From convergence to divergence? Some new insights into the evolution of the European Union

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Abstract

The promotion of economic, social, and territorial cohesion has been one of the main pillars of the construction of the European Union. This general principle has been manifest in the objectives of achieving a higher level of economic convergence, territorial competitiveness, and fostering employment creation in EU countries. The recent economic crisis has implied profound changes, not only in the path of growth but also in the structural and technological characteristics of EU countries, with these elements highly conditioning their inter-dependencies, economic outcomes, and convergence. This paper analyzes the role that the evolution of economic structures has played in the evolution of recent convergence in Europe expanding the traditional measures of economic convergence extended to a multi-regional input-output framework. Our study shows a trend towards convergence among EU countries and a significant breakpoint with the arrival of the economic crisis in 2008. Moreover, we observe a continuous change in the role of different components, raising the participation of trade (intra and extra European trade) in income for most of the countries and sectors analyzed. In addition, the different behavior of services, in particular, knowledge intensive services in the EU countries notably condition income generation in countries. Nevertheless, our results show that despite services economy explains significantly income growth in Europe over the period 2000-2014, income growth in Eastern Europe countries has notably relied on the positive reliance of manufacturing sectors (particularly medium and low technology sectors), and the expansion of conventional services, with a lower representativeness of the knowledge intensive sectors. Domestic and intra-EU markets are dominant, although also with an increasing share of extra-EU exports. The opposite can be said for central EU economies, which a smoother evolution over the period but a clear

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dominance of the knowledge intensive services and, in some cases, the high and medium-high technology industry.

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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[1].

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 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

[1] 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.

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 (1990) 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, our paper 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, our paper also analyzes the evolution of *sigma* convergence on global value-added (embodied value-added), 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[2] which serve as empirical basis for multiregional input-

[2] 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).

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 Sourding, 2017). 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 paper 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 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 paper 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).

Let us begin by representing the equilibrium equation for the world economy formed of m countries and n sectors as in (1). Our starting point is the representation of the world economy in this multiregional context, with m countries and n sectors, where **x** denotes the total output, $\mathbf{Z} = \mathbf{[Z_{ij}^{rs}]}$ is the matrix of multiregional intermediate flows, **y** is the vector of total final demand of countries and **i** a unitary vector of the adequate dimension.

$$\mathbf{x} = \mathbf{Zi} + \mathbf{y} \qquad (1)$$

Let us denote by $\mathbf{A} = \mathbf{[A_{ij}^{rs}]}$ 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*. Equation (1) can be expressed on the basis of **A** and in terms of the Leontief inverse **L** for the whole multiregional economy.

$$\mathbf{x} = \mathbf{Ax} + \mathbf{y} \Leftrightarrow \mathbf{x} = \mathbf{(I - A)}^{-1}\mathbf{y} = \mathbf{Ly} \qquad (2)$$

Each element in $\mathbf{L} = \mathbf{[L_{ij}^{rs}]}$ 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 **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.

We work within this multi-sectoral and multi-regional 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.

For simplicity, in order to better understand the approach followed, let us consider now 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.

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

Let us also consider a vector **w** including the value added (income) vector of each country.

As we are interested in the EU countries, let us focus on the EU production and the associated domestic technology.

We denote by $\mathbf{x}^{EU}=\begin{bmatrix}\mathbf{x}^{1}\\ \mathbf{x}^{2}\end{bmatrix}$ the production generated in the EU countries**.** Similarly, we can define

$$\mathbf{w}^{EU}=\begin{bmatrix}\mathbf{w}^{1}\\ \mathbf{w}^{2}\end{bmatrix},\ \mathbf{Z}^{EU}=\begin{bmatrix}\mathbf{Z}^{11} & \mathbf{Z}^{12}\\ \mathbf{Z}^{21} & \mathbf{Z}^{22}\end{bmatrix},\ \mathbf{f}^{EU,EU}=\begin{bmatrix}\mathbf{f}^{11} & \mathbf{f}^{12}\\ \mathbf{f}^{21} & \mathbf{f}^{22}\end{bmatrix}\ \text{and}\ \mathbf{e}^{EU}=\begin{bmatrix}\mathbf{e}^{13} & \mathbf{e}^{14}\\ \mathbf{e}^{23} & \mathbf{e}^{23}\end{bmatrix}=\begin{pmatrix}\mathbf{f}^{13}+\mathbf{Z}^{13}\mathbf{i} & \mathbf{f}^{14}+\mathbf{Z}^{14}\mathbf{i}\\ \mathbf{f}^{23}+\mathbf{Z}^{23}\mathbf{i} & \mathbf{f}^{24}+\mathbf{Z}^{24}\mathbf{i}\end{pmatrix}$$

Based on these matrices, we can derive the corresponding $\mathbf{A}^{EU}$ matrix, which represents the domestic technology of the EU

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

Thus, it holds that:

$$\mathbf{x}^{EU}=\mathbf{A}^{EU}\mathbf{x}^{EU}+\mathbf{f}^{EU},\ \text{with}\ \ \mathbf{f}^{EU}=\begin{bmatrix}\mathbf{f}^{11}+\mathbf{f}^{12}+\mathbf{e}^{13}+\mathbf{e}^{14}\\ \mathbf{f}^{21}+\mathbf{f}^{22}+\mathbf{e}^{23}+\mathbf{e}^{24}\end{bmatrix}=\mathbf{f}^{EU,EU}\mathbf{i}+\mathbf{e}^{EU}\mathbf{i} \qquad (3)$$

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

$$\mathbf{x}^{EU} = \left(\mathbf{I} - \mathbf{A}^{EU}\right)^{-1}\mathbf{f}^{EU} = \mathbf{L}^{EU}\mathbf{f}^{EU} = \begin{pmatrix} \mathbf{L}^{11} & \mathbf{L}^{12} \\ \mathbf{L}^{21} & \mathbf{L}^{22} \end{pmatrix}\mathbf{f}^{EU} \tag{4}$$

Moreover, considering the value-added directly generated in the EU, we can define the following value-added coefficients:

$$\mathbf{v}^{EU'} = \mathbf{w}^{EU'}\left(\hat{\mathbf{x}}^{EU}\right)^{-1}, \text{ and their corresponding diagonal form } \hat{\mathbf{v}}^{EU} = \begin{pmatrix} \hat{\mathbf{v}}^{1} & \mathbf{0} \\ \mathbf{0} & \hat{\mathbf{v}}^{2} \end{pmatrix} \tag{5}$$

Thus, let us define the following matrix $\mathbf{\Omega}^{EU}$, 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 $\mathbf{\Omega}^{EU}$ can be broken down into the EU income ending within the EU ($\mathbf{\Omega}^{EU,EU}$) and the EU income ending abroad, through EU exports to non-EU countries ($\mathbf{\Omega}^{EU,noEU}$).

$$\begin{aligned} &\mathbf{\Omega}^{EU} = \hat{\mathbf{v}}^{EU}\mathbf{L}^{EU}\hat{\mathbf{f}}^{EU} = \\ &\begin{pmatrix} \hat{\mathbf{v}}^{1} & \mathbf{0} \\ \mathbf{0} & \hat{\mathbf{v}}^{2} \end{pmatrix}\begin{pmatrix} \mathbf{L}^{11} & \mathbf{L}^{12} \\ \mathbf{L}^{21} & \mathbf{L}^{22} \end{pmatrix}\begin{pmatrix} \mathbf{f}^{11} + \mathbf{f}^{12} & 0 \\ 0 & \mathbf{f}^{21} + \mathbf{f}^{22} \end{pmatrix} + \begin{pmatrix} \hat{\mathbf{v}}^{1} & \mathbf{0} \\ \mathbf{0} & \hat{\mathbf{v}}^{2} \end{pmatrix}\begin{pmatrix} \mathbf{L}^{11} & \mathbf{L}^{12} \\ \mathbf{L}^{21} & \mathbf{L}^{22} \end{pmatrix}\begin{pmatrix} \mathbf{e}^{13} + \mathbf{e}^{14} & 0 \\ 0 & \mathbf{e}^{23} + \mathbf{e}^{24} \end{pmatrix} \\ &= \mathbf{\Omega}^{EU,EU} + \mathbf{\Omega}^{EU,noEU} \end{aligned} \tag{6}$$

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.

Specifically reading by columns, the EU value-added embodied in intra-EU demands and the EU value-added embodied in extra-EU exports will be given by:

$$\begin{aligned} &\mathbf{\omega}^{EU,EU'} = \mathbf{i}'\mathbf{\Omega}^{EU,EU} = \begin{pmatrix} \mathbf{v}^{1'} & \mathbf{v}^{2'} \end{pmatrix}\begin{pmatrix} \mathbf{L}^{11} & \mathbf{L}^{12} \\ \mathbf{L}^{21} & \mathbf{L}^{22} \end{pmatrix}\begin{pmatrix} \mathbf{f}^{11} + \mathbf{f}^{12} & \mathbf{0} \\ \mathbf{0} & \mathbf{f}^{21} + \mathbf{f}^{22} \end{pmatrix} = \\ &= \begin{pmatrix} \mathbf{v}^{1'}\mathbf{L}^{11}\mathbf{f}^{11} + \mathbf{v}^{2'}\mathbf{L}^{21}\mathbf{f}^{11} + \mathbf{v}^{1'}\mathbf{L}^{11}\mathbf{f}^{12} + \mathbf{v}^{2'}\mathbf{L}^{21}\mathbf{f}^{12} & \mathbf{v}^{1'}\mathbf{L}^{12}\mathbf{f}^{21} + \mathbf{v}^{2'}\mathbf{L}^{22}\mathbf{f}^{21} + \mathbf{v}^{1'}\mathbf{L}^{12}\mathbf{f}^{22} + \mathbf{v}^{2'}\mathbf{L}^{22}\mathbf{f}^{22} \end{pmatrix} \end{aligned} \tag{7}$$

$$\begin{aligned} &\mathbf{\omega}^{EU,noEU'} = \mathbf{i}'\mathbf{\Omega}^{EU,noEU} = \begin{pmatrix} \mathbf{v}^{1'} & \mathbf{v}^{2'} \end{pmatrix}\begin{pmatrix} \mathbf{L}^{11} & \mathbf{L}^{12} \\ \mathbf{L}^{21} & \mathbf{L}^{22} \end{pmatrix}\begin{pmatrix} \mathbf{e}^{13} + \mathbf{e}^{14} & \mathbf{0} \\ \mathbf{0} & \mathbf{e}^{23} + \mathbf{e}^{24} \end{pmatrix} = \\ &= \begin{pmatrix} \mathbf{v}^{1'}\mathbf{L}^{11}\mathbf{e}^{13} + \mathbf{v}^{2'}\mathbf{L}^{21}\mathbf{e}^{13} + \mathbf{v}^{1'}\mathbf{L}^{11}\mathbf{e}^{14} + \mathbf{v}^{2'}\mathbf{L}^{21}\mathbf{e}^{14} & \mathbf{v}^{1'}\mathbf{L}^{12}\mathbf{e}^{23} + \mathbf{v}^{2'}\mathbf{L}^{22}\mathbf{e}^{23} + \mathbf{v}^{1'}\mathbf{L}^{12}\mathbf{e}^{24} + \mathbf{v}^{2'}\mathbf{L}^{22}\mathbf{e}^{24} \end{pmatrix} \end{aligned} \tag{8}$$

Note equations (7) and (8) attribute to each EU country the income generated across the EU to produce the inputs and final goods traded and consumed within the EU ($\mathbf{\Omega}^{\mathbf{EU,EU}}$) and the income generated across the EU to produce the inputs and final goods exported to non-EU countries ($\mathbf{\Omega}^{\mathbf{EU,noEU}}$).

Reading these matrices by rows, we can also calculate the value-added generated in each EU country due to its sales to other countries (EU and non-EU)

$$\begin{aligned}\mathbf{w}^{\mathbf{EU}} &= \begin{bmatrix}\mathbf{w}^{\mathbf{1}}\\ \mathbf{w}^{\mathbf{2}}\end{bmatrix} = \mathbf{w}^{direct\mathbf{EU,EU}} + \mathbf{w}^{direct\mathbf{EU,noEU}} \\ &= \mathbf{\Omega}^{\mathbf{EU,EU}}\mathbf{i} + \mathbf{\Omega}^{\mathbf{EU,noEU}}\mathbf{i} = \hat{\mathbf{v}}^{\mathbf{EU}}\mathbf{L}^{\mathbf{EU}}\hat{\mathbf{f}}^{\mathbf{EU}}\mathbf{i} = \hat{\mathbf{v}}^{\mathbf{EU}}\mathbf{L}^{\mathbf{EU}}\hat{\mathbf{f}}^{\mathbf{EU,EU}}\mathbf{i} + \hat{\mathbf{v}}^{\mathbf{EU}}\mathbf{L}^{\mathbf{EU}}\hat{\mathbf{e}}^{\mathbf{EU}}\mathbf{i}\end{aligned} \tag{9}$$

These sums by rows, for each country and sector, reproduce the value-added generated in each country. Again, this global evaluation consists of two parts. The first component, $\mathbf{w}^{direct\mathbf{EU,EU}}$ contains elements of intra-EU trade while the second component $\mathbf{w}^{direct\mathbf{EU,noEU}}$ contains the value-added generated in each EU country to fulfil its exports to the non-EU countries.

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.

$$\begin{aligned}\mathbf{\Omega}^{domestic\mathbf{EU,EU}} &= \begin{pmatrix}\hat{\mathbf{v}}^{\mathbf{1}} & \mathbf{0}\\ \mathbf{0} & \hat{\mathbf{v}}^{\mathbf{2}}\end{pmatrix}\begin{pmatrix}\mathbf{L}^{\mathbf{11}} & \mathbf{0}\\ \mathbf{0} & \mathbf{L}^{\mathbf{22}}\end{pmatrix}\begin{pmatrix}\mathbf{f}^{\mathbf{11}} & 0\\ 0 & \mathbf{f}^{22}\end{pmatrix} \\ \mathbf{\Omega}^{trade\mathbf{EU,EU}} &= \begin{pmatrix}\hat{\mathbf{v}}^{\mathbf{1}} & \mathbf{0}\\ \mathbf{0} & \hat{\mathbf{v}}^{\mathbf{2}}\end{pmatrix}\begin{pmatrix}0 & \mathbf{L}^{\mathbf{12}}\\ \mathbf{L}^{\mathbf{21}} & 0\end{pmatrix}\begin{pmatrix}\mathbf{f}^{\mathbf{11}}+\mathbf{f}^{\mathbf{12}} & 0\\ 0 & \mathbf{f}^{21}+\mathbf{f}^{22}\end{pmatrix} + \begin{pmatrix}\hat{\mathbf{v}}^{\mathbf{1}} & \mathbf{0}\\ \mathbf{0} & \hat{\mathbf{v}}^{\mathbf{2}}\end{pmatrix}\begin{pmatrix}\mathbf{L}^{\mathbf{11}} & 0\\ 0 & \mathbf{L}^{\mathbf{22}}\end{pmatrix}\begin{pmatrix}\mathbf{f}^{\mathbf{12}} & 0\\ 0 & \mathbf{f}^{\mathbf{21}}\end{pmatrix}\end{aligned} \tag{10}$$

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 basis, 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:

$$\sigma_t = \left[\frac{\sum_{i=1}^{n} (\log(VA_{i,t}) - u_t)^2}{N} \right]^{\frac{1}{2}} \tag{11}$$

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 multi-sectoral 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[3].

As a first approximation to the differences in the evolution of income in the EU countries, Table 1 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[4].

(Table 1 about here)

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

[4] 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.

	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, 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 have a share above the sample average in this relevant group of sectors.

Regarding the role in the VA 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 1 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

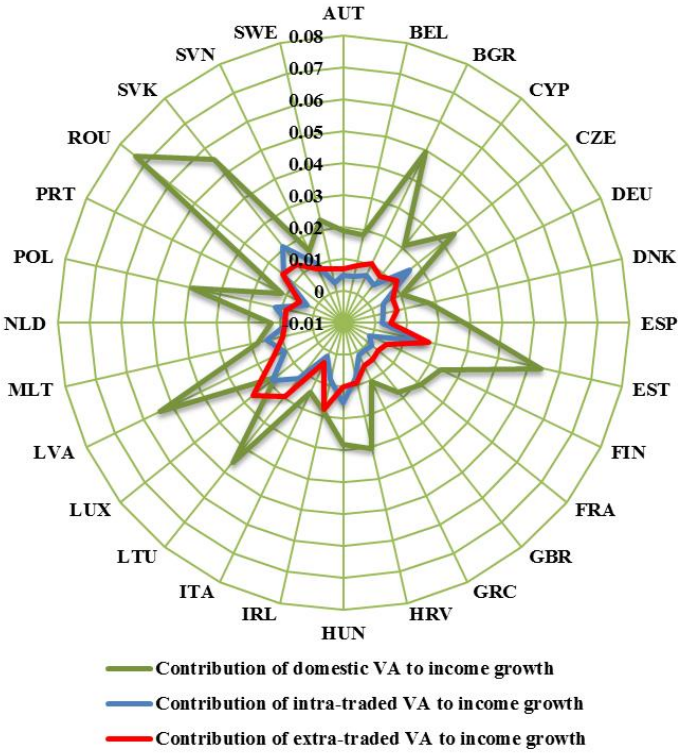
on basic and intermediate goods to fulfill domestic demands as well as supplying western economies and, increasingly, extra-EU markets.

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 1 we present the contributions of the three categories of VA to overall income growth for the 28 European countries included in the WIOD database.

(Figure 1 about here)

Figure 1. Contributions of domestic demand, intra-EU trade, and extra-EU trade to average income growth, by country, 2000-2014

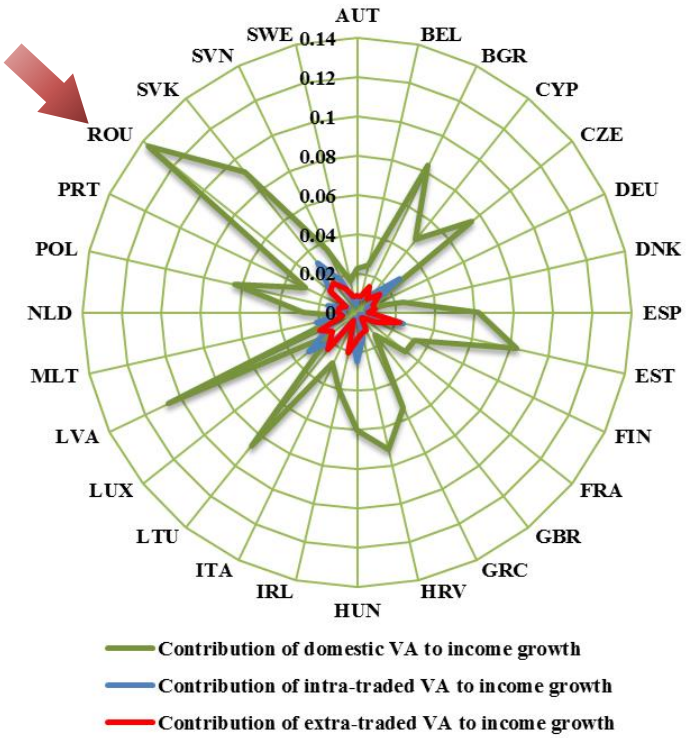


Source: Own elaboration

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 1, 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 2 and 3 show the contribution of the same variables, now in two different sub-periods, 2000-2008 and 2008-2014.

Figure 2. Contributions of domestic demand, intra-EU trade, and extra-EU trade to average income growth by country, 2000-2008

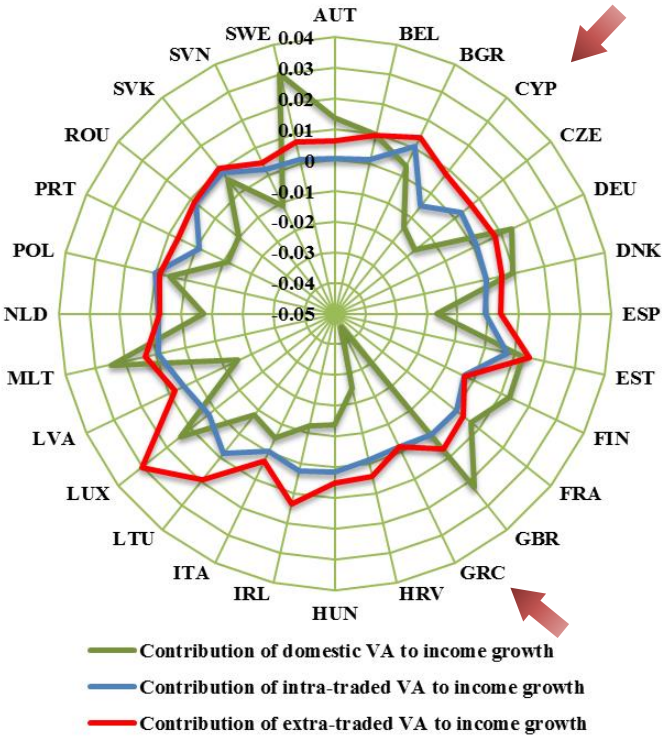


Source: Own elaboration

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 76.15%. 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 3 about here)

Figure 3. Contributions of domestic demand, intra-EU trade, and extra-EU trade to average income growth, by country, 2008-2014



Source: Own elaboration

As can be seen in Figure 3, 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 2008 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.

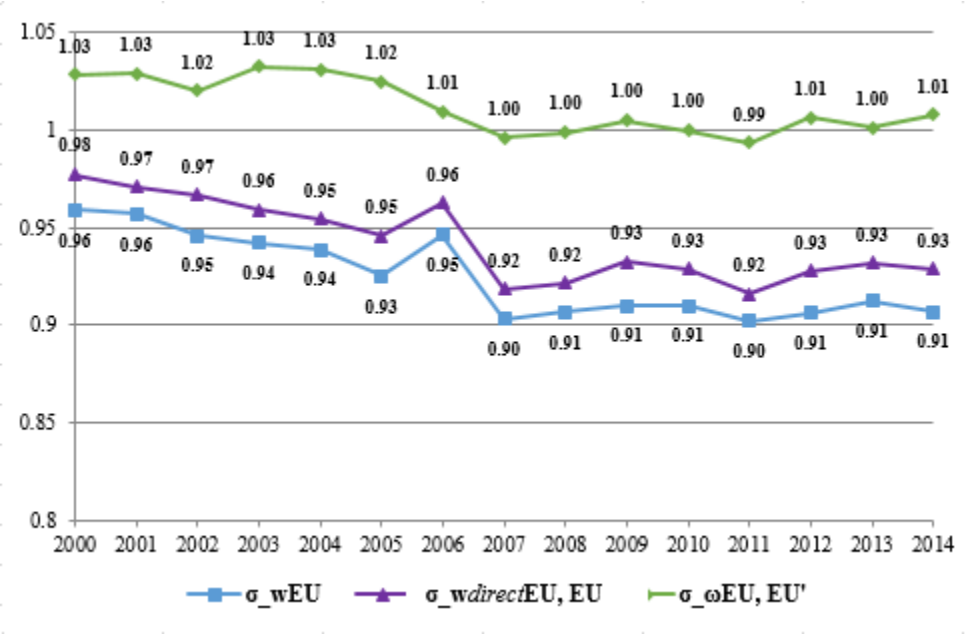
This first analysis offers a scenario of several behaviours in Europe regarding recent economic growth and leading factors and evidence that there may have been a real structural rupture around the beginning of the crisis, in 2008, which will be tested later. The following questions are, in consequence, whether these differential behaviours 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 4 shows the evolution of *sigma* over the period 2000-2014, calculated as described in (10), 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 $\mathbf{w}^{\mathbf{EU}}$). 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 $\mathbf{w}^{direct\mathbf{EU,EU}} = \mathbf{\Omega}^{\mathbf{EU,EU}}\mathbf{i}$). 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 ($\boldsymbol{\omega}^{\mathbf{EU,EU'}} = \mathbf{i}'\mathbf{\Omega}^{\mathbf{EU,EU}}$). 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 4. *Sigma* convergence in income (total direct VA, total intra-EU direct VA, and total embodied VA), 2000-2014



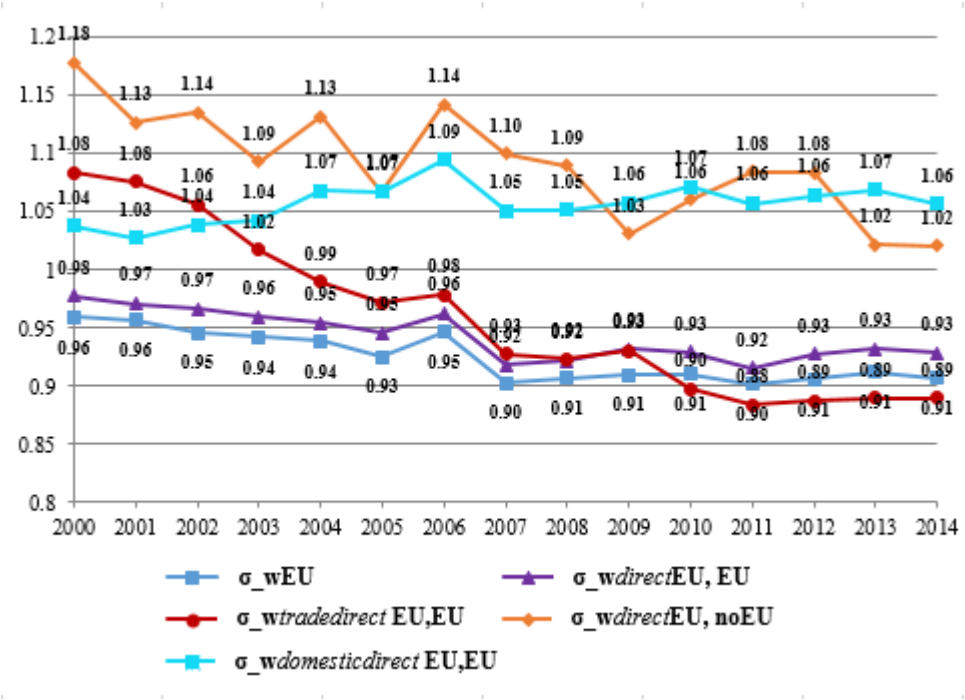
Source: Own elaboration

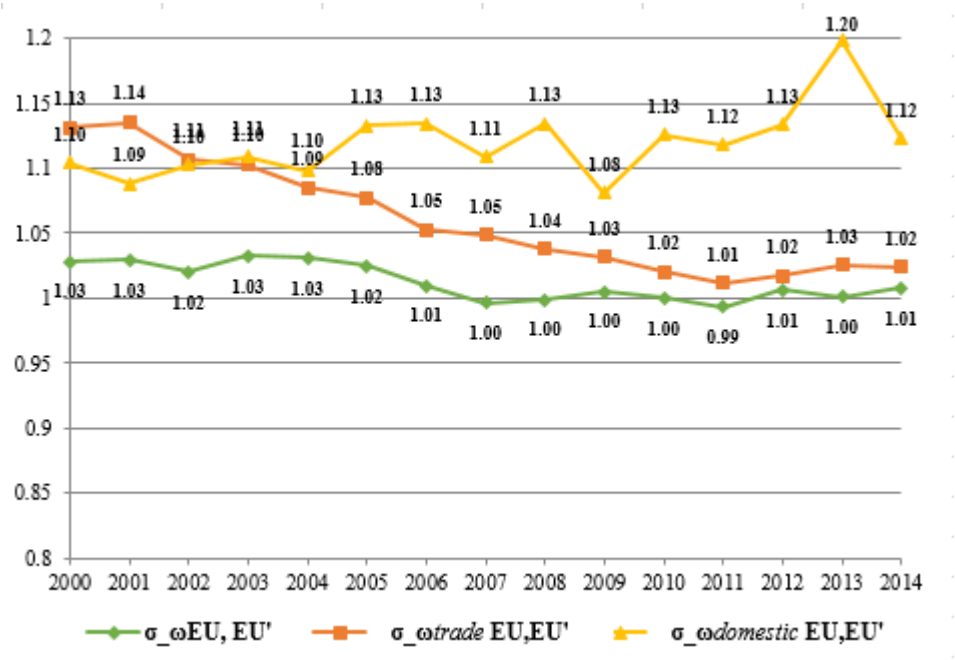
Figure 4 shows in the blue line the *sigma* convergence calculated as a measure of dispersion in the value-added generated by each country ("$\mathbf{w}^{EU}$ = total direct VA"). It also shows the evolution of *sigma* calculated over the total income generated in the European Union and embodied in the 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 $\sigma_{\_wEU}$ reflects the convergence or reduction in production disparities across countries, the decline in $\sigma_{\_\omega EU,EU}$ 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 $\mathbf{w}^{EU}$ = total direct VA, and $\boldsymbol{\omega}^{EU,EU'}$ = total embodied VA. The three σ from Figure 4 and the four new σ are shown in Figure 5. The equations (6), (8) and (9) show the significance of these components.

Figure 5. *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 = $\mathbf{w}^{direct\mathbf{EU,EU}}$ 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 5 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-multisectorial nature of our data, in what follows we perform a decomposition analysis of the standard deviation $\boldsymbol{\sigma}_{\_wEU}$ previously obtained. With this study, we want to verify which part of the total variation of convergence or divergence $\boldsymbol{\sigma}_{\_wEU}$ 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:

$$\boldsymbol{\sigma}_{\_wEU}^{\,2} = \sigma_{INTER}^{\,2} + \sigma_{INTRA}^{\,2}$$

The above formulation can be expressed as:

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

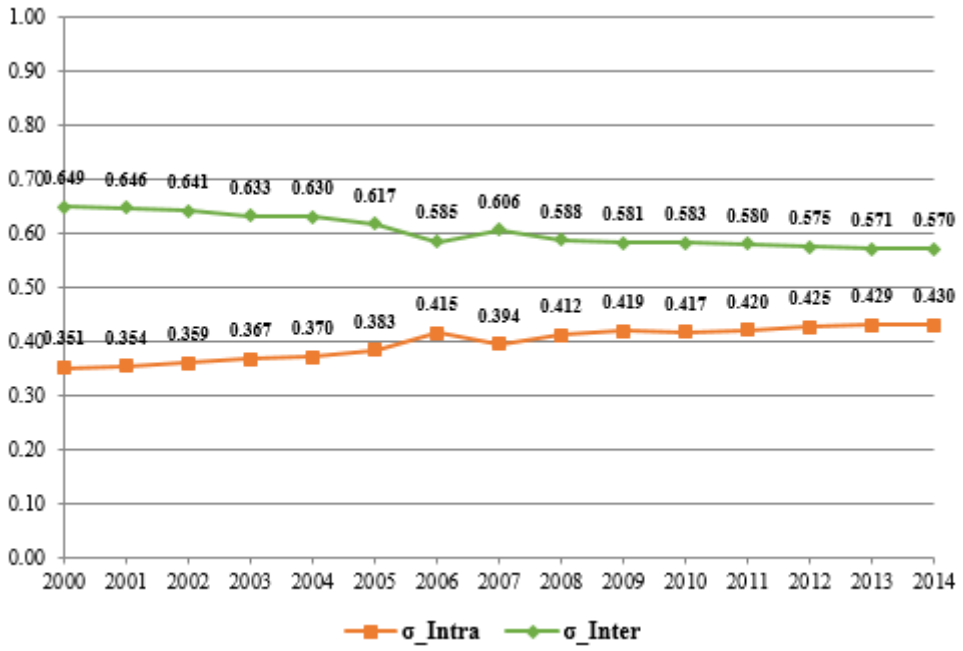
where $\overline{\mu}_{\bullet\bullet}$ is the total average and $\overline{\mu}_{\bullet j}$ is the average of each European country.

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



Source: Own elaboration

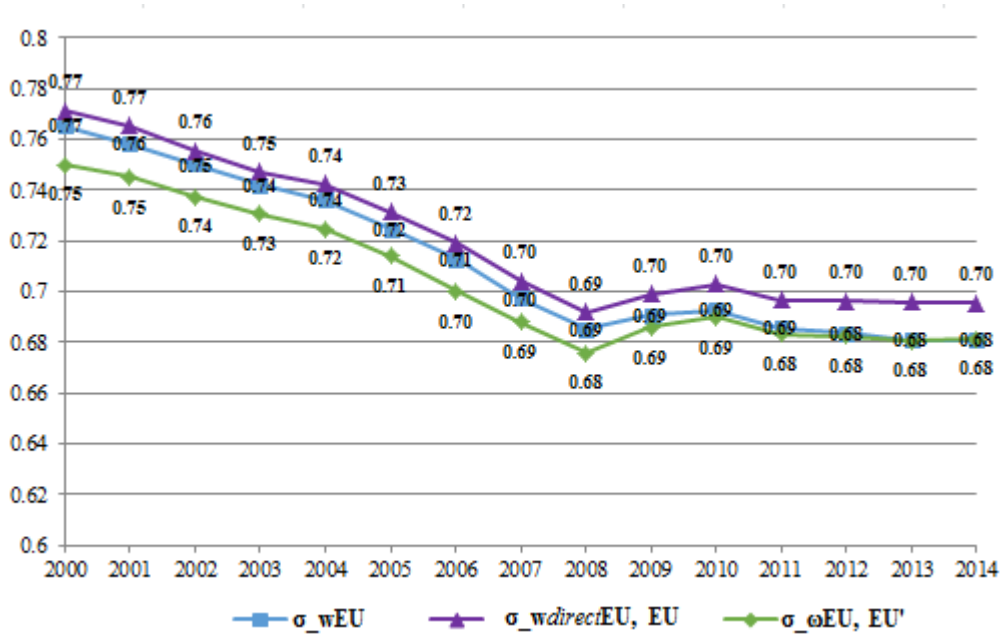
3.2. Country-convergence

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 2.

Figure 7. *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 7 confirm the general results obtained at the disaggregated level (see Figure 4). 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 2 the values of the coefficients of the regression equations.

Table 2. Results of regression equations

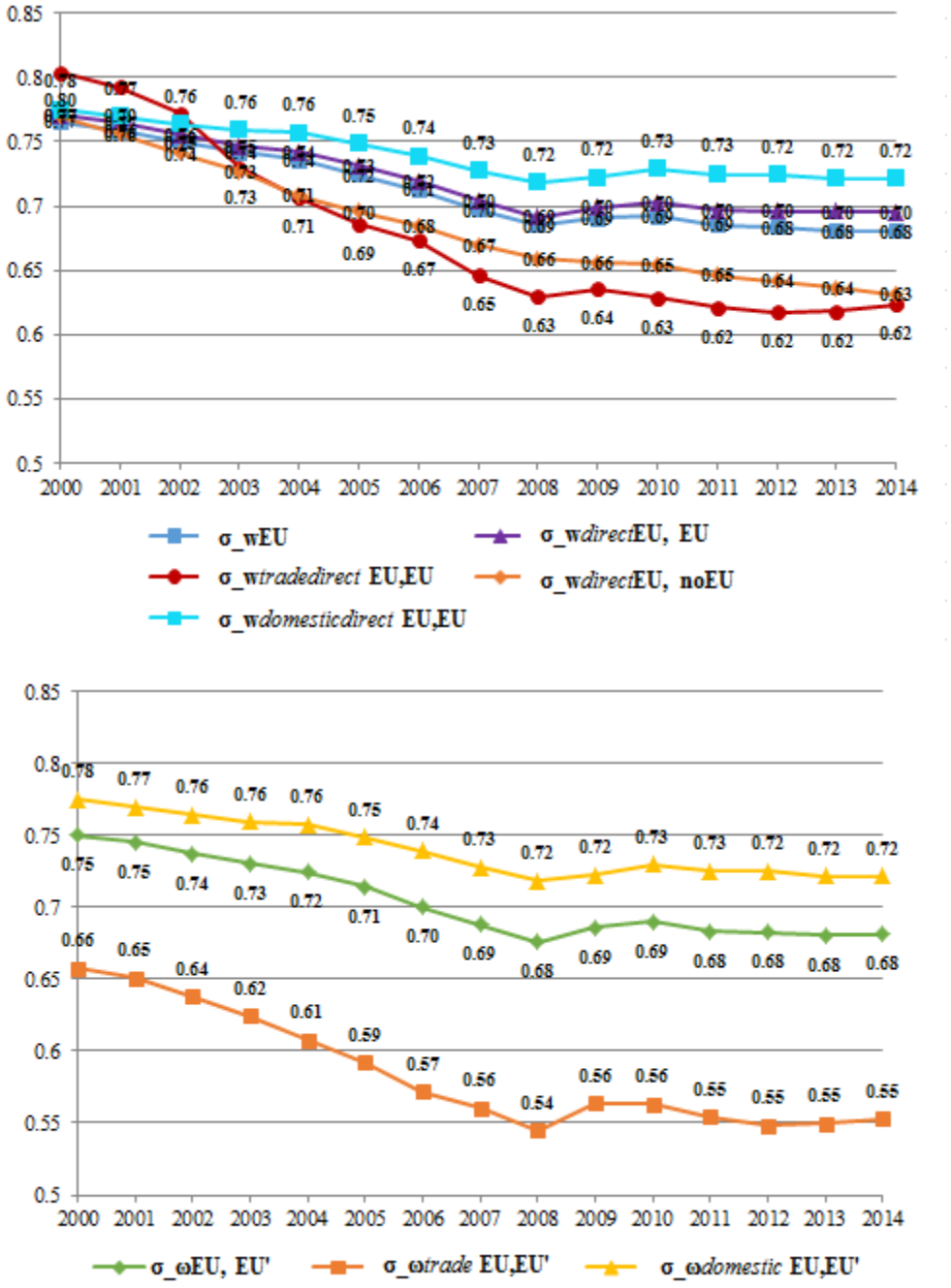
	$\sigma_{\_wEU}$	$\sigma_{\_wdirect\,EU,EU}$	$\sigma_{\_\omega EU,EU}$
	2000-2014		
α	0.7649	0.7681	0.7479
β	-0.006	-0.0059	-0.0054
p-value	3.61e-08 ***	5.86e-07 ***	1.15e-06 ***
	2000-2008		
α	0.7798	0.7854	0.7650
β	-0.0099	-0.0098	-0.0093
p-value	3.51e-07 ***	3.81e-07 ***	9.02e-07 ***
	2009-2014		
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 values of the constant and the values 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 7) 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 8 about here)

Figure 8. *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 5), Figure 8 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 5; there the domestic components did not converge due mainly to increasing differences between domestic sectoral structures, which are not captured in Figure 8 because we are only focusing on the countries, not on sectors.

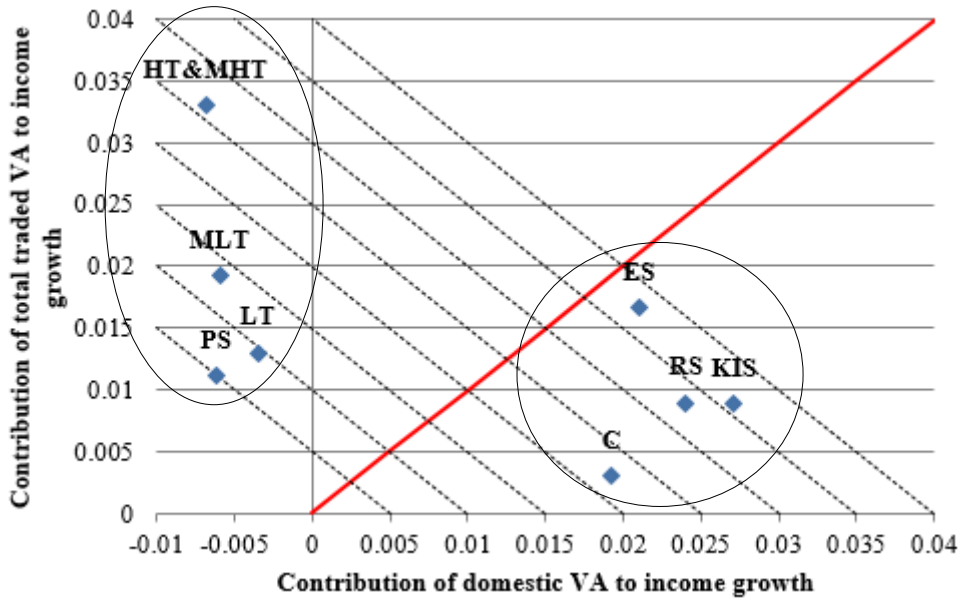
3.3. Convergence by industry-blocks

Our final analysis refers to the convergence in the generation of income by sector in the EU. According to the results obtained in Table 1, 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 9 shows the sectoral contribution by domestic demand and trade (intra-EU and extra-EU trade) to income growth in Europe.

Figure 9. Average contributions of domestic demand and trade to income growth in Europe, by sectoral blocks, 2000-2014

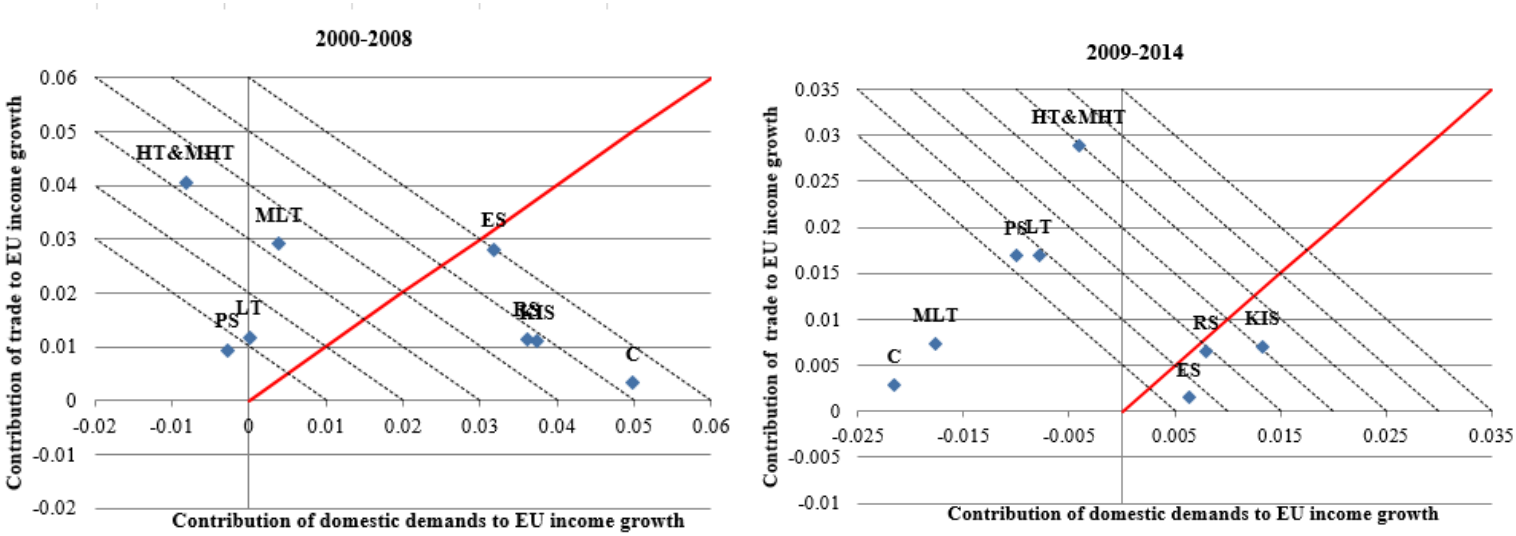


Source: Own elaboration. PS: Primary sector; ES: Energy sector; HT&MHT: High and medium-high technology industry, MLT: Medium-low technology industry, LT: Low technology industry, C: Construction, KIS: Knowledge intensive services, RS: Rest of services

In Figure 9, 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 1, which highlighted the dynamism of manufacturing in Eastern European countries (see Table 1) 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 10. Contributions of domestic demand and trade to income growth in Europe, by sectoral blocks and sub-periods



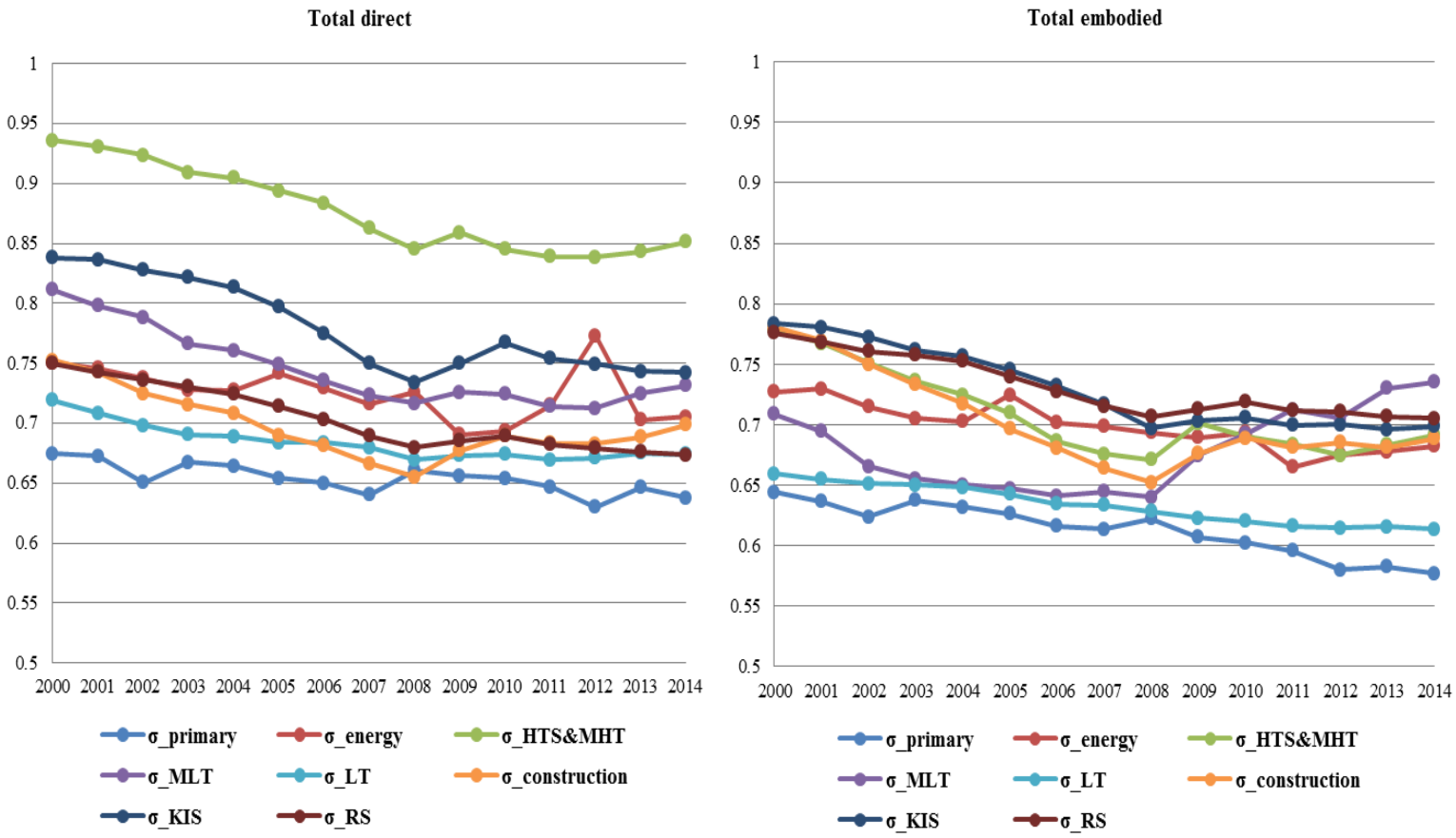
Source: Own elaboration. PS: Primary sector; ES: Energy sector; HT&MHT: High and medium-high technology industry, MLT: Medium-low technology industry, LT: Low technology industry, C: Construction, KIS: Knowledge intensive services, RS: Rest of services

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 11.

Figure 11. *Sigma* convergence in total direct and embodied VA, by block sector, 2000-2014



Source: Own elaboration

Figure 11 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. Final comments

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 paper 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.

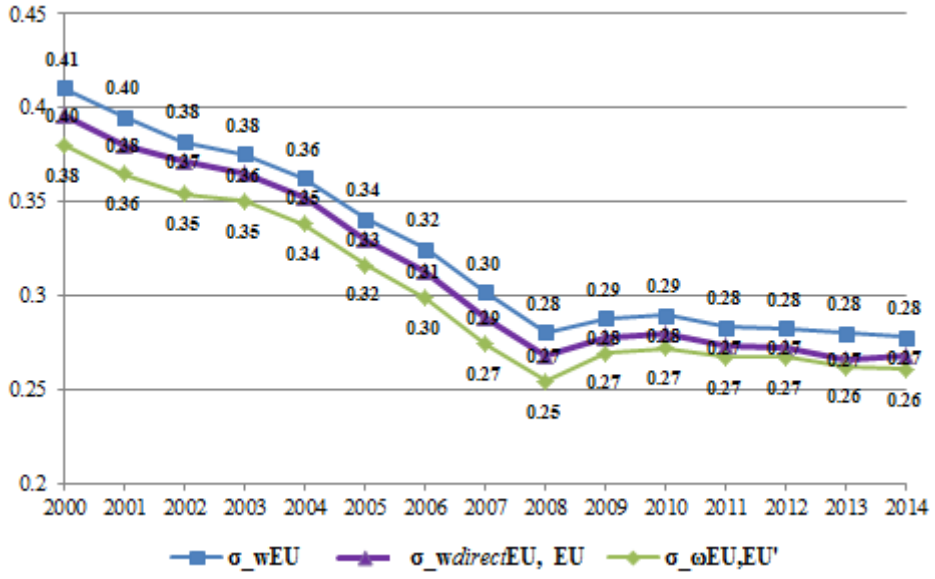
Our results point out the need of including the productive structure and structural change in the analysis of global processes such as convergence. Income generation in countries cannot be understood without acknowledging the complex interaction of sectors, countries and institutions worldwide. In this 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.

ANNEX I. 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 (the structural change demonstrated by the Chow's contrast), 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: $\sigma_{\_wEU}$), and also show a similar composition of their final products in net terms, i.e. convergence in technologically-integrated productivity (measured by convergence embodied: $\sigma_{\_\omega EU,EU'}$).

ANNEX II. Correspondence among WIOD sectors and blocks of sectors

Table II.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	
Fishing and aquaculture	
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	
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	
Manufacture of paper and paper products	
Printing and reproduction of recorded media	
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	
Manufacture of rubber and plastic products	Block 4: MTS
Manufacture of other non-metallic mineral products	
Manufacture of basic metals	
Manufacture of fabricated metal products, except machinery and equipment	
Manufacture of computer, electronic and optical products	Block 3: HT&MTS
Manufacture of electrical equipment	
Manufacture of machinery and equipment n.e.c.	
Manufacture of motor vehicles, trailers and semi-trailers	
Manufacture of other transport equipment	
Manufacture of furniture; other manufacturing	Block 5: LTS
Repair and installation of machinery and equipment	
Electricity, gas, steam and air conditioning supply	Block 2: ES
Water collection, treatment and supply	
Sewerage; waste collection, treatment and disposal activities; materials recovery; remediation activities and other waste management services	
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	
Retail trade, except of motor vehicles and motorcycles	
Land transport and transport via pipelines	
Water transport	Block 8: Rest of services
Air transport	

Warehousing and support activities for transportation	**Block 7: KIS**
Postal and courier activities	
Accommodation and food service activities	
Publishing activities	**Block 8: Rest of services**
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	
Real estate activities	**Block 7: KIS**
Legal and accounting activities; activities of head offices; management consultancy activities	**Block 8: Rest of services**
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	
Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	**Block 7: KIS**
Activities of extraterritorial organizations and bodies	

Source: Own elaboration

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