, in Chapter 2 we deepen into the processes of convergence and divergence in the European context, connecting the traditional measures with new indicators offering information on the structural dependences within and between countries. In order to do that, we use, as convergence measures, the traditional *sigma* and *beta* convergence in a multiregional and multisectoral context, applied not only to the value added directly generated by countries but also to the value added embodied, that is to say, the value added incorporated by each of the countries of the European Union along the overall value chain of EU products. The study of convergence processes in the evaluation of economic growth by countries has been a recurrent topic in the literature. However, the most common practice has been to study convergence by considering countries as homogeneous units, without considering the specific structural characteristics, the specialization of countries and the linkages among them. Therefore, through the decomposition of global value added into its main components, the objective of Chapter 2 is to examine, for each country and group of sectors, whether income and income embodied in the trade transactions between European countries have tended to converge in the analyzed period.

The empirical results show a clear break point in the European Union's convergence process in 2008, coinciding with the outbreak of the international financial crisis and its impact on the structural relations, which contribute to increasing inequality in Europe in recent years. In addition, we obtain that trade is again a key factor in the explanation of the national and global evolution of income in Europe, and that there is a differential contribution of the sectors analyzed according to their technological nature.

In this same line, the results show a clear tendency of European countries towards divergence from that structural break in 2008. The domestic component remains a key and important factor for all of them (accounting for around 40% of the total), followed by intra-EU trade, especially for the newly incorporated countries in the EU. This is the case of Romania, Estonia, Slovakia and Latvia. On the other hand, in the countries of Central Europe, the domestic component and intra-EU trade have a smaller role, being the extra-EU trade the most relevant driver. The upward trend of the dispersion measures used in Chapter 2 would reflect this differential behaviour of countries within the European context. In addition, the analysis by industry blocs also reveals significant differences between European countries. The service sectors and those that incorporate a high degree of technology into their production processes are those that have a significant share in income generation in Europe. The results show a clear *sigma* convergence process in income in these sectors from 2000 to 2008, mainly driven by trade (intra-EU and extra-EU). However, after the crisis, the convergence process stops, even though trade remains a key factor in ensuring that heterogeneity among countries is not greater. Convergence in non-technological sectors is less affected by the international crisis than in technological ones. In addition, the evolution of the construction and energy sectors has been an important source of instability and divergence in recent years.

From the results of Chapter 2 we can conclude, as a general rule, there is a clear need to include the productive structure and structural change in the analysis of global processes such as convergence. In this sense, the analysis carried out with multiregional and multisectoral models (MRIO) shows the capacity of these models to link economic growth, structural and technological change and complex trade relations between sectors, regions and countries.

Due to the results obtained in this chapter, it is interesting to analyze the behavior of convergence processes from different perspectives. In Chapter 3 the main objective is to study the evolution of this phenomenon from an environmental perspective, expanding the European scenario to the global context; are there also environmental factors behind the growing process of divergence presented by European countries from 2008? Does the same process take place on the global scenario?

The literature related to these questions has focused on identifying the main drivers of international inequality in environmental emissions, in order to design global policies against climate change and to determine the criteria for the distribution of mitigation efforts throughout the world. In this context, we wonder whether the signs of economic convergence resulting from world globalization are leading to cleaner and less unequal environmental pressures between countries, or on the contrary, we have a growing process of inequality in global emissions resulting from the relocation of carbon-intensive industries. We have to note that an input-output framework allows us to analyze the role of domestic demand and international trade in driving current emissions, recognizing the multiregional and multisectoral nature of economic flows, their associated environmental impacts, and the relationship among supply and demand perspectives for a more detailed understanding of environmental responsibilities by sectors, regions, and countries.

First, our empirical results show that global emissions embodied in international trade have experienced a clear growth over the last few years, along with a process of divergence at the global level. As in the economic convergence study, countries experienced a process of convergence in emissions until the outbreak of the financial crisis in 2008, followed by a clear process of divergence. It should be noted that the temporary reduction in the amount of emissions generated by trade and domestic production during the first years of the crisis was mainly due to the contraction of economies and not to the reduction in the amount of emissions per unit. The growing divergence experienced by the countries since 2008 is mainly due to the different behaviour of sectors. Again, the high technological sectors are the ones with the greatest divergence among the countries in the sample, not only in direct emissions but also in those embodied. So, it seems that the general trend in emissions is toward increasing inequality in countries' CO2 emissions, which also implies a certain specialization of countries in production, with global values strongly driven by the growth of domestic demand of countries.

The results obtained with *sigma* convergence suggest the need for *beta* convergence analysis to study whether the *sigma* divergence in emissions is due to the smaller growth rate of emissions in less polluting countries, or on the contrary, due to the increasing rate of the most polluting countries. The *beta* convergence analysis presents interesting conclusions. Our results show that the observed *sigma* divergence process is the result of a clear process of *beta* divergence, marked by the fact that the major polluters at the beginning of the analyzed period have continued to increase emissions over the period, and at the highest rate. For example, developed countries such as China, the United States and some Central European countries presented a process of divergence in emissions, showing that there are significant differences among them. On the other hand, some developing countries, such as the Eastern European countries, showed a clear process of convergence in emissions among themselves. Therefore, the empirical results of Chapter 3 open new dimensions to the issue of international inequality. These different levels of economic and environmental growth experienced by countries will lead us in Chapter 4 to study different scenarios to try to explain the results obtained in the previous chapters.

In this context, the main objective of Chapter 4, based on the MRIO model and inspired by the synthetic indicators methodology and hypothetical extraction methods, is to explore the progress of the integration of countries within the EU, expansion to include Eastern European countries and the impact of the 2008 Great Recession on the progression of this phenomenon. Focusing on a case study, through the design of hypothetical scenarios, Chapter 4 explores the effects of a possible and hypothetical non-integration of Eastern European countries in the European Union at the global level, taking advantage of the full map of intersectoral and interregional relationships along the complete supply chain that a MRIO model captures. This analysis allows us to obtain some relevant ideas about the interdependence of EU economies and their possible exposure to changes in the demands of other EU countries.

From the analysis of the different hypothetical scenarios we can obtain interesting results. The effect of a possible exit from Eastern Europe would be almost three times greater for themselves than for the rest of European economies. The results show the vulnerability of Eastern countries to the effects of trade from the rest of the EU. As shown in previous chapters, the weight of intra-EU trade for this group of countries is much greater than for the rest, causing a great decrease in the evolution of their economies and much more damaging effects on their economic growth. In addition, the empirical results show that the geographical proximity to this group of countries is a key factor in explaining the impacts on economic growth in these hypothetical scenarios, but not only for purely geographical reasons, but also because the East bloc countries have a stronger trade relationship with those around them. Therefore, it can be concluded that geographical proximity remains a key factor in the configuration of global value chains, which significantly determines the evolution of global interregional trade. In this way, the reduction of physical barriers, the improvement of communication infrastructures, remains an important factor to boost trade integration in the European Union.

The fragmentation of global value chains, the new globalization and the trade internationalization have caused the behavior of sectors, regions and countries, and their main drivers of economic growth evolve according to this new globalized world. In this context, in the last chapter of this dissertation, we ask whether relations between the EU countries, from the point of view of global chains, have changed over the last few years due to globalization and whether the *participation* and *position* of the most in global production processes affects the productive structure of countries. Again, the use of MRIO models allows us to obtain a more complex view of intersectoral and interregional linkages from a spatial perspective, as well as providing systematic evidence of the spatial influence of the nearest neighbors on the *position* and *participation* of the global value chain from a regional perspective.

The empirical results of Chapter 5 show that spatial dependence is a key factor in explaining the behaviour of regions and countries within global production processes. In addition, we obtain that spillover effects are relevant to explain the behavior and evolution of different global value chains. In this context, it can be concluded that the role of an individual region in the global value chain is influenced not only by its own behaviour, but also by the behaviour of its neighbors, which influences the production structure of a specific region, as well as the level of globalization of their production processes. In addition, this analysis allows us to conclude that the process of globalization at the regional level is important, which would lead us again to link this result with Chapter 1 of the dissertation. Globalization processes are global, but also regional, which would support the previously stated conclusion that we may be facing a process of globalization that is less global, more regional and clustered.

To sum up, five main conclusions are possible to achieve from this dissertation. First, the phenomenon of globalization is not only influenced by the major structural, economic and technological changes experienced by countries, but also by more concentrated and specific factors by area. In the European Union case, we obtain that intra-European trade along with the domestic component would be explaining a large part of the phenomenon of globalization. Second, the different economic growth patterns presented by countries can be explained by the *sigma* divergence processes experienced in recent years. They are important, and also reveal the clear need to include the productive structure and structural change in the analysis of global processes such as convergence. For example, in the European context, countries show a clear trend towards divergence driven mainly by the domestic component and intra-EU trade. Third, in the environmental context, the trends observed are quite similar to those in the economic context suggesting that the evolution of emissions is highly dependent on the economic trajectories, that is, there is not a clear decoupling process. The phenomenon of globalization has caused that countries not only diverge in the evolution of their economic growth, but also in the generation of emissions. Fourth, despite the heterogeneous and sometimes divergent processes observed for the evolution of income, the configuration of global value chains, characterized by a high fragmentation of production in different areas and, therefore, the intensification of direct trade relations and indirect, has led to a strong dependence on the productive structures of the countries. In this sense, the example studied in chapter 4 shows how in a hypothetical disintegration scenario of the European Union, the Member States would be the most affected, because of the great weight of intra-EU trade in this economic area. Finally, although the phenomenon of globalization is recognized as a global process, it is also regional. The regional and spatial conditions, linked in many cases to the special nature of the territories and their capabilities such as history, business culture, among other, and importantly, the capabilities of the neighbors, significantly condition the development of the regions and sectors in the global value chains. This means that the processes of divergence, as well as the different evolutions of economic growth and the responses to the crisis experienced by sectors, regions and countries, are marked by a clear spatial influence. Therefore, the geographical factor is a key factor to explain the evolution of production processes and global value chains.

This dissertation opens the door to further research around these topics in order to have a deeper insight about economic performance at different scales and the role of structural, technological and territorial factors in their evolution. In that sense, from Chapter 5, we can make several extensions. The proposed methodology can be naturally extended both geographically and temporarily to confirm the results obtained in different regions around the world, and to study the evolution of these trends over time.

In addition, the growing heterogeneity between countries is another important aspect reflected in this dissertation. In this sense, we could analyze what is happening at regional level in different real cases such as the European Union disintegration, to capture regional patterns. This would help to better understand the different evolution of regions in Europe. Also, the hypothetical processes of disintegration of the European Union have shown the clear differences in behavior patterns among the member countries. The study at regional level would allow us to observe the behavior of these European clusters which has been observed to be a key factor in the configuration of global value chains and production processes of different European economies.

Following with global supply chains, little research has been done on the analysis of the concepts associated with GVC from a spatial perspective that is, exploring the role of spatial location in the composition of these chains. As it has been shown that geographical aspects are really important to explain the behavior of economies, the results obtained show that it may be necessary to reformulate some traditional concepts related to Global Value Chains.

Besides, we have been talking about the different patterns of economic growth experienced by the countries as the main explanatory factor for the divergence processes. Therefore, the simulation of policies that can influence aspects such as convergence between countries or regions, sustainable growth (which takes into account the environment) or various social aspects can be another way of future research.

Also results interesting the application of more flexible models such as CGE models, which would imply a natural extension of the dissertation. Throughout the different chapters, the importance of structural changes over time to explain the global impacts on countries has been demonstrated; the consideration of structural and technological change, the transformation of productive relations and the allocation of substitutability between inputs within the region/country or between inputs from different regions/countries. In this way, with the application of CGE models, we could capture in a more detailed, complex and exhaustive way the economic changes that have occurred in recent years.

As it is possible to see so many research lines are opened and, by sure, more research questions would arise in the development of these future lines of research, as economic growth remains a key factor and subject of study in explaining the current processes of globalization. Along these lines, MRIO models are a very useful tool and can be used to carry out numerous studies and to analyze in depth the complex intersectoral and interregional links between countries. In this way, this dissertation aims to be a contribution to the new questions that have emerged around the methodological and empirical basis behind the input-output models.

Conclusiones

Esta tesis doctoral ha tenido como objetivo profundizar en el papel que juega el comercio internacional, la globalización y el progreso tecnológico como principales impulsores del crecimiento económico a diferentes escalas (países, regiones y sectores) en un mundo globalizado. El fenómeno de la globalización ha influido drásticamente en la evolución del crecimiento económico de los países y está cada vez más vinculado a su capacidad para involucrarse en las cadenas globales de valor.

Recientemente, algunos trabajos han defendido la idea de una “nueva globalización”, que está provocando la creación de macro regiones con diferentes patrones de especialización y dentro de las cuales habría una creciente especialización de países. Así, los países de altos ingresos se beneficiarían de la producción y el comercio de bienes finales y/o de alto valor añadido, mientras que otros países operarían como proveedores de inputs para los primeros o como fabricantes de bienes de bajo valor añadido. De esta manera, en el capítulo 1 realizamos un análisis en profundidad de este fenómeno y nos preguntamos, en el contexto europeo, si ha habido un cierto fenómeno de "Europeización" en contraste con el fenómeno anterior de “Globalización”.

De este análisis podemos concluir en primer lugar que el comercio intra-europeo ha jugado un papel muy importante en la generación de renta y empleo dentro de la Unión Europea en las últimas décadas, acompañado de un creciente aumento del papel del comercio extra-europeo, principalmente en los países de la Europa Central. Por ejemplo, Italia, Francia, España, Países Bajos, Bélgica y el Reino Unido se presentan como los principales destinatarios europeos de valor añadido y empleo incorporado en el comercio para numerosos países europeos. Además, Alemania representó en 2011 el 30% del valor añadido generado con el comercio intra-europeo en Austria, República Checa, Hungría, Lituania, Polonia y Eslovenia. Respecto a las importaciones, se observa un claro aumento de las interconexiones entre los países de la Unión Europea en el periodo estudiado de 1995 a 2011.

En esta misma línea, a través del análisis realizado, obtenemos que la mayoría de países europeos muestran una clara tendencia hacia el comercio de inputs intermedios, lo que significa que los países de la Unión Europea tenderían a situarse en los pasos intermedios de las cadenas globales de producción. Este es el caso de países como Austria, República Checa, Finlandia, Luxemburgo y Eslovaquia. Sin embargo, y a pesar de la homogeneidad que presentan en cuanto al tipo de comercio realizado, hay una clara divergencia respecto al destino de este comercio. Por un lado, los países del Este han experimentado un importante incremento de la renta y el empleo ligado al comercio intra-europeo en el período analizado, revelando su dinamismo desde su incorporación a la Unión Europea. Por otro lado, aunque los países de Europa central también han experimentado un aumento del comercio intracomunitario, estos países muestran un claro giro hacia el comercio extracomunitario, sin olvidar la gran relevancia del componente doméstico. Por tanto, los resultados del primer capítulo apoyan firmemente la contribución del comercio dentro de la UE a la expansión de la producción, así como la irrupción del comercio exterior de la UE como motor central de su empleo e ingresos.

Habiendo observado las principales tendencias del comercio intracomunitario y extracomunitario y su comportamiento heterogéneo, en el capítulo 2 profundizamos en los procesos de convergencia y divergencia en el contexto europeo, enlazando las medidas tradicionales con nuevos indicadores que ofrezcan información sobre las dependencias dentro y entre países. Para ello, utilizamos como medidas de convergencia las tradicionales *sigma* y *beta* convergencia en un contexto multirregional y multisectorial, aplicadas no solo al valor añadido generado directamente por los países sino también al valor añadido global, es decir, al valor añadido incorporado por cada uno de los países de la Unión Europea a lo largo de la cadena global de valor de los productos de la UE. El estudio de los procesos de convergencia en la evaluación del crecimiento económico por parte de los países ha sido un tema recurrente en la literatura. Sin embargo, la práctica más común ha sido evaluar la convergencia considerando a los países como unidades homogéneas, sin considerar las características estructurales específicas, la especialización de los países y los vínculos entre ellos. Por ello, a través de la descomposición del valor añadido global en sus principales componentes, el principal objetivo del capítulo 2 es estudiar para cada país y grupo de sectores si la renta y la renta incorporada en las distintas transacciones comerciales entre países europeos han tendido a converger en el período estudiado.

Los resultados empíricos muestran la existencia de una clara ruptura en el proceso de convergencia de la Unión Europea en el año 2008, coincidiendo con el estallido de la crisis financiera internacional y su impacto en las relaciones estructurales, lo que contribuye a incrementar la desigualdad en Europa en los últimos años. Además, obtenemos que el comercio vuelve a ser un factor clave en la explicación de la evolución nacional y global de la renta en Europa, y que hay una contribución diferencial de los sectores analizados de acuerdo a su naturaleza tecnológica.

En esta línea, los resultados muestran una clara tendencia de los países europeos hacia la divergencia a partir de esa ruptura del año 2008. El componente doméstico sigue siendo un factor clave e importante para todos ellos (representa alrededor del 40% del total), seguido por el comercio intracomunitario, sobre todo para los países de reciente incorporación. Este es el caso de Rumania, Estonia, Eslovaquia y Letonia. Por otro lado, los países de la Europa Central presentan un peso menor del componente doméstico y del comercio intracomunitario, y una mayor relevancia del comercio extra-europeo. La tendencia al alza, de las medidas de dispersión utilizadas en el capítulo 2, estaría reflejando este comportamiento diferencial de los países dentro del contexto europeo. Además, el análisis realizado por bloques de industrias también revela importantes diferencias entre los países europeos. Los sectores de servicios, y los que incorporan un alto grado de tecnología en su producción, son los que presentan una participación significativa en la generación de renta en Europa. Los resultados muestran un claro proceso de convergencia en renta en estos sectores desde 2000 hasta 2008, principalmente impulsado por el comercio (intra-europeo y extra-europeo). Sin embargo, tras la crisis, el proceso de convergencia se detiene, a pesar de que el comercio sigue siendo un factor clave para que la heterogeneidad entre los países no sea mayor. La convergencia en los sectores no tecnológicos parece menos afectada por la crisis internacional que en los tecnológicos. Además, la evolución de los sectores de la construcción y la energía ha sido una fuente importante de inestabilidad y divergencia en los últimos años.

De los resultados de capítulo 2 podemos concluir, como normal general, que existe una clara necesidad de incluir la estructura productiva y el cambio estructural en el análisis de procesos globales como la convergencia. En este sentido, el análisis realizado con los modelos multirregionales y multisectoriales muestra la capacidad de estos modelos para vincular el crecimiento económico, el cambio estructural y tecnológico y las complejas relaciones comerciales existentes entre sectores, regiones y países.

Debido a los resultados obtenidos en este último capítulo, resulta interesante analizar el comportamiento de los procesos de convergencia desde diferentes perspectivas. En el capítulo 3 el objetivo principal es mostrar la evolución de este fenómeno desde una perspectiva medioambiental, ampliando el escenario europeo al contexto global; ¿hay también factores ambientales detrás del creciente proceso de divergencia presentado por los países europeos a partir de 2008?, ¿ocurre lo mismo en el escenario global?

La literatura relacionada con estas preguntas se ha centrado en identificar las principales fuerzas impulsoras de la desigualdad internacional en las emisiones ambientales, para informar del diseño de políticas globales contra el cambio climático y para determinar los criterios para la distribución de los esfuerzos de mitigación en todo el mundo. En este contexto, nos preguntamos si los signos de convergencia económica resultantes de la globalización mundial están dando lugar a presiones ambientales más limpias y menos desiguales entre los países, o, por el contrario, tenemos un proceso creciente de desigualdad en las emisiones mundiales resultante de la deslocalización de las industrias intensivas en carbono. Tenemos que destacar que un marco input-output nos permite analizar el papel de la demanda interna y el comercio internacional en el impulso de las emisiones actuales, reconociendo la naturaleza multirregional y multisectorial de los flujos económicos, sus impactos ambientales asociados, y la relación entre las perspectivas de oferta y demanda, para una comprensión más detallada de las responsabilidades ambientales por parte de los sectores, regiones y países.

En primer lugar, nuestros resultados empíricos muestran que las emisiones globales incorporadas en el comercio mundial han experimentado un claro crecimiento a lo largo de los últimos años, acompañado de un proceso de divergencia a nivel mundial. Tal y como sucedía con la convergencia económica, los países experimentaron un proceso de convergencia en emisiones hasta el estallido de la crisis financiera en 2008, seguido de un proceso de divergencia. Cabe destacar que la reducción temporal de la cantidad de emisiones generadas con el comercio y la producción doméstica durante los primeros años de la crisis, se debió principalmente a la contracción de las economías y no a la reducción en la cantidad de emisiones por unidad. La divergencia creciente experimentada a partir de 2008 por los países se debe en su mayoría al diferente comportamiento experimentado por los sectores. De nuevo, los sectores de alto contenido tecnológico son los que presentan mayor divergencia entre los países de la muestra, no sólo en las emisiones directas sino también en las incorporadas. Parece que la tendencia general en las emisiones es hacia una creciente desigualdad en las emisiones de CO_2 de los países, lo que también implica una cierta especialización de los países en la producción, con valores globales fuertemente impulsados por el crecimiento de la demanda interna de los países.

Los resultados obtenidos con la convergencia sigma sugieren la necesidad de un análisis de convergencia beta para estudiar si la divergencia sigma en las emisiones se debe a la menor tasa de crecimiento de las emisiones en los países menos contaminantes, o por el contrario, a la tasa creciente de los países más contaminantes. Esta última plantea también conclusiones interesantes. Nuestros resultados muestran que la divergencia sigma observada es el resultado de un claro proceso de divergencia beta, marcado por el hecho de que los mayores contaminadores al comienzo del período han seguido aumentando las emisiones durante el período, y a la tasa más alta. Por ejemplo, países desarrollados como China, Estados Unidos y algunos países de la Europa central, presentaron un proceso de divergencia en las emisiones, demostrando que existen diferencias significativas entre ellos. Por otro lado, países menos desarrollados, como los países del Este de Europa, mostraron un claro proceso de convergencia en emisiones entre ellos. Por tanto, los resultados empíricos del capítulo 3 aportan nuevas dimensiones al tema de la desigualdad internacional. Estos diferentes niveles de crecimiento económico y medioambiental experimentados por los países nos llevarán en el capítulo 4 a estudiar diferentes escenarios hipotéticos para intentar explicar los resultados obtenidos en los capítulos anteriores.

De esta forma, el objetivo principal del capítulo 4, sobre la base del modelo MRIO e inspirados en la metodología de indicadores sintéticos y los métodos de extracción hipotética, es explorar el progreso de la integración de los países dentro de la UE, la expansión para incluir a los países de Europa del Este y el impacto de la Gran Recesión de 2008 en la progresión de este fenómeno. Centrándonos en un caso de estudio, a través del diseño de escenarios hipotéticos, en el capítulo 4 se exploran los efectos de una posible e hipotética no adhesión de países de Europa del Este en la Unión Europea a nivel mundial, aprovechando el mapa completo de relaciones intersectoriales e interregionales a lo largo de la cadena de suministro completa, que un modelo MRIO captura. Este análisis nos permite obtener algunos conocimientos relevantes sobre la interdependencia de las economías de la UE y su posible exposición a cambios en las demandas de otros países de la UE.

Del análisis de los diferentes escenarios podemos obtener resultados interesantes. El efecto que supondría una posible salida de los países del Este de Europa sería casi el triple para ellos mismo que para el resto de economías europeas. Los resultados obtenidos reflejan la vulnerabilidad de los países del Este a los efectos del comercio que proviene del resto de países de la Unión Europea. Tal y como se mostró en capítulos anteriores, el peso del comercio intracomunitario para este grupo de países es mucho mayor que para el resto, provocando una caída de sus economías y unos efectos mucho más perjudiciales para su crecimiento económico. Además, los resultados muestran que la cercanía geográfica a este grupo de países es un factor clave a la hora de explicar los impactos sobre el crecimiento económico en estos hipotéticos escenarios, pero no solo por motivos puramente geográficos, sino también porque los países del bloque del Este mantienen un mayor comercio con los que se encuentran a su alrededor. Por tanto, se puede concluir que la proximidad geográfica sigue siendo un factor clave en la configuración de las cadenas globales de valor, que determina de manera importante la configuración del comercio interregional en el mundo. Por todo ello, la reducción de barreras físicas, la mejora de las infraestructuras de comunicación, sigue siendo un canal importante para impulsar la integración comercial en la Unión Europea.

La fragmentación de las cadenas globales de valor, la globalización y la internacionalización comercial han provocado que el comportamiento de los sectores, regiones y países, y sus principales motores de crecimiento económico evolucionen de acuerdo a este nuevo mundo globalizado. En este contexto, en el último capítulo de la tesis, nos preguntamos si las relaciones entre los países de la EU desde el punto de vista de las cadenas globales han cambiado a lo largo de los últimos años debido a la globalización y si la participación y posición de los vecinos más cercanos en los procesos productivos globales afecta a la estructura productiva de los países. De nuevo, el uso de los modelos MRIO nos permite obtener una visión más compleja de los vínculos intersectoriales e interregionales desde una perspectiva espacial, así como proporcionar evidencia sistemática de la influencia espacial de los vecinos más cercanos en la posición y participación de la cadena global de valor desde una perspectiva regional.

Los resultados empíricos del capítulo 5 muestran que la dependencia espacial es un factor clave para explicar el comportamiento de las regiones y países dentro de los procesos productivos globales. Además, obtenemos que los efectos *spillover* son relevantes para explicar el comportamiento y la evolución de las diferentes cadenas globales de valor. En este contexto, se puede concluir que el papel de una región individual en la cadena global de valor se ve influenciado no solo por su propio comportamiento, sino también por el comportamiento de sus vecinos, lo que influye en la estructura productiva de una región específica, así como en el nivel de globalización de sus procesos de producción. Además, el análisis llevado a cabo en el capítulo 5, nos permite concluir que el proceso de globalización a nivel regional es importante, lo que nos llevaría de nuevo a enlazar este resultado con el capítulo 1 de la tesis. Los procesos de globalización son globales, pero también regionales, lo que apoyaría la conclusión establecida anteriormente de que quizás nos encontremos ante un proceso de globalización más reducido, no tan global, sino más regional y agrupado en conglomerados.

En resumen, cinco son las principales conclusiones que se pueden extraer de esta tesis. En primer lugar, el fenómeno de la globalización no sólo está influenciado por los grandes cambios estructurales, económicos y tecnológicos experimentados por los países, sino también por factores específicos y concentrados por áreas más pequeñas. En el caso de la Unión Europea, obtenemos que el comercio intracomunitario, junto con el componente doméstico, estarían explicando gran parte del fenómeno de la globalización. En segundo lugar, los diferentes patrones de crecimiento económico que presentan los países pueden explicarse por los procesos de divergencia sigma experimentados en los últimos años. Son importantes, y además revelan la clara necesidad de incluir la estructura productiva y el cambio estructural en el análisis de procesos globales como la convergencia. Por ejemplo, en el contexto europeo, los países muestran una clara tendencia hacia la divergencia impulsada mayoritariamente por el componente doméstico y por el comercio intracomunitario. Tercero, en el contexto medioambiental, las tendencias observadas son bastante similares a las del contexto económico, lo que sugiere que la evolución de las emisiones es altamente dependiente de las trayectorias económicas, es decir, no existe un proceso de desacoplamiento claro. El fenómeno de la globalización ha causado que los países no solo presenten divergencia en la evolución de su crecimiento económico, sino también en cuanto a la generación de emisiones. En cuarto lugar, a pesar de los procesos heterogéneos y en ocasiones divergentes observados para la evolución de la renta, la configuración de las cadenas de valor globales, caracterizadas por una alta fragmentación de la producción en diferentes áreas y, por tanto, la intensificación de las relaciones comerciales directas e indirectas, ha llevado a una fuerte dependencia de las estructuras productivas de los países. En este sentido, el ejemplo estudiado en el capítulo 4 muestra cómo en un hipotético escenario de desintegración de la Unión Europea, los Estados miembros serían los más afectados, debido al gran peso del comercio intracomunitario en esta área económica. Finalmente, aunque el fenómeno de la globalización sea reconocido como un proceso global, también es regional. Las condiciones regionales y espaciales, ligadas en muchos casos a la especialidad de los territorios y sus capacidades como la historia, la cultura empresarial, entre otras, y lo más importante, las capacidades de los vecinos, condicionan significativamente el desarrollo de las regiones y sectores en las cadenas globales de valor. Esto significa que los procesos de divergencia, así como las diferentes evoluciones del crecimiento económico y las respuestas a la crisis experimentadas por sectores, regiones y países, están marcadas por una clara influencia espacial. Por tanto, el factor geográfico es un factor clave para explicar la evolución de los procesos productivos y las cadenas globales de valor.

Esta tesis abre la puerta a nuevas investigaciones en torno a estos temas con el fin de profundizar en el desempeño económico a diferentes escalas y el papel de los factores estructurales, tecnológicos y territoriales en su evolución. Así, en la línea del capítulo 5 podemos realizar varias ampliaciones. La metodología propuesta se puede ampliar de forma natural tanto geográfica como temporalmente para confirmar los conocimientos obtenidos en diferentes regiones del mundo y estudiar la evolución de estas tendencias a lo largo del tiempo.

Además, la creciente heterogeneidad entre países es otro aspecto importante reflejado en esta tesis doctoral. En este sentido, podríamos analizar lo que está sucediendo a nivel regional en diferentes casos reales como podría ser la desintegración de la Unión Europea, para captar patrones regionales. Esto ayudaría a comprender de una manera más clara la diferente evolución de las regiones de Europa. Asimismo, los hipotéticos procesos de desintegración de la Unión Europea han mostrado claras diferencias en los patrones de comportamiento entre los países miembros. El estudio a nivel regional nos permitiría observar el comportamiento de estos clústeres europeos como un factor clave en la configuración de las cadenas de valor globales y los procesos productivos de las diferentes economías europeas.

Continuando con las cadenas globales de producción, poca investigación se ha realizado sobre el análisis de los conceptos asociados a las CGV desde una perspectiva espacial, es decir, explorando el papel de la ubicación espacial en la composición de estas cadenas. Como se ha demostrado que los aspectos geográficos son realmente importantes para explicar el comportamiento de las economías, los resultados obtenidos muestran que podría ser necesario reformular algunos conceptos tradicionales relacionados con las Cadenas Globales de Producción.

Además, hemos estado hablando de los diferentes patrones de crecimiento económico que experimentan los países como principal factor explicativo de los procesos de divergencia. Por tanto, la simulación de políticas que puedan incidir en aspectos como la convergencia entre países o regiones, el crecimiento sostenible (teniendo en cuenta el medio ambiente) o diversos aspectos sociales, puede ser otra vía de investigación futura.

También resulta interesante la aplicación de modelos más flexibles como los modelos CGE, que supondrían una extensión natural de la presente tesis doctoral. A lo largo de los diferentes capítulos, se ha demostrado la importancia de los cambios estructurales propuestos en el tiempo para explicar los impactos globales en los países, la consideración del cambio estructural y tecnológico, la transformación de las relaciones productivas y la afectación de la sustituibilidad entre inputs dentro de la región/país o entre inputs de diferentes regiones/países. De esta forma, a través de la aplicación de los modelos CGE podríamos captar de una manera más detallada, compleja y exhaustiva los cambios que se han producido en los últimos años.

Como se puede ver, varias líneas de investigación están abiertas, y, seguramente, muchas más cuestiones surgirán en el desarrollo de estas futuras líneas de investigación, ya que el crecimiento económico sigue siendo un factor clave y objeto de estudio en la explicación de los actuales procesos de globalización. En esta línea, los modelos MRIO son una herramienta muy útil y pueden ser utilizados para realizar numerosos estudios y estudiar en profundidad los complejos vínculos intersectoriales e interregionales existentes entre los países. De esta forma, esta tesis trata de ser una contribución a las nuevas cuestiones que han ido surgiendo alrededor de la gran base metodológica y empírica que hay detrás de los modelos input-output.