Doctorado en Economía Internacional y Turismo

Global value chains and international relocation of production

TESIS DOCTORAL

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Chapter 1:

INTRODUCTION

INTRODUCTION

The last decades have seen significant changes in the organization of production and international trade. On the one hand, emerging countries have increased their participation in world income and trade, while the share of developed countries in global production and trade has decreased. At the beginning of the nineties, high-income countries, that represented just 16% of global population, accounted for around 60% of world production and 80% of total trade. The group of low- and lower-middle income countries represented around 20% of world GDP and 10% of world exports at that time, and in 2015, their weight in GDP and exports increased up to 41% and 25%, respectively. These figures reveal the scope of the international relocation of production that is taking place: many goods and services that were produced and exported by advanced countries are now being exported by lower-income countries.

On the other hand, the reduction in transport costs and the ICT revolution, together with trade policy reforms leading to greater trade liberalization, have led to an acceleration of the globalization of production processes. The most striking manifestation of these changes is the fragmentation of production across borders, which is reflected in the rising share of trade in intermediate goods as a result of the internationalisation of supply chains. Some authors estimate that intermediate inputs already account for two thirds of international trade (Johnson and Noguera, 2012a). Hence, goods and services are no longer produced in a single country. As firms spread their production world-wide and countries specialize according to their comparative advantage, production processes become increasingly interconnected around the so-called *global value chains* (GVCs). GVCs are described as full range of activities that are part of the production process of a good or service, where the different stages are located across different countries.

In this context, this thesis focuses on the analysis of different aspects of the above mentioned phenomena: the process of international production relocation across country income groups, as well as the fragmentation of production processes and the subsequent emergence of global value chains. The main objective of this thesis is to analyse how these transformations in the nature of production and trade have changed the way in which countries participate in international trade, as well as the implications of these changes on countries' economic performance. The study of these issues raises several questions: how international relocation and the emergence of GVCs affect the way in which countries participate in international trade? What are the implications of these changes for countries' specialization trade patterns and their economic performance? What are the trends regarding countries' participation in GVCs and the dynamics of international relocation of production? What is the impact of international relocation on cross-country growth?

These are the questions that are addressed in the different chapters of this thesis, although they are approached using two different methodologies and datasets because the statistics available to tackle these issues and the techniques needed are different. The analyses of these questions have required the use of big databases and the application of a wide array of complex techniques. The methodology used to address the analysis conducted in each chapter is briefly described in the **second chapter**.

After this chapter, the **third chapter** analyses the participation of countries in global value chains, with a focus on the Spanish economy, from the trade in value-added perspective. This statistical approach is used to trace the value that is added in the production of goods and services and allocates it to the industries and countries of origin. Second, the **fourth chapter** focuses on the production relocation processes across country income groups at the product and sector level and discusses the trends in international relocation of production over the last decades, using highly disaggregated trade data. Then, the **fifth chapter** examines the impact of production relocation on countries' economic growth. The analysis in the third chapter relies on the statistical approach of trade in value-added, while the fourth and fifth chapter are based on standard international trade data.

The three chapters that represent the core of the thesis focus around the changes in production and international trade that took place in the last decades, which have witnessed significant advances in globalization. Until the outburst of the global crisis in 2009, the world economy enjoyed a period of extraordinary economic growth, with great advances in trade integration. In parallel with these events, the employment and the share of the manufacturing sector in advanced economies significantly decreased. This has led to the impression that globalization and international trade are the cause of manufacturing's decline in these economies, and thus, the source of rising wage inequality and job losses in advanced countries. Many people feel that they are being left behind by globalization. Some workers, particularly the less skilled ones, are probably among the hardest hit by globalization. Hence, advances in international integration came along with the revival of nationalisms and the rise of advocates of protectionist trade policies. The consequences of the Great Recession have exacerbated these positions. The most relevant manifestations of this tendency are the rise of populism and extremist parties in Europe, and more recently, the Brexit[1] and the election of Donald Trump as president of the US.

Almost to everyone's surprise, Donald Trump became president of the US on 8 November, 2016. During his campaign, and as president-elect, he has repeatedly threatened to impose high tariffs on imported products (35% on some Mexican imports and 45% on products from China) and to renegotiate –or terminate- trade agreements (i.e., the NAFTA), as he considers that free trade is the cause of US manufacturing decline and thus, a source of job destruction. He has had tough words for companies that produce their products abroad (i.e., carmaker companies like General Motors and Ford, or the tech company Apple) and pushed them about "bringing jobs back" with the threat of making these companies pay a higher border tax.[2] He argues that his protectionist trade policies "will keep jobs and wealth inside the United States".

In a world with increasing integration in production, investment and trade flows, and with those organized in GVCs, protectionist trade policies make no sense. As it is shown in the **third chapter** of this thesis, there is a growing fragmentation of production across borders and countries increasingly rely on imports to produce their exports. Imposing higher tariffs on imports would only make exporters and consumers worse-off. As prices of imported inputs rise up, consumers will end up paying higher prices and exporters will become less competitive. Besides, in GVCs, taxing imports has a higher cumulative effect, since goods cross borders multiple times for further processing. Thus, this kind of measures, instead of helping the country, is more likely to be harmful, not only for foreign suppliers, but also for domestic firms and households.

[1] The referendum to decide whether the UK should leave or remain in the European Union was held on 23 June, 2016. The "leave" option won with 52% of the vote. On March 29, 2017, the United Kingdom has officially notified to the European Union (EU) its decision to leave the EU.

[2] In his official twitter account, Donald Trump has published some comments that reflect his position towards companies that produce overseas: (@realDonaldTrump). "General Motors is sending Mexican made model of Chevy Cruze to U.S. car dealers-tax free across border. Make in U.S.A.or pay big border tax!". 3 January 2017, 1:30 pm. Also see: (@realDonaldTrump). "Toyota Motor said will build a new plant in Baja, Mexico, to build Corolla cars for U.S. NO WAY! Build plant in U.S. or pay big border tax." 5 January 2017, 7:14 pm.

Protectionist positions arise as a reaction to globalization and competition from low-wage countries. As it is documented in the **fourth chapter,** there have been important relocation processes across countries with different income levels in the last decades, and actually the **fifth chapter** estimates that international production relocation has had, on aggregate, a negative influence on countries' economic growth. However, adopting protectionist trade policies is not the solution to countries' competitiveness problems. As it is suggested in the fifth chapter, countries should adapt to the loss of some industries by specializing in activities more in line with the country's comparative advantage, not by protecting industries in which the country is not competitive.

The three dissertation chapters of this doctoral thesis are grouped around the two issues that have been outlined in this introduction: the fragmentation of production across borders and the emergence of global value chains, as well as the international relocation of production across country income groups. The first issue is addressed in the third chapter with the statistical approach of trade in value added, while the analysis in the other two chapters relies on standard trade statistics. The rest of this introductory chapter briefly explains the content of each chapter and their approaches.

International fragmentation of production and GVCs

As mentioned before, the fall in transport and coordination costs, as well as advances in trade liberalization, have transformed the structure of production and trade, leading to the international fragmentation of production and the globalization of supply chains. Goods are no longer produced in a single country and cross borders several times at different stages of production for further processing. Measuring trade flows in the context of international fragmentation and GVCs represents a challenge to standard trade statistics. The key problem with conventional trade statistics is that they record the value of goods at each border crossing and the value of products that cross borders several times as intermediate inputs to be embodied in final goods are counted multiple times. The value of the same labour, capital or intermediate input is implicitly counted as many times as it crosses a border, potentially overstating the importance of trade.

With production and trade increasingly organized within GVCs, a certain amount of exports does not generate an equivalent amount of benefits to the producing economy, since exports may contain a significant share of imported intermediate inputs. This implies that part of the export revenues may accrue abroad as payments for those imported goods. Another shortcoming of conventional trade statistics is that they are not necessarily able to reveal those sectors of the economy where value-added originates. This is especially the case for services: services are essential in GVCs (business services, transport and communications, finance), but they represent a small share of total exports in gross terms. However, since they are used as inputs in the production and exports of manufactured goods, they account for a large share of the total value added generated.

Hence, to trace a country's participation in global supply chains and allocate the value-added embodied in final goods back to its source (i.e., the country and industry of origin), new statistics that complement traditional trade data (i.e. gross trade flows) are needed. The direct measurement of value-added is extremely difficult; we would need detailed surveys at the firm-level about the origin of every intermediate input. Some case studies have addressed this question (see for instance the iPod in Dedrick et al. (2010) or the Barbie doll (Tempest, 1996)). However, it would be impossible to have this level of detail for every traded product. So, a pragmatic approach to measure the value-added content of trade is by exploiting International Input-Output tables (IIOTs). IIOTs are based on national supply and use tables or input-output tables, which are developed by countries' National Statistical Offices (NSO). These tables represent the interdependencies between sectors within an economy. To construct an IIOT and study the interdependencies between country-sectors in international production networks, national IO tables are linked with each other using international trade data.

One of the first examples of IIOTs was the one elaborated by the Institute of Developing Economies - Japan External Trade Organization (IDE-JETRO), with a focus on Asia-Pacific region. Other examples of academic initiatives in this field are the Global Trade Analysis Project (GTAP), coordinated by Purdue University, or the EORA multi-region Input-Output tables (MRIO) produced by the University of Sydney. In the last years, there have been two remarkable, large-scale initiatives: the World Input-Output Database (WIOD), funded by the European Commission and developed by a consortium of 11 institutions, and the Trade in Value Added Database (TiVA database), which is the result of the joint effort by the OECD and the WTO. Both databases are based on official sources, i.e., the supply and use tables and national input-output tables published by the National Statistics Offices.

In a context of international production fragmentation, IIOTs enable us to follow goods through the supply chain from input producers to final consumers, and reallocate them to their original producing sector. This statistical approach allows us to measure the value-added content of trade and identify the countries (and industries) where the value is added. However, a shortcoming of these indicators is their level of aggregation. Data in global input-output tables are available at the industry-level, which provides a low level of product disaggregation.[3] On the contrary, standard trade statistics are available at a high level of product disaggregation.

Trade in value added data should not be seen as an alternative to gross trade data; neither are they meant to replace standard trade flows. They should be seen as complementary statistics that are useful to study different phenomena. While trade in value added statistics are better suited to the analysis of the complex interactions among countries around global production networks, their current level of aggregation is very low compared to international trade statistics. Hence, in the third chapter, whose aim is to analyse Spain's involvement in these global supply chains and derive measures of the value added content of trade and vertical specialization, the statistical approach of trade in value added is followed. The fourth and fifth chapter, which focus on the dynamics of international production relocation across country income groups and its impact on countries' economic growth, rely on standard trade statistics, since the country coverage and the level of data disaggregation in these statistics are more appropriate to study this phenomenon. Besides, in the fourth chapter it is shown that the level of data disaggregation is very relevant when it comes to measure production relocation. Thus, standard trade flows, with the high level of product disaggregation available, are more appropriate since they capture a larger share of this phenomenon.

The **third chapter** of this thesis addresses the evolution of Spain's integration in GVCs at an aggregate level and by sectors. Its main features are compared with other major players in international trade. The analysis of the production and trade specialization patterns of the Spanish economy from the perspective of trade in value added and vertical specialization allows us to answer to several questions: what's the degree of integration of the Spanish economy and its different sectors in GVCs? What's the value added content of Spanish exports? Does its specialization foster the generation of value

[3] For instance, the IIOT in the WIOD Release of 2013 are available at a disaggregation level of 35 sectors. The release of 2016 includes 56 sectors.

added? To answer to these questions, the analysis in this chapter relies on the World Input-Output database (WIOD). The WIOD provides a set of world input-output tables for the period 1995-2011. The information is available for 41 countries and a level of disaggregation of 35 industries. Working with the years that followed the collapse of global trade that took place in 2009 allows us to assess how vertical integration and participation in GVCs have recovered after the sharp and abrupt fall in world trade. The analysis ends in 2011 because at the time of writing the chapter, the reference database (WIOD) was only available up to that year.

The analysis conducted in this chapter is based on the methodology proposed by Koopman, Wang and Wei (2014), henceforth (KKW). KKW (2014) decompose gross exports into several components that can be broadly grouped into "domestic" and "foreign" content. Measures of the value-added content of trade, as well as indicators of vertical specialization that capture a country's participation in GVCs are derived from this framework. Vertical specialization measures reflect how countries are interconnected through trade in intermediate inputs. There are two ways in which a country can participate in a vertical chain: by importing inputs to produce its exports (*backward participation*) or by producing inputs that will be used by other countries to produce their exports (*forward participation*).

The results obtained in this chapter reveal that the Spanish economy is integrated in GVCs and actively participates in vertical trade. The value-added content of Spanish gross exports has declined over the sample period from 79% in 1995 to 70% in 2011. These shares are similar to those of its main European partners. The decrease in the value-added content of trade is symptomatic of a higher participation in GVCs, as the gap between value added and gross exports increases with the import content of exports. Regarding the country's participation in GVCs, the analysis shows that Spain's *backward participation* is more relevant than its *forward participation*: it participates in vertical supply chains mainly as an importer of intermediate inputs that are then used in the production of exports, rather than as an exporter of intermediate goods that will be used by third countries in the production of their exports.

The analysis by sectors shows significant differences between manufacturing and services. One of the most striking features that arises when trade flows are examined in value added terms is that gross trade statistics understate the importance of the services sector. Services are essential for a well-functioning of GVCs and they are used as inputs in the production and exports of the manufacturing sector. Thus, their share in value added exports is higher than in gross exports: they account for 50% of total exports when measured in value-added terms versus 20% in gross terms.

Regarding sectors' participation in GVCs, manufacturing is more intensive in the use of imported inputs to produce their exported goods, whereas services exhibit a greater forward participation. As a result, these sectors have a different capacity to contribute to value added, which is higher in the services sector. This analysis contributes to shed light into the debate about the convenience of increasing the share of the manufacturing industry in advanced countries, since from a trade in value added perspective, it is clear that a significant share of value-added has its origin in the services sector.

International relocation of production

In turn, the **fourth and fifth chapters** of the thesis focus on the study of international production relocation. This process, which has intensified in the past years with production fragmentation across borders and the emergence of GVCs, has been a key feature of the increase in economic globalization in the last decades, with important implications for countries' economic performance. Some of the empirical studies on this subject are focused on the trends observed in specific industries, like the apparel, the automotive industry or the electronics (see for instance Gereffi (1999), Lall, Albaladejo and Zhang (2004), Sturgeon, Van Biesebroeck, Gereffi (2008), Timmer et al. (2015)). Another strand of the literature explores the impact of exposure to low-income countries' imports on the economic performance of developed countries, in terms of income and employment (Feenstra and Hanson (1996, 1999); Bernard, Jensen and Schott (2006); Autor, Dorn and Hanson (2013); Ebenstein et al. (2014); Acemoglu et al. (2016); Pierce and Schott (2016)). However, despite the large literature on this subject, the phenomenon of international relocation has not been analysed in a systematic way across sectors, neither there is a general assessment of its impact on countries' economic performance. The fourth and fifth chapters of this thesis contribute to fill this gap in two ways.

The **fourth chapter** analyses the dynamics of international relocation of production across country income groups from an aggregate perspective and at the product and sector level. The aim of this analysis is to assess the sign and intensity of production relocation over the past decades. The work in this chapter allows us to answer several questions: what have been the main trends in international relocation over the last decades? Has this phenomenon intensified in the last years? What kind of stochastic process follows production relocation? In which sectors has been relocation more widespread and intense? Is it possible to predict which industries will relocate in the future?

The analysis is conducted over two different time periods, 1962-2000 and 1995-2007. For the longer temporal span, the NBER-World Trade Flows database from Feenstra et al. (2005) is used. Trade data is available at a 4-digit level of disaggregation under the Standard International Trade Classification (SITC Rev. 2). For the more recent period (1995-2007), the analysis is based on trade data from BACI (CEPII), which provides data at a 6-digit level of disaggregation under the Harmonised System (HS1992). The dynamics of the relocation process over the two sample periods are compared to determine if relocation has intensified over the last decade.

The analysis in this chapter assumes that the dynamics of production relocation are driven by the interplay between innovation and standardization. This is at the basis of the product life-cycle theory described in Vernon (1966) and in models of technology diffusion (Krugman (1979), Dollar (1986), Jensen and Thursby (1986), Grossman and Helpman (1991a, b), Acemoglu, Gancia and Zilibotti (2012)). These product shocks, i.e. innovation and standardization, change countries' comparative advantage by affecting products' factor intensities. Since the production of different goods involves different degrees of sophistication or complexity, an increase in the sophistication of a product will relocate its production towards the countries with higher human capital or a previous specialization in that product (i.e., these countries will increase their revealed comparative advantage (*RCA*) in that product). On the contrary, standardization will lead to relocation towards countries with lower human capital and no previous specialization in the good. Thus, by affecting factor intensities, innovation and standardization change countries' *RCA*, thereby leading to product relocation.

To analyse the dynamics of production relocation at the product and sector level and answer to the questions raised in this chapter, product and sector specific relocation indices are defined. For each product, we calculate a weighted average of the GDP per capita of the product's exporting countries, where the weights are given by the revealed comparative advantage (*RCA*) of each country in that product. Then, the relocation indices are defined as the changes in the average income of the exporters of a product to measure the extent to which production has relocated across countries with different income levels. However, the change over time in this index has two potential components: the change in the exporting countries' *RCA* and the change in their per capita GDP. Since we are mainly interested in changes in *RCA*, a *pure* relocation index that isolates the effect of increases in GDP is also defined. This index holds constant the GDP per capita of the preceding period, so that changes in *RCA* are the only possible source of changes in this index. It can be interpreted as the *pure relocation* effect because it only depends on the shift of production across countries with different income levels.

Thus, the evolution of these indices is analysed to determine, first, the direction of international production relocation across countries at different stages of development. An increase in the relocation index of a product indicates that higher income countries have increased their *RCA* in that good, that is, the product has experienced an *upward* relocation. On the contrary, a decrease in the relocation index implies that the product has undergone a *downward* relocation (its production has moved towards lower-income countries). Then, the intensity of production relocation is analysed by measuring the dispersion in the relocation indices. A higher dispersion implies greater production relocation, which is the result of products undergoing *upward* and *downward* relocations.

The analysis is also conducted using a model of distribution dynamics, a technique that is typically used in the growth and income convergence literature (Quah (1993, 1996); Jones (1997), among others). It allows us to assess the evolution over time of the entire products' distribution (its shape and intra-distribution dynamics). The study of the intra-distribution dynamics is based on the estimation of transition matrices. These matrices reflect products' transitions across country income groups and thus, give insight into the relocation processes at the product-level. Then, the ergodic or long-run distribution of products by country income groups is obtained by extrapolating the trends observed under the periods analysed. The comparison of the initial and ergodic distributions over a sample period and across the two sample periods enables us to identify the type of stochastic process that drives production relocation. Then, after the overview of relocation aggregate trends, the analysis is performed at the sector level. Finally, the chapter tries to shed light into the potential drivers of this phenomenon to determine if subsequent production relocation can be predicted. If so, anticipating which industries are more likely to relocate in the following years could be very useful from the viewpoint of economic policy.

The results obtained in this chapter reveal that production has moved, on average, towards lower income countries during the periods analysed. Regarding the intensity of production relocation, it appears that it has been relatively constant, as shown by the evolution of the aggregate dispersion index and the stability in the shape of the distribution over the two sample periods. This stability, however, is compatible with considerable relocation processes at the product level: there is substantial mobility in the products' intra-distribution dynamics and a great heterogeneity in the relocation dynamics at the sector level. In relation to the potential drivers of relocation, the analysis reveals that relocation largely appears as an unpredictable phenomenon on the basis of the variables considered, with some exceptions, like R&D. Thus, there is little room for implementing industrial policies aimed at preventing the loss of some industries or to attract the production of new goods by implementing the right policies. Nonetheless, horizontal policies that promote investment in R&D can be helpful to prevent future relocations towards lower-income areas.

After the analysis of the relocation processes in the fourth chapter, the **fifth chapter** explores the impact that production relocation has had on countries economic growth. The analysis focuses on the period 1995-2007 using 6-digit trade data from BACI (CEPII). It ends in 2007 to avoid the impact of the Great Recession. The aim of this chapter is to assess how countries have been affected by international production relocation depending on their specialization at the beginning of the period. To do so, relocation impact indices for each country are defined based on the products' indices developed in the fourth chapter. The indicators at the country level are calculated as a weighted average of products' relocation indices, where the weights are given by the share of each product in a country's exports.

The country's relocation impact index measures the extent to which the country's export basket is made up of products whose production has moved, on average, towards relatively richer or poorer countries over the period analysed. As in chapter four, two relocation indices are defined: a *product-shocks impact index (PSI)*, whose changes may arise due to changes in countries' *RCA* but also as a result of changes in countries GDP per capita not related to relocation, and a *pure relocation impact index* (*PRI)* that exclusively captures the impact due to changes in countries' *RCA*. Besides, the analysis implements an instrumental variables strategy to control for the fact that, if a country is sufficiently large in the context of world trade, country-specific shocks changing this country's per capita GDP can significantly affect the index of the products it exports. This could affect the relocation indices, without products undergoing any relocation. To control for this possibility, country-specific relocation indices that exclude all the information relative to the country (i.e., its GDP and trade data) from the construction of the indices are calculated. These indices are used as instruments for the relocation indices in the two-stage least square regressions.

Both indices are regressed on countries' average GDP per capita growth during the period 1996-2006,[4] together with the standard covariates in growth regressions that include initial GDP per capita, human capital, capital intensity and measures of institutional quality. A measure of initial export sophistication is also included. The results obtained imply that countries that were specialized in 1996 in products that, on average, experienced a relocation process towards lower-income (higher-income) economies over the following years, exhibited lower (greater) growth over the 1996-2006 period. The impact is statistically significant, robust, and economically important: a difference of one standard deviation in the country's relocation impact index resulted in a difference of about 1 percentage point in the country's average annual growth.

[4] As in the fourth chapter, the indices are calculated using average trade data of three years. The value of the indices is attributed to the central year of each subperiod. Thus, although we refer to 1996-2006 as the period of analysis, it actually draws on data from 1995 to 2007.

Chapter 2:

METHODOLOGY

METHODOLOGY

This chapter briefly describes the methodology used to address the questions raised in each chapter to comply with the Universitat de València requirements in terms of the doctoral thesis structure. The specific methodology will be then explained in detail in each chapter.

As mentioned in the introduction, the **third chapter** of this thesis analyses the production and specialization trade patterns of the Spanish economy in a context of international fragmentation of production and global production sharing. The aim of this chapter is to assess the participation of Spain in global value chains (GVCs) from the trade in value-added perspective. This statistical approach allows us to estimate the value added content of Spanish exports and assess the degree of integration of the economy and its different sectors in GVCs. As explained in the introduction, the direct measurement of the value-added content of trade is extremely difficult. Thus, to answer the questions raised in this chapter, the analysis relies on a set of international input-output tables (IIOTs). IIOTs are constructed based on national supply and use tables or national input-output tables, which are linked together using bilateral international trade flows. In that way, the basic input-output framework for a single economy is expanded into an interregional input-output model that enables us to trace the interconnectedness across countries and sectors.

Several papers have tried to estimate the value-added content of trade using global input-output tables, such as the Global Trade Analysis Project (GTAP) (Trefler and Zhu (2010), Daudin, Rifflart and Schweisguth (2011), Johnson and Noguera (2012a), Koopman, Wang and Wei (2014)), or the World Input Output Database (WIOD) (Timmer et al. (2013), Baldwin and López-González (2014) and Johnson (2014)). The analysis in the third chapter draws on the WIOD, a time series of world input output tables. The measurement of the value-added content of trade is based on the analysis of sectoral interdependencies introduced by Leontief (1936). The fundamental equation of the input-output framework can be expressed as:

$$x = (I - A)^{-1} y, \qquad (1)$$

where $(I - A)^{-1}$ is the Leontief inverse matrix (Leontief, 1936). This matrix shows the total input requirements (both direct and indirect) needed to produce a unit of output.

Multiplying it by the final demand vector, the term $(I - A)^{-1}y$ reflects the output needed to satisfy a certain level of final demand.

With many countries and sectors, the equation in (1) can be expanded into an inter-regional input output model:

$$\begin{bmatrix} X_{11} & X_{12} & \dots & X_{1N} \\ X_{21} & X_{22} & \dots & X_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ X_{N1} & X_{N2} & \cdots & X_{NN} \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} & \dots & B_{1N} \\ B_{21} & B_{22} & \dots & B_{2N} \\ \dots & \dots & \ddots & \dots \\ B_{N1} & B_{N2} & \dots & B_{NN} \end{bmatrix} \begin{bmatrix} Y_{11} & Y_{12} & \dots & Y_{1N} \\ Y_{21} & Y_{22} & \dots & Y_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ Y_{N1} & Y_{N2} & \cdots & Y_{NN} \end{bmatrix} \quad (2)$$

Matrix **X** on the left-hand side of the equation is the gross output decomposition matrix, which gives the breakdown of gross output in each producing country by country of destination. Matrix **B** is the Leontief inverse or total requirement matrix, which gives the amount of gross output in producing country *i* needed to satisfy a one-unit increase in final demand in destination country *j*. The final demand matrix **Y** shows the final goods produced in *i* and consumed in *j*.

The domestic value added generated in a country's gross output can be obtained by pre-multiplying a matrix of value-added ratios to gross output (**V**) with the gross output decomposition matrix **X** equation in (2):

$$\begin{bmatrix} \hat{V}_1 & 0 & \dots & 0 \\ 0 & \hat{V}_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \hat{V}_N \end{bmatrix} \begin{bmatrix} X_{11} & X_{12} & \dots & X_{1N} \\ X_{21} & X_{22} & \dots & X_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ X_{N1} & X_{N2} & \cdots & X_{NN} \end{bmatrix}$$

$$= \begin{bmatrix} \hat{V}_1 \sum_j^N B_{1j} Y_{j1} & \hat{V}_1 \sum_j^N B_{1j} Y_{j2} & \dots & \hat{V}_1 \sum_j^N B_{1j} Y_{jN} \\ \hat{V}_2 \sum_j^N B_{2j} Y_{j1} & \hat{V}_2 \sum_j^N B_{2j} Y_{j2} & \dots & \hat{V}_2 \sum_j^N B_{2j} Y_{jN} \\ \dots & \dots & \ddots & \dots \\ \hat{V}_N \sum_j^N B_{Nj} Y_{j1} & \hat{V}_N \sum_j^N B_{Nj} Y_{j2} & \dots & \hat{V}_N \sum_j^N B_{Nj} Y_{jN} \end{bmatrix} \quad (3)$$

The result is the value-added production matrix $\mathbf{\hat{V}BY}$. The elements on the main diagonal represent the domestic value added absorbed at home; the elements outside the diagonal correspond to a country's production of value added that is absorbed abroad, i.e. value added exports.

Value-added exports are calculated following Johnson and Noguera (2012a):

$$VA\ Exports_i = \sum_{j \neq i}^{N} VX_{ij} = V_i \sum_{j \neq i}^{N} B_{ii}\, Y_{ij} + V_i \sum_{j \neq i}^{N} B_{ij}\, Y_{jj} + V_i \sum_{j \neq i}^{N} \sum_{t \neq i,j}^{N} B_{ij} Y_{jt} \qquad (4)$$

The first term represents the value added in exports of final goods; the second corresponds to the value added in exports of intermediate goods which will be used for the production of goods consumed in the importing country, and the third corresponds to exports of intermediate goods that are used in the importing country to produce final goods that will be exported. This last term reflects *indirect* value added exports.

With production and trade increasingly organized within GVCs, VA exports are only a share of gross exports. These are defined as:

$$E_{i^*} = \sum_{j \neq i}^{N} E_{ij} = \sum_{j \neq i}^{N} (A_{ij} X_j + Y_j). \qquad (5)$$

Gross exports can be split into several components following the work of KWW (2014):

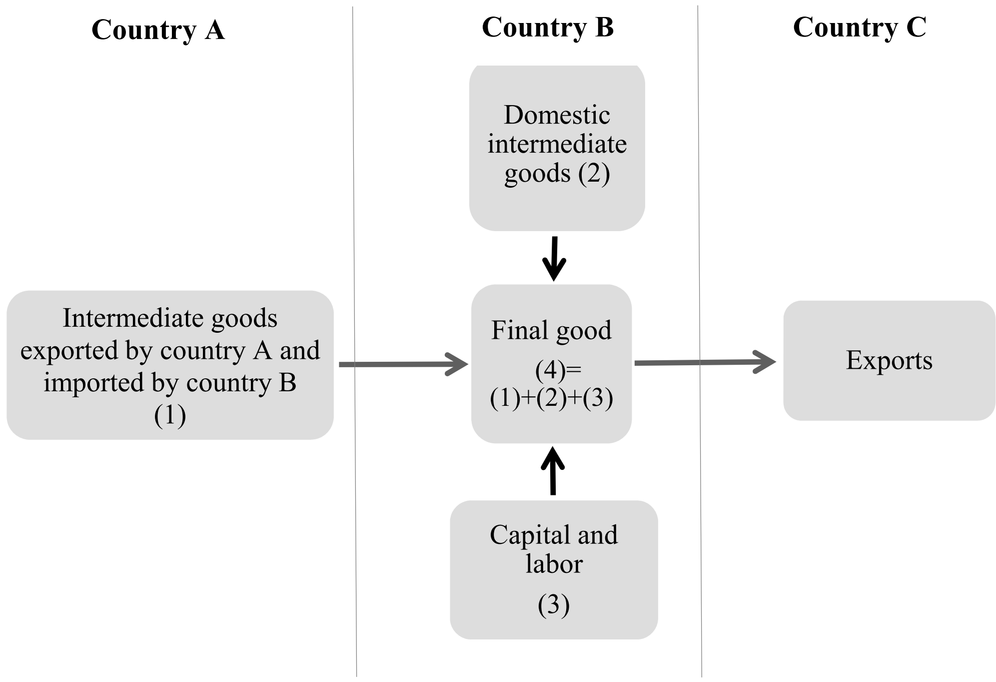
$$\begin{aligned} uE_{i^*} = {} & \{V_i \sum_{j \neq i}^{N} B_{ii}\, Y_{ij} + V_i \sum_{j \neq i}^{N} B_{ij}\, Y_{jj} + V_i \sum_{j \neq i}^{N} \sum_{t \neq i,j}^{N} B_{ij} Y_{jt}\} \\ & + \{V_i \sum_{j \neq i}^{N} B_{ij}\, Y_{ji} + V_i \sum_{j \neq i}^{N} B_{ij} A_{ji} (I - A_{ii})^{-1}\, Y_{ii}\} + V_i \sum_{j \neq i}^{N} B_{ij} A_{ji} (I - A_{ii})^{-1}\, E_{i^*} \\ & + \{\sum_{t \neq i}^{N} \sum_{j \neq i}^{N} V_t B_{ti} Y_{ij} + \sum_{t \neq i}^{N} \sum_{j \neq i}^{N} V_t B_{ti} A_{ij} \left(I - A_{jj}\right)^{-1} Y_{jj}\} + \sum_{j \neq i}^{N} V_t B_{ti} \left(I - A_{jj}\right)^{-1} E_{j^*} \end{aligned} \qquad (6)$$

The decomposition of gross exports presented in (6) constitutes a conceptual framework that integrates the literature on trade in value added and the literature of vertical specialization. Value added exports are the first three terms in (6). Vertical specialization measures can be derived as the sum of some components in the above equation.

The **third chapter** of this thesis also explores countries' vertical integration in global supply chains. This dimension is related to how countries are interconnected in GVCs through trade in intermediate inputs. There are several ways in which a country can participate in a vertical specialization chain. The first indicator of vertical specialization, denoted by *VS,* is a measure of the direct and indirect import content of exports. This index reflects a country's *backward participation* in GVCs; it captures the extent to which a country relies on imported inputs to produce its exports.

The *VS* index was first developed in the seminal work by Hummels, Ishii and Yi (henceforth HIY) (2001). It highlights how countries can participate in a vertical chain from the import side. Figure 1 provides a representation of a simplified vertical trade chain:

Figure 1. Schematic representation of a vertical specialization chain.



Source: Own elaboration based on HIY (2001).

Country A produces and exports an intermediate good to Country B. Country B combines the imported inputs from country A with capital and labour (thereby generating value added) and domestically produced intermediate inputs to produce a final good that is exported to Country C. Formally, vertical specialization occurs when a good is produced in two or more stages, two or more countries provide value-added, and at least one country uses imported inputs in the production of final goods that will be exported (HIY, 2001).

According to HIY, the *VS* index is equivalent to the foreign content of exports. However, the formulation of their index has a shortcoming: it does not account for the fact that imports may contain a share of domestic value added. Thus, HIY's measure can overestimate the foreign content of exports, since in a world with multiple back and forth linkages, imported intermediate goods can embed domestic content.

Hence, we follow KKW (2014) and derive a measure for the *VS* index that is equivalent to the foreign content of exports. The *VS* index is obtained as the sum of the last three elements in (6):

$$VS_i = \sum_{t\neq i}^{N}\sum_{j\neq i}^{N} V_t B_{ti} Y_{ij} + \sum_{t\neq i}^{N}\sum_{j\neq i}^{N} V_t B_{ti} A_{ij} \left(I - A_{jj}\right)^{-1} Y_{jj} + \sum_{i\neq j}^{N} V_t B_{ti} \left(I - A_{jj}\right)^{-1} E_{j^*}$$
$$= \sum_{i\neq j}^{N} V_j B_{ji} E_{i^*} \qquad (7)$$

A similar indicator of vertical specialization can be obtained from the viewpoint of the exporter country. This index, labeled as *VS1*, reflects a country's *forward participation*: it measures the share of a country's exports of intermediate goods that are used by other countries to produce their exports. That is, the domestic content of a country embodied in the exports of the rest of the world:

$$VS1_i = V_i \sum_{j\neq i}^{N} B_{ij} E_{j^*} = V_i \sum_{j\neq i}^{N}\sum_{t\neq i,j}^{N} B_{ij} Y_{jt} + V_i \sum_{j\neq i}^{N}\sum_{t\neq i,j}^{N} B_{ij} A_{jt} X_t + V_i \sum_{j\neq i}^{N} B_{ij} Y_{ji}$$
$$+ V_i \sum_{j\neq i}^{N} B_{ij} A_{ji} X_i \qquad (8)$$

Finally, a third concept of vertical specialization is provided by the index *VS1**, which reflects the share of the domestic content that returns home embedded in imports from the rest of the world. It represents the domestic content of imports. The index, originally defined in Daudin et al. (2011) and refined by KWW (2014) is a subset of *VS1*. It is calculated as follows:

$$VS1^*{}_i = \sum_{j\neq i}^{N} V_i B_{ij} E_{ji} = V_i \sum_{j\neq i}^{N} B_{ij} Y_{ji} + V_i \sum_{j\neq i}^{N} B_{ij} A_{ji} X_i \qquad (9)$$

Another indicator used in the literature on trade in value added is the *global value chain income* (*GVCI*) index, developed by Timmer et al. (2013). The *GVCI* index is equivalent to the value-added production matrix defined in equation (3). Expressed in compact notation, $GVCI = \hat{v}\,(I - A)^{-1}y$, this index represents the value added by all the country-sectors directly and indirectly involved in the production process of a final good. It is a broader concept than value-added exports, since it also accounts for the value added in the production of goods consumed domestically.

The scheme in Table 1 summarizes the indicators calculated in the **third chapter**.

Table 1. Vertical specialization and trade in value-added indicators

Authors	Index	Definition	Interpretation
Hummels, Ishii & Yi (HIY, 2001).	*VS*	$VS = uA^m(I - A^d)^{-1}$	Vertical specialization from the import side: import content of exports.
	VS1	Formulation not provided by these authors.	Vertical specialization from the export side: domestic content embodied in intermediate goods used in third countries' exports.
Daudin, Rifflart & Schweisguth (2011).	*VS1**	See equation (9)	Subset of *VS1*: domestic content that returns embedded in imports.
Johnson & Noguera (2012a).	*VAX* ratio	$VAX\ ratio = \frac{VAX}{X}$	Value added content of gross exports.
Koopman, Wang & Wei (KWW, 2014).		See equation (6) for the complete decomposition of gross exports and (7) to (9) for the *VS, VS1* and $VS1^*$ indices, respectively.	Conceptual framework that provides a full decomposition of gross exports. It integrates the different measures of vertical specialization and value added proposed by the literature.
Timmer et al. (2013)	*GVCI*	$GVCI = \hat{v}(I - A)^{-1}y$	Value added in the production of final manufacturing goods. It considers both goods to be consumed abroad (value-added exports) or at home.

The **fourth chapter** of this thesis analyses the dynamics of the relocation processes across country income groups from an aggregate perspective and at the product and sector level. This analysis relies on standard, highly disaggregated trade data. To capture the extent to which production has relocated across countries with different income levels, product and sector-specific relocation indices are calculated. These indices are based on the changes in the average income of the exporters of a product. Thus, for each product, we calculate a weighted average of the GDP per capita of the product's exporting countries. The weights are given by the revealed comparative advantage (*RCA*) of each country in that product, as in Hausmann, Hwang and Rodrick (henceforth HHR) (2007). Specifically, HHR calculate the sophistication of a good by means of an index called *PRODY*. The *PRODY* index of good *k* in period *t* is defined as:

$$PRODY_k^t = \sum_{c=1}^{C} \frac{RCA_{ck}^t}{\sum_{c=1}^{C} RCA_{ck}^t} GDPpc_c^t. \tag{10}$$

The relocation index is defined as the change in the average per capita GDPs of the exporting countries over a given time period. Because countries' GDP tend to grow over time, good *k*'s relocation index between periods 0 and T is defined as the difference between the growth of product *k*'s *PRODY* and the average growth of world per capita GDP:

$$\begin{aligned} R_k^{0,T} &= \frac{1}{T}\log\left(\frac{PRODY_k^T}{PRODY_k^0}\right) - g_w^{0,T} \\ &= \frac{1}{T}\log\left(\sum_{c=1}^{C} \frac{RCA_{ck}^t}{\sum_{c=1}^{C} RCA_{ck}^t} GDPpc_c^t \Bigg/ \sum_{c=1}^{C} \frac{RCA_{ck}^0}{\sum_{c=1}^{C} RCA_{ck}^0} GDPpc_c^0\right) - g^{0,T}. \end{aligned} \tag{11}$$

A positive (negative) $R_k^{0,T}$ indicates that the relative income of the average exporter of *k* has increased (decreased) between periods 0 and T. Notice that the change over time in a product's *PRODY* has two potential components: the change in the exporting countries' *RCA* and the change in their per capita GDP. The first component can be interpreted as the *pure relocation* effect because it only depends on the shift of production across countries with different income levels (e.g., lower income countries may increase their *RCA* in the product, while higher income countries decrease their *RCA*), whereas the second component does not involve a migration of production. To isolate the GDP per capita effect, a variant of the *PRODY* index is defined. This index, labeled as the *constant income-PRODY* and denoted by *ciPRODY*, is computed using per capita GDPs of the immediately preceding period and current-period *RCAs*:

$$ciPRODY_k^{0,T} = \sum_{c=1}^{C} \frac{RCA_{ck}^T}{\sum_{c=1}^{C} RCA_{ck}^T} GDPpc_c^0. \tag{12}$$

Then, the good *k*'s *pure* relocation index $PR_k^{0,t}$ is defined as:

$$\begin{aligned} PR_k^{0,T} &= \frac{1}{T}\log\left(\frac{ciPRODY_k^{0,T}}{PRODY_k^0}\right) \\ &= \frac{1}{T}\log\left(\sum_{c=1}^{C} \frac{RCA_{ck}^T}{\sum_{c=1}^{C} RCA_{ck}^T} GDPpc_c^0 \Bigg/ \sum_{c=1}^{C} \frac{RCA_{ck}^0}{\sum_{c=1}^{C} RCA_{ck}^0} GDPpc_c^0\right) \end{aligned} \tag{13}$$

Changes in *RCA* are the only possible source of changes in this index. Thus, the evolution of this index over time is used to determine the direction of international production relocation across countries at different stages of development; that is, if products have experienced an *upward* relocation (if higher income countries have increased their *RCA* in these products) or a *downward* relocation (if production has moved towards lower-income countries).

To assess the intensity of production relocation, an index of dispersion is used. Specifically, this dispersion is calculated using the mean absolute deviation (MAD), using as weights the average share of each product in world trade (the formula is analogous for the $PR_k^{0,T}$ indices):

$$MAD(R^{0,T}) = \sum_{k=1}^{K} \left| R_k^{0,T} - \left(\sum_{k=1}^{K} R_k^{0,T} * \frac{\omega_{Wk}^0 + \omega_{Wk}^T}{2}\right)\right| \frac{\omega_{Wk}^0 + \omega_{Wk}^T}{2}. \tag{14}$$

A higher dispersion of the relocation indices reflects a more intense relocation across country income groups, with products undergoing *upward* and *downward* relocations.

Then, the dynamics of the cross-section distribution of the *PRODYs* are analysed using a Markov chain method. Within this empirical approach, the changes in the overall distribution of products' *PRODY*, as well as the mobility or persistence within products (the intra-distribution dynamics) are analysed based on the estimation of transition probability matrices. The transitions across the categories defined in the matrices reveal how products switch across country income groups and therefore, these transitions reflect the probability of products undergoing *upward* and *downward* relocations.

To estimate the transition matrices, the set of values of the *PRODYs* are divided into a finite number of cells $k \in \{1, \ldots, K\}$. P^* is the transition probability matrix which is time invariant, such that $\lambda_{t+\tau} = P^* \lambda_t$, where λ_t is a *K*x1 vector of probabilities that a product is located in a given cell at time *t*. The entries of the P^* matrix, p_{ij}, denote the probability that a product beginning in cell *i* moves to cell *j*. Each row of the matrix is a vector of transition probabilities that adds up to one. By taking the limit $\tau \rightarrow \infty$ in the expression $\lambda_{t+\tau} = (P^*)^\tau \lambda_t$, the implied ergodic distribution is obtained. The ergodic distribution is the long-run distribution to which patterns of relocation will evolve if the dynamics represented by the transition matrices went on indefinitely. This analysis enables us to identify the type of stochastic process that arises from products' intra-distribution dynamics.

Finally, the **fourth chapter** also explores the potential determinants of production relocation. The aim of this analysis is to determine if future relocation can be predicted on the basis of some observable industry characteristics. For that purpose, several variables are considered: the product's initial sophistication or complexity, skill and capital intensity, TFP growth and R&D intensity. These measures are regressed on industry specific relocation indices (*R* and *PR*) to assess if they are relevant in predicting subsequent production relocation. Several variations of this basic specification are run:

$$R_k^{0,T} = \beta_0 + \beta_1 \log\left(\frac{s}{l}\right) + \beta_2 \log\left(\frac{k}{l}\right) + \beta_3 \log\left(0.001 + \frac{R\&D}{Sales}\right) + \beta_4 TFP + \beta_5 logPRODY_k + u_k, \quad (15)$$

where (s/l) is skill intensity, (k/l) is capital intensity, $\log\left(0.001 + \frac{R\&D}{Sales}\right)$ stands for R&D expenditures, TFP is TFP growth and *PRODY* captures the initial product sophistication. The same specification is run using the *PR* index as dependent variable.

The **fifth chapter** analyses the impact of production relocation on countries' economic growth. The aim of this chapter is to establish a link between the relocation processes studied in the **fourth chapter** and the economic performance of countries over a given time period, which is likely to have been affected by international relocation. To estimate the impact of production relocation on cross-country growth, first a country specific impact index is defined. This index measures whether the country's export basket at the beginning of the period was composed of products that have relocated towards higher- or lower-income countries. Using these country measures, the impact of international relocation on the countries' economic growth is estimated within the framework of cross-country growth regressions (Barro (1991), Mankiw, Romer, and Weil (1992), and Barro and Sala-i-Martin (2003)).

Specifically, the country *c*'s product-shocks impact index between periods 0 and T, denoted by $PSI_c^{0,T}$, is defined as:

$$PSI_c^{0,T} = \log \frac{\sum_k PRODY_k^T \, \omega_{ck}^0}{\sum_k PRODY_k^0 \, \omega_{ck}^0}. \tag{16}$$

Notice that the shares ω_{ck}^0 in country *c*'s exports are kept constant. Thus, this index only depends on the change in the *PRODYs*. A high (low) value of the product-shock impact index *PSI* means that the country's export basket is made up of products whose production, on average, has moved towards higher (lower) income countries.

As in chapter four, an index that captures the specific impact of the product shocks that lead to international production relocation is also calculated. The pure relocation impact index, *PRI*, is defined as follows:

$$\begin{aligned} PRI_c^{0,T} &= \log \frac{\sum_k ciPRODY_k^{0,T} \, \omega_{ck}^0}{\sum_k PRODY_k^0 \, \omega_{ck}^0} \\ &= \log \left(\sum_{c=1}^{C} \frac{RCA_{ck}^T}{\sum_{c=1}^{C} RCA_{ck}^T} GDPpc_c^0 \Bigg/ \sum_{c=1}^{C} \frac{RCA_{ck}^0}{\sum_{c=1}^{C} RCA_{ck}^0} GDPpc_c^0 \right) \end{aligned} \tag{17}$$

The *PRI* index captures changes in revealed comparative advantage across country income groups and averages these changes using each product’s share in the country's exports.

For both the *PSI* and the *PRI,* alternative indices that exclude a country’s data from the computation of the index are defined. The reason to do so is that, if a country represents a large share in world trade, country specific shocks that change this country’s GDP per capita can affect the value of the *PRODYs* of the products it exports, thereby affecting the *PSI*, not because of product shocks but because of country shocks. To deal with this potential problem, specific *PRODYs* for each country are calculated. These country-specific product indices are constructed excluding all the data relative to the country (i.e., the information on this country's exports and GDP per capita is excluded). Country *c*'s specific *PRODY* for good *k* (which is denoted by adding a '*csp'* prefix) is calculated as follows:

$$cs\_PRODY_{k,-c}^{t} = \sum_{i \neq c}^{C} \frac{RCA_{i-c,k}^{t}}{\sum_{c=1}^{C} RCA_{i-c,k}^{t}} GDPpc_{i}^{t}, \tag{18}$$

where $RCA_{i-c,k}^{t}$ is the country *i*'s revealed comparative advantage in good *k* calculated by excluding country *c*'s exports from world trade; $GDPpc_{i}^{t}$ is the per capita GDP of countries other than *c* exporting product *k*.

Then, the country-specific *PRODYs* are used to construct instruments for the country's product-shocks index (*PSI*):

$$csp\_PSI_{c}^{0,T} = \log \frac{\sum_{k} cs\_PRODY_{k,-c}^{T}\, \omega_{ck}^{0}}{\sum_{k} cs\_PRODY_{k,-c}^{0}\, \omega_{ck}^{0}}. \tag{19}$$

The index as defined in (19) is not affected by country *c* shocks. Only product shocks to *k* are captured by the *csp_PSI,* as they impact on all the remaining exporters of *k*.

In the same vein, country-specific shocks could also significantly affect the *ciPRODY*s of a country's exports by affecting the country's *RCAs*. Thus, to separate the impact of country-specific shocks from the impact of product shocks leading to international relocation, country-specific indices for the *PRI* are also calculated:

$$csp\_PRI_{c}^{0,T} = \log \frac{\sum_{k} cs\_ciPRODY_{k,-c}^{T}\, \omega_{ck}^{0}}{\sum_{k} cs\_PRODY_{k,-c}^{0}\, \omega_{ck}^{0}}. \tag{20}$$

The *csp_PSI* and *csp_PRI* are used as instruments for the *PSI* and *PRI*, respectively, in the econometric analysis in order to identify the impact of product shocks on each country's growth.

The econometric analysis of the relationship between international production relocation and economic growth in this chapter is conducted within the framework of growth regressions. GDP per capita growth is regressed on initial per-capita GDP, the product-shocks (*PSI*) and relocation impact (*PRI*) indices, and a vector of controls X_c^0, that includes human and physical capital and measures of institutional quality. In addition, the HHR (2007) measure for a country's initial export sophistication is also included, in levels as well as interacted with per capita GDP to account for the possibility that the growth impact of export sophistication decreases with income. A country's initial export sophistication is defined as $iEXPY_c^0 = \sum_k PRODY_k^0 \omega_{ck}^0$, and is somewhat different to the original *EXPY* defined in HHR (2007).[5]

Denoting the error term by u_c, the econometric specifications are the following:

$$\frac{1}{T}\log\frac{GDPpc_c^T}{GDPpc_c^0} = \beta_0 + \beta_1\log(GDPpc_c^0) + \beta_2\log(iEXPY_c^0) + \beta_3 X_c^0 + \beta_4 PSI_c^{0,T} + u_c, \tag{21}$$

$$\begin{aligned}\frac{1}{T}\log\frac{GDPpc_c^T}{GDPpc_c^0} = \beta_0 + \beta_1\log(GDPpc_c^0) + \beta_2\log(iEXPY_c^0) + \beta_3 X_c^0 + \beta_4 PRI_c^{0,T} \\ + \beta_5\left(PSI_c^{0,T} - PRI_c^{0,T}\right) + u_c.\end{aligned} \tag{22}$$

Equations (21) and (22) are estimated using OLS and 2SLS. Panel data regressions that include year fixed effects are also run using these specifications.

5 In HHR (2007), the *EXPY* is defined as: $EXPY_c = \sum_k PRODY_k^T \omega_{ck}^0$. Contrary to the initial export sophistication used here, it mixes data from two different periods: country *c* initial export specialization and products' sophistication at the end of the period.

Chapter 3:

VALUE ADDED AND PARTICIPATION IN GLOBAL VALUE CHAINS: THE CASE OF SPAIN

Abstract

Following Koopman, Wang and Wei (2014) and using the data and indicators derived from the international input-output tables of the World Input-Output Database (WIOD), this chapter addresses the participation of the Spanish economy and its sectors in global value chains (GVCs) during the period 1995-2011 and its implications for the value added content of trade. The analysis reveals the increasing integration of the country in GVCs and the heterogeneity between manufacturing and services in their vertical specialization and their contribution to value added. The importance of sectors heavily dependent on foreign inputs and the relatively low share of exports in GDP limit the capacity of the external sector to stimulate a sustained recovery.

1. INTRODUCTION

The nature of production and international trade has changed dramatically in the last decades. The reduction of transport costs, the ICT revolution, and greater trade liberalization have transformed the structure of production and trade, leading to the international fragmentation of production and the globalization of supply chains. International trade and production are increasingly organized within global value chains, which are described as the full range of activities that are part of the production process of a good or service, with the different stages of production located across different countries.

Inasmuch as production is carried out in different countries, goods and services cross borders several times at different stages of production for further processing. At each stage the producer uses intermediate inputs (imported or domestically produced) to which value can be added before exporting the good to another country, where they can, in turn, be assembled into final goods and exported again. The intermediate inputs and the payments to the factors of production (labour and capital) used in the exporting country are part of the cost of the intermediate goods used in the next stage. Since trade flows are measured in gross terms at each border crossing, the same labour, capital and intermediate inputs are counted multiple times as goods cross borders for further processing. As a consequence, gross trade data includes substantial multiple counting.

The increasing interconnection of countries around global supply chains is a dominant characteristic of world trade and poses a challenge to conventional trade statistics. The use of imported inputs for the production of exports generates an increasing disconnection between exports and the generation of income and employment associated with trade, since part of the income obtained from exports may accrue abroad, reflecting payments for the use of imported intermediates. It is therefore important to have indicators that reflect the value added content of exports. Consequently, in addition to traditional statistics based on gross values, complementary statistics are needed to deal with the complexity of global production chains and to measure and identify the origin of the value added content of trade.

The aim of this chapter is to analyse the production and trade specialization patterns of the Spanish economy from the perspective of trade in value added and vertical specialization, using world input-output tables. The literature on vertical specialization focuses on the degree of interconnectedness between countries in global production chains through trade in intermediate inputs. In a seminal paper, Hummels, Ishii and Yi (2001) (HIY hereafter) provide a formulation for calculating the import content of exports, a variable which is called *vertical specialization*. The higher the use of imported inputs in the production of exports, the lower the value added generated in the domestic economy, and therefore a larger share of revenue from selling the exported goods corresponds to the payments made to foreign suppliers.

Recently, several papers have tried to estimate the value-added content of trade using global input-output tables, such as the Global Trade Analysis Project (GTAP) (Trefler and Zhu (2010), Daudin, Rifflart and Schweisguth (2011), Johnson and Noguera (2012a), Koopman, Wang and Wei (2014)), or the World Input Output Database (WIOD) (Timmer et al. (2013), Baldwin and López-González (2014) and Johnson (2014)). The work by Koopman, Wang and Wei (2014), hereafter KWW, integrates the literature on vertical specialization and trade in value added through the development of a conceptual framework which breaks down gross exports into several components. The different measures of vertical specialization and value added trade that have been proposed in the literature can be derived from this general framework as linear combinations of these components.

This chapter analyzes the integration of the Spanish economy in global value chains (GVCs) at an aggregate level and by sectors. Unlike previous works, such as Blázquez et al. (2011 and 2012), which examines Spain's participation in international production networks using data on trade in parts and components, or more recently Gandoy (2014), which uses the OECD Trade in Value Added (TiVA) database, this work analyzes the evolution of the Spanish participation in GVCs during the period 1995-2011, following the methodology proposed by KWW (2014).

The analysis carried out in this chapter draws on the World Input-Output database (WIOD). This statistical source provides harmonised annual series of world input-output tables for the period 1995-2011. The information is available for 41 countries (40 plus an estimated aggregate representing the other countries not included in the database) with a level of disaggregation of 35 industries. Unlike the work of KWW (2014), which uses the Global Trade Analysis Project (GTAP) database and focuses on

2004, this chapter covers the period of expansion and crisis from 1995 to 2011. Having data available for some years after 2009 allows us to assess how trade has recovered in the aftermath of the *great trade collapse*.[6]

The use of indicators obtained from global input-output tables allows us to trace the origin of value added generated in the production of a particular final good, therefore making it possible to assess how economies contribute to generating value in a context characterized by the fragmentation of production. This paper focuses on specialization in manufacturing and services, and assesses how it affects the generation of income. The analysis shows that a significant share of value added by the manufacturing sector does not originate in industries belonging to this sector but rather in other sectors, particularly the services sector.

The main contribution of this chapter consists in the analysis of specialization trade patterns applying these new tools to the case of Spain, whose main features will be compared with other major players in international trade. This analysis brings a new perspective that allows us to better evaluate the role of the Spanish foreign sector as an engine of the economy and to answer the following questions: what's the degree of integration of the Spanish economy and its different sectors in GVCs? What's the value added content of Spanish exports? Does its specialization foster the generation of value added? This information is particularly relevant to be able to understand the link between trade and growth at a time when Spain has to rely on foreign demand to stabilize its recovery and improve its competitive position.

The chapter is organized as follows: section 2 describes the methodology and defines the indicators used in the analysis; section 3 presents the statistical sources; section 4 focuses on the empirical analysis and finally, section 5 concludes.

[6] This term is used to describe the sudden, deep and synchronized fall in world trade that occurred between the third quarter of 2008 and the second quarter of 2009.

2. METHODOLOGY

The methodology used in this work combines the approaches of KKW (2014), Johnson and Noguera (2012a) and Timmer et al. (2013). These studies are based on the analysis of sectoral interdependencies introduced by Leontief (1936). The basic input-output framework for a single economy is expanded into a multi-regional input-output (MRIO) model to trace the interconnectedness across countries and sectors. MRIO models allow us to analyse the specific features of international trade in a world where production increasingly fragments across borders.

To obtain the value added flows underlying gross exports, we need to follow goods through the supply chain from input producers to final consumers, and reallocate them to their original producing sector. By definition, the expenditure on final goods is equivalent to the amount of value added generated in the production process. Global input-output tables describe the intermediate deliveries across both sectors and countries and also the destinations to which final goods from each sector are sold. This allows us to trace the origin of gross output flows from each source country that are needed to produce a unit of final demand. On the basis of these production flows, the value added in each country-sector can be obtained by multiplying the production required to meet certain levels of final demand by the corresponding ratio of domestic value added over gross output.

The methodology is based on an *ex-post* analysis, i.e. we take final demand as given and trace back the flows of value added generated to meet this demand. The measurement of trade in value added enables us to assess the contribution of trade to an economy's well-being, since it is value added, and not gross exports, what generates income and employment.

2.1. The input-output framework

Assume that there are S sectors, F factors of production and N countries. Each country produces a single good within each sector, so that there are SN products. Henceforth, we will refer to each sector in a given country with the term "country-sector". The production of each country-sector is obtained by combining local factors of production with domestic and imported intermediate inputs. Production is either used to satisfy final demand (domestic or foreign) or used as an intermediate input in production, both in the domestic and the foreign economy. To track the shipments of output for final and intermediate goods, the source and destination country, as well as the source and destination sector, must be defined.

For a given product, let *i* be the country of origin and j the country of destination, and *s* and *t* the sector of origin and destination, respectively. The market clearing condition can be expressed as follows:

$$x_i(s) = \sum_j y_{ij}(s) + \sum_j \sum_t z_{ij}\,(s,t), \qquad (1)$$

where $x_i(s)$ is the output of sector *s* in country *i*, $y_{ij}(s)$ is the value of goods produced in sector *s* destined for final use in country *j*, and $z_{ij}(s,t)$ reflects the shipments of intermediate goods from sector *s* to sector *t* in country *j*. Condition in (1) implies that total output is split between intermediate and final demand, either for domestic use or to be absorbed abroad. To express market clearing conditions in a framework with multiple countries and sectors in a compact form, we use matrix notation. We define a set of matrices and vectors which group together the *SN* goods.

Let **x** be the *SN x1* output vector, consisting of the production of each country-sector, and **y** the vector *SNx1*, representing the final demand of goods produced in a country-sector. To describe the shipments of intermediate inputs, we define the matrix **A**, with elements $a_{ij}(s,t) = z_{ij}(s,t)/x_j(t)$, known as technical coefficients. The technical coefficients reflect the value of goods produced in sector *s* in country *i* used in the production of sector *t* in country *j*, as a share of total output in this country-sector. **A** is the *SNxSN* technical coefficient matrix, which describes how the production of each country-sector is obtained through a particular combination of intermediate inputs.

Using this compact matrix notation, the market clearing condition in (1) can be written as $x = Ax + y$. By rearranging the terms, we obtain the fundamental equation of the input-output framework:

$$x = (I - A)^{-1} y, \qquad (2)$$

where $(I - A)^{-1}$ is the Leontief inverse matrix (Leontief, 1936). This matrix shows the total input requirements (both direct and indirect) to produce a unit of output. Multiplying it by the final demand vector, the term $(I - A)^{-1} y$ reflects the output needed to satisfy the final demand absorbed in country j.

The equation in (2) can be rewritten as the following set of matrices:

$$\begin{bmatrix} X_{11} & X_{12} & \dots & X_{1N} \\ X_{21} & X_{22} & \dots & X_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ X_{N1} & X_{N2} & \cdots & X_{NN} \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} & \dots & B_{1N} \\ B_{21} & B_{22} & \dots & B_{2N} \\ \dots & \dots & \ddots & \dots \\ B_{N1} & B_{N2} & \dots & B_{NN} \end{bmatrix} \begin{bmatrix} Y_{11} & Y_{12} & \dots & Y_{1N} \\ Y_{21} & Y_{22} & \dots & Y_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ Y_{N1} & Y_{N2} & \cdots & Y_{NN} \end{bmatrix} \quad (3)$$

With many countries and sectors, the equation in (3) is a representation of a multi-regional input output model. Matrix **X** on the left-hand side of the equation is the gross output decomposition matrix, which gives the breakdown of gross output in each producing country by country of destination. For $\mathrm{i} = \mathrm{j}$, $\mathrm{X_{ij}}$ is the domestic production absorbed in the domestic market. When $\mathrm{i} \neq \mathrm{j}$, $\mathrm{X_{ij}}$ is the production of country *i* absorbed abroad. Matrix **B** is the Leontief inverse or total requirement matrix, which gives the amount of gross output in producing country *i* needed to satisfy a one-unit increase in final demand in destination country *j*. The final demand matrix **Y** shows the final goods produced in *i* and consumed in *j*.

With *N* countries and *S* sectors, the matrix **B** has a dimension of $SNxSN$; matrix **Y** and matrix **X** have a dimension of $SNxN$, although in equation (3) the subindex corresponding to the sector has been omitted to simplify the notation. In equation (3), $X_i = \sum_i^N X_{ij}$ is a $Sx1$ vector, that gives the total gross output of country i, and $Y_i = \sum_i^N Y_{ij}$, also of dimension $Sx1$, shows the global demand for final goods from country *i*.

2.2. Decomposition of gross exports

$\hat{V}_i$ is a diagonal matrix which contains the direct value added coefficients (the share of domestic value added in country i's gross output) on the main diagonal and zeros elsewhere. With *N* countries and *S* sectors, matrix $\hat{V}$ has a dimension SN x SN:

$$\begin{bmatrix} \hat{V}_1 & 0 & \dots & 0 \\ 0 & \hat{V}_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \hat{V}_N \end{bmatrix} \quad (4)$$

The domestic value added generated in a country's gross output can be obtained by pre-multiplying the value-added coefficient matrix with the gross output decomposition matrix **X** equation in (3):

$$\begin{bmatrix} \hat{V}_1 & 0 & \dots & 0 \\ 0 & \hat{V}_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \hat{V}_N \end{bmatrix} \begin{bmatrix} X_{11} & X_{12} & \dots & X_{1N} \\ X_{21} & X_{22} & \dots & X_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ X_{N1} & X_{N2} & \cdots & X_{NN} \end{bmatrix} = \begin{bmatrix} \hat{V}_1 \sum_j^N B_{1j} Y_{j1} & \hat{V}_1 \sum_j^N B_{1j} Y_{j2} & \dots & \hat{V}_1 \sum_j^N B_{1j} Y_{jN} \\ \hat{V}_2 \sum_j^N B_{2j} Y_{j1} & \hat{V}_2 \sum_j^N B_{2j} Y_{j2} & \dots & \hat{V}_2 \sum_j^N B_{2j} Y_{jN} \\ \dots & \dots & \ddots & \dots \\ \hat{V}_N \sum_j^N B_{Nj} Y_{j1} & \hat{V}_N \sum_j^N B_{Nj} Y_{j2} & \dots & \hat{V}_N \sum_j^N B_{Nj} Y_{jN} \end{bmatrix} \quad (5)$$

The result is the value-added production matrix $\hat{\mathbf{V}}\mathbf{BY}$, of dimensions *SN* x *N*. The elements on the main diagonal represent the domestic value added absorbed at home; the elements outside the diagonal correspond to a country's production of value added that is absorbed abroad, i.e. value added exports.

Therefore, total value-added exports of country *i* can be expressed as:

$$VA\ Exports_i = \sum_{j \neq i}^{N} VX_{ij} = V_i \sum_{j \neq i}^{N} \sum_{n=1}^{N} B_{in} Y_{nj} \quad (6)$$

Value added exports are the exports produced in country of origin *i* which are absorbed in country of destination *j*. This concept is defined in Johnson and Noguera (2012a), where the authors propose using the ratio of value added to gross exports (*VAX ratio*) as a measure of the value added content of gross exports and the intensity of production sharing. Equation (6) can be written as the sum of three components, which reflect the destination and use of value-added exports:

$$VA\ Exports_i = \sum_{j \neq i}^{N} VX_{ij} = V_i \sum_{j \neq i}^{N} B_{ii} Y_{ij} + V_i \sum_{j \neq i}^{N} B_{ij} Y_{jj} + V_i \sum_{j \neq i}^{N} \sum_{t \neq i,j}^{N} B_{ij} Y_{jt} \quad (7)$$

The first term is the value added in the country's exports of final goods; the second corresponds to the value added in exports of intermediate goods which will be used for the production of goods consumed by the importing country, and the third corresponds to exports of intermediate goods that are used in the importing country to produce final goods which will be exported. This last term reflects *indirect* value added exports (that is, exports via third countries).

In turn, total gross exports of a country can be defined as:

$$E_{i^*} = \sum_{j \neq i}^{N} E_{ij} = \sum_{j \neq i}^{N} (A_{ij} X_j + Y_j), \tag{8}$$

which includes both exports of intermediate goods and final goods. Gross exports are the part of gross output that is exported, whereas value-added exports are the part of the GDP that is exported and consumed abroad.

Equation (9) presents the complete decomposition of gross exports, following the work of KWW (2014):

$$\begin{aligned} uE_{i^*} = {} & \{V_i \sum_{j \neq i}^{N} B_{ii} Y_{ij} + V_i \sum_{j \neq i}^{N} B_{ij} Y_{jj} + V_i \sum_{j \neq i}^{N} \sum_{t \neq i,j}^{N} B_{ij} Y_{jt}\} + \{V_i \sum_{j \neq i}^{N} B_{ij} Y_{ji} + V_i \sum_{j \neq i}^{N} B_{ij} A_{ji} (I - A_{ii})^{-1} Y_{ii}\} \\ & + V_i \sum_{j \neq i}^{N} B_{ij} A_{ji} (I - A_{ii})^{-1} E_{i^*} + \{\sum_{t \neq i}^{N} \sum_{j \neq i}^{N} V_t B_{ti} Y_{ij} + \sum_{t \neq i}^{N} \sum_{j \neq i}^{N} V_t B_{ti} A_{ij} \left(I - A_{jj}\right)^{-1} Y_{jj}\} \\ & + \sum_{j \neq i}^{N} V_t B_{ti} \left(I - A_{jj}\right)^{-1} E_{j^*} \end{aligned} \tag{9}$$

Two large components can be singled out within gross exports: domestic content (the first six terms) and foreign content (the last three terms). These two large components can be further broken up into several subcomponents. Within the domestic content, the first three terms are value-added exports as defined in Johnson and Noguera (2012a). These consist of three elements (see equation (7)): domestic value added in exports of final goods, domestic value added in exports of intermediate goods, and indirect value added exports via third countries, i.e. domestic value added in exports of intermediate goods that are re-exported to third countries. These three components are a country's value added exports and, as was already mentioned, are considered to be so only if they are absorbed abroad.

The fourth and fifth terms represent the domestic value added that returns embodied into final and intermediate goods imports, respectively. Since it is part of the country's GDP, it is domestic value added, and although it is exported, it is not considered part of value-added exports given that it is not absorbed abroad. The sixth component is a pure double-counted term, which arises due to the two-way trade of intermediate goods with all trading partners. In this case, it is assigned to the domestic economy because it corresponds to goods originally produced in the home country. The sum of these first six components corresponds to the domestic content of gross exports.

The three remaining terms account for the foreign content of exports. The seventh and eighth terms are foreign value added in the source country's exports of final and intermediate goods respectively. That is, foreign GDP embodied in the country's exports. The last term is another pure-double counted component, also due to two-way trade in intermediate goods and whose production can be attributed to other countries. These elements (both 6 and 9) have to be taken into account to obtain a complete accounting of gross exports. Figure A1 in the Annex illustrates the different terms of this decomposition and the indexes that are derived from it.

2.3. Measuring vertical specialization.

The accounting of gross exports in (9) is a formal conceptual framework that integrates the literature on vertical specialization and trade in value added. The different indicators that have been proposed in the literature can be obtained as linear combinations of some of the terms in equation (9). These indicators are: value added exports, vertical specialization (*VS*), vertical specialization from the point of view of the exporter (*VS1*) and returned domestic content (*VS1**).

Before turning to these indices, a reference should be made to one of the first indicators used in the literature to measure the fragmentation of production processes. Feenstra and Hanson (1996, 1999) defined an index to measure outsourcing as the share of imported intermediate inputs in the value of total intermediate inputs used. While straightforward and easy to calculate, measures of vertical specialization developed from the work of HIY (2001) are a narrower concept to determine the countries' participation in global supply chains.

The concept of vertical specialization *VS*, defined in the seminal work of HIY (2001), measures the direct and indirect import content of exports. According to the authors, this index is equivalent to the foreign content in a country's exports. This statement is based on the assumption that the imported inputs have been produced entirely abroad, without any contribution from the exporting country. This is a restrictive assumption in a context of multi-country production networks, where a country's exports of intermediates can eventually return home embodied in imports. In such a scenario, some of the imported goods may contain a share of domestic value added, and the *VS* formulation proposed by HIY would be overestimating the foreign content of exports. The HIY's original index is equivalent to the foreign content of exports only when there is no returned domestic value-added. It is therefore a framework which offers a simplified view of the interrelationships in global production chains, since it does not consider the multiple back and forth trade in intermediates, which is characteristic of vertical trade.

The VS_i index as expressed in (10) generalizes the expression proposed by HIY (2001), removing the restriction of considering that there is no two-way trade in intermediate goods. This participation in GVCs - import to export - is called *backward participation*, and it can be expressed as the sum of the last three components in (9):

$$VS_i = \sum_{t\neq i}^{N}\sum_{j\neq i}^{N} V_t B_{ti} Y_{ij} + \sum_{t\neq i}^{N}\sum_{j\neq i}^{N} V_t B_{ti} A_{ij} \left(I - A_{jj}\right)^{-1} Y_{jj} + \sum_{i\neq j}^{N} V_t B_{ti} \left(I - A_{jj}\right)^{-1} E_{j^*}$$
$$= \sum_{i\neq j}^{N} V_j B_{ji} E_{i^*} \qquad (10)$$

The other way that a country can participate in vertical trade is measured through the *VS1* index. Also defined in HIY (2001), this index measures the exports of intermediate goods that are used by other countries to produce their exports, i.e. the domestic content of country *i* in exports from the rest of the world.[7] This participation in GVCs is referred to as *forward participation*:

$$VS1_i = V_i \sum_{j\neq i}^{N} B_{ij} E_{j^*} = V_i \sum_{j\neq i}^{N}\sum_{t\neq i,j}^{N} B_{ij} Y_{jt} + V_i \sum_{j\neq i}^{N}\sum_{t\neq i,j}^{N} B_{ij} A_{jt} X_t + V_i \sum_{j\neq i}^{N} B_{ij} Y_{ji}$$
$$+ V_i \sum_{j\neq i}^{N} B_{ij} A_{ji} X_i \qquad (11)$$

As is shown in equation (11), indirect value added exports (the first term) are only a part of the *VS1* index. It also includes the domestic content in the exported goods of the source country that is used in other countries to produce exports of intermediate goods,

[7] HIY (2001) do not provide a mathematical formulation of this expression.

as well as the domestic content that returns home embedded in imports from the rest of the world. This last term is measured through the $VS1*$ index, and represents the domestic content of imports. The index, originally defined in Daudin et al. (2011), is a subset of $VS1$. However, these authors only consider the share that returns incorporated in the imports of final goods, leaving out the domestic content in imports of intermediate goods. Equation (12) shows the complete definition of $VS1$ *:

$$VS1^*{}_i = \sum_{j\neq i}^{N} V_i B_{ij} E_{ji} = V_i \sum_{j\neq i}^{N} B_{ij} Y_{ji} + V_i \sum_{j\neq i}^{N} B_{ij} A_{ji} X_i \qquad (12)$$

Another indicator used in the literature on trade in value added is the *global value chain income* (*GVCI*) index by Timmer et al. (2013). The *GVCI* index corresponds to the value-added production matrix defined in equation (6). The authors have called it the *global value chain income* because it offers information on the participation of countries in the world manufacturing production. Expressed in compact notation, $GVCI = \hat{v}\,(I-A)^{-1}y$, the *GVCI* represents the value added generated to satisfy a certain level of final demand. This vector includes the value added by all the country-sectors directly and indirectly involved in the production process of a particular final product. This indicator allows us to assign the final demand of a given country-sector to the value added in all country-sectors, directly and indirectly involved in the production of that good.

3. STATISTICAL SOURCES AND CONSTRUCTION OF THE INDICATORS

The analysis outlined in the previous section requires a set of international input-output tables. The database used in this work is the World Input-Output Database (WIOD). This dataset provides a series of international input-output tables (WIOTs) for the period 1995-2011. The classification list in the WIOTs covers 35 sectors in NACE Rev. 1. Data is available for 40 countries, including the 27 member states of the European Union and 13 other major countries. Together, these countries account for more than 85% of the world's GDP. To complete the WIOTs, an estimate for a region called “Rest of the World” was added. The WIOTs are based on official statistical sources; that is, they are based on the national supply and use tables (SUTs) developed by national statistical institutes. National SUTs have been linked using international trade data from UN COMTRADE to create an international IOT.[8]

Given the dimensions of the matrices used, the calculations presented in this work have been programmed using Matlab, a mathematical software tool. The complete decomposition of gross exports was carried out following the methodology of KWW (2014)[9] for the period 1995-2011. Figure A1 shown in the Annex diagrams the components of gross exports identified in equation (9).

In addition, other indicators have been calculated such as the indices of vertical specialization *VS* and *VS1*, the *VS1** and the global value chain income (*GVCI*).

4. THE SPANISH ECONOMY IN GLOBAL VALUE CHAINS.

This section examines the vertical integration of the Spanish economy in GVCs and the link between production and trade specialization and the subsequent capacity to generate value added. The analysis is based on the dataset and the indicators constructed following the methodology described in section 2. Section 4.1 presents an overview of the evolution of Spain's participation in GVC. Section 4.2 takes an in-depth look at sectors in order to identify which branches contribute the most to the generation of value added.

4.1. Spanish trajectory: aggregate perspective.

In 1995 the Spanish economy entered a phase of high growth based on capital accumulation and job creation that ended with the outbreak of the crisis. The imbalances accumulated during this expansionary phase, including a large deficit in the trade balance among others, are hampering the recovery. One of the main causes of Spain’s trade deficit has been an insufficient adaptation to the new international competitive environment. Until a few decades ago Spain was a cost-competitive manufacturing country, but the increase of production costs, the emergence of low-wage competitors and the fall in transport and coordination costs meant that Spain lost some of its advantages, especially when faced with new emerging manufacturing countries. In this

[8] For a more in-depth look at the construction of WIOD, see “The construction of world input-output tables in the WIOD project” by Dietzenbacher et al. (2013).

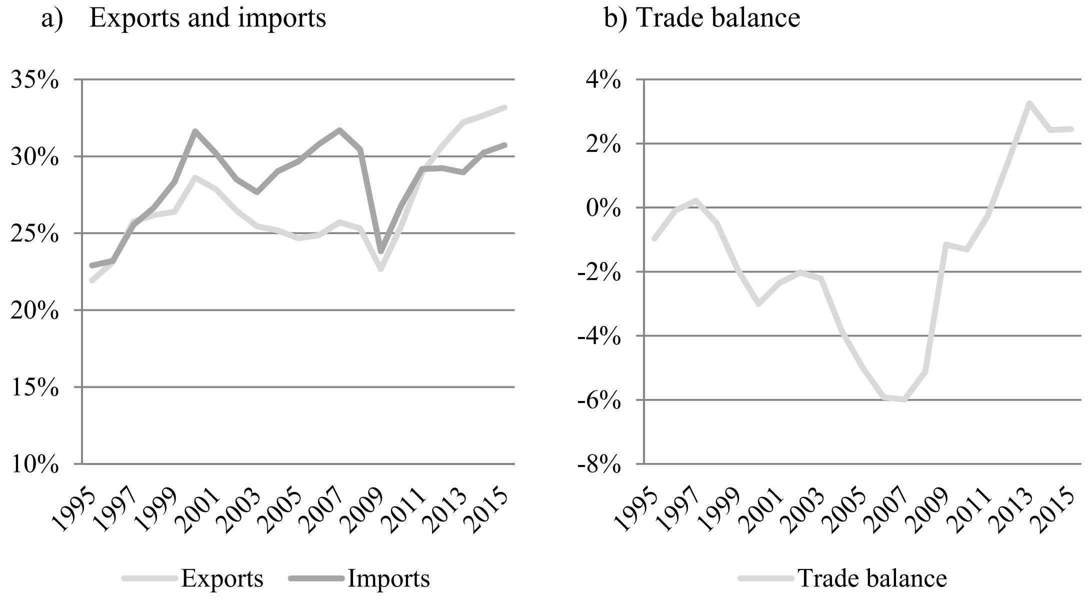
[9] KKW (2014) apply their methodology to the database of the Global Trade Analysis Project (GTAP) for the year 2004.

context, Spain should have redefined its productive specialization, reorienting towards activities more characteristic of developed countries. However, the absence of the right incentives during the boom years slowed down this adaptation process (Pérez et *al*. (2012a, 2012b)).

During this period Spain has faced chronic external competitiveness problems, which were reflected in the trade balance (Figure 1). Despite the growth of exports, imports increased more, thus generating an intense and ongoing trade deficit. This deficit only improved during the recent economic crisis due to the contraction of internal demand and the subsequent reduction in the demand for imports, combined with greater efforts to export. On the other hand, the import content of exports, derived from the so-called *vertical specialization*, makes that growth in exports generate an increase in imports. This implies a lower domestic value added per unit of exports.

Figure 1. Exports and imports of goods and services and trade balance. Spain, 1995-2015.

(Share of GDP, %)



Source: INE (2016).

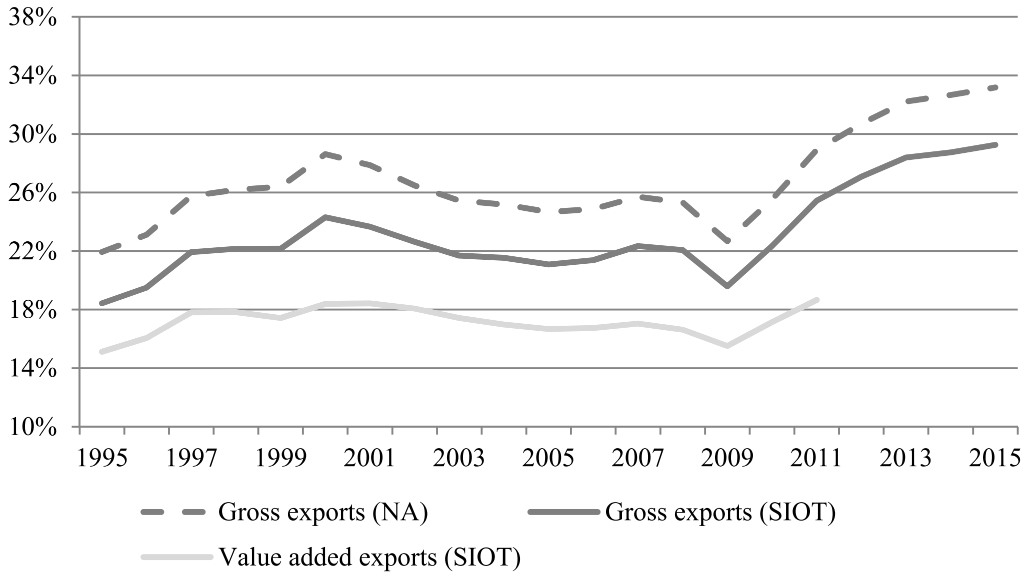
Figure 2 shows the evolution of exports as a share of GDP,[10] a measure of export openness, in gross and value added terms. The latter measures the share of domestic

[10] It is important to note that there are differences between the figures of total exports provided in the National Accounts and in the symmetric tables of the input-output framework, due to the item "purchases by non-residents in the economic territory". In National Accounts, these are included in total exports

value added that is exported, while the former also includes all the imported intermediate goods embodied in the production of exports. The difference between the gross and the value-added measures of export openness is substantial: currently more than 8 percentage points.[11] Moreover, in recent years export openness has increased more in gross terms than in value added, a common feature in economies which have increased their participation in GVCs. The share of exports in GDP remains modest compared with that of some European countries, such as Germany (46%), although its export openness is similar to that of France (26%) and Italy (29%).

Figure 2. Export openness, in gross and value-added terms. Spain, 1995-2011.

(Share of GDP, %)



Note: The dashed line represents the share of gross exports over GDP based on total exports from National Accounts (NA), which include the item "purchases by non-residents in the economic territory". It is on average 3 points higher than the ratio of exports to GDP calculated from input-output tables (SIOT).

Source: INE (2016) and WIOD (November 2013 release).

Table 1 shows how the different components of gross exports identified in figure A1 have evolved from 1995 to 2011. The numbers in parentheses correspond to the terms in equation (9) and also to the numbers in Figure A1. The accounting of Spain's gross

while in input-output tables this item is given in a separate row. This is due the fact that the composition of these expenditures is typically unknown and cannot be distributed at the product or sector level. In countries like Spain, where the tourism sector is a relevant industry, this concept represents between 12% and 16% of exports.

[11] The comparison is established between the two series from the input-output tables, since none of these includes the item "non-resident purchases" in the economic territory.

exports shown in Table 1 has been replicated for all the countries included in the WIOD database. Results can be found in Table A2 in the Appendix.

The share of value-added to gross exports *(*i.e. *VAX ratio*) has declined over the period as the foreign value added content increased. The gap between value-added and gross exports has widened with the exports' content in imported intermediate inputs. This is symptomatic of the growing interdependence of countries around global supply chains, as it is the case of Spain. In 1995, value added exports accounted for 79% of total exports. The *VAX* ratio fell by more than 9 percentage points to under 70% in 2011. Between 2008 and 2009, the period where the *great trade collapse* took place, vertical integration decreased, as reflected in the fall of the *VS* and *VS1*. The *VAX* ratio increased by nearly 6 percentage points, reflecting a reduction in the foreign value added content of exports.[12] However, data available after 2009 show that the trend observed in vertical integration before the crisis has recovered.

Table 1. Accounting of gross exports. Spain, 1995-2011.

(Share of total gross exports, %)

	1995	1996	1997	1998	1999	2000	2001	2002	2003
Gross exports									
Value-added exports [1 to 3]	78.71	78.78	77.49	76.66	75.55	71.78	73.39	74.54	74.56
Domestic value added in gross exports [1 to 5]	79.29	79.40	78.13	77.36	76.34	72.54	74.18	75.31	75.42
Double counted intermediate exports produced at home [6]	0.15	0.16	0.17	0.18	0.20	0.23	0.22	0.22	0.24
Domestic content [1 to 6]	79.44	79.55	78.30	77.55	76.54	72.78	74.40	75.53	75.66
Foreign value added in gross exports [7 to 8]	16.94	16.65	17.58	18.25	18.89	21.53	20.10	19.33	19.02
Double counted intermediate exports produced abroad [9]	3.62	3.79	4.12	4.20	4.57	5.70	5.50	5.14	5.32
Foreign content [7 to 9]	20.56	20.45	21.70	22.45	23.46	27.22	25.60	24.47	24.34
Vertical specialization indicators									
VS	20.56	20.45	21.70	22.45	23.46	27.22	25.60	24.47	24.34
VS1	17.39	17.73	18.14	17.92	18.80	19.62	20.62	20.23	21.02
*VS1**	0.73	0.78	0.80	0.89	0.98	1.00	1.02	1.00	1.10

(continues)

[12] This phenomenon is associated to the switch to domestic suppliers caused by lack of availability of trade finance as well as by the higher risks associated with international suppliers (Backer and Miroudot, 2013).

Table 1 (*cont*). Accounting of gross exports. Spain, 1995-2011.

(Share of total gross exports, %)

	2004	2005	2006	2007	2008	2009	2010	2011
Gross exports								
Value-added exports [1 to 3]	73.26	72.42	70.16	69.50	69.49	74.95	71.77	69.41
Domestic value added in gross exports [1 to 5]	74.17	73.36	71.10	70.50	70.39	75.75	72.46	70.06
Double counted intermediate exports produced at home [6]	0.26	0.25	0.27	0.30	0.27	0.22	0.23	0.24
Domestic content [1 to 6]	74.42	73.61	71.37	70.80	70.65	75.96	72.69	70.30
Foreign value added in gross exports [7 to 8]	19.78	20.36	21.87	22.00	22.16	18.91	20.98	22.62
Double counted intermediate exports produced abroad [9]	5.79	6.02	6.76	7.20	7.19	5.13	6.33	7.07
Foreign content [7 to 9]	25.58	26.39	28.63	29.20	29.35	24.04	27.31	29.70
Vertical specialization indicators								
VS	25.58	26.39	28.63	29.20	29.35	24.04	27.31	29.70
VS1	22.05	22.37	22.90	24.47	23.24	21.24	21.53	21.66
*VS1**	1.16	1.19	1.22	1.30	1.16	1.01	0.92	0.90

Note: The numbers in parentheses correspond to the components of gross exports identified in Figure A1.

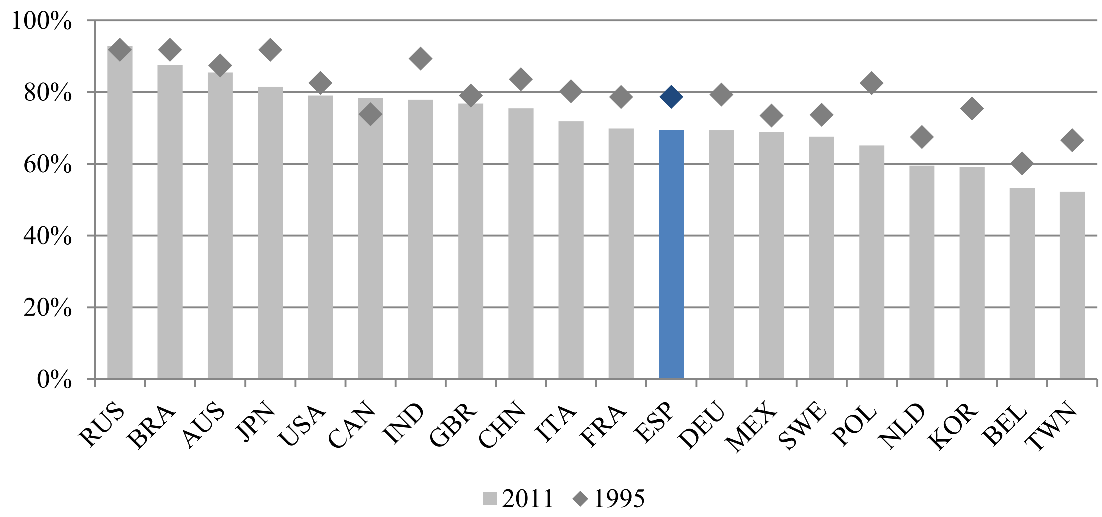
Source: Author's calculations based on WIOD (November 2013 release).

Figure 3 shows the evolution of the value added content of gross exports (*VAX ratio*) for a set of 20 countries (the main world exporters) between 1995 and 2011. With the exception of Russia and Canada, the ratio of value added to gross exports has decreased in 2011 compared to 1995, reflecting a higher intensity of production sharing. The value added content of Spanish exports (69.4%) is similar to that of its main European partners: Germany with 69.4%, France with 69.9% and Italy with 71.9%. These values are typical of similar sized countries belonging to an integrated trade area with a high degree of production sharing.

The highest *VAX* ratios in 2011 where those of Russia, Brazil and Australia; the value-added in gross exports was over 85%. On the other side, the *VAX* ratio of the Netherlands, South Korea, Belgium and Taiwan was less than 60%. The share of domestic value added in exports is closely related to the size of the country: the degree of input self-reliance is positively correlated with economic size. Big countries have a larger internal market that makes them less dependent on foreign sourcing and thus, have a lower foreign content (a higher share of domestic value-added in exports). On the contrary, smaller countries are less input self-sufficient and rely to a larger extent on imported intermediates.

Figure 3. Value-added content of gross exports (*VAX* ratio). Selected countries, 1995-2011.

(Share of total gross exports, %)



Source: Author's calculations based on WIOD (November 2013 release).

The evolution of the value added content of exports is closely linked to the participation in GVCs, measured through the vertical specialization indices *VS* and *VS1*. The *VS* index reflects the *backward participation* or *backward linkages* of a country in vertical supply chains, i.e. the share of imported intermediate inputs in exports (i.e. foreign value added). The *VS1* index captures the *forward participation*, i.e. the domestic inputs exported by a country which will be used in other countries to produce their exports, that is, the value added contained in the exports of other countries.

Figure 4 shows how the participation of countries in vertical trade has changed from 1995 to 2011. With the exception of Russia and Canada, the *backward* linkages of all the countries included in the sample have intensified: the foreign value-added content of exports, as measured by the *VS* index, has increased over this period. The forward participation, as captured by the *VS1*, has also increased.

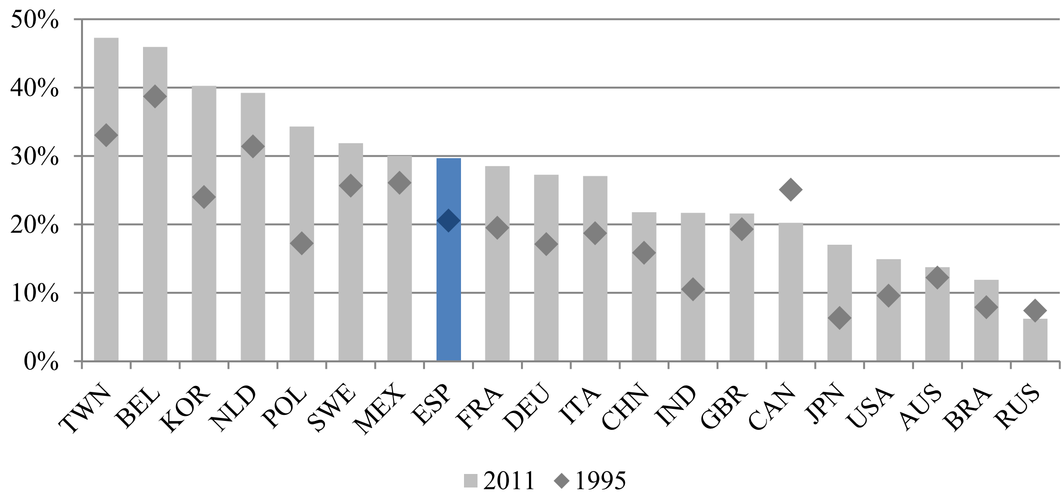
It is also worth to mention the high variability that is observed in the indices, especially for the *VS*: the value of this index ranges from a value of 40% in Taiwan, Belgium and South Korea, to a 6% in Russia or 11% in Australia and Brazil. In the case of the *VS1* index, with the exception of Russia (50%), the values range from 33% in Australia to

17% in Mexico. High values of the *VS1* index are typically observed in countries where natural resources account for a large share of their exports, as those exports are embodied in the exports of other countries that are located more downstream in the supply chain. It is the case of Russia, Australia and Brazil. On the contrary, smaller countries are more dependent on foreign inputs, and this is reflected in higher values of the *VS* index.

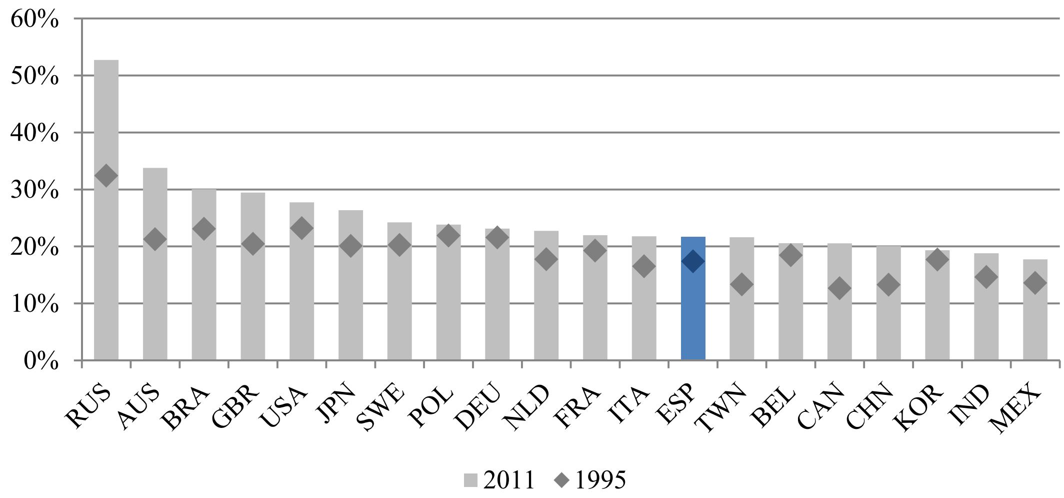
Figure 4. Vertical specialization *VS* and *VS1*. Selected countries, 1995-2011.

(Share of total gross exports, %)

a) *VS*



b) *VS1*



Source: Author's calculations based on WIOD (November 2013 release).

As shown in Figure 4, Spain participates in GVCs mainly as an importer of intermediate goods which are subsequently used in the production of its exports: the import content of exports (*VS*), which is equivalent to the foreign content, increased by 9 percentage points during the period analysed, up to nearly 30% in 2011. The *VS1* index, which measures the share of Spanish value added that is contained -through intermediate inputs- in the exports of other countries, shows a more moderate development, although it exceeded 20% in recent years. This trend is shared by the big European economies. However, the Spanish economy exhibits a higher *backward* participation (as shown by the *VS* index) as compared with its *forward* participation (measured by the *VS1* index). The distance between these indices has increased in recent years.

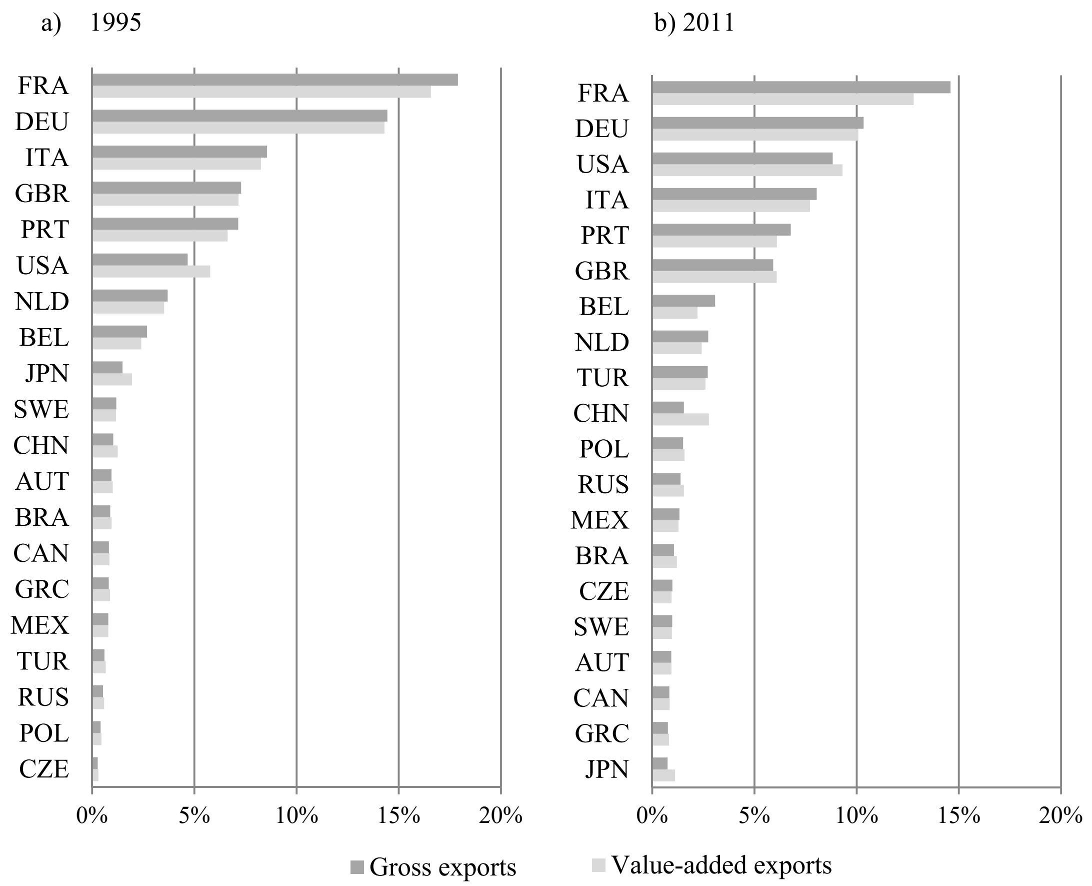
On the other hand, the Spanish domestic value added that returns embodied in imports (*VS1*)* is around 1%. This component of gross exports (the term *VS1**) is greater in countries which play a prominent role in the supply-chain trade of their regions, which lead to greater back and forth trade in intermediates. For instance, in economies such as Germany or the United States, the domestic value added that comes back embedded in re-imported goods represents around 3.4% and 6% of total exports, respectively (see table A2).

The reliance on foreign inputs to produce exports decreases the share of domestic value added per unit of exports. Therefore, if the exported goods contain a significant –and increasing- amount of imported inputs and exports do not increase, the revenues obtained from foreign trade will decrease. Some studies draw attention to the import content of Spanish production as one of the causes of its high and persistent trade deficit (Cabrero and Tiana, 2012). This feature could condition the role of the external sector as a driver of the economy, since the spillover effects of an increase in foreign demand are largely filtered abroad. However, resorting to imports of intermediate goods should not necessarily be seen as something negative, since it gives access to intermediate goods that are produced more efficiently abroad. In fact, some recent works point out that imports of intermediate goods may be positive for the external competitiveness and that participation in global value chains is positively correlated with the generation of domestic value added (Kummritz (2015)).

As is highlighted in the introduction, the value added flows underlying gross exports allow us to identify which countries and industries contribute to the production of exports and where the final consumer is. Gross exports between partner countries do not reveal where the goods or services exported are finally consumed. The existence of multi-country production networks gives rise to indirect trade: the direct export destination may be an *intermediate* country in the chain, where imported inputs will be processed to produce goods that are exported to other countries, whose final demand is what ultimately determines domestic production.

Figure 5 shows the main destinations of Spanish exports,[13] in gross and value added terms. The 20 selected countries represent 75% of Spain's total gross exports and 73% of value-added exports in 2011 (compared to 76% and 75% in 1995, respectively). The largest trading partners of Spain are European countries (France, Germany, Italy, United Kingdom and Portugal), together with the United States.

Figure 5. Partner shares in exports, in gross and value-added terms.
(Share of total gross exports, %)



Source: Author's calculations based on WIOD (November 2013 release).

[13] The selection of countries was made from those available in the WIOD database. There are other countries which have a greater weight as a destination for Spanish exports but they are not included in the database, such as Morocco or Algeria.

Compared to 1995, exports to its main European trade partners decreased their share in Spanish exports in favour of the United States, China or Poland. In value added terms, the selection of countries does not change, indicating that the main export destinations in gross terms are the same ones in value added, even if the relative position of the countries changes. The share of China, United States, Japan and United Kingdom as a destination of Spain's value-added exports is higher than their share in gross exports. The opposite is the case with France, Germany, Italy and Portugal, whose share as a destination of Spanish exports is larger in gross than in value-added exports. This is consistent with the literature which indicates that the average distance that travels gross trade from source to destination is shorter than the distance travelled by value added trade. Consequently, bilateral *VAX* ratios tend to fall most among neighbouring countries (Johnson and Noguera, 2012b).

4.2. Sectoral Analysis

After the overview of Spain's aggregate exports in the previous section, we focus now on the sector level. The aim of this section is to assess which sectors contribute the most to the generation of value added and how they participate in GVCs. This analysis can shed light on the debate about whether it is advisable to increase the industry's share in GDP,[14] since one of the most relevant facts that arises from a trade in value added perspective is that a significant share of it has its origin in the services sector.

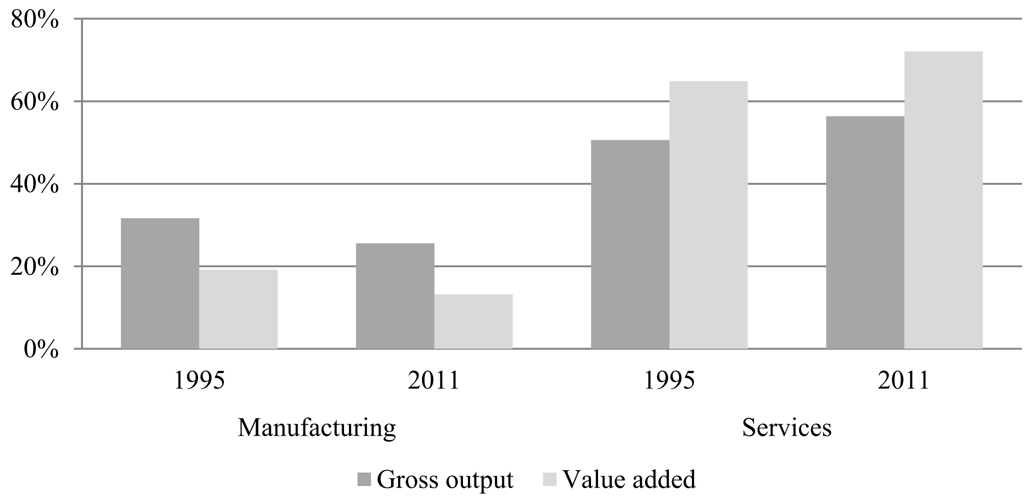
In developed countries, services account for more than two thirds of GDP, but only to around 20% in gross exports, while manufacturing accounts for nearly 70% of total gross exports. However, when we turn to value-added trade flows, the trade share of these sectors is reallocated: the share of the service sector (manufacturing) increases (decreases). The greater importance of services in terms of value added is because manufacturing companies outsource part of their activities and buy inputs from the services sector. This increasing sectoral interdependence can be explained by changes in specialization, derived from greater reliance on external sourcing: companies specialize in certain stages of the production process and increasingly resort to purchasing inputs in the markets. In 2011, inputs acquired from other manufacturing industries and the rest of sectors accounted for 72% of the total value of manufacturing production, with

[14] A flagship initiative of the *Europe 2020* strategy is to increase the share of industry in Europe's GDP by 2020.

only the remainder corresponding to value added. In services, these shares are very different (37% is intermediate consumption, whereas value added accounts for more than 60% of gross output).

These differences in the relative shares of intermediate inputs and value added also lead to very different relative shares in gross output and value added: the percentage share of manufacturing is higher in total production (25%) than in value added (13%). On the other hand, the services sector accounts for a greater share in value added (72%) than in gross output (56%). Compared to 1995, the share of manufacturing in both production and trade has decreased, whereas the share of services in both variables has increased (Figure 6).

Figure 6. Gross output and value-added. Manufacturing and services. Spain, 1995-2011



Source: Author's calculations based on WIOD (November 2013 release).

The difference in the participation of these two sectors in international trade according to whether it is measured in gross or value added terms is also very striking (Figure 7). Manufacturing accounts for more than 70% of total gross exports, while services have barely exceeded 20% in recent years. On the other hand, when flows in value added are observed, services overtake manufacturing to account for 50% of value added exports. Manufacturing represents 40% of value-added exports, which is almost half its share in gross terms. Moreover, the share of services has increased by more than 10 percentage points in value added exports, while manufacturing's share in gross and value added terms has decreased.

This reallocation of trade shares is due to the fact that gross manufacturing exports incorporate inputs from the services sector, and thus, they have a high content of services' value added. When flows are analysed in value added, they are reassigned to the sector they came from. The services' share in gross exports underestimates their actual contribution to the generation of value added: they are fundamental in international supply chains (transport, communications, business and financial services), and play an important role as inputs in the production and exports of the manufacturing sector.

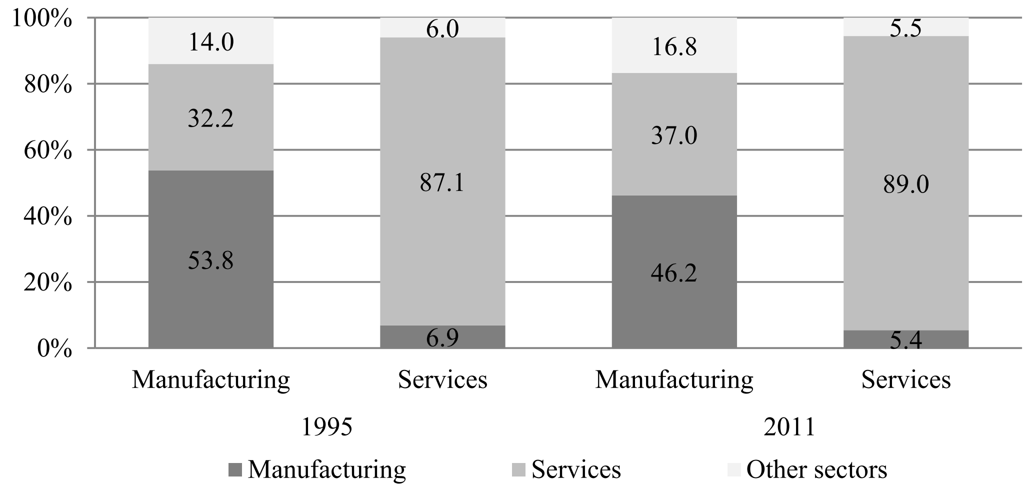
Figure 7. Gross exports and value-added exports. Manufacturing and services. Spain, 1995-2011

Source: Author's calculations based on WIOD (November 2013 release).

The interrelationships between sectors can also be measured with the *GVCI* indicator. This index measures the value added that is directly and indirectly generated in each sector to produce one unit of final demand. Therefore, it is possible to obtain the share of value added in a producing sector that originates in other sectors, i.e., the services' value added share in manufacturing production and vice versa. As shown in Figure 8, 37% of the total value added generated in 2011 to meet final demand in the manufacturing industry comes from the services sector. The value added share in the production of services coming from manufacturing industries is much lower (5.4%).

Figure 8. Global value chain income (*GVCI)*. Manufacturing and services. Spain, 1995-2011

(Value added per unit of final demand, %)



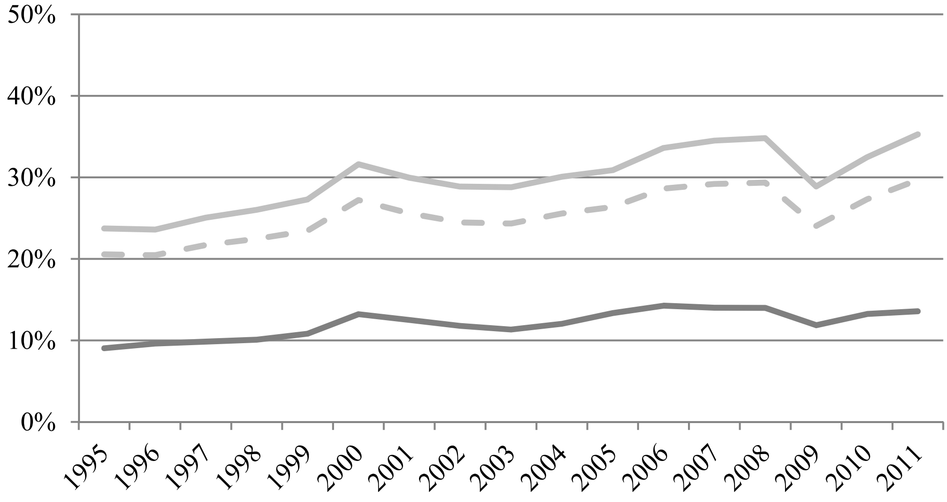
Source: Author's calculations based on WIOD (November 2013 release).

The way manufacturing and services participate in vertical trade is also very different (Figure 9). Manufacturing has a higher backward participation, as measured by the *VS* index, since manufacturing industries are more intensive in the use of imported inputs for the production of exports. On the other hand, services exhibit a higher forward participation, as captured by the *VS1* index, i.e. they participate in value chains mainly as suppliers of inputs that will be used in the production of other sectors or countries' exports.

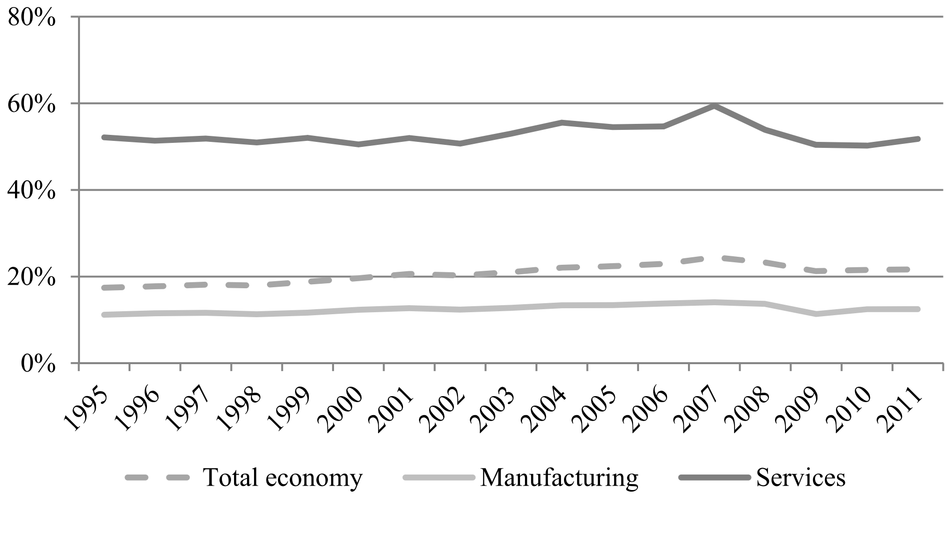
Figure 9. Vertical specialization *VS* and *VS1*. Manufacturing and services. Spain, 1995-2011

(Share of gross exports, %)

a) VS



b) VS1

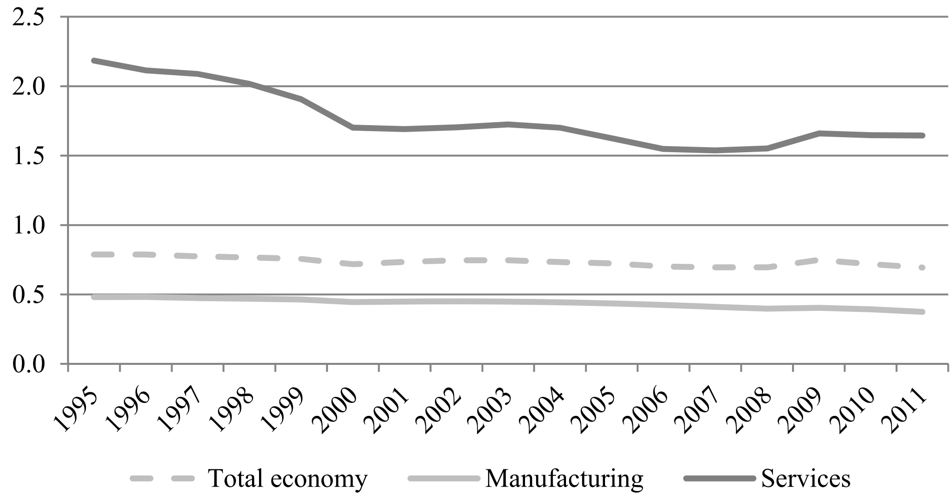


Source: Author's calculations based on WIOD (November 2013 release).

This distinct participation in GVCs leads to a very different ratio of value added to gross exports. Figure 10 shows the value added content of each sector's gross exports (*VAX* ratio). At the country level, the *VAX* ratio cannot be greater than 1, but at sector level this can happen if the value added is indirectly generated through other sectors. This is what happens with the services sector, whose *VAX* ratio exceeds 1.5; in manufacturing, value added in gross exports does not reach 50%.

Figure 10. Value-added content of exports (*VAX* ratio). Manufacturing and services. Spain, 1995-2011

(Share of gross exports, %)



Source: Author's calculations based on WIOD (November 2013 release).

After the analysis of the two large sectors (manufacturing and services), we turn to the analysis of the branches which are part of these aggregates. The share of the manufacturing industry in gross output is higher than in value added, while the opposite is seen in the services sector. This also occurs in the different branches that are included in these two large sectors,[15] which also differ in the foreign value added content of their exports.

Table 2 shows the breakdown of the *VS* index in the intensity of the use of imported inputs at the sector level and the weight of each sector in total exports. With the exception of *real estate,* all branches have increased their import content. The most intensive branch in the use of imported inputs to export is coke and refined petroleum products, which requires 0.76 imported inputs to produce a unit of exports, followed by transport equipment, electrical and optical equipment and metal products, whose exports contain more than 30% of foreign value added. The branches with the least import content belong to the services sector.

[15] Table A3 of the Appendix shows the share of each industry in gross output, value added, gross exports and value added exports.

The *VS* index for the whole economy has two sources of variation: changes in the *VS* index of each sector (component *within sectors*) and changes in the composition of exports (that is, changes in the share of each sector in the export basket of the country, also called component *between sectors*). To determine which of the two components has contributed the most to the change in the *VS* index, a shift-share analysis is used (see Appendix A4 for the details).

The analysis reveals that 89% of the variation of the *VS* index for the Spanish economy is due to changes in the vertical specialization across sectors. The *VS* index has increased in almost all sectors. Thus, the *within sectors* component accounts for most of the growth in the overall *VS* index. Besides, some of the sectors with the highest *VS* index have increased their share in total exports (coke and refined petroleum products and the chemical industry). The largest increases in the foreign content of exports, in addition to those just mentioned, have occurred in electrical and optical equipment, metallic products, and air transport. From 1995 to 2011, the import content of exports from these sectors increased by more than 10 percentage points.

Table 2. Sources of growth of the VS index, 1995-2011

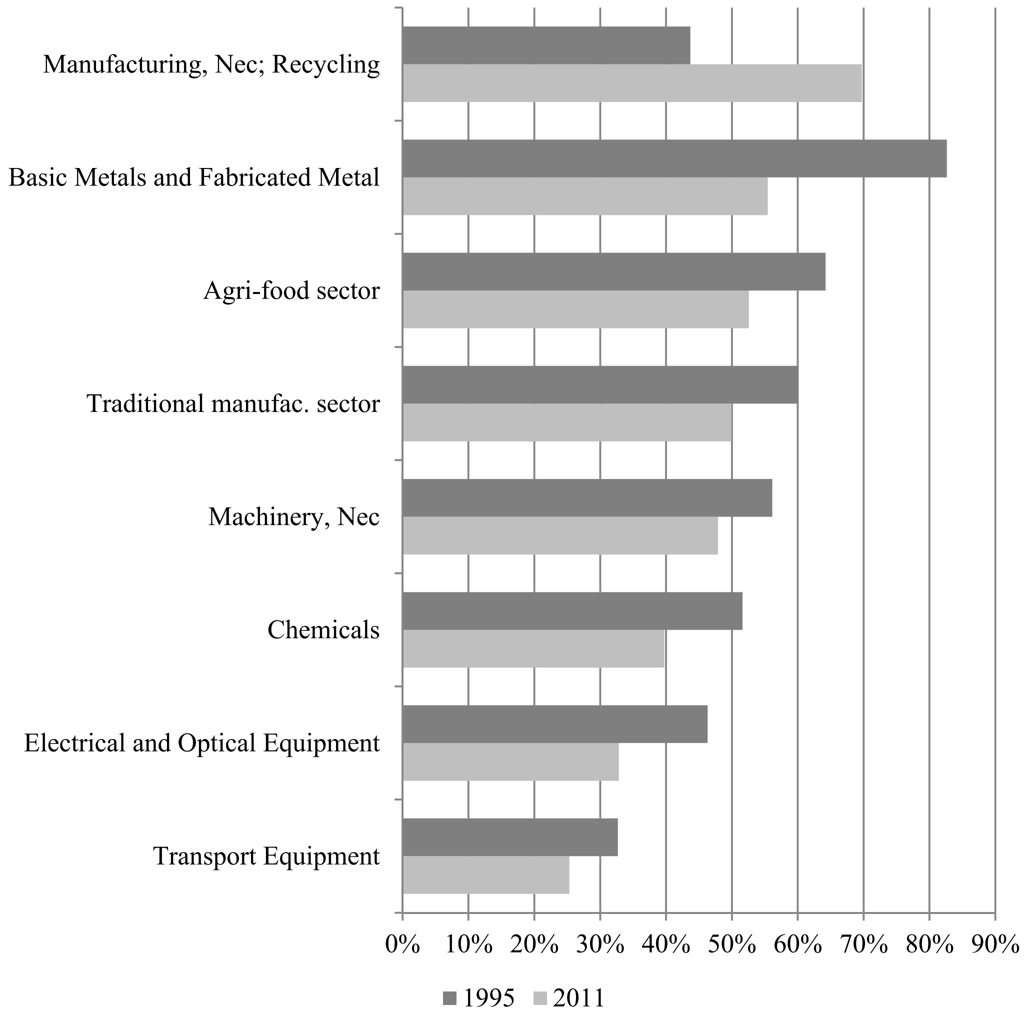
	Sector share of total exports		Sector VS index		Variation in VS
	1995	**2011**	**1995**	**2011**	**1995-2011**
Primary sector	**6.44**	**4.18**	**7.91**	**12.92**	**-**
Agriculture, Hunting, Forestry and Fishing	6.44	4.18	7.91	12.92	5.01
Manufacturing	**78.78**	**74.05**	**23.73**	**35.28**	**-**
Food, Beverages and Tobacco	6.90	7.37	15.34	20.34	5.00
Textiles and Textile Products	3.45	3.82	19.56	27.64	8.08
Leather and Footwear	2.30	1.17	19.10	24.97	5.87
Wood and Products of Wood and Cork	0.64	0.45	14.99	20.84	5.85
Pulp, Paper, Paper , Printing and Publishing	2.96	1.99	18.29	20.49	2.19
Coke, Refined Petroleum and Nuclear Fuel	2.14	8.17	51.92	75.78	23.86
Chemicals and Chemical Products	8.35	10.40	20.81	29.92	9.10
Rubber and Plastics	2.76	2.75	23.22	28.58	5.36
Other Non-Metallic Mineral	3.20	1.85	12.51	19.98	7.46
Basic Metals and Fabricated Metal	7.75	9.26	20.24	30.25	10.01
Machinery, Nec	5.43	4.36	19.53	25.65	6.12
Electrical and Optical Equipment	7.41	5.52	23.57	34.65	11.09
Transport Equipment	23.61	15.76	30.81	39.29	8.48
Manufacturing, Nec; Recycling	1.88	1.18	18.30	24.69	6.39
Services	**14.15**	**20.89**	**9.04**	**13.57**	**-**
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	0.04	0.20	19.10	21.42	2.32
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	1.03	0.52	6.47	9.87	3.39
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	0.38	0.28	4.30	6.42	2.12
Hotels and Restaurants	0.01	0.03	6.91	9.71	2.80
Inland Transport	1.99	2.71	10.99	18.84	7.86
Water Transport	1.12	0.59	13.05	20.56	7.51
Air transport	2.06	2.26	12.66	24.71	12.05
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	1.46	1.82	11.06	16.24	5.17
Post and Telecommunications	0.60	0.58	4.47	13.40	8.93
Financial Intermediation	0.78	2.39	4.40	8.45	4.05
Real Estate Activities	0.05	0.02	3.06	2.95	-0.11
Renting of M&Eq and Other Business Activities	3.88	8.17	7.48	10.15	2.67
Public Admin and Defense; Compulsory Social Security	0.17	0.53	5.27	8.32	3.05
Education	0.00	0.00	2.14	3.36	1.22
Health and Social Work	0.01	0.01	8.59	11.19	2.60
Other Community, Social and Personal Services	0.56	0.78	6.70	10.33	3.64
Other sectors					
Mining and Quarrying	0.38	0.44	11.53	21.26	9.73
Electricity, Gas and Water Supply	0.10	0.31	13.14	28.03	14.89
Construction	0.15	0.12	12.64	13.18	0.54
Total economy	**100**	**100**	**20.56**	**29.70**	**9.14**
Contribution of: (%) Changes in VS intensity					89.4
Changes in sector composition					10.6

Source: Author’s calculations based on WIOD (November 2013 release).

In general, the exports of the different branches in the manufacturing industry contain a significant share of foreign value added (Figure 11). In the analysis that follows, the textile industry, leather and footwear, wood, paper and printing and publishing, rubber and plastics and other non-metallic mineral products have been grouped in the aggregate "traditional manufacturing industry". Given their importance, the food, beverages and tobacco industry and the primary sector (agriculture, hunting, forestry and fishing) have been grouped in the agri-food sector. The value added per unit of exports has fallen significantly since 1995, except for the branch manufacturing, nec; recycling, which was the only sector whose VAX ratio increased in 2011 with respect to 1995. In 2011, the VAX ratio of the majority of branches was less than 50%. This evolution reflects the high participation of the Spanish economy in global production chains, which is mainly as an importer of intermediate inputs that will be used in the production of exports.

These figures show that, in general, exports from manufacturing industries contain little value added. This is particularly noticeable in the case of the transport equipment industry. The value added directly generated in this industry per unit of exports is the lowest of all the sectors considered: in 2011, only a quarter of the exports of transport equipment were value added by the sector. The rest comes from the production of other sectors of the economy (domestic fragmentation) and from abroad (international fragmentation). However, despite the lower share of value added directly generated in the sector, it is an industry with significant spillover effects on the other sectors of the economy, as we shall see in the Table 3.

Figure 11. Value-added content of exports (*VAX* ratio) by industries. Spain, 1995-2011



Source: Author’s calculations based on WIOD (November 2013 release).

Value-added exports reflect the income derived from the production of exports. The *GVCI* index can offer a more complete picture as it allows us to identify the sectors of origin (both domestic and foreign) of the value added that is generated to meet total final demand; that is, the income derived from the production of final manufacturing goods, to be consumed at home or abroad. This approach enables us to assess the degree of penetration of foreign value added in the production of goods in the domestic market. This dimension is also relevant, because local firms also compete with foreign ones in the domestic territory, not only in international markets.

The breakdown of the *GVCI* index in Table 3 provides insight into the degree of production fragmentation, at the international level and within the home country. It shows how the interdependence between sectors has evolved: the value added by sectors other than the sector of origin has increased. The share of domestically produced value added outside the sector of origin has increased with respect to 1995, and a growing share of value added comes from abroad. It is particularly relevant the share of value added that comes from the domestic services sector, which accounted for 25.3% of the value added generated domestically in the production of manufacturing goods in 2011.

The foreign value added content is close to 30% in the chemical industry, and nearly to 40% in transport equipment. In the sector of coke and refined petroleum products, foreign value added represented more than 75% in 2011, which is an increase of more than 20 percentage points since 1995. On the other hand, the agri-food industry has the lowest foreign content (18%). Due to its characteristics, this sector is more domestically reliant (its main source is the local market), which makes it the sector that generates more value added not only domestically, but within the sector itself (54.7%).

The breakdown of value added by sectors shown in Table 3 reveals the importance of the value-added by the domestic services sector, though part of the value added generated abroad (identified in the column "Foreign VA") also comes from services. The total services value-added content (domestic and foreign) of manufacturing goods is shown in Figure 12. It appears that the role of services as an input for the manufacturing industry is indeed very significant. The services value-added content has increased in all branches during the period of analysis. In 2011, it accounted for more than 30% of the total value added in the production of the Spanish manufacturing industries. Its contribution is especially relevant in transport equipment, where it represents 40% of total value added, followed by the chemical industry (38%). Although the share of value added by the foreign-sourced services has increased, the value added by the domestic services sector remains dominant.

Table 3. Global value chain income (*GVCI)* of the manufacturing industries. Spain, 1995-2011

a) 1995

	Sector of origin (1)	Other manufac. industries (2)	Services (3)	Other sectors (4)	Domestic VA (1) to (4)	Foreign VA
Agri-food sector	54.7	5.5	24.2	2.7	87.0	13.0
Manufacturing, nec; recycling	34.9	16.5	26.3	4.0	81.7	18.3
Traditional manufac. Sector	44.1	5.0	26.1	5.8	81.1	18.9
Machinery, Nec	41.2	14.6	21.6	3.0	80.5	19.5
Basic Metals and Fabricated Metal	46.6	6.5	21.7	5.0	79.8	20.2
Chemicals	40.8	7.6	26.1	4.7	79.2	20.8
Electrical and Optical Equipment	39.6	10.5	23.2	3.1	76.4	23.6
Transport Equipment	32.1	13.6	20.5	3.1	69.2	30.8
Total Manufacturing	43.2	-	24.9	9.9	78.0	22.0

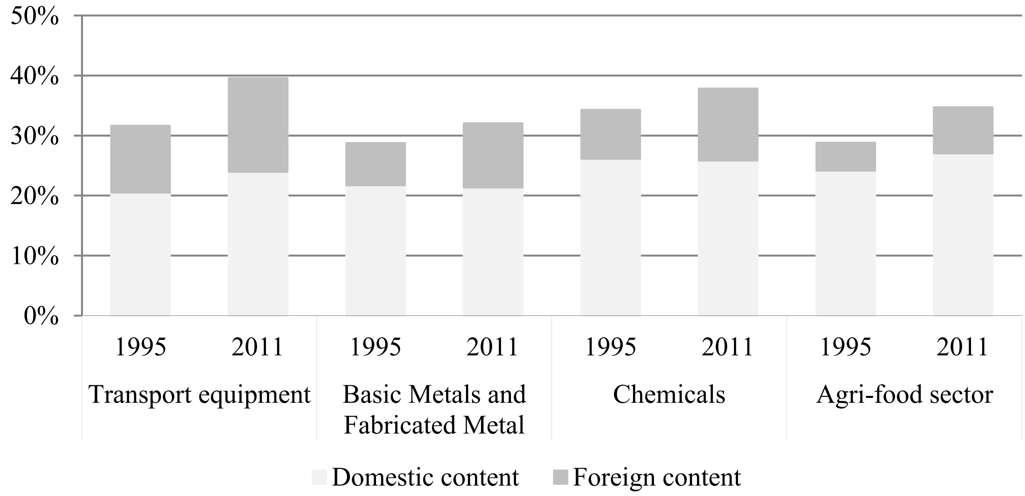
b) 2011

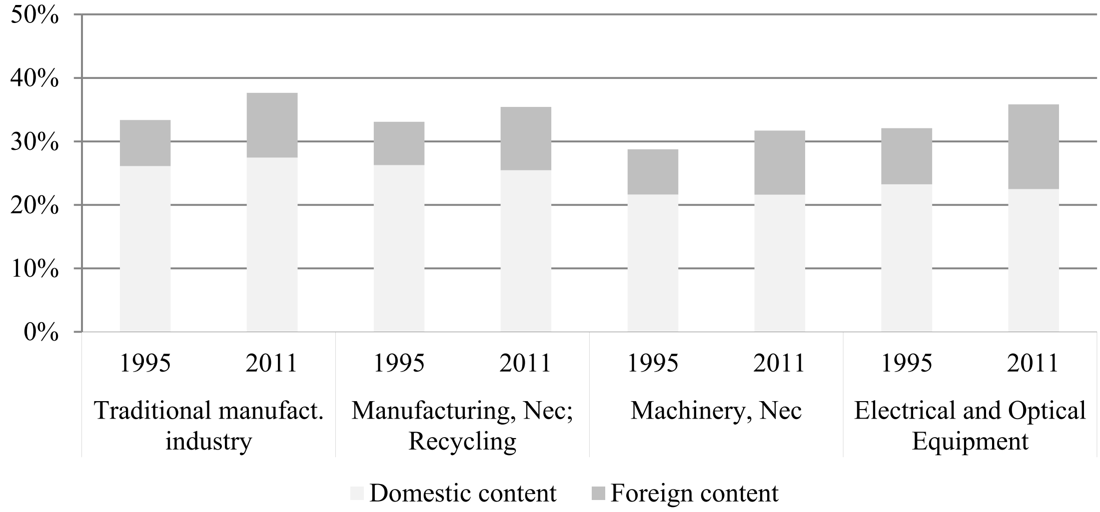
	Sector of origin (1)	Other manufac. industries (2)	Services (3)	Other sectors (4)	Domestic VA (1) to (4)	Foreign VA
Agri-food sector	46.4	4.5	27.0	3.7	81.6	18.4
Traditional manufac. Sector	39.4	3.5	27.5	5.3	75.7	24.3
Manufacturing, nec; recycling	32.0	14.3	25.5	3.5	75.3	24.7
Machinery, Nec	38.6	11.0	21.6	3.1	74.4	25.6
Chemicals	35.7	3.9	25.8	4.7	70.1	29.9
Basic Metals and Fabricated Metal	37.8	6.2	21.3	4.4	69.7	30.3
Electrical and Optical Equipment	30.5	9.3	22.5	3.1	65.3	34.7
Transport Equipment	25.2	8.7	24.0	2.9	60.7	39.3
Total Manufacturing	35.9	-	25.3	7.2	68.5	31.5

Source: Author's calculations based on WIOD (November 2013 release)

Figure 12. Services value-added content of manufacturing goods. Spain, 1995-2011

(share of value added, %)





Source: Author's calculations based on WIOD (November 2013 release).

5. CONCLUSIONS

The fragmentation of production processes across borders and the subsequent emergence of global value chains (GVCs) have changed the way in which countries participate in world trade. This chapter has studied the production and trade specialization patterns of the Spanish economy from the perspective of trade in value added and vertical specialization. Following the methodology proposed by Koopman, Wang and Wei (2014) and with the indicators created from the WIOD database, the analysis focuses on the integration of the Spanish economy and its sectors in global value chains (GVCs) over the period 1995-2011, as well as the implications of its specialization for the creation of value added.

The analysis shows that the Spanish economy is integrated in GVCs and participates actively in vertical trade. The value-added content of Spanish gross exports has declined over the sample period from 79% in 1995 to 70% in 2011. This tendency is shared by the other economies included in the analysis and it is symptomatic of a higher interconnectedness around GVCs. Regarding the vertical specialization, its *backward participation* as measured by the VS index is more relevant than its *forward participation* (as captured by VS1). Spain's foreign dependency, as measured by the intensity in the use of imported intermediate goods for producing exports, has increased by more than 9 percentage points since 1995. In 2011, the foreign value added content of gross exports reached around 30%. On the other hand, its *forward participation*, which measures the share of Spanish intermediate inputs embodied in the exports of other countries, shows a more moderate development and is around 20% in the last years of the period analysed.

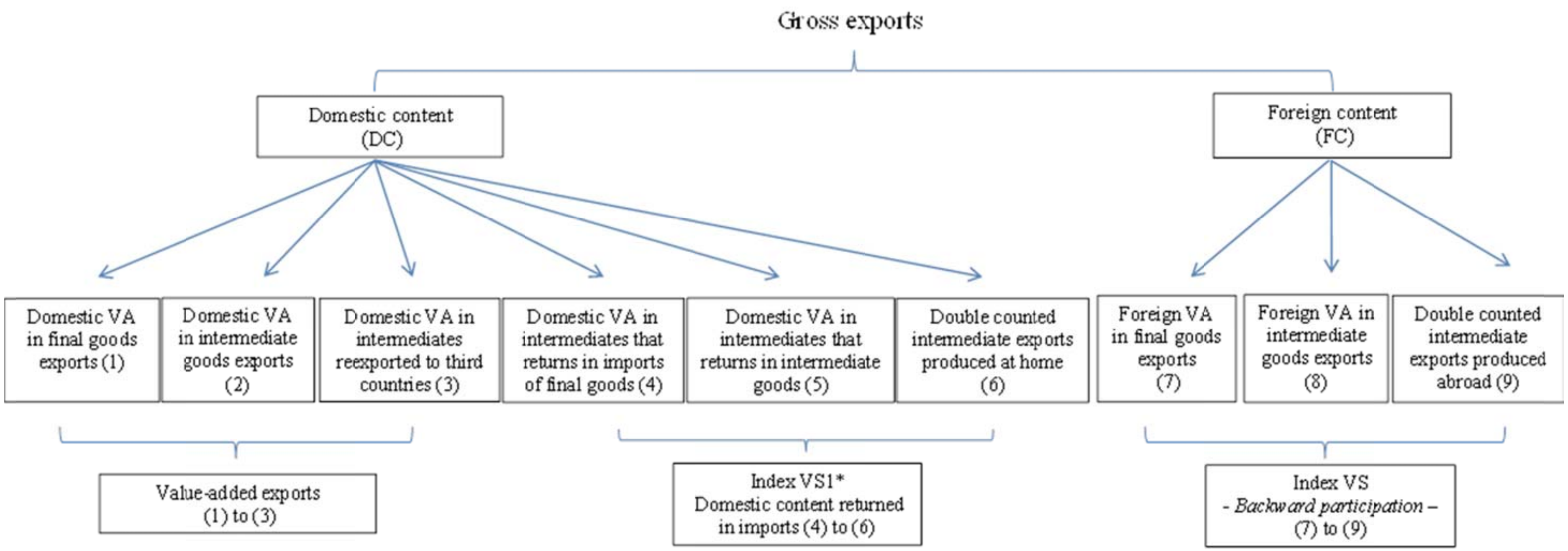
The analysis by sectors shows significant differences between manufacturing and services. Manufacturing is very intensive in the use of imported inputs to produce exports, while services exhibit a greater *forward participation*. These factors lead to a very different capacity to generate value added, which is higher in the services sector. Actually, one of the most striking features from the analysis under a trade in value added perspective is that gross trade statistics underestimate the importance of services: the share of services in gross exports is around 20%, but they account for 50% of total exports when value added flows are considered, since they are embodied in manufacturing exports. This aspect sheds light on the debate about increasing the share of the manufacturing sector in advanced economies, since a significant share of value added has its origin in the services sector. It is clear that services play a crucial role in GVCs as inputs in the production and exports of manufacturing goods. Global production networks rely on transport, logistics, finance, communication, business and other services. Thus, enhancing the efficiency of the services sector becomes more relevant to help improve the competitiveness of Spanish exports.

The industries within these two major sectors also exhibit substantial differences in their participation in vertical trade and the subsequent ability to generate value added. As a result of the country's participation in global production networks, the import content of exports in many sectors has increased. The most intensive industry in the use of imported inputs is *coke and refined petroleum products* with a 76% foreign value added content, followed by *transport equipment, electrical and optical equipment* and *metallic products,* with more than 30%. *Transport equipment* stands out as an important sector for the Spanish economy and its foreign sector, whose production and exports contain almost 40% of foreign value added. These shares reflect a high integration in global value chains.

The use of imported inputs should not necessarily be seen as something negative since it can respond to the use of the advantages of the international division of labour, with each country specializing in tasks according to its comparative advantage, and not to a lack of internal technology. In any case, the higher the import content of production and exports, the lesser the effect of an increase in final demand on the domestic economy, since the revenues obtained from exports may accrue abroad. This may compromise the role of the foreign sector as a driver of growth. However, involvement in global value chains and access to inputs that are produced more efficiently abroad can contribute positively to external competitiveness. Importing intermediates can help to increase domestic value added, since it allows a country to specialize in the part of the value chain where production is more efficient. The reallocation of factors could lead to efficiency improvements, which could promote an increase in the participation of some sectors of the economy in world trade. This constitutes an aspect that deserves further research in the future.

6. APPENDIX

Figure A1. Decomposition of gross exports



Note: Value-added exports are the sum of terms (1) to (3); domestic content in exports equals (1) to (6); terms (3) to (6) are part of VS1, the index that captures *forward participation.* Terms (7) to (9) are the VS (*backward participation*), which is equivalent to the foreign content of exports. Index VS1* stands for the domestic content that returns embodied in imports of intermediate goods (terms (4) a (6)).

Source: Koopman, Wang and Wei (2014).

Table A2. Accounting of gross exports. 2011

(Millions of current $US)

Country name	Country code	DVA in final goods exports (1)	DVA in intermediate exports (2)	DVA in intermediates re-exported to third countries (3)	DVA in intermediates that returns in imports of final goods (4)	DVA in intermediates that returns in intermediate goods (5)	Double counted intermediate exports produced at home (6)	FVA in final goods (7)	FVA in intermediate goods (8)	Double counted intermediate exports produced abroad (9)	Gross exports (1) to (9)
Australia	AUS	38,568	205,778	35,021	1,059	1,102	373	6,877	24,984	13,056	326,818
Austria	AUT	43,451	75,418	19,433	475	309	491	23,549	26,148	22,992	212,267
Belgium	BEL	63,703	106,599	27,643	842	582	1,356	58,377	59,344	52,951	371,397
Bulgaria	BGR	5,379	8,386	1,817	9	7	6	2,951	3,258	2,084	23,898
Brazil	BRA	69,783	154,034	34,039	614	790	172	10,113	15,966	8,942	294,453
Canada	CAN	108,855	263,917	33,532	2,986	2,453	1,581	38,696	47,683	18,467	518,170
China	CHN	743,907	676,226	154,289	12,638	28,114	16,799	203,764	152,015	98,437	2,086,189
Cyprus	CYP	1,418	1,856	267	1	1	0	507	552	266	4,868
Czech Republic	CZE	31,617	41,938	13,629	261	257	535	30,567	23,081	22,945	164,829
Germany	DEU	450,712	539,129	122,317	19,941	13,124	20,787	179,315	143,964	113,690	1,602,979
Denmark	DNK	37,769	50,216	11,075	345	213	394	21,836	25,472	11,797	159,118
Spain	ESP	108,733	128,867	30,682	1,280	1,237	946	46,321	41,121	27,345	386,534
Estonia	EST	2,343	4,391	918	4	3	5	1,228	1,514	1,077	11,484
Finland	FIN	15,689	42,838	9,505	117	106	109	9,095	15,799	11,040	104,298
France	FRA	201,159	226,976	55,016	4,719	3,268	3,085	85,157	62,903	49,176	691,460
United Kingdom	GBR	168,697	303,336	66,767	5,292	3,757	2,179	59,049	52,445	39,953	701,475
Greece	GRC	10,093	19,235	2,831	26	28	5	3,118	5,054	2,171	42,561
Hungary	HUN	22,673	29,983	8,813	97	58	155	21,003	16,171	15,368	114,320
Indonesia	IDN	33,750	129,077	22,692	279	795	191	9,797	14,521	7,687	218,789
India	IND	119,819	119,718	23,805	443	689	273	40,526	22,149	10,666	338,088
Ireland	IRL	40,834	69,548	9,707	77	64	180	37,435	41,622	17,775	217,243
Italy	ITA	195,063	184,786	48,977	2,582	2,084	1,632	69,139	53,294	39,081	596,637

Table A2 (*cont*). Accounting of gross exports. 2011

(Millions of current $US)

Country name	Country code	DVA in final goods exports (1)	DVA in intermediate exports (2)	DVA in intermediates re-exported to third countries (3)	DVA in intermediates that returns in imports of final goods (4)	DVA in intermediates that returns in intermediate goods (5)	Double counted intermediate exports produced at home (6)	FVA in final goods (7)	FVA in intermediate goods (8)	Double counted intermediate exports produced abroad (9)	Gross exports (1) to (9)
Japan	JPN	257,623	379,428	92,770	5,744	5,040	2,494	43,695	69,116	39,575	895,486
Korea	KOR	119,122	197,437	45,609	936	1,075	1,736	67,939	114,749	64,027	612,630
Lithuania	LTU	4,937	7,103	1,348	15	8	8	2,214	2,780	1,892	20,305
Luxembourg	LUX	6,800	23,906	4,284	14	11	35	9,599	33,766	12,103	90,519
Latvia	LVA	2,671	4,425	817	11	6	5	829	1,066	699	10,529
Mexico	MEX	80,889	134,842	20,797	1,518	1,460	926	49,573	37,931	15,689	343,625
Malta	MLT	984	1,986	357	0	0	0	636	965	584	5,513
Netherlands	NLD	111,550	164,843	43,178	2,161	1,245	3,351	78,431	73,041	59,308	537,108
Poland	POL	58,869	67,817	21,013	403	386	487	30,798	24,090	22,969	226,831
Portugal	PRT	15,518	20,885	4,828	101	60	39	6,474	5,651	3,912	57,468
Romania	ROM	14,274	21,432	5,319	56	59	27	4,825	4,597	3,537	54,126
Russia	RUS	39,486	331,411	79,710	2,381	1,813	643	2,967	15,187	11,921	485,518
Slovakia	SVK	13,263	16,754	6,185	70	49	97	11,113	6,968	8,324	62,822
Slovenia	SVN	6,207	7,614	2,227	7	4	8	3,914	2,838	2,494	25,314
Sweden	SWE	51,433	95,944	21,216	482	368	515	28,173	30,246	21,108	249,485
Turkey	TUR	50,280	56,754	14,343	400	244	133	15,267	11,287	8,312	157,020
Taiwan	TWN	40,167	105,916	30,587	369	197	1,034	31,580	75,647	52,711	338,209
United States	USA	463,317	851,744	140,131	51,242	47,406	12,650	100,169	109,385	65,030	1,841,074
Rest of the World	ROW	562,856	1,527,932	242,708	58,202	92,997	41,364	241,779	261,790	167,548	3,197,176

Source: Author's calculations based on WIOD (November 2013 release).

Table A2 (*cont*). Accounting of gross exports. 2011

(Share of gross exports, %)

Country name	Country code	VAX ratio	Domestic value added	Pure double counting (domestic)	Domestic content	Foreign value-added	Pure double counting (foreign)	Foreign content	Vertical specialization indices		
		[1 to 3]	[1 to 5]	[6]	[1 to 6]	[7 to 8]	[9]	[7 to 9]	***VS***	***VS1***	***VS1****
Australia	AUS	85.48	86.14	0.11	86.26	9.75	3.99	13.74	13.74	33.77	0.78
Austria	AUT	65.16	65.52	0.23	65.76	23.41	10.83	34.24	34.24	24.13	0.60
Belgium	BEL	53.30	53.68	0.36	54.05	31.70	14.26	45.95	45.95	20.58	0.75
Bulgaria	BGR	65.20	65.27	0.03	65.30	25.98	8.72	34.70	34.70	21.38	0.09
Brazil	BRA	87.57	88.05	0.06	88.11	8.86	3.04	11.89	11.89	30.04	0.54
Canada	CAN	78.41	79.46	0.31	79.77	16.67	3.56	20.23	20.23	20.54	1.35
China	CHN	75.47	77.42	0.81	78.23	17.05	4.72	21.77	21.77	20.08	2.76
Cyprus	CYP	72.75	72.78	0.00	72.78	21.75	5.47	27.22	27.22	17.25	0.03
Czech Republic	CZE	52.89	53.21	0.32	53.53	32.55	13.92	46.47	46.47	21.20	0.64
Germany	DEU	69.38	71.44	1.30	72.74	20.17	7.09	27.26	27.26	23.14	3.36
Denmark	DNK	62.26	62.61	0.25	62.85	29.73	7.41	37.15	37.15	19.47	0.60
Spain	ESP	69.41	70.06	0.24	70.30	22.62	7.07	29.70	29.70	21.66	0.90
Estonia	EST	66.63	66.70	0.04	66.74	23.88	9.38	33.26	33.26	24.13	0.11
Finland	FIN	65.23	65.44	0.10	65.55	23.87	10.58	34.45	34.45	25.51	0.32
France	FRA	69.87	71.03	0.45	71.48	21.41	7.11	28.52	28.52	21.96	1.60
United Kingdom	GBR	76.81	78.10	0.31	78.41	15.89	5.70	21.59	21.59	29.47	1.60
Greece	GRC	75.56	75.69	0.01	75.70	19.20	5.10	24.30	24.30	19.93	0.14
Hungary	HUN	53.77	53.90	0.14	54.04	32.52	13.44	45.96	45.96	19.23	0.27
Indonesia	IDN	84.79	85.28	0.09	85.37	11.12	3.51	14.63	14.63	30.85	0.58
India	IND	77.89	78.23	0.08	78.31	18.54	3.15	21.69	21.69	18.79	0.42
Ireland	IRL	55.28	55.34	0.08	55.43	36.39	8.18	44.57	44.57	13.65	0.15
Italy	ITA	71.87	72.66	0.27	72.93	20.52	6.55	27.07	27.07	21.78	1.06
Japan	JPN	81.50	82.70	0.28	82.98	12.60	4.42	17.02	17.02	26.36	1.48
Korea	KOR	59.12	59.45	0.28	59.73	29.82	10.45	40.27	40.27	19.32	0.61
Lithuania	LTU	65.93	66.05	0.04	66.09	24.60	9.32	33.91	33.91	19.46	0.15

Table A2 (*cont*). Accounting of gross exports. 2011

(Share of gross exports, %)

Country name	Country code	VAX ratio	Domestic value added	Pure double counting (domestic)	Domestic content	Foreign value-added	Pure double counting (foreign)	Foreign content	Vertical specialization indices		
		[1 to 3]	[1 to 5]	[6]	[1 to 6]	[7 to 8]	[9]	[7 to 9]	***VS***	***VS1***	***VS1****
Luxembourg	LUX	38.66	38.68	0.04	38.72	47.91	13.37	61.28	61.28	12.94	0.07
Latvia	LVA	75.15	75.32	0.05	75.36	18.00	6.64	24.64	24.64	24.19	0.21
Mexico	MEX	68.83	69.70	0.27	69.97	25.46	4.57	30.03	30.03	17.73	1.14
Malta	MLT	60.34	60.35	0.00	60.35	29.05	10.60	39.65	39.65	18.34	0.01
Netherlands	NLD	59.50	60.13	0.62	60.76	28.20	11.04	39.24	39.24	22.73	1.26
Poland	POL	65.11	65.46	0.21	65.68	24.20	10.13	34.32	34.32	23.83	0.56
Portugal	PRT	71.75	72.03	0.07	72.09	21.10	6.81	27.91	27.91	22.14	0.35
Romania	ROM	75.79	76.01	0.05	76.06	17.41	6.53	23.94	23.94	25.63	0.26
Russia	RUS	92.81	93.67	0.13	93.81	3.74	2.46	6.19	6.19	52.72	1.00
Slovakia	SVK	57.63	57.81	0.15	57.97	28.78	13.25	42.03	42.03	25.22	0.34
Slovenia	SVN	63.40	63.44	0.03	63.47	26.67	9.85	36.53	36.53	22.53	0.08
Sweden	SWE	67.58	67.92	0.21	68.12	23.42	8.46	31.88	31.88	24.23	0.55
Turkey	TUR	77.30	77.71	0.08	77.79	16.91	5.29	22.21	22.21	24.80	0.50
Taiwan	TWN	52.24	52.40	0.31	52.71	31.70	15.59	47.29	47.29	21.61	0.47
United States	USA	79.04	84.40	0.69	85.09	11.38	3.53	14.91	14.91	27.73	6.05
Rest of the World	ROW	72.99	77.72	1.29	79.01	15.75	5.24	20.99	20.99	27.59	6.02

Source: Author’s calculations based on WIOD (November 2013 release).

Table A3. Share of sectors in gross output, value added, gross exports and value added exports. Spain, 1995-2011

	Gross output		Value added	
	1995	**2011**	**1995**	**2011**
Primary sector	**4.23**	**2.25**	**5.45**	**2.73**
Agriculture. Hunting. Forestry and Fishing	4.23	2.25	5.45	2.73
Manufacturing	**31.67**	**25.60**	**19.19**	**13.23**
Food. Beverages and Tobacco	6.57	5.12	3.01	2.27
Textiles and Textile Products	1.71	0.61	1.12	0.38
Leather and Footwear	0.74	0.23	0.33	0.13
Wood and Products of Wood and Cork	0.70	0.39	0.44	0.23
Pulp. Paper. Printing and Publishing	2.28	1.61	1.59	1.23
Coke. Refined Petroleum and Nuclear Fuel	1.24	2.37	0.43	0.26
Chemicals and Chemical Products	2.80	2.73	1.83	1.59
Rubber and Plastics	1.13	0.99	0.77	0.59
Other Non-Metallic Mineral	1.69	1.30	1.43	0.83
Basic Metals and Fabricated Metal	3.87	3.84	2.84	2.26
Machinery. Nec	1.55	1.35	1.18	0.99
Electrical and Optical Equipment	2.00	1.25	1.33	0.68
Transport Equipment	4.07	2.88	2.04	1.21
Manufacturing. Nec; Recycling	1.31	0.93	0.85	0.56
Services	**50.59**	**56.40**	**64.86**	**72.12**
Sale. Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	1.87	1.98	1.75	1.79
Wholesale Trade and Commission Trade. Except of Motor Vehicles and Motorcycles	3.70	3.47	4.21	4.09
Retail Trade. Except of Motor Vehicles and Motorcycles; Repair of Household Goods	3.68	3.78	5.34	5.12
Hotels and Restaurants	6.14	6.11	6.93	7.44
Inland Transport	2.66	2.71	2.79	2.56
Water Transport	0.17	0.16	0.14	0.13
Air transport	0.48	0.59	0.34	0.41
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	1.86	2.43	1.52	1.89
Post and Telecommunications	1.56	2.16	2.36	2.22
Financial Intermediation	3.69	3.72	4.85	4.53
Real Estate Activities	5.38	6.03	8.20	10.61
Renting of M&Eq and Other Business Activities	4.98	7.24	5.67	8.51
Public Admin and Defense; Compulsory Social Security	4.34	4.56	6.45	6.64
Education	2.79	2.86	4.95	5.19
Health and Social Work	3.67	4.67	5.01	6.42
Other Community. Social and Personal Services	3.63	3.94	4.35	4.56
Other sectors				
Mining and Quarrying	0.44	0.25	0.42	0.19
Electricity. Gas and Water Supply	2.63	3.71	2.58	3.63
Construction	10.44	11.79	7.50	9.10

Table A3 (*cont*). Share of sectors in gross output, value added, gross exports and value added exports. Spain, 1995-2011

	Gross exports		Value added exports	
	1995	**2011**	**1995**	**2011**
Primary sector	**6.44**	**4.18**	**8.16**	**5.35**
Agriculture, Hunting, Forestry and Fishing	6.44	4.18	8.16	5,35
Manufacturing	**78.78**	**74.05**	**48.09**	**39.96**
Food, Beverages and Tobacco	6.90	7.37	2.73	3,41
Textiles and Textile Products	3.45	3.82	2.16	1,96
Leather and Footwear	2.30	1.17	1.04	0,57
Wood and Products of Wood and Cork	0.64	0.45	0.67	0,46
Pulp, Paper, Printing and Publishing	2.96	1.99	2.86	2,20
Coke, Refined Petroleum and Nuclear Fuel	2.14	8.17	0.98	1,99
Chemicals and Chemical Products	8.35	10.40	5.47	5,96
Rubber and Plastics	2.76	2.75	2.56	2,14
Other Non-Metallic Mineral	3.20	1.85	2.40	1,31
Basic Metals and Fabricated Metal	7.75	9.26	8.14	7,40
Machinery, Nec	5.43	4.36	3.87	3,01
Electrical and Optical Equipment	7.41	5.52	4.36	2,61
Transport Equipment	23.61	15.76	9.81	5,75
Manufacturing, Nec; Recycling	1.88	1.18	1.05	1,18
Services	**14.15**	**20.89**	**39.27**	**49.49**
Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel	0.04	0.20	1.35	1.48
Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles	1.03	0.52	4.05	4.45
Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods	0.38	0.28	4.29	4.70
Hotels and Restaurants	0.01	0.03	0.90	0.72
Inland Transport	1.99	2.71	4.76	4.84
Water Transport	1.12	0.59	0.66	0.44
Air transport	2.06	2.26	1.28	1.39
Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies	1.46	1.82	3.00	3.33
Post and Telecommunications	0.60	0.58	2.03	1.95
Financial Intermediation	0.78	2.39	4.63	4.87
Real Estate Activities	0.05	0.02	2.02	3.02
Renting of M&Eq and Other Business Activities	3.88	8.17	7.82	14.16
Public Admin and Defense; Compulsory Social Security	0.17	0.53	0.62	1.34
Education	0.00	0.00	0.16	0.41
Health and Social Work	0.01	0.01	0.26	0.35
Other Community, Social and Personal Services	0.56	0.78	1.44	2.04
Other sectors				
Mining and Quarrying	0.38	0.44	0.69	0.48
Electricity, Gas and Water Supply	0.10	0.31	2.58	3.24
Construction	0.15	0.12	1.20	1.49

A4. Decomposition of the variation in vertical specialization over time.

The VS index is a weighted average of sectors' VS intensity, where the weights are given by each sector's share in the country's total exports. The variation in *vertical specialization* over time can be attributed to changes in sectors' requirements of imported inputs and changes in the sector composition of overall exports. Hence, the variation in the country's VS index between 0 and T ($\Delta VS^{0,T}$) can be decomposed into changes in the import content of sectors ($\Delta VS_k^{0,T}$) and changes in each sector's weight in total exports ($\Delta\omega k^{0,T}$).

Following a shift-share analysis, the decomposition is given by:

$$VS^t - VS^0 = \underbrace{\Sigma_k\left(\Delta VS_k^{0,t}\right) * 0.5 * (\omega_k^0 + \omega_k^t)}_{\text{Changes in the sector } VS \text{ shares (within sectors)}} + \underbrace{\Sigma_k\left(\Delta\omega_k^{0,t}\right) * 0.5 * (VS_k^t + VS_k^0)}_{\text{Changes in the sector export shares (between sectors)}}$$

where VS^t and VS^0 are the country's VS indices in time *t* and 0, respectively; VS_k is the sector *k*'s VS index and ω_k^0 is the share of sector *k* in total exports.

A sector's contribution to changes in the aggregate VS index can be decomposed into the contribution due to the changes in sectors' VS intensity (the *within* component) and the contribution due to changes in the sectors' shares in the country's export basket (the *between* component).

Chapter 4:

THE DYNAMICS OF INTERNATIONAL RELOCATION OF PRODUCTION: AN ANALYSIS AT THE PRODUCT-LEVEL

Abstract

This chapter studies the dynamics of international relocation of production across countries at different levels of development from an aggregate perspective and at the product and sector level. For that purpose, we calculate product and sector-specific relocation indices using highly disaggregated trade data over two different time periods, 1995-2007 and 1962-2000. Then, we assess the evolution of these indicators to determine the sign and intensity of production relocation. Our analysis also relies on a model of distribution dynamics that allows us to obtain the long-run distribution that arises from products' intra-distribution dynamics. We find that the intensity of production relocation has been surprisingly constant over the two sample periods. However, the stability in the shape of the distribution does not prevent considerable relocation processes at the product level. This chapter also looks into the potential drivers of relocation and finds that international production relocation largely appears as an unpredictable phenomenon.

1. INTRODUCTION

The distribution of world production and trade has experienced major changes during the last decades. Emerging countries have increased their participation in world income and trade, and the export shares of this group of countries have expanded. The production and exports of many manufacturing products has moved from higher to lower-income countries, leading to a continuous process of international relocation of production. This phenomenon has given rise to a large and growing literature that discusses the effects of exposure to international trade and production relocation on specific industries or countries (Feenstra and Hanson (1996, 1999); Gereffi (1999); Bernard, Jensen and Schott (2006); Lall, Albaladejo and Zhang (2004); Marin (2006); Sturgeon, Van Biesebroeck and Gereffi (2008); Autor, Dorn and Hanson (2013); Ebenstein et al. (2014), Timmer et al. (2015); Acemoglu et al. (2016); Pierce and Schott (2016)). However, despite the rich and large literature on this topic, the intensity and dynamics of international relocation processes across sectors or industries have not been analysed in a systematic way. This is the gap that this work intends to fill. Using highly disaggregated trade data over two different periods (1995-2007 and 1962-2000), this chapter studies the dynamics of international relocation of production between richer and poorer countries.

The dynamics of production relocation are potentially driven by different factors. The theoretical literature on trade and growth suggests that comparative advantage is dynamic and evolves endogenously over time. Factors such as sector-specific learning by doing are a source of persistence, while knowledge spillovers and technology transfer would give rise to mobility in international specialization patterns. The latter is at the basis of the *product life-cycle theory* described in Vernon (1966) and in models of technology diffusion (Krugman (1979), Dollar (1986), Jensen and Thursby (1986), Grossman and Helpman (1991a, b), Acemoglu, Gancia and Zilibotti (2012)). The product life cycle theory put forward in Vernon (1966) provided the first analysis of the dynamics of the reorganization of production across countries at different levels of development. In a seminal paper, he argued that most new goods are initially manufactured in the country where they are first developed, with innovations taking place in developed countries. As the demand for a product expands, production techniques standardize and it becomes feasible to shift production to less-developed countries. This shift in production is a profit-maximizing decision from the point of view of the innovating firm aimed at exploiting the wage differential across countries.

Although the international reorganization of production has been reinforced in recent times with production fragmentation and offshoring, the relocation processes at work seem to fit the dynamics described by the product-life cycle theory: the interplay between innovation and standardization lead to a continuous process of international relocation of production. Since goods are produced using a combination of generic knowledge and skills (which are relatively abundant in rich countries) and product-specific knowledge and skills (which are relatively abundant in countries that were specialized in the product in the recent past), the production of different goods involves different degrees of sophistication (or complexity). Therefore, if the sophistication of a product increases, its production will relocate towards the countries with higher human capital or a previous specialization in that product (i.e., these countries will increase their revealed comparative advantage (*RCA*) in that product). On the contrary, standardization leads to relocation towards countries with lower human capital and no previous specialization in the good. Thus, by affecting factor intensities, innovation and standardization change countries' *RCA*, thereby leading to product relocation.

Hence, while some product categories exhibit a strong relocation trend towards low-wage countries, which is likely due to standardization and low innovation intensity in the sector, others products experience a relocation trend towards more advanced economies, which is likely to be the result of product innovation or increasing technical sophistication in the sector. These dynamics are consistent with models of technology diffusion that argue that patterns of trade are determined by a continuous process of innovation and technology transfer. Besides, more recent empirical work finds that plants or industries react to import competition from low-income countries by adjusting their product mix, specializing in products which are more consistent with the country's comparative advantage (see for instance Feenstra and Hanson (1996); Bernard, Jensen and Schott (2006); Pierce and Schott (2016)). This chapter's approach deals with relocation movements in either direction.

The empirical analysis in this chapter intends to answer to several questions related to the phenomenon of international relocation. First, we assess the direction of production relocation to determine if on average, products have experienced an *upward* relocation (towards higher-income countries) or a *downward* relocation (towards lower-income countries). Second, we examine the intensity of the relocation process from an aggregate perspective. In our attempt to characterize the dynamic empirical properties of production relocation, we also rely on a model of distribution dynamics that allows us to assess the degree of persistence or mobility in production relocation and to shed light into the stochastic properties of the long-run scenario that arises from products' intra-distribution dynamics.

The analysis relies on trade data and is conducted over two different sample periods: 1995-2007, for which we have data on around 6-digit 5,000 products, and a longer temporal span (1962-2000), with around 4-digit 600 products. The dynamics of the relocation process over the two sample periods are compared to determine if the spatial reorganization of manufacturing processes has intensified over the last decade. This analysis also enables us to uncover the stochastic process that governs international production relocation. In addition to this general overview, we examine the sign and intensity with which each industry has been affected by this phenomenon.

For that purpose, we calculate product and sector-specific relocation indices. The relocation indices used in this chapter are based on the changes in the average income of the exporters of a product. The idea of these measures is to assess the extent to which a good's production has relocated across countries with different income levels. Thus, for each product, we calculate a weighted average of the GDP per capita of the product's exporting countries, where the weights are given by the revealed comparative advantage (*RCA*) of each country in that product. Then, we consider the change in the average per capita GDP of the exporting countries to assess whether the production of a good has been relocated towards richer or poorer countries. However, GDP per capita tends to grow over time and we are mainly interested in changes in *RCA*. Hence, to isolate the GDP per capita effect, we define a *pure* relocation index that holds constant the GDP per capita of the preceding period, so that changes in *RCA* are the only possible source of changes in this index. Thus, the evolution of this index over time will be used to determine the direction of international production relocation across countries at different stages of development; that is, if products have experienced an *upward* relocation (if higher income countries have increased their *RCA* in these products) or a *downward* relocation (if production has moved towards lower-income countries).

Then, the intensity of international production relocation is analyzed in two stages. First, the intensity of the relocation process is approached through the dispersion observed in the indices at the product-level. Then, the evolution of these indices is more formally analyzed using a model of distribution dynamics, a technique that is typically used in the growth and income convergence literature (Quah (1993, 1996); Jones (1997), among others). This analysis allows us to examine the evolution over time of the entire products' distribution (its shape and intra-distribution dynamics). The study of the intra-distribution dynamics provides evidence on the persistence or mobility in the products' distribution and gives insight into the relocation processes at the product-level. Then, based on the trends observed under the periods analyzed, we can obtain the ergodic or long-run distribution of products by country income groups. Comparing the initial and ergodic distributions over a sample period and, more importantly, comparing these distributions across the two sample periods, allows us to identify the type of stochastic process that drives relocation processes. As we will show, the intensity of international relocation has been relatively constant, and the stability in the shape of the distribution over the two sample periods provides evidence that international production relocation appears as a stochastic stationary process. This stability is compatible with substantial relocation processes at the product level: we observe considerable mobility in the products' intra-distribution dynamics and a great heterogeneity in the relocation dynamics at the sector level.

Finally, we look at the potential determinants of relocation and try to identify the driving forces of this phenomenon. The aim of this analysis is to assess if the sign of future production relocation can be predicted on the basis of some observable measures. This is a relevant question: if we can anticipate which industries are more or less likely to migrate abroad, economic policy can be oriented to prevent the loss of some industries or to attract the production of new goods. For that purpose, we first consider the potential role of a product's initial sophistication or complexity as a determinant of subsequent relocation. Then, we also test if other factors, such as the skill and capital intensity in an industry or its R&D intensity play a role in explaining future relocation. We run industry regressions where these measures are regressed on industry specific relocation indices to assess if production relocation can be predicted based on some product of sector characteristics or, on the contrary, it appears as an unpredictable phenomenon.

The chapter is organized as follows: Section 2 includes a review of the related literature. Section 3 introduces the indices used to measure production relocation and presents the model that will be used for the analysis of distribution dynamics. Section 4 analyzes the relocation process using the indices previously defined and the distribution dynamics model. Section 5 takes a look at relocation patterns at the industry level. Section 6 addresses the potential determinants of relocation and Section 7 concludes.

2. RELATED LITERATURE

The analysis in this chapter relates to different literatures. First, the product life cycle hypothesis (Vernon 1966) and the models of technology diffusion (Krugman (1979), Dollar (1986), Jensen and Thursby (1986), Grossman and Helpman (1991a, b), Antràs (2005), Acemoglu et al. (2012)) provide a theoretical framework for the phenomenon of international relocation. Second, the empirical work in this chapter is related to the literature that addresses the effects of exposure to international trade on countries' economic performance (Bernard, Jensen and Schott (2006); Autor, Dorn and Hanson (2013); Ebenstein et al. (2014); Pierce and Schott (2016), among others) and studies on production relocation of specific sectors (Gereffi (1999); Lall, Albaladejo and Zhang (2004); Sturgeon, Van Biesebroeck and Gereffi (2008); Pavlínek and Ženka (2010), Timmer et al. (2015)). On the other hand, the analysis of relocation dynamics conducted in this chapter is based on a model of distribution dynamics from the cross-country growth literature (Jones (1997); Quah (1993, 1996) among others). This kind of analysis has also been applied to the study of specialization dynamics (Proudman and Redding (2000); Redding (2002)) and trade integration dynamics (Arribas, Pérez and Tortosa-Ausina (2014)).

As mentioned in the introduction, the dynamics of production relocation across countries at different levels of development analyzed in this chapter seem to fit the product life-cycle theory described in Vernon (1966), although this phenomenon has been reinforced in recent times by production fragmentation and the slicing of value chains. The first attempt to formalise the concept of the product cycle was carried out by

Krugman (1979). He developed a general-equilibrium model in which the pattern of trade is determined by a continuing process of innovation and technology transfer. Innovation takes place in rich countries (the North) in the form of production of new goods, which are exported to less developed countries (the South). New products can be produced by South only after a lag. This lag in the adoption of technology by South is what gives rise to trade: the North exports new products and imports old ones.16 The North enjoys a temporary monopoly position (and a positive wage differential) in the production of new goods derived from its ability to exploit new technology. However, changes in the rates of innovation and technology transfer can alter income distribution between regions. To maintain the wage differential and earn higher incomes and grow, rich countries need to continuously improve the type of goods they produce.

Krugman's work has been extended by Dollar (1986), Jensen and Thursby (1986, 1987) and Grossman and Helpman (1991a). More recently, Acemoglu et al. (2012) have studied the interplay between innovation and standardization and their effect on growth. In their model, innovation takes the form of the creation of new goods that, initially, can only be produced by skilled workers. After a process of standardization, new goods can be produced by unskilled workers. Standardization alleviates the pressure on high-skill workers, thereby stimulating further innovation, but at the same time, the anticipation of standardization may discourage innovation because if reduces the potential profits from new products. Although Acemoglu et al. (2012) do not focus on the interactions between advanced and less developed countries (contrary to Krugman and Grossman and Helpman), the fact that innovation and standardization require different types of labor is closely related to this chapter's assumption, according to which product sophistication shocks (innovation or standardization) have an impact on factor intensities. This changes countries' comparative advantage and leads to international relocation of production.

The empirical literature has proposed different alternatives to measure production relocation. For instance, Feenstra and Hanson (1996, 1999) estimate the impact of foreign outsourcing on wage inequality using the share of imported intermediate inputs over total inputs. Ebenstein et al. (2014) define offshore activity in an industry as the

[16] In the model, the technical progress takes the form of the availability of new products rather than an increase in productivity in the manufacturing of old goods; technology transfer turns new goods into old goods.

total employment of foreign affiliates among multinational U.S. firms. With this measure, they examine the impact of globalization (offshoring and trade) on U.S. workers' wages. In Bernard, Jensen and Schott (2006), they focus on import penetration from low-income countries and study their impact in the outcome of US manufacturing plants. The choice of imports from low-income countries instead of the overall level of imports is motivated by the factor proportions framework and the endowment driven trade theory that states that richer countries like United States are expected to produce more capital and skill intensive goods than countries with relatively more abundance of labor. This approach allows them to test the influence of comparative advantage and provide evidence that US plants change their product mix in response to exposure to low-wage country imports. This point is related to the empirical work in this chapter, although we focus on the changes in countries' *RCA* over a given time period, which we suggest are driven by product shocks that affect factor intensities.

On the other hand, the empirical literature that studies the global sourcing strategies of multinational firms typically measures the level of offshoring through the share of intrafirm trade (Marin (2006); Antràs and Helpman (2004); Antràs and Chor (2013)). Blinder and Krueger (2013) have defined a measure of "offshorability" of occupations, which is defined as the ability to perform the work from abroad. A similar measure that has been used to capture the offshorability of occupations is the Routine Task Index (RTI) defined in Autor, Levy and Murnane (2003). Their measure of "routineness" is defined as the percentage share of routine task input in an industry.[17] This measure has been later used Ebenstein et al. (2014) as a determinant of subsequent offshoring to low-income locations: since routine tasks are more easily monitored offshore than more complex tasks, domestic workers engaged in routine activities may be more affected by offshoring and trade.

The empirical literature cited above has made use of rich and highly disaggregated data, at the plant or industry level. However, their analysis is focused on specific countries. Our approach to the measurement of production relocation across country income groups differs from the strategies used in the papers discussed above. We propose a

[17] This index was used to analyze the changes in the demand for workplace tasks in response to a decline in the price of computer capital. They find that an industry's share of routine task is a strong determinant of subsequent computer adoption. Their model predicts that the decline in prices of computer capital led to an increase in the aggregate demand for labor input of nonroutine cognitive tasks and to a decline in the aggregate demand for labor input of routine tasks.

more comprehensive and straightforward measure that is based on the changes in revealed comparative advantages across countries with different income levels. This allows us to study this phenomenon using highly disaggregated trade data over a long temporal span and, contrary to the literature cited above, we provide a more comprehensive perspective of the process of international relocation of production. The evolution of our relocation indices over time enables us to assess the sign and intensity of relocation processes from an aggregate perspective, as well as the changes experienced by specific sectors.

On the other hand, the analysis of the ergodic or long-run distribution allows us to uncover the type of stochastic process that follows international production relocation. The results obtained from this analysis are related to the work in Hanson, Lind and Muendler (2015), although their approach to the study of the dynamics of comparative advantage is much more complex. These authors develop a model that reveals that the shape of comparative advantage is stable across a large sample of countries and over a 40 year period and, at the same time, they observe substantial turnover in countries' top exporting industries. Our conclusions also support that there is great mobility at the product and sector level, which is likely to be the result of continuous product shocks that change countries' comparative advantage. Despite this internal mobility, the overall products' distribution across country income groups presents a stationary distribution in the long-run.

3. METHODOLOGY

3.1.Measuring production relocation

The indices used in this chapter to measure production relocation are based on the changes in the average income of the exporting countries. To calculate an average income, we follow Hausmann, Hwang and Rodrick (2007) (henceforth HHR) and use the exporters' revealed comparative advantage (*RCA*) in a product as weights. Specifically, HHR calculate the sophistication of a good by means of an index called *PRODY*. The *PRODY* index of good *k* in period *t* is defined as:

$$PRODY_k^t = \sum_{c=1}^{C} \frac{RCA_{ck}^t}{\sum_{c=1}^{C} RCA_{ck}^t} GDPpc_c^t, \tag{1}$$

where $RCA_{ck}^{t} = \omega_{ck}^{t}/\omega_{Wk}^{t}$ is the revealed comparative advantage of country c in product k at period t (ω_{ck}^{t} and ω_{Wk}^{t} are the value-shares of product k in country c's exports and world trade, respectively), C is the number of countries and $GDPpc_{c}^{t}$ is the per-capita GDP of country c in constant PPP terms. Thus, the *PRODY* index is a weighted average of the exporting countries' GDP per capita, where the weights are given by the countries' specialization in the product.[18]

In turn, the index of sector s is defined as the weighted average of the 6-digit products' *PRODYs* included in the sector, using the value-shares of each product in the world trade of each sector as weights. That is:

$$PRODY_{s}^{t} = \sum_{k \in s} PRODY_{k}^{t}(\omega_{Wk}^{t}/\omega_{Ws}^{t}), \tag{2}$$

where ω_{Ws}^{t} is the value-share of sector s in world trade.

Note that if the production of a good moves from rich to developing countries, the good's *PRODY* decreases. Conversely, an increase in a good's *PRODY* indicates that its average exporter is now a more developed country. Thus, the rate of variation in each good's *PRODY* is used to measure its production relocation across countries at different stages of development. Specifically, because all the *PRODYs* tend to grow over time as countries' GDP per capita tend to increase, good k's (annual average) relocation index between periods 0 and T, $R_{k}^{0,t}$, is defined as the difference between the growth of product k's *PRODY* and the average growth of world per capita GDP: [19]

$$R_{k}^{0,T} = \frac{1}{T}\log\left(\frac{PRODY_{k}^{T}}{PRODY_{k}^{0}}\right) - g_{W}^{0,T}, \tag{3}$$

where $g_{W}^{0,T} = \frac{1}{T}\log(\sum_{c=1}^{C} GDP_{c}^{t}/\sum_{c=1}^{C} Pop_{c}^{t})$. A positive (negative) $R_{k}^{0,t}$ indicates that the relative income of the average exporter of k has increased (decreased) between periods 0 and T.

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[18] In HHR, the index is presented as: $PRODY_{k}^{t} = \sum_{c=1}^{C} \frac{(x_{ck}/X_{c})}{\sum_{c=1}^{C}(x_{ck}/X_{c})} GDPpc_{c}^{t}$, which is equivalent to the expression in (1).

[19] The "world" in this chapter is made up of the aggregation of exporters in our sample. Thus, GDP per capita for the aggregate "world" is obtained as the sum of GDP divided by the sum of population across all the countries used in the calculation of the *PRODYs*.

In turn, we define the relocation index of sector *s* as the weighted average of the 6-digit products' $R_k^{0,T}$ indices included in the sector:

$$R_s^{0,T} = \sum_{k \in s} R_k^{0,T} \frac{\omega_{Wk}^0 + \omega_{Wk}^T}{\sum_{k \epsilon s}(\omega_{Wk}^0 + \omega_{Wk}^T)}. \tag{4}$$

To capture how the relocation index has evolved in aggregate terms, we define the relocation index for the whole economy as a weighted average of the $R_k^{0,t}$ at the product-level, where the weights are the shares of product *k* in world trade:

$$R^{0,T} = \sum_{k=1}^{K} R_k^{0,T} \frac{\omega_{Wk}^0 + \omega_{Wk}^T}{2}. \tag{5}$$

Note that the change over time in a product's *PRODY* has two potential components: the change in the exporting countries' *RCA* and the change in their per capita GDP. The first component can be interpreted as the *pure relocation* effect because it only depends on the shift of production across countries with different income levels (e.g., lower income countries may increase their *RCA* in the product, while higher income countries decrease their *RCA*), whereas the second component does not involve a migration of production. To measure the first component, we define a variant of the *PRODY* index that we call the *constant income-PRODY*, denoted by *ciPRODY*, which is computed using per capita GDPs of the immediately preceding period and current-period *RCAs*:

$$ciPRODY_k^{0,T} = \sum_{c=1}^{C} \frac{RCA_{ck}^T}{\sum_{c=1}^{C} RCA_{ck}^T} GDPpc_c^0. \tag{6}$$

Then, we define the good *k*'s (annual average) *pure* relocation index $PR_k^{0,t}$ as:

$$\begin{aligned} PR_k^{0,T} &= \frac{1}{T}\log\left(\frac{ciPRODY_k^{0,T}}{PRODY_k^0}\right) \\ &= \frac{1}{T}\log\left(\sum_{c=1}^{C} \frac{RCA_{ck}^T}{\sum_{c=1}^{C} RCA_{ck}^T} GDPpc_c^0 \Big/ \sum_{c=1}^{C} \frac{RCA_{ck}^0}{\sum_{c=1}^{C} RCA_{ck}^0} GDPpc_c^0\right) \end{aligned} \tag{7}$$

Because we keep per capita GDPs constant, $PR_k^{0,T}$ is positive or negative depending only on the changes of RCA_k across exporters with different initial incomes. A negative (positive) $PR_k^{0,T}$ indicates that the production of *k* is moving from richer (poorer) countries, which are decreasing (increasing) their RCA_k, to poorer (richer) countries whose RCA_k is increasing. As in (4), the pure relocation index of sector s is defined as the weighted average of the 6 (or 4)-digit products' $PR_k^{0,T}$ indices included in the sector:

$$PR_s^{0,T} = \sum_{k \in s} PR_k^{0,T} \frac{\omega_{Wk}^0 + \omega_{Wk}^T}{\sum_{k \epsilon s}(\omega_{Wk}^0 + \omega_{Wk}^T)}. \tag{8}$$

The Pure Relocation index for the whole economy is defined as:

$$PR^{0,T} = \sum_{k=1}^{K} PR_k^{0,T} \frac{\omega_{Wk}^0 + \omega_{Wk}^T}{2}. \tag{9}$$

The relocation and pure relocation indices reflect the change in the average income of the exporters of a product. Thus, these indices are used to determine the direction of the international relocation of production across countries with different income levels. The pure relocation index captures exclusively the changes of RCA across exporters, which are potentially driven by technological product shocks (innovation and standardization) that affect products' factor intensities. The difference between the R and PR can be attributed to other product shocks that affect countries' GDP pc without products experiencing any relocation (for instance, demand shocks affecting a product's price).

In turn, the intensity of the international production relocation process at a given point in time can then be assessed by measuring the dispersion of the $R_k^{0,T}$ and $PR_k^{0,T}$ indices. This dispersion is calculated using the mean absolute deviation (MAD), using as weights the average share of each product in world trade (the formula is analogous for the $PR_k^{0,T}$ indices):

$$MAD(R^{0,T}) = \sum_{k=1}^{K} \left| R_k^{0,T} - \left(\sum_{k=1}^{K} R_k^{0,T} * \frac{\omega_{Wk}^0 + \omega_{Wk}^T}{2} \right) \right| \frac{\omega_{Wk}^0 + \omega_{Wk}^T}{2}. \tag{10}$$

A higher dispersion of the relocation indices reflects a more intense relocation across the exporting countries' income groups. Similarly, we can measure the intensity of the international relocation within sector s by calculating the MAD of the $R_k^{0,T}$ of the goods in that sector:

$$MAD_s(R^{0,T}) = \sum_{k \in s} \left| R_k^{0,T} - \left(\sum_{k \in s} R_k^{0,T} * \frac{\omega_{Wk}^0 + \omega_{Wk}^T}{\omega_{Ws}^0 + \omega_{Ws}^T} \right) \right| \frac{\omega_{Wk}^0 + \omega_{Wk}^T}{\omega_{Ws}^0 + \omega_{Ws}^T}. \tag{11}$$

The contribution of each sector to the global transformation of international trade not only depends on the intensity of the sector's international relocation but also on the sector's weight in world trade. The contribution of each sector to the global intensity of production relocation as measured by $MAD(R_k^{0,T})$ is calculated as follows (the formula is analogous for the $PR_k^{0,T}$ indices):

$$Contribution\ of\ s\ to\ MAD(R_k^{0,T}) = \frac{\sum_{k \in s} \left| R_k^{0,T} - \left(\sum_{k=1}^{K} R_k^{0,T} * \frac{\omega_{Wk}^{0} + \omega_{Wk}^{T}}{2} \right) \right|}{\sum_{k=1}^{K} \left| R_k^{0,T} - \left(\sum_{k=1}^{K} R_k^{0,T} * \frac{\omega_{Wk}^{0} + \omega_{Wk}^{T}}{2} \right) \right|}. \qquad (12)$$

The sum of all sectors' contribution adds up to one.

3.2. Empirical modelling of relocation dynamics.

The dynamics of the cross-section distribution of the *PRODYs* are analyzed using a Markov chain method. This analysis enables us to address a variety of issues relating to relocation dynamics. Specifically, we examine the changes in the overall distribution (the evolution of the external shape of the products' *PRODYs*), as well as the mobility or persistence within products (the intra-distribution dynamics) based on the estimation of transition probability matrices. These transitions reflect how products switch across country income groups and therefore, the matrices give the probabilities of products undergoing *upward* and *downward* relocations.

Then, based on the trends observed in the periods analyzed, the hypothetical long-run distribution of products' *PRODY* can be obtained. This provides evidence on the distribution of world trade across country-income groups. Different scenarios may arise: if there is a tendency towards a concentration of exports in a specific income group, the long-run distribution will yield a higher probability in certain product categories. On the contrary, if there are *upward* and *downward* product relocations (driven by a continuous interplay between innovation and standardization) the probability of being in a particular cell will be roughly the same across all product categories. Finally, comparing the results obtained in the two sample periods sheds light into the stochastic properties of production relocation.

A product's index of sophistication at time *t* is denoted by $PRODY_k^t$. λ_t refers to the cumulative distribution of $PRODY_k^t$ across products in period *t.* We divide the set of values of $PRODY_k^t$ into a finite number of cells $k \in \{1, \dots, K\}$ and define P^* as the transition probability matrix which is time invariant, such that $\lambda_{t+\tau} = P^* \lambda_t$, where λ_t is a Kx1 vector of probabilities that a product is located in a given cell at time *t.* The entries of the P^* matrix, p_{ij}, denote the probability that a product beginning in cell i moves to cell *j.* Thus, each row of the matrix is a vector of transition probabilities, which add up to one.

Once each product-year observation is classified into one of the K states, the matrix can be estimated by counting the number of transitions out of and into each cell. We chose to divide the sample in quintiles ($K = 5$); these categories are defined over all products and year observations. Thus, the cut-off values of the categories are the same in every subperiod. Transitions are estimated over 5-year periods ($\tau = 5$); that is, we evaluate transitions from state i to state j after 5 years. If we take the limit $\tau \to \infty$ in the expression $\lambda_{t+\tau} = (P^*)^\tau \lambda_t$, we obtain the implied ergodic distribution of the *PRODYs.* The ergodic distribution represents the stationary distribution to which patterns of relocation will evolve if the dynamics represented by the transition matrices went on indefinitely. This long-run distribution corresponds to the eigenvector associated to the largest eigenvalue of the transition probability matrix.

Finally, to summarize the overall degree of mobility of the distribution, we calculate two indices of mobility that have been proposed by the literature of income inequality (Shorrocks, 1978; Geweke et al. 1986; Quah, 1996). The mobility indices collapse the information in matrix P into a scalar $M(P)$ and provide a ranking with respect to mobility: $M(P_1) > M(P_2)$ means that P_1 exhibits greater mobility than P_2. The first of these indices evaluates the trace of the transition probability matrix. It is defined as:

$$M^1 = \frac{K - tr(P^*)}{K - 1},$$

where *tr* is the trace of the transition probability matrix. A value of 0 indicates absence of mobility (if $K = 5$, and no product moves from its initial state, the trace of the matrix is 5 (all elements on the diagonal are equal to 1)). A value of 1.25 (the maximum) indicates perfect mobility (all products change their state every 5 years). The higher is *M*, the less persistence is there in $P*$. The second index, which we denote by M^2, evaluates the determinant, *det*, of the matrix. This index ranges between 0 (absence of mobility) and 1 (perfect mobility):

$$M^2 = 1 - |\det(P^*)|.$$

3.3. Data

Trade data for the analysis of production relocation comes from two sources. For the more recent period (1995-2007), the *PRODY* and *ciPRODY* indices are constructed with the data from BACI (Base pour l'Analyse du Commerce International, Gaulier and Zignago (2010)), a database provided by CEPII (Centre d'Études Prospectives et d'Informations Internationales). The original data in BACI come from the United Nations Statistical Division (COMTRADE database), over which an harmonization procedure is applied for reconciling the data reported by the exporting and importing countries in order to generate a single figure consisting of each bilateral flow in FOB values. We use the Harmonized System (HS)-1992 classification, which comprises more than 5,000 goods at the 6-digit level.

To construct the *PRODY* and *ciPRODY* indices for the previous period (1962-2000) we use the NBER-UN database "World Trade Flows: 1962-2000" developed by Feenstra et al. (2005) from United Nations trade data. It consists of a set of bilateral trade data by commodity at the 4-digit Standard International Trade Classification, revision 2 (SITC Rev. 2) for the period 1962-2000. The NBER-UN dataset is constructed from United Nations trade data over two periods: data for the early years (1962-1983) were classified by SITC Rev. 1 and converted to SITC Rev. 2 and are taken from UN data collected at various times; data for 1984-2000 was purchased from current UN Comtrade data, provided that trade flows exceeded $100.000 per year.[20] The country codes are similar to the United Nations Classification. However, for some countries a harmonization of codes has been applied.[21]

Unlike BACI, the NBER-UN database has not been built in a reconciliation perspective. As explained in Feenstra et al. (2005), in the construction of the NBER-UN dataset the authors give primacy to the importers' reports if they are available, since these are assumed to be more accurate than reports by the exporter. If the importer report is not available for a country pair, the corresponding exporter report is used. However, as stated in the methodology of the construction of BACI, the evolution of the total world trade according to these two databases is rather convergent. In general, the values of

[20] As explained in Feenstra et al. (2005), these limits were due to budget constraints.

[21] Country codes in NBER-UN database consists of 6 digit codes, which not always match with the UN codes. For further details, see the correspondence table in the Appendix A in Feenstra et al. (2005).

trade in the NBER database are higher than in BACI, which could be explained by the absence of harmonization of flows, i.e. the fact that CIF costs are not removed from NBER data. Actually, the difference with BACI is around 2%, close to the mean CIF estimated by BACI.[22]

Data on GDP per capita for the period 1995-2007, measured in 2005 prices PPP, come from the World Bank's World Development Indicators (WDI). For the period 1962-2000, data on GDP per capita from the Penn World Tables (PWT 8.1) are used.[23] To calculate the *PRODYs*, we look for a consistent sample of countries offering trade information over all the reference period (1995-2007 or 1962-2000) and having a population of at least 500,000 inhabitants.[24] As emphasized in HHR (2007), it is essential to use a consistent sample of countries to avoid index changes due to a changing composition of the sample. Moreover, since non-reporting is likely to be correlated with income, constructing *PRODY* using a different set of countries at different points in time could introduce serious bias into the index.

For the years 1995-2007, a group of 141 countries report trade data over all the reference period, but the variable GDP (which is used in the construction of the *PRODY* indices) shows a number of potential outliers that appear to be the result of important shocks on some countries, especially in the 90s, such as civil wars, large ethnic conflicts or the traumatic dismemberment from the Soviet Union, as well as the discovery of natural resources. Including these countries in the calculations of the *PRODY* can distort the indices and the subsequent analysis.

To check for potential outliers in our sample, we identify the countries whose value for the output gap deviated more than three times the interquartile range from the sample median of the corresponding variable. The output gap is calculated as actual GDP over Hodrick-Prescott filtered GDP at each 3-year subperiod from 1995-1997 to 2005-2007. The output gap outliers are Liberia, Tajikistan, Azerbaijan, Ukraine, Georgia, Rwanda,

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22 See Gaulier, G., & Zignago, S. (2010). BACI: International Trade Database at the Product-Level (The 1994-2007 version).

23 In PWT, data for pc GDP is available from the expenditure side, which allows comparison of relative living standards across countries and over time and from the output side, which allows comparison of productive capacity across countries and over time. We use GDP at chained PPPs (in 2005 US$) measured from the output-side.

24 The reason for excluding countries with less than 500,000 inhabitants is that their productive structure is more volatile. Besides, they are typically small islands where tourism is the main activity.

Kyrgyz Republic, Belarus, Moldova, Turkmenistan, Guinea Bissau, Chad, Russia, Kazakhstan, Sierra Leona, Uruguay, Togo, Argentina, Angola and Venezuela. Thus, we end up with a sample of 121 countries, which will be used in the construction of the *PRODY*s for the whole period. Nonetheless, results of the analysis will also be presented using the whole sample of 141 countries in the construction of the *PRODY*s as a robustness test. The list of countries can be found in the Appendix (Table A1).

For the period 1962-2000, the sample of countries available is more limited. Besides, some countries have been excluded from the analysis because their territorial entity has changed over the period of analysis. The dissolution of the Union of Soviet Socialist Republics (USSR) led to the independence of the former Soviet republics; some countries resulting from the dismemberment split into two (e.g., Czechoslovakia) and formerly divided states have reunified (the Federal and the Democratic Republic of Germany). The criterion that has been adopted is to exclude the countries that divide or unite over the sample period. This leaves us with a sample of 97 countries that reported trade data over all the reference period. However, seven of them are excluded because they have a population of less than 500.000 inhabitants (Barbados, Fiji, Gabon, Gambia, Guinea Equatorial, Iceland and Malta).

The same procedure for identifying outliers is applied to this sample of 90 countries. The output gap of Nigeria, Iran, Congo, Syria, Sierra Leona, Argentina, Cyprus, Jordan, Zambia and Morocco deviated more than three times the interquartile range from the sample median in at least two 3-year subperiods over the sample period 1963-1999. These countries are excluded from the analysis and the sample is reduced to 80 countries. China, Egypt, Mauritania, Mauritius, Norway, El Salvador, Chad and Democratic Republic of Congo appear as outliers in only one subperiod. Given that the temporal span from 1962-2000 is larger and the sample is more limited, we do not exclude those countries. Only countries that appear as outliers in at least two subperiods are excluded. The list of countries can be found in the Appendix (Table A2).

The *PRODYs* and *ciPRODYs* are calculated using average trade data of three years to attenuate the potential distorting effect of atypical values that may arise from unusual exports in a given year. Our analysis ends in 2007 to avoid the impact of the Great Recession. We assign each three-year average index to the central year of the corresponding period (for instance, *PRODYs* calculated using average data for the period 1995-1997 are referred as *PRODY*s for the year 1996). Thus, although our analysis draws on data from 1995 to 2007 (1962 to 2000), we refer to 1996-2006 (1963-1999) as the period of analysis.

3.4. Classifications

As mentioned before, data for 1995-2007 come from BACI (CEPII). The data is presented according to the HS Classification. For the period 1962-2000, data from the NBER-UN World Trade Flows database are used, which is classified under the SITC Rev. 2. The level of disaggregation available in these classifications is quite different. In the HS, there is detailed data on more than 5,000 products at the 6 digit-level. Those products are grouped into 2-digit chapters (96 chapters) and 1-digit sections (21 sections). The number of products in the SITC Rev. 2 is 1276, although this includes several product categories that represent “residual” trade. Products are grouped into 2-digit divisions (69 chapters) and 1-digit sections (10 sections).

In order to analyse the relocation process at the product level over the periods 1995-2007 and 1962-2000, we have to keep a constant sample of products; otherwise, changes in the indices could be due to a changing composition of the product sample. Because we look for a consistent sample of products that were exported every year by at least one country over the whole reference period, we exclude the products that do not appear in the statistics of world trade in one or more years between 1995 and 2007 and 1962 and 2000. For the period 1995-2007, the list of 6-digit products for which we construct the indices comprises 4,996 products out of the 5,036 products in the original list of the HS92 classification (5,000 when the 141-country sample is used). These 4,996 products represent the 99.9% of world trade during these years.

The number of products which are available every year from 1962 to 2000 is 508. From 1962 to 1983, these products account for 76%-72% of total world trade, around 60% from 1984 to mid-nineties, and only 50% until 2000. Since working just with 50% of world trade is quite restrictive, we take into account the rest of world trade by creating a new product code at the 2-digit level that captures the sum of the products in an industry which are not available every year. To do so, we calculate total trade at the 2-digit level using all the information available each year (that is, all the products that are traded in each year). Then, we calculate trade at the 2-digit level only with the constant sample of products. The difference between these two figures is attributed to a different product category. We create a code that combines the first two digits of the SITC with an ending of Y (00Y, 01Y, 16Y, etc.). By creating this Y codes, we end up with a sample of 565 products at the 4-digit level. This adjustment follows the same procedure used in the NBER-UN database (Feenstra et al. 2005) for the creation of the A and X codes.[25]

In turn, for the 1996-2006 period, we consider an 18 sector classification that results from amending the 21 sections in the HS92 classification by breaking into two sectors some sections that are quantitatively very important while merging other sections that encompass a very small share of international trade. Specifically, section 6 is split into pharmaceuticals and the rest of the chemicals; section 15 into iron and steel, on the one hand, and the rest of metals and its manufactures, on the other; section 16 (machinery) into electrical equipment and mechanical appliances; section 17 (transport equipment) into motor vehicles and the rest of transport equipment. Conversely, we group together sections 8, 11 and 12 (leather, textiles and footwear); sections 9 and 10 (wood and paper); sections 13 and 20 (furniture and other manufactures and stones); and sections 3, 14, 19 and 21 (fats and oils, pearls, arms and works of art). This last sector is called *miscellanea*. Table A3 in the Appendix shows the HS sector classification. Alternatively, the relocation indices are calculated only for the manufacturing sector; that is, sections 1 (live animals), 2 (vegetable products), 3 (fats and oils), 5 (minerals), 14 (pearls) and 21 (works of art) will be excluded.

For the 1963-1999 period, products under the SITC Rev. 2 are originally grouped into 10 sections, which is a very aggregate and rather uninformative classification for our purposes. Thus, we consider an alternative classification that enables us to work with a similar sector detail over the two sample periods. This classification is the result of breaking down into two or more sectors some of the ten SITC sections. Specifically, section 5 (chemicals and related products) is split into pharmaceuticals, plastics and the rest of the chemicals; section 6 (Manufactured goods classified chiefly by material) is

[25] For the later years in the NBER-UN dataset (1984-2000), trade flows at the 4-digit level are excluded if they are less than $100,000 per year. As a result, for some products the sum across the 4-digit flows does not add up to the corresponding flow at the 3-digit level. To deal with this inconsistency, an adjustment is made by creating an artificial code that combines the first 3 digits of the SITC with an ending of X that stands for “extra trade”. This residual category represents the difference between the 3-digit and the 4-digit flows. Another set of codes is created for the cases in which trade flows are available at a higher level of aggregation (3 or 2-digit), but no data is reported at the 4-digit level. An additional SITC is created which combines the beginning of the 3-digit SITC with an ending of A.

broken down into four sectors: leather and textiles, which are grouped with articles of apparel and footwear from section 8; wood and paper, iron and steel and the rest of manufactured goods. Section 7 (machinery and transport equipment) is split into electrical equipment, mechanical appliances, motor vehicles and the rest of transport equipment. Section 8 (miscellaneous manufactured articles, excluding apparel and clothing, which are grouped with leather and textiles) is split into instruments and the rest of manufactured articles. Table A4 in the Appendix shows the resulting 19 sector classification.

4. DYNAMICS OF INTERNATIONAL RELOCATION OF PRODUCTION

This section turns to the analysis of the dynamics of the international relocation of production over the two sample periods (1996-2006 and 1963-1999) using the relocation indices that were defined in subsection 3.1. Subsection 4.1 presents the evolution of the relocation and pure relocation indices to determine the sign of production relocation. Subsection 4.2 focuses on the intensity of the relocation process as measured by the mean absolute deviation (MAD) of the relocation indices. In subsection 4.3, we formally assess the intra-distribution dynamics of the relocation process using the transition probability matrices and the mobility indices. The ergodic or long-run distribution is also analyzed to determine the kind of stochastic process that follows production relocation.

4.1. Direction of production relocation, 1996-2006 and 1963-1999.

This section studies the sign of the international relocation of production over the periods 1996-2006 and 1963-1999 based on the evolution of the relocation indices. The aim of this analysis is to determine if, on average, production has moved towards higher or lower-income countries during the periods analyzed. Recall that an increase in the Relocation (*R*) or Pure Relocation (*PR*) index of a product means that higher-income countries have increased their *RCA* in that product (*upward* relocation), whereas a decrease in the relocation indices indicates that lower-income countries have increased their *RCA* and the product has experienced a *downward* relocation.

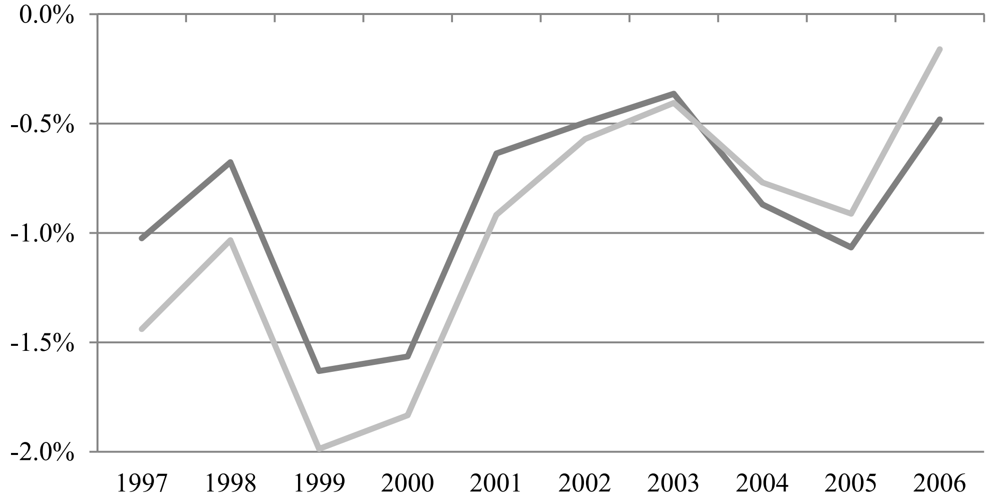
Figure 1 shows the evolution of the Relocation (*R*) and Pure Relocation (*PR*) indices for the total economy over the period 1996-2006, using the whole sample (141 countries) and the sample that excludes the output gap outliers (121 countries). Although the indices are presented as an aggregate for the whole economy, they are calculated using data at the 6-digit level disaggregation, following the expressions (5) and (9), respectively. The Pure Relocation Index (PR) is calculated as a chained index: in each year we keep constant the GDP per capita of the immediately preceding period. By construction, the evolution of the R and PR may differ: changes in RCA are the only possible source of changes in the PR index, whereas changes in R may also reflect changes in countries' GDP pc that do not involve any product relocation. The difference between the R and PR can be attributed to product shocks other than innovation and standardization that, contrary to those, do not lead to production relocation.

The evolution of the relocation and pure relocation indices in Figure 1 exhibit a similar trend. The mean of the relocation indices is around -1% and the conclusions are the same with the two country samples: the negative values for $R^{0,t}$ and $PR^{0,t}$ indicate that production has moved, on average, from richer to poorer countries over the period 1996-2006. Based on the results in Figure 1, the income of the average exporter has decreased by 0.9% during the 1996-2006 period.

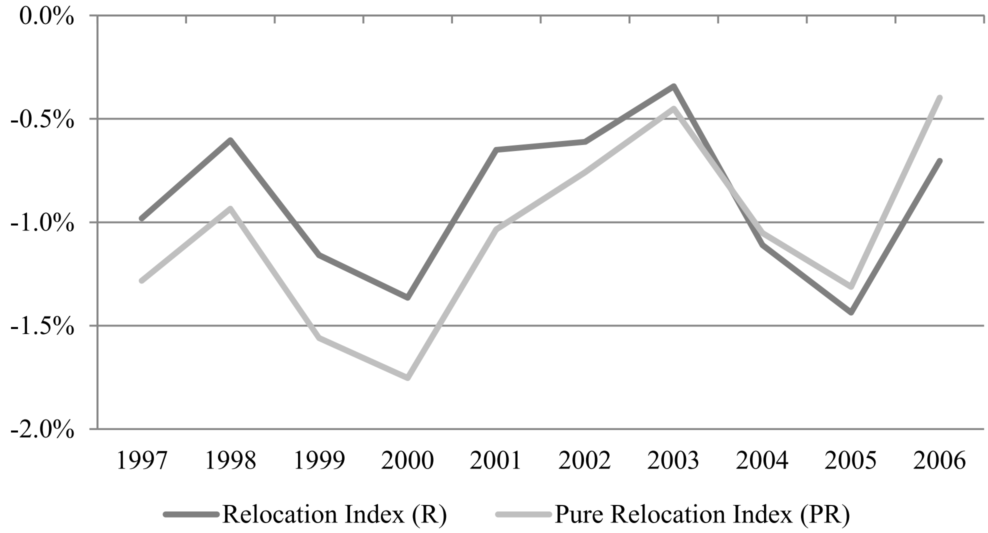
It is often argued that manufacturing sectors are more prone to fragmentation and relocation than other industries. Thus, to check that the analysis is not affected by the inclusion of other industries which are less likely to undergo relocations (minerals, for instance), we exclude sections 1 (live animals), 2 (vegetable products), 3 (fats and oils), 5 (minerals), 14 (pearls) and 21 (works of art) and calculate the relocation index only for the manufacturing sectors. Results are shown in Figure 2. The evolution of the relocation index for the total economy (calculated as a weighted average of the relocation indices for all products) is very similar to that of the relocation index for the manufacturing industries (calculated as a weighted average of the relocation indices for all the products in sections 4, 6, 7 to 13, and 15 to 20). Thus, the rest of the analysis is based on all the sections included in the HS 1992.

Figure 1. International Relocation of Production, 1996-2006. 141-country sample vs. 121-country sample.

a) 141-country sample.

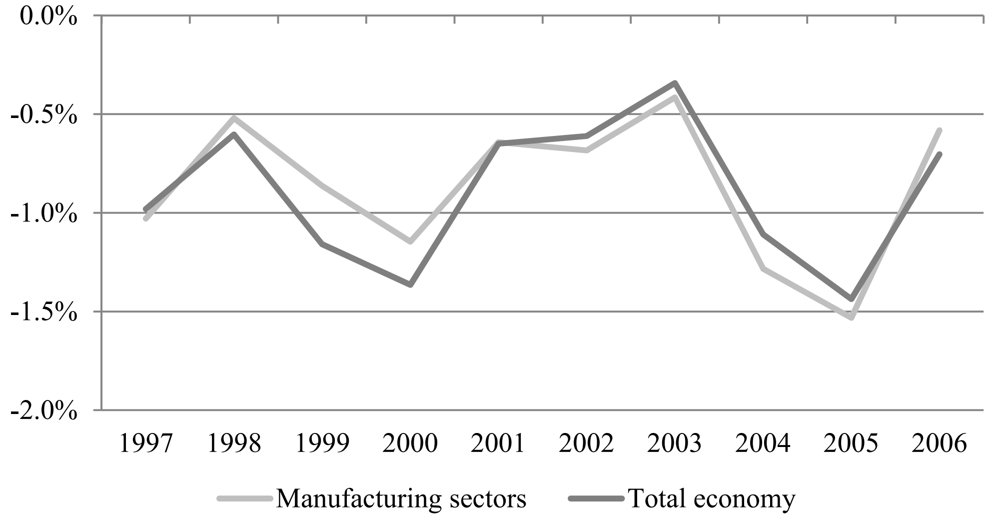


b) 121-country sample.



Note: International Production Relocation is measured by the Relocation Index $R^{0,t}$, following the formula in (5). Pure Relocation is measured by the Pure Relocation Index $PR^{0,t}$, following the formula in (9).

Figure 2. International Relocation of Production, 1996-2006. Total economy and manufacturing sectors.

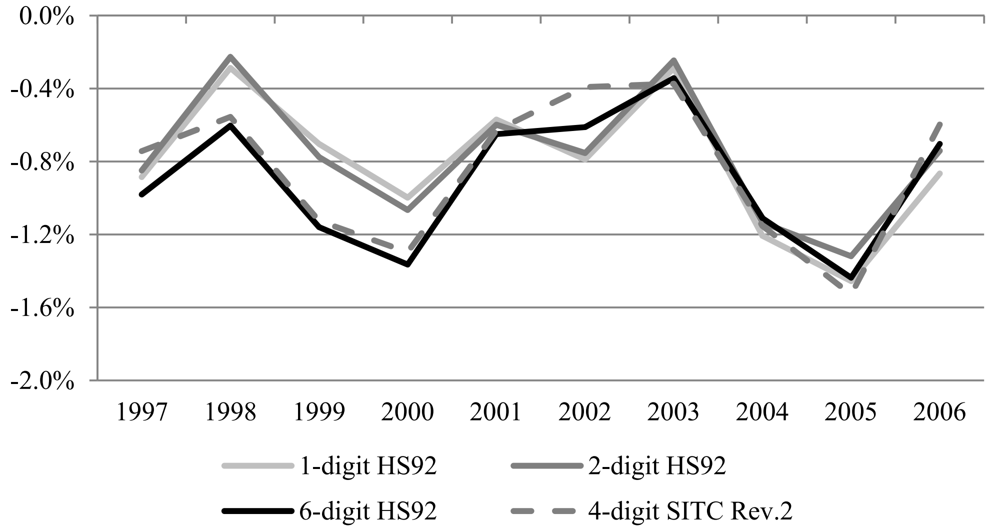


Note: International Production Relocation is measured by the Relocation Index $R^{0,t}$, following the formula in (5). The calculations are based on the 121 country sample.

Before turning to the analysis of international production relocation over the period 1963-1999 using 4-digit data under the SITC Rev. 2, we check if this level of disaggregation allows us to capture the phenomenon we are trying to characterize. To do so, we apply the correspondence between the HS92 and the SITC Rev. 2 to convert the 6-digit data from BACI into 4-digit data for the 1996-2006 period, to see how the evolution of the relocation indices looks like with this level of disaggregation. The nearly 5,000 products available in BACI turn into 774 products under the SITC Rev.2 classification.

Figure 3 compares the relocation indices calculated from the HS 6-digit data with the indices obtained after converting the data into the SITC. Despite the lower disaggregation available and the fact that we are comparing data from two different international commodity classifications, the evolution of the relocation index for the total economy is very similar. The correlation between them is 96.6%. Nonetheless, data at the 1 or 2-digit level are also relatively similar, except for the first years, where the 6-digit and 4-digit data indicate a greater relocation trend towards lower-income countries.

Figure 3. International Relocation of Production, 1996-2006. Different disaggregation levels.



Note: International Production Relocation is measured by the Relocation Index $R^{0,t}$, following the formula in (5). The 1-digit line is obtained using data for 18 sectors as explained in Subsection 3.4, whereas the 2-digit and the 6-digit lines correspond to data for the 96 industries and 5,000 products, respectively, in the HS-92 classification. The 4-digit line corresponds to the 774 products in the SITC Rev.2 classification. The calculations are based on the 121 country sample.

Figure 4 shows the evolution of the Relocation (*R*) and Pure Relocation (*PR*) indices for the total economy over the period 1963-1999, using the "World Trade Flows: 1962-2000 database". As in Figure 1, results are presented for the whole sample (90 countries) and the sample that excludes the output gap outliers (80 countries). The indices are calculated using data at the maximum level of disaggregation available in the database (4-digit level), following the expressions (5) and (9), respectively.

Panels a) and b) in Figure 4 show a quite divergent evolution of the *R* and *PR* indices. The difference between *R* and *PR* arises because of a different evolution of the average world income and the average exporter's income by product groups.[26] The divergence can be explained by other product shocks that affect countries' GDP pc without products undergoing any relocation; for instance, product demand shocks that affect the product's prices and the income of the exporters without leading to production relocation. It is also remarkable the peak that appears in 1983 in both series, regardless of the country sample used. This peak could reveal a break in the series, as the data in

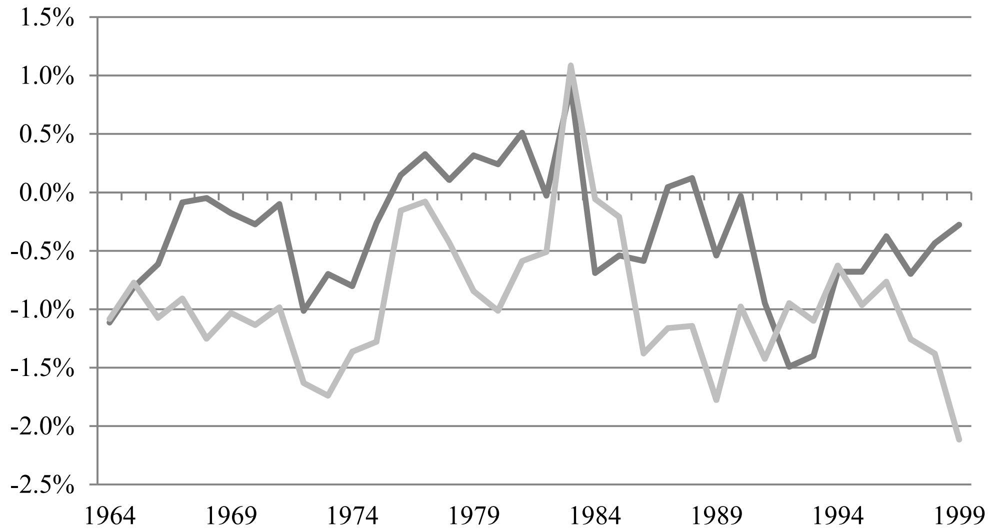
[26] Recall that the "world" in this chapter is made up of the aggregation of exporters in our sample. However, the evolution of world income may differ from the evolution of exporters' income by product groups because of the different country composition within products.

this dataset has been constructed over two different periods (1962-1983 and 1984-2000).[27] However, it is more likely to be related to the oil crisis in 1979. A plausible hypothesis is that advanced countries made an effort to increase their exports to compensate the collapse that followed the oil crisis at the same time that they tried to reduce their imports.[28]

The negative values for the $PR^{0,t}$ index and, in most years, also for the $R^{0,t}$, indicate that there has been a relocation of production towards low-income countries over this period. On average, the *PR* index fluctuates around a mean of -1%, with the exception of the period comprised between 1975 and 1985 (the mean of the *PR* index during this period is -0.4%). This indicates that the income of the average exporter has decreased by 1%, which is similar to the conclusions obtained using the more recent sample period.

Figure 4. International Relocation of Production, 1963-1999. 90-country sample vs. 80-country sample.

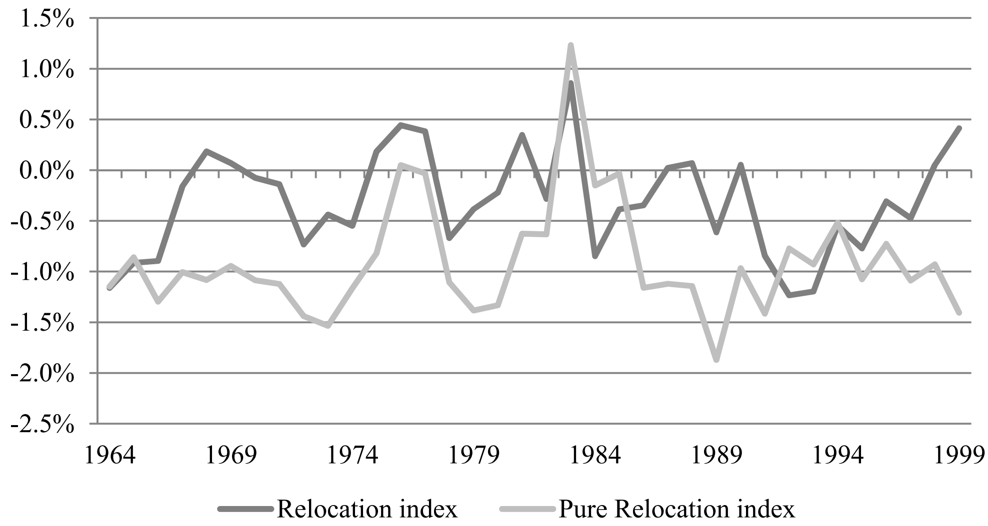
a) 90-country sample.



[27] In Kehoe and Ruhl (2013), the authors point to a critical inconsistency that arises in some databases (as the one used in this chapter) due to the adoption of the HS. The adoption of this system has introduced a break in trade series around the year 1988. However, the peak observed in Figure 3 cannot be attributed to this phenomenon, since it is appears before.

[28] This hypothesis is consistent with the evolution of world trade shares during this period: within this country sample, the participation of high income countries fell after the oil crisis and then slightly rebounded until the beginning of the nineties, when their share started to decrease again.

b) 80-country sample.

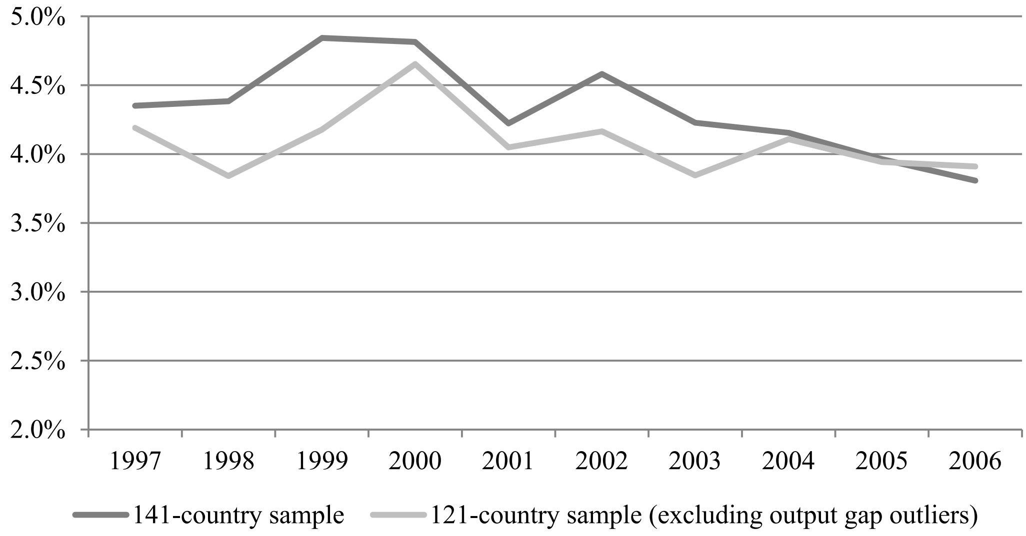


Note: International Production Relocation is measured by the Relocation Index $R^{0,t}$, following the formula in (5). Pure Relocation is measured by the Pure Relocation Index $PR^{0,t}$, following the formula in (9).

4.2.Intensity of production relocation, 1996-2006 and 1963-1999.

The intensity of production relocation can be approached using a measure of dispersion of the relocation indices. As explained in Section 3.1, the dispersion across products' relocation indices provides evidence on the intensity of production relocation: a higher (lower) dispersion reflects a more intense relocation across country income groups. Figure 5 shows the evolution of the intensity of the international production relocation over the period as measured by the mean absolute deviation (MAD) of the relocation indices, using the two country-samples over the period 1996-2006. The intensity of relocation is larger in the 141-country sample, especially until 2000. It is precisely in this first part of the period where there are a larger number of outliers (some African countries and post-soviet countries from the dismemberment of the USSR). Although the evolution of the index is quite similar in both samples, including those countries in the analysis could be artificially raising the value of the index due to factors that are not related to production relocation. Thus, the rest of the analysis in this subsection is presented for the sample that excludes the output gap outliers. Results are reported for the MAD of the relocation indices; the MAD of the pure relocation indices is very similar. This suggests that the MAD of other product-shocks, which are captured by the difference between the relocation and pure relocation indices, is very flat. Thus, the intensity of global relocation seems to be driven by changes in countries' *RCA,* not by changes in countries' GDP pc that do not involve production relocation.

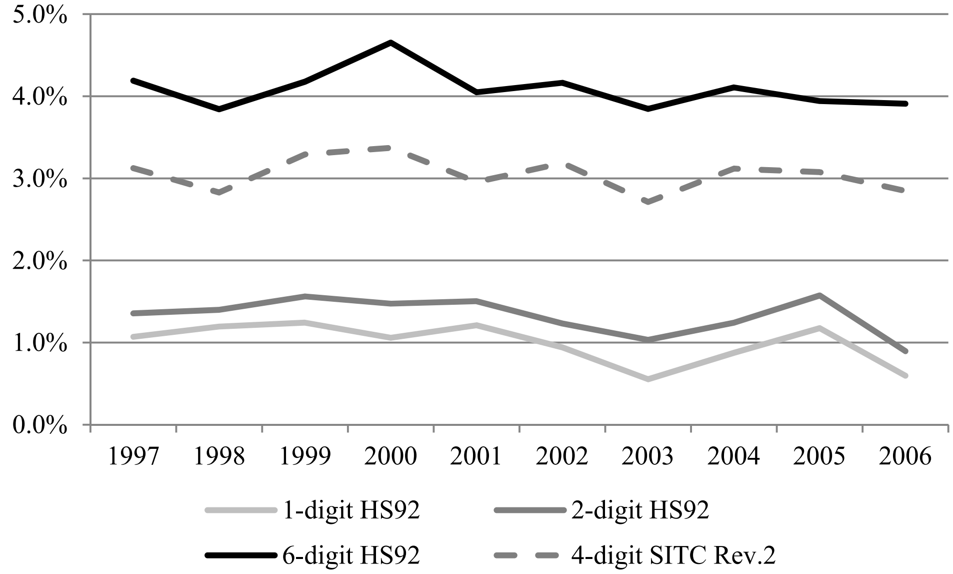
Figure 5. Intensity of International Production Relocation, 1996-2006. 141-country sample vs. 121-country sample.



Note: The intensity of international relocation is measured by the MAD of the 6-digit products relocation indices, following the formula in (10).

It is also worth to mention that, although the analysis in this chapter is presented for the whole economy and by sectors, it is based on the data and *PRODYs* at the 6-digit level of disaggregation. To see the importance of working with the highest level of disaggregation available to capture the intensity of the relocation process, Figure 6 shows the evolution over time of the MAD of the relocation indices calculated at lower levels of disaggregation. The 1-digit line is obtained after computing the relocation indices for the 18 sectors defined in Subsection 3.4, whereas the calculations for the 2-digit and the 6-digit lines use the *PRODYs* of the 96 industries and nearly 5,000 products, respectively, corresponding to the HS-92 classification. Figure 6 also depicts the MAD of the relocation indices based on the 4-digit products resulting from the HS conversion to the SITC.

Figure 6. Intensity of International Production Relocation, 1996-2006. Different disaggregation levels.

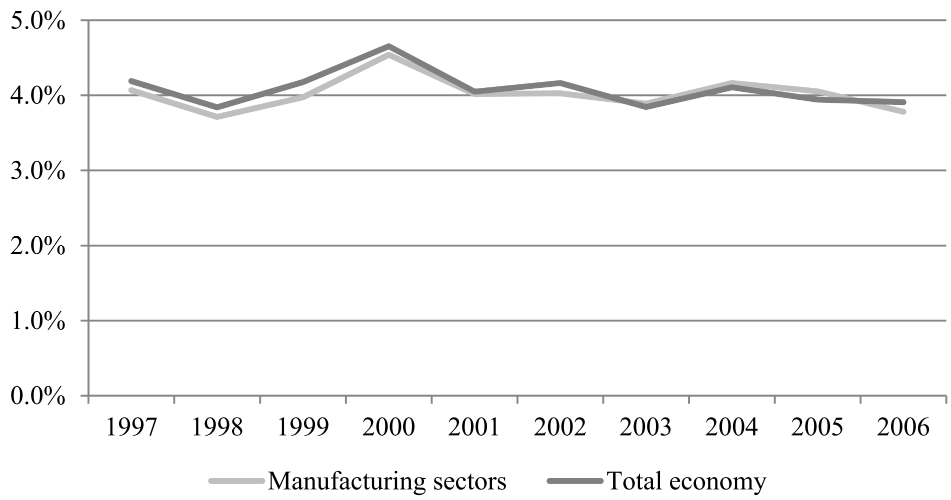


Note: The intensity of international relocation is measured by the MAD of the Relocation Index, following the formula in (10). The 1-digit line is obtained using data for 18 sectors as explained in Subsection 3.4, whereas the 2-digit and the 6-digit lines correspond to data for the 96 industries and 5,000 products, respectively, in the HS-92 classification. The 4-digit line corresponds to the 774 products in the SITC Rev.2 classification. The calculations are based on the 121 country sample.

The intensity of the relocation process calculated at the 6-digit level more than triples, on average, the intensity at the 2- and 1-digit level. This is due to the heterogeneity of the dynamics of the 6-digit products within each sector, which is likely to increase as a consequence of production fragmentation. As products within the same sector can move in opposite directions along the exporters' income ladder, some movements cancel out and disappear when we use data at the sector level to measure international relocation. As a consequence, using data at the one or two-digit level to measure the intensity of the relocation of production misses two thirds of the process. Compared with the 1 or 2-digit lines, the 4-digit data captures a higher share of the intensity of the relocation process. Still, it is roughly one percentage point below the 6-digit line. The analysis carried out over the 1963-1999 period is based on the 4-digit level, since it is the maximum level of disaggregation available, but it is important to bear in mind that the 4-digit level analysis may be missing part of the relocation phenomenon.

It may also be noted that the intensity of the relocation process appears to be almost constant over the 1996-2006 period. As in the previous section, to check that this result is not driven by the inclusion of industries which are less likely to experience relocations, we calculate the MAD excluding sections 1 (live animals), 2 (vegetable products), 3 (fats and oils), 5 (minerals), 14 (pearls) and 21 (works of art). The intensity of production relocation is not higher for the manufacturing industry relative to that for the total economy (Figure 7). These results may be driven by the fact that the sections excluded (animals, vegetables, part of the miscellanea aggregate and minerals) do not represent a large share of world trade (except for minerals, which account for 10.6% of world trade over the period). More than 80% of world trade corresponds to manufacturing sectors.

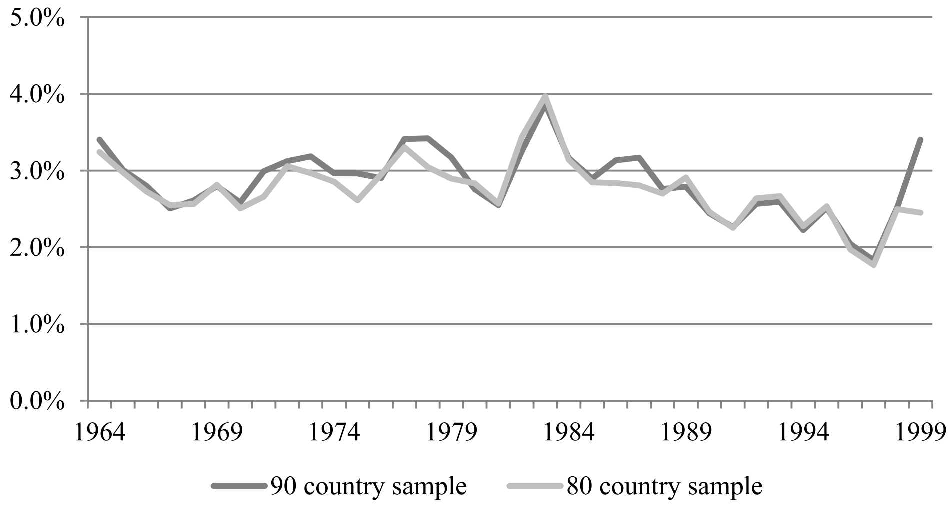
Figure 7. Intensity of International Relocation of Production, 1996-2006. Total economy and manufacturing sectors.



Note: The intensity of international relocation is measured by the MAD of the Relocation Index, following the formula in (10). The calculations are based on the 121 country sample.

Figure 8 represents the evolution of the intensity of international production relocation as measured by the MAD of the relocation indices over the 1963-1999 sample period. Results are shown for the two country-samples to assess if the exclusion of output gap outliers has an impact on the intensity of relocation. The evolution of the index is very similar in both samples, with the exception of the last year available (the difference between the two series is around one percentage point).

Figure 8. Intensity of International Production Relocation, 1963-1999. 90-country sample vs. 80-country sample.



Note: The intensity of international relocation is measured by the MAD of the Relocation Index, following the formula in (10).

The intensity of international production relocation over this period also appears quite constant, with a slightly decreasing trend from the late eighties onwards: the MAD over this period ranges from less than 2% to almost 4% in 1983. The average is around 3%, as for the 1996-2006 period using data at the 4-digit level (see Figure 6). However, for the years that can be compared in both samples (1997-1999), the MAD calculated using the country sample that excludes the output gap outliers is around 2.5%. This value is lower than the one found when using the data in BACI at the 4-digit level (around 3%). The difference could be due to the different number of countries used in the calculations of the indices or to the different number of products considered (774 products in BACI vs. 565 in the World Trade Flows database, including the Y-code products).

In fact, the slightly decreasing trend that can be observed from the late eighties onwards in the intensity of production relocation could be related to a composition effect of the "product basket". Recall that we work with a constant sample of products, and the homogeneous basket of 1963 may not be completely representative of the products traded 20 or 30 years later. The relocation process of those products after a long temporal span is more stabilized, which would explain the lower intensity in the last years. Anyway, the main conclusion from the analysis based on the MAD is the stability in the intensity of production relocation over the two sample periods. This stability is confirmed with the analysis of the long-run distributions in Section 4.3.

4.3. The analysis of intra-distribution dynamics, 1996-2006 and 1963-1999.

We analyze the dynamics of the cross-section distribution of the *PRODYs* using a Markov chain method, as described in Section 3.2.[29] The set of values of the *PRODY* indices are divided in 5 categories. The quintiles are calculated across all products and years so that the boundaries between cells are equal in every period. Product-year observations are divided roughly equally between cells. The transitions across different product categories indicate how products switch across country income groups. As mentioned before, we work with a constant sample of products that consists on those goods for which data for calculating the *PRODY* indices are available every single year during the period of analysis. For the 1996-2006 period, this sample contains 4995 HS products.[30] For the longer period (1963-1999), the sample consists of 565 products 4-digit products.

Recall that, by construction, *PRODYs* grow over time because of GDP per capita growth. Thus, given that we are interested in the changes of the index that imply a migration of production, we apply some transformations to our index to detrend the series and compare the results obtained using alternative transformations of the *PRODYs*. The numbers in panel a) of Table 1 show the results for the first normalization of the *PRODYs:* we consider the *PRODY* relative to the mean of the *PRODYs* in the corresponding year, expressed in logs. Panel b) shows results for the standardized *PRODY*s.[31] This latter transformation would make sense if, together with the increase in per capita GDPs over time, there was an increase in income dispersion during this period. An analysis based on the sigma convergence index reveals that income dispersion has not increased significantly during this period within countries in our sample (see Figure 9). Nonetheless, we show results using both normalizations.

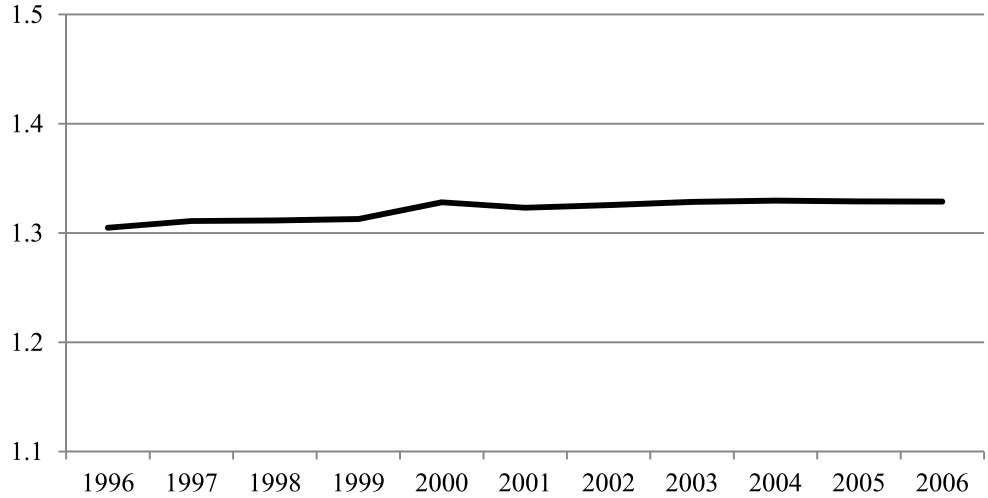
[29] For ease of reading, we only report the estimation of the transition matrices for the *PRODYs*, since the *ciPRODYs* yield almost identical results.

[30] The sample contained 4996 products but product 720834 has been identified as an outlier and has been removed from the sample (it had a *PRODY* larger than 60,000$, which exceeds the median (15,851.59) plus three times the interquartile range (20,921.04-10,051.17)). This product has not been removed from the analysis in the previous section because it represents a small share in world trade and excluding it does not alter the results.

[31] Standardized *PRODYs* are calculated as $\frac{(PRODY_k^t - \frac{1}{K}\sum_k PRODY_k^t)}{std.deviationPRODY_k^t}$

Figure 9. Sigma-convergence of GDP per capita, 1996-2006.

(Standard deviation of ln (GDPpc))



Source: Author's elaboration based on World Bank's WDI. The calculations are based on the 121 country sample.

Results for the transition probability matrices of the *PRODYs* are presented in Table 1. The matrices are estimated by averaging the observed five-year transitions over the two five-year subperiods contained within the sample period 1996-2006. The numbers in the first column indicate the number of product-year observations which have their starting point in that state, regardless of whether they remain in that category or transit to other states. The numbers in the first row of each panel denote the upper limits on each quintile. Each row represents the probability of transiting from one state into another; the sum of the probabilities in each row adds up to one. The products' transitions to other states reflect production relocation across countries with different income levels.

Panel a) in Table 1 shows the transition probabilities estimated using the log of the *PRODYs* relative to the average *PRODY*. The cross-section mean of the index is 1. The first left cell of the matrix in Table 1a indicates that 80% of products that where in state 1 at the beginning of the period remained in the same category (the bottom quintile of *PRODYs'* distribution), whereas the remaining 14% transited to state 2; 3% to state 3, and 2% and 1% respectively to states 4 and 5. If a product begins in the fifth quintile of the distribution, there is a 72% probability of remaining there after 5 years.

The estimated probability of moving out of a quintile of the distribution after 5 years ranges from 0.20 to 0.52. We observe that the probability of transiting to upper states is very similar to the probability of transiting to lower states. Mobility is smaller at the extremes of the distribution (states 1 and 5) and higher in the centre. Thus, for a product located in the lower-intermediate, intermediate and upper-intermediate cells of the distribution, the probability of moving out of this state is higher compared with the probability at the low and high categories of the distribution.

The long-run distribution is approximately uniform, which indicates that the probability of being in a category is roughly the same for all categories. If we compare the initial, final and ergodic distributions, they are very similar. This provides evidence of the stationarity of relocation processes. This stationary distribution will be supportive of the product life cycle hypothesis (Vernon, 1966) and models of technology diffusion (e.g. Krugman, 1979), according to which world trade tends to a moving equilibrium driven by innovation in higher-income countries and subsequent standardization and technology transfer, which make technology available in lower-income countries, that start producing and exporting the goods previously exported by developed countries. If patterns of trade are driven by such a process, product relocation (as captured by products' transitions to other states) may lead to a distribution with roughly equally distributed probability in each category, as a result of a continuous process of production relocation driven by innovation and standardization.

The other transformation of the index is shown in panel b). The *PRODY* is standardized so that the cross-section mean of the normalized index is 0 and the standard deviation 1. Results are very similar to those in panel a) and the ergodic distribution leads us to the same conclusions than before: production relocation appears as a time-invariant process.

Table 1. Transition probability matrices. *PRODYs*. 1996 to 2006, 5-year transitions.

a) $\ln(PRODY_k^t / \frac{1}{K}\sum_k PRODY_k^t)$

Number of observations	Upper limit, all years: -0.58	-0.13	0.14	0.34	0.96
1,968	0.80	0.14	0.03	0.02	0.01
2,034	0.16	0.56	0.21	0.04	0.02
2,035	0.04	0.21	0.48	0.22	0.05
1,924	0.01	0.04	0.20	0.54	0.21
2,029	0.01	0.02	0.05	0.20	0.72
Initial distribution	0.19	0.21	0.21	0.20	0.20
Final distribution	0.21	0.19	0.19	0.21	0.19
Ergodic distribution	0.22	0.19	0.18	0.20	0.20

b) Standardized $PRODYs$

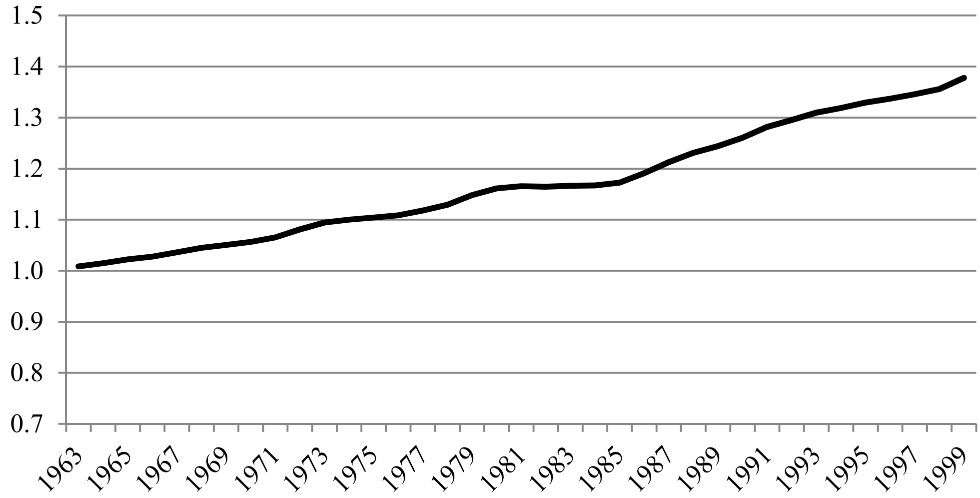
Number of observations	Upper limit, all years: -0.99	-0.26	0.34	0.91	3.54
1,988	0.79	0.15	0.03	0.02	0.01
2,021	0.15	0.57	0.22	0.04	0.02
2,023	0.04	0.21	0.49	0.22	0.05
1,912	0.01	0.04	0.21	0.55	0.19
2,046	0.01	0.02	0.05	0.21	0.71
Initial distribution	0.20	0.20	0.20	0.19	0.21
Final distribution	0.20	0.20	0.19	0.22	0.19
Ergodic distribution	0.21	0.20	0.20	0.21	0.19

Note: Initial is the distribution in 1996. Final is the distribution in 2006. Ergodic distribution corresponds to the hypothetical long-run or stationary distribution implied by the estimated transition probability matrix. The sum of probabilities by rows may not add up exactly to one due to rounding.

We repeat the analysis of distribution dynamics over the period 1963-1998. Again, we divide the sample into 5 categories and estimate 5-year transition matrices. The matrices are estimated by averaging the observed five-year transitions over every five-year subperiod within the sample period 1963-1998. The same transformations are applied to the *PRODYs*. Before going to the results, Figure 10 shows the sigma-convergence of GDP per capita within the country sample for the 1962-2000 period. The standard deviation of income levels in our country sample has increased during this period. Thus, the standardization of the indices makes sense given the increases in income dispersion during this period.

Figure 10. Sigma-convergence of GDP per capita, 1963-1999.

(Standard deviation of ln (GDPpc)



Source: Author's elaboration based on PWT 8.1. The calculations are based on the 80-country sample.

Results for the transition matrices of the *PRODYs* are given in Table 2. As before, panels a) and b) provide alternative normalizations for this index. Both panels yield very similar results in terms of mobility of the intra-distribution dynamics and in terms of their overall evolution (the shape). The ergodic distribution shows roughly the same probability in each category and it is very similar to the initial and final distribution.

Table 2. Transition probability matrices. *PRODYs*. 1963 to 1998, 5-year transitions.

a) $\ln(PRODY_k^t / \frac{1}{K}\sum_k PRODY_k^t)$

	Upper limit, all years:				
Number of observations	-0.61	-0.09	0.17	0.34	0.96
788	0.87	0.11	0.01	0.00	0.01
794	0.13	0.67	0.17	0.03	0.01
803	0.01	0.17	0.56	0.23	0.03
786	0.00	0.02	0.22	0.57	0.19
784	0.00	0.02	0.03	0.19	0.76
Initial distribution	0.19	0.22	0.21	0.19	0.19
Final distribution	0.22	0.18	0.18	0.19	0.23
Ergodic distribution	0.21	0.19	0.19	0.20	0.21

b) Standardized $PRODYs$

Number of observations	Upper limit, all years: -1.02	-0.20	0.41	0.91	3.63
790	0.87	0.11	0.01	0.00	0.01
793	0.13	0.67	0.16	0.03	0.01
798	0.01	0.16	0.57	0.22	0.04
787	0.00	0.02	0.22	0.57	0.19
787	0.00	0.02	0.03	0.18	0.76
Initial distribution	0.19	0.22	0.21	0.19	0.19
Final distribution	0.20	0.20	0.19	0.21	0.21
Ergodic distribution	0.20	0.19	0.19	0.20	0.21

Note: Initial is the distribution in 1963. Final is the distribution in 1998. Ergodic distribution corresponds to the hypothetical long-run or stationary distribution implied by the estimated transition probability matrix. The sum of probabilities by rows may not add up exactly to one due to rounding.

The patterns of mobility implied by the transition matrices estimated in this section can be summarized with the indices of mobility presented before, M^1 and M^2. Results are presented in Table 3. With the distribution of the indices divided in five categories, the value of M^1 ranges between 0 (absence of mobility) and 1.25 (perfect mobility). M^2 ranges between 0 (absence of mobility) and 1 (perfect mobility). As we observe in Table 3, the different transformations of the indices provide very similar results in terms of mobility. On the other hand, mobility appears to be higher during the more recent period, as measured by both indices. However, we cannot conclude that mobility has been higher during the years 1996 to 2006 because of the different disaggregation levels.

Table 3. Mobility indices. Comparison between the two sample periods.

		1996-2006		**1963-1998**	
Variable		M^1	M^2	M^1	M^2
PRODY	ln(*PRODY*/mean*PRODY*)	0.476	0.953	0.391	0.901
	Standardized *PRODY*	0.472	0.950	0.390	0.899

Regarding the long-run distribution of the *PRODYs*, the fact that the ergodic distributions over the 1996-2006 and the 1963-1998 periods are similar suggests that products' transitions, which reflect production relocation across country income groups, lead to a long-run distribution that follows a stochastic stationary process. According to this analysis, relocation processes appear to be time-invariant. This does not prevent important intra-distribution dynamics to take place. The results obtained in this section are somewhat related to the results in Hanson, Lind and Muendler (2015), although their approach to the analysis of comparative advantage is more complex. These authors find that the stability in the shape of the distribution of comparative advantage co-exists with considerable changes in countries' top export industries.

Unlike Hanson, Lind and Muendler (2015), this chapter does not formally develop a model to interpret this result, but we provide an explanation of the potential shocks that may lead to this stationary distribution. We have suggested that technological shocks such as innovation and standardization lead to production relocation across countries because they affect factor intensities: if the sophistication of a product increases, its production will relocate towards the countries with higher human capital or a previous specialization in that product (i.e., these countries will increase their revealed comparative advantage (*RCA*) in that product). On the contrary, standardization leads to relocation towards countries with lower human capital and no previous specialization in the good. Hence, we suggest that the interplay between innovation and standardization is one of the potential mechanisms that influence the dynamics of countries' comparative advantage. On the other hand, the empirical evidence supports the existence of a reorientation in export specialization towards products more consistent with countries' comparative advantage in response to exposure to import competition from low-wage countries (see for instance Bernard et al. (2006) and Pierce and Schott (2016)). This production reallocation acts as some sort of compensating mechanism when the production of some goods in which the country was specialized migrates towards lower-income countries.

5. SECTORAL DYNAMICS

After the overview of the aggregate trends and dynamics analyzed in the previous section, we turn to the analysis of relocation dynamics by sectors over the two sample periods. Table 4 shows the sectors' relocation indices together with the initial *PRODYs* (referring to 1996). Sectors are ordered according to the *PR* index. The sectors with the strongest relocation towards lower-income countries over the period 1996-2006 are textiles/footwear, electrical equipment, metals and manufactures excluding iron, and motor vehicles. Some of these sectors are well-known examples of industries that have experienced intense production fragmentation and offshoring processes, such as electrical equipment. On the other side of the spectrum, the sectors showing the weakest relocation towards low-income exporters (or the greatest towards high-income exporters) are –omitting the miscellanea sector- pharmaceuticals and chemicals. These sectors are likely to be experiencing more intense innovation.

Table 4. International Relocation of Production by sector, 1996-2006.

Sector	Initial *PRODY* 1996	Relocation Index (R)	Pure Relocation Index (PR)	Difference R-PR
Textiles, footwear, leather	9,052.3	-1.25%	-1.79%	0.54%
Electrical equipment	17,260.0	-1.23%	-1.63%	0.40%
Metals and manufactures, exc. Iron	15,175.9	-1.43%	-1.62%	0.19%
Motor vehicles	19,583.5	-1.46%	-1.55%	0.08%
Machinery and mechanical appliances	19,770.1	-1.26%	-1.51%	0.25%
Plastics	17,440.6	-1.04%	-1.19%	0.15%
Furniture and other manufactures; stone	14,593.7	-0.64%	-1.13%	0.49%
Food, beverage and tobacco	12,055.0	-0.89%	-1.07%	0.18%
Minerals	13,689.3	-1.61%	-1.00%	-0.61%
Vegetable products	9,363.7	-1.07%	-0.93%	-0.14%
Iron and manufactures thereof	14,981.5	-0.38%	-0.76%	0.38%
Animal products	14,084.0	-0.60%	-0.71%	0.11%
Transport equipment, exc. Motor vehicles	17,382.6	-0.46%	-0.52%	0.05%
Instruments	19,646.2	-0.27%	-0.35%	0.08%
Wood and paper	15,242.5	0.30%	-0.20%	0.50%
Chemicals exc. Pharmaceuticals	18,348.0	0.08%	-0.19%	0.26%
Miscellanea	8,994.9	0.23%	0.70%	-0.47%
Pharmaceuticals	16,815.3	2.13%	1.78%	0.36%

Note: Initial *PRODY* is calculated using expression (2). International Production Relocation is measured by the Relocation Index $R^{0,t}$, following the formula in (5). Pure Relocation is measured by the Pure Relocation Index $PR^{0,t}$, following the formula in (9).

The relocation indices show very similar patterns. The correlation between the relocation indices (*R*) and the pure relocation indices (*PR*) of the 6-digit products is extremely high: 0.985. The rankings of sectors according to these two indices are also very similar. The main differences between the two indices (*R-PR*) occur for the minerals (-0.61%) and textiles and footwear (0.54%). Note that the *PRODY* index of minerals is the most exposed to changes in commodity prices, which would affect the exporters' income (and, therefore, the *R* index), without production undergoing any relocation across countries (which is the only possible source of changes in the *PR* index). This can explain that the greatest difference between the *PR* and the *R* indices corresponds to minerals.

In turn, the size and the sign of the *PR* index of the textiles (-1.79%) indicate that the *RCA* of low-income countries in this sector has increased, and the fact that it is larger than the *R* index (-1.25%) implies that the increase in the average income of the exporters of this sector has been larger than world pc GDP growth. The *PRODYs* of some sectors such as textiles could increase as well without any geographic relocation of production if low-income countries are relatively specialized in this sector and there is income convergence across countries over the period (i.e., low-income countries grow relatively more than rich countries). This could explain the discrepancy between the *R* and *PR* indices for textiles.

Table 5 shows each sector's contribution to the global intensity of production relocation as measured by $MAD(R_k^{0,T})$ and $MAD(PR_k^{0,T})$, where these contributions are calculated as in (12) (the formula is analogous for the $PR_k^{0,T}$ indices). These contributions measure each sector's role in the reorganization of world trade across country income groups that took place over the 1996-2006 period. The contribution of each sector to the global transformation of international trade not only depends on the intensity of the sector's international relocation but also on the sector's weight in world trade. The highest contributions came from machinery and mechanical appliances, electrical equipment, textiles and footwear and chemicals excluding the pharmaceutical industry.

Table 5. Sector contributions to global relocation of production, 1996-2006.

Sector	Contribution to MAD (*R*)	Contribution to MAD (*PR*)	Weight in world trade
Machinery and mechanical appliances	11.1%	13.0%	14.7%
Electrical equipment	10.4%	11.5%	13.4%
Textiles, footwear, leather	9.8%	10.5%	7.4%
Chemicals exc. Pharmaceuticals	8.3%	7.6%	6.8%
Miscellanea	6.4%	7.0%	3.0%
Motor vehicles	5.2%	5.2%	9.3%
Metals and manufactures, exc. Iron	4.7%	4.8%	3.3%
Minerals	9.2%	4.8%	10.6%
Wood and paper	5.0%	4.4%	3.6%
Plastics	3.9%	4.1%	4.4%
Pharmaceuticals	4.3%	4.1%	2.0%
Iron and manufactures thereof	4.1%	4.0%	4.3%
Food, beverage and tobacco	3.6%	3.6%	3.2%
Instruments	3.1%	3.4%	3.4%
Transport equipment, exc. Motor vehicles	2.9%	3.3%	2.6%
Furniture and other manufactures; stone	2.8%	3.1%	3.4%
Vegetable products	2.8%	3.0%	2.6%
Animal products	2.4%	2.5%	2.1%
Total economy	100.0%	100.0%	100.0%

Note: MAD (*R*) and MAD (*PR*) are the mean absolute deviations of the 6-digit relocation and pure relocation indices. The contribution of each sector *s* to MAD (*R*) and MAD (*PR*) are calculated using the formula in (12).

The same analysis can be performed over the period 1963-1999. Given the longer temporal span, the sample period is divided in three 10-year subperiods and a final shorter one (1993-1999). In the case of the Pure Relocation index, we hold constant the GDP per capita at the beginning of each 10-year (6-year) subperiod. Table 6 shows the relocation indices together with the initial *PRODYs* (referring to 1963) and each sector's weight in world trade at the beginning (1963) and the end of the period (1999). The Relocation index (*R*) is shown in panel a) and the Pure Relocation Index (*PR*) in panel b). Sectors are ordered according to the values of the *R* and *PR* indices in the last subperiod (1993-1999), respectively.

A comparison between both panels reveals that the Relocation Index has a negative sign in many sectors in every 10-year subperiod. On the contrary, the negative sign in the Pure Relocation index only appears in two sectors in 1983-1993 and in all sectors in 1993-1999 (except in sector "commodities and transactions not classified elsewhere in the SITC" and electrical equipment, although the latter is very close to zero). The divergence between the two relocation indices that was observed at the aggregate level (Figure 4) is also evident in the sectoral analysis. The negative sign in the *R* index may arise because of a divergence between the average growth of world GDP pc and the average growth of the exporters' income in each sector. This can be symptomatic of the dispersion observed in the income levels within countries in our sample (see Figure 10).

Table 7 presents the sector contributions to global relocation of production over the period 1963-1999, divided by 10-year subperiods and a 6-year subperiod (1993-1999). For ease of exposition, we only report results for the *PR* index, which are very similar to those yielded by the *R* index. The sectors that appear to have contributed the most to the intensity of production relocation in the last subperiod (1993-1999) are machinery and mechanical appliances, and electrical equipment, which are also the sectors with the higher share in world trade. These are also the two sectors that have contributed the most to the intensity of production relocation during the more recent period (1996-2006). During the subperiod 1983-1993, textiles, leather and footwear, followed by electrical equipment, were the sectors that contributed the most to global production relocation.

The analysis conducted in this section reveals substantial heterogeneity in the dynamics across sectors. Despite the apparent stability in the intensity of production relocation at an aggregate level, as measured by the index of dispersion (MAD) and the shape of the long-run distributions, sectors and products experience shocks that lead to *upward* and *downward* relocations. These movements are consistent with the degree of mobility in the intra-distribution dynamics observed in the transition matrices. On the other hand, the sign of production relocation does not seem to be correlated with the initial level of product sophistication, as measured by the *PRODYs*: there are sectors with high initial *PRODY* that have undergone *upward* relocations (as reflected by the positive *PR* indices, like pharmaceuticals and chemicals) and others that have experienced a relocation trend toward low income countries, with very negative *PR* indices (e.g., machinery and motor vehicles). The role of initial product sophistication as a possible determinant of subsequent relocation, together with other potential drivers, is analyzed in the next section.

Table 6. International Relocation of Production by sector, 1963-1999.

a) Relocation Index

Sector name	Initial *PRODY* (1963)	1963-1973	1973-1983	1983-1993	1993-1999	Weight in world trade 1963	Weight in world trade 1999
Commodities and transactions not classified elsewhere in the SITC	7,580.2	-0.2%	0.1%	0.4%	1.7%	1.5%	1.3%
Electrical equipment	9,581.8	-2.0%	-0.1%	0.1%	0.9%	4.1%	15.6%
Iron and steel	8,097.4	0.0%	-1.2%	0.0%	0.7%	4.4%	2.3%
Pharmaceuticals	8,594.7	-0.3%	1.3%	1.4%	0.5%	0.9%	1.9%
Manufactured goods classified chiefly by material	6,772.6	-0.5%	-0.2%	-0.7%	0.3%	7.8%	6.8%
Road vehicles	9,679.3	0.7%	0.2%	-0.8%	0.3%	4.4%	8.7%
Instruments	11,615.3	-0.9%	-0.4%	-0.2%	0.3%	1.8%	3.3%
Chemicals	7,762.9	0.1%	0.1%	-0.4%	0.2%	4.7%	5.7%
Wood and paper	8,699.6	-0.1%	1.0%	-0.8%	0.0%	3.0%	2.3%
Beverages and tobacco	5,068.0	0.2%	0.9%	-0.3%	-0.1%	1.8%	1.0%
Animal and vegetable oils, fats and waxes	5,607.5	-0.5%	1.4%	-2.2%	-0.2%	1.0%	0.4%
Miscellaneous manufactured articles	7,276.5	-0.4%	0.8%	-0.6%	-0.3%	2.7%	6.4%
Plastics	10,208.1	-0.7%	0.2%	0.0%	-0.4%	0.9%	2.0%
Crude materials, inedible, except fuels	4,978.2	-0.3%	0.0%	-1.2%	-0.6%	15.7%	3.7%
Food and live animals	5,537.3	-0.5%	0.7%	-0.2%	-0.8%	17.9%	6.3%
Other transport equipment	9,718.8	0.0%	-1.1%	-0.8%	-0.9%	2.9%	2.8%
Machinery and mechanical appliances	10,831.1	-0.6%	-0.3%	-0.1%	-1.0%	10.0%	16.8%
Mineral fuels, lubricants and related materials	6,098.6	-0.2%	-0.1%	-0.5%	-1.5%	6.4%	4.9%
Leather, textiles and footwear	5,884.4	-1.1%	-0.5%	-1.3%	-1.7%	8.0%	7.7%

(cont)

Table 6 (*cont*). International Relocation of Production by sector, 1963-1999.

b) Pure Relocation Index

Sector name	Initial *PRODY* (1963)	1963-1973	1973-1983	1983-1993	1993-1999	Weight in world trade 1963	Weight in world trade 1999
Commodities and transactions not classified elsewhere in the SITC	7,580.2	0.9%	0.6%	2.0%	1.2%	1.5%	1.3%
Electrical equipment	9,581.8	-1.4%	0.2%	0.8%	0.2%	4.1%	15.6%
Iron and steel	8,097.4	0.7%	-0.3%	1.4%	-0.1%	4.4%	2.3%
Instruments	11,615.3	0.2%	0.2%	0.8%	-0.1%	1.8%	3.3%
Manufactured goods classified chiefly by material	6,772.6	0.6%	0.6%	0.4%	-0.3%	7.8%	6.8%
Road vehicles	9,679.3	1.7%	1.1%	0.3%	-0.3%	4.4%	8.7%
Animal and vegetable oils, fats and waxes	5,607.5	0.6%	1.9%	-1.2%	-0.4%	1.0%	0.4%
Pharmaceuticals	8,594.7	0.8%	2.1%	2.6%	-0.6%	0.9%	1.9%
Crude materials, inedible, except fuels	4,978.2	1.0%	0.8%	0.3%	-0.8%	15.7%	3.7%
Miscellaneous manufactured articles	7,276.5	0.2%	1.2%	0.1%	-0.9%	2.7%	6.4%
Beverages and tobacco	5,068.0	0.9%	2.1%	1.0%	-1.0%	1.8%	1.0%
Chemicals	7,762.9	1.2%	1.0%	0.9%	-1.0%	4.7%	5.7%
Plastics	10,208.1	0.2%	1.0%	0.9%	-1.2%	0.9%	2.0%
Food and live animals	5,537.3	0.7%	1.7%	1.1%	-1.2%	17.9%	6.3%
Wood and paper	8,699.6	0.8%	1.5%	0.8%	-1.2%	3.0%	2.3%
Other transport equipment	9,718.8	1.2%	-0.4%	0.5%	-1.5%	2.9%	2.8%
Machinery and mechanical appliances	10,831.1	0.6%	0.4%	0.9%	-1.9%	10.0%	16.8%
Leather, textiles and footwear	5,884.4	-0.5%	0.1%	-0.7%	-2.0%	8.0%	7.7%
Mineral fuels, lubricants and related materials	6,098.6	0.9%	0.6%	1.1%	-2.0%	6.4%	4.9%

Note: Initial *PRODY* is calculated using expression (2). International Production Relocation is measured by the Relocation Index $R^{0,t}$, following the formula in (5). Pure Relocation is measured by the Pure Relocation Index $PR^{0,t}$, following the formula in (9).

Table 7. Sector contributions to global relocation of production, 1963-1999.

	Contribution to MAD (*PR*)				Weight in world trade			
Sector name	**1963-1973**	**1973-1983**	**1983-1993**	**1993-1999**	**1963-1973**	**1973-1983**	**1983-1993**	**1993-1999**
Machinery and mechanical appliances	5.4%	6.8%	6.4%	14.3%	10.0%	11.0%	11.8%	15.3%
Electrical equipment	7.7%	6.5%	10.7%	13.2%	4.1%	5.6%	7.7%	11.9%
Mineral fuels, lubricants and related materials	10.2%	7.1%	8.3%	10.7%	6.4%	6.9%	12.9%	5.3%
Leather, textiles and footwear	7.7%	6.8%	13.2%	9.9%	8.0%	7.8%	7.0%	8.9%
Manufactured goods classified chiefly by material	5.8%	9.3%	8.0%	8.8%	7.8%	8.2%	7.5%	7.0%
Food and live animals	14.3%	21.5%	12.0%	7.4%	17.9%	14.1%	10.8%	8.0%
Chemicals	5.4%	6.7%	5.2%	6.5%	4.7%	5.6%	5.7%	5.6%
Miscellaneous manufactured articles	2.5%	2.3%	5.4%	4.8%	2.7%	3.1%	3.9%	6.3%
Crude materials, inedible, except fuels	18.7%	12.8%	9.9%	4.7%	15.7%	11.2%	7.1%	4.8%
Road vehicles	5.5%	1.9%	3.3%	4.7%	4.4%	7.4%	8.0%	8.9%
Iron and steel	4.1%	5.2%	3.8%	2.7%	4.4%	5.4%	3.8%	2.8%
Instruments	1.6%	2.4%	2.4%	2.5%	1.8%	2.4%	2.8%	3.1%
Wood and paper	2.0%	1.8%	2.8%	2.3%	3.0%	2.9%	2.3%	2.5%
Commodities and transactions not classified elsewhere in the SITC	0.8%	0.7%	1.7%	2.3%	1.5%	1.1%	1.4%	1.4%
Other transport equipment	3.3%	2.9%	2.4%	1.9%	2.9%	2.5%	2.7%	3.1%
Beverages and tobacco	2.4%	1.8%	1.0%	1.2%	1.8%	1.4%	1.1%	1.2%
Animal and vegetable oils, fats and waxes	1.3%	2.0%	1.2%	1.1%	1.0%	0.9%	0.7%	0.4%
Pharmaceuticals	0.9%	1.3%	2.0%	0.6%	0.9%	1.0%	0.9%	1.4%
Plastics	0.4%	0.4%	0.4%	0.4%	0.9%	1.6%	1.7%	2.0%

Note: MAD (*PR*) is the mean absolute deviation of the 4-digit pure relocation indices. The contribution of each sector *s* to MAD (*PR*) is calculated using the formula in (12).

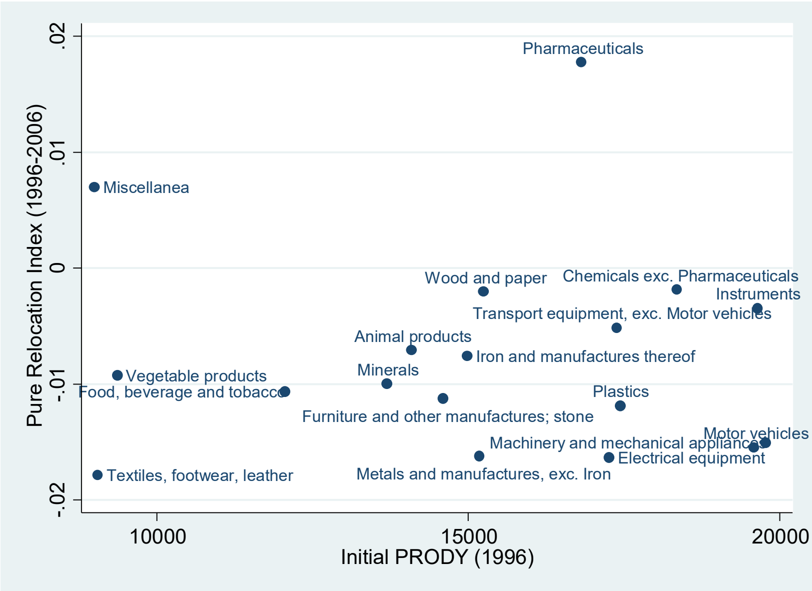
6. DETERMINANTS OF RELOCATION

This section turns to the analysis of the potential determinants of production relocation to try to shed light into the drivers of this phenomenon. The aim of this analysis is to determine if production relocation can be predicted on the basis of some product or sector characteristics or, on the contrary, it largely appears as an unpredictable phenomenon. Knowing if some specific features make an industry more or less likely to migrate abroad could be very valuable, since it may help countries to prevent the loss of industries or attract the production of new goods by implementing the right policies. To answer to this question, several variables are considered. First, we consider the initial level of product sophistication to determine if it is a relevant factor in predicting subsequent production relocation. Then, other industry characteristics, such as skill and capital intensity, R&D and total factor productivity (TFP), are brought into the analysis.

We begin by assessing if the sign of international relocation of each product or sector over the 1996-2006 (1963-1999) period could have been predicted based on their initial sophistication. As shown in Figures 11 and 12, the direction of international relocation, both at the sector and at the 6-digit product level, appears largely unpredictable on the basis of their sophistication at the beginning of the period. Among the sectors with high initial *PRODY* we can find both industries with positive *PR* indices (e.g., pharmaceuticals and chemicals) and very negative ones (e.g., machinery and motor vehicles). The same occurs among the sectors with low initial *PRODYs*: we find industries with positive *PR* indices (e.g., miscellanea) as well as with negative ones (e.g., textiles) (see Figure 11). At the 6-digit level, production relocation is only weakly negatively correlated with the initial *PRODY*. Regressing the *PR* indices on the initial *PRODYs*, we find a statistically significant negative relationship but with a very small coefficient (see Figure 12).

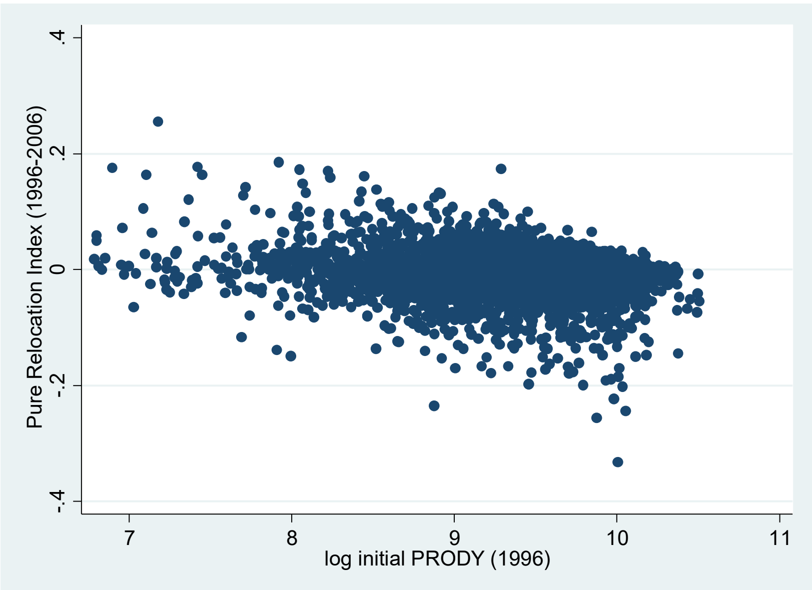
This means that the current level of a product's or sector's sophistication is of no real help in predicting whether the product or the sector will relocate towards richer or poorer countries in the following years. The same analysis performed over the 1963-1999 period yields the same conclusion: the direction of subsequent international relocation cannot be predicted on the basis of the initial levels of product sophistication, neither at the 4-digit level nor at the sector level. Regressing the *PR* indices on the initial *PRODYs* yields a statistically significant negative relationship but with a very small coefficient (see Figure A1 in the Annex).

Figure 11. Initial 1996-*PRODY* and Pure Relocation index (*PR*) for the 1996-2006 period. 18 sectors.



Note: Initial *PRODY* is calculated using expression (2). The Pure Relocation Index is calculated following the formula in (9).

Figure 12. Initial 1996-*PRODY* and Pure Relocation index (*PR*) for the 1996-2006 period. 6-digit products.



Note: Initial *PRODY* is calculated using expression (1). The Pure Relocation Index is calculated following the formula in (7). Estimating the equation $PR_k = \beta_0 + \beta_1 \log(PRODY_k^0) + u_k$ yields a coefficient $\beta_1 = -0.012$ with a standard deviation of 0.001 and an $R^2 = 0.04$.

We now explore the role of other variables as potential determinants of production relocation: factor intensities (capital and skill), R&D expenditures and TFP growth. On the one hand, we would expect that relatively more capital intensive industries and industries with relatively more skilled labour are less prone to suffer relocations towards lower income countries, since these factors are relatively abundant in higher income countries. Thus, we would expect to obtain a positive correlation between these variables and the relocation indices: more capital (skill) intensive industries should show a relocation trend towards higher income countries, whereas less capital (skill) intensive industries would be more likely to relocate towards lower income countries.

On the other hand, expenditure in R&D is a variable that one would expect to be a determinant of future relocation: industries that invest more (less) in R&D are more likely to stay or relocate towards high (low) income countries. The inclusion of this variable in the analysis is also motivated by the fact that some models of innovation and standardization assume that new products are invented via costly R&D (Acemoglu et al. (2012)), and innovations typically take place in more technologically advanced countries.[32] A measure of Total Factor Productivity (TFP) growth is also included to control for the fact that industries with a high TFP growth are more likely to engage in innovations that would lead to upward relocations.

Thus, our analysis includes factor intensities, R&D and TFP growth as potential determinants of relocation, together with the initial level of product sophistication.[33] Capital intensity is defined as the capital stock per worker (i.e., a capital-to-labour ratio), whereas skill intensity is measured as the share of non-production workers in total employment. We also construct alternative measures in monetary units: skill intensity is calculated as the ratio of non-production workers' wages to total payroll (in

[32] Factor intensities and R&D are commonly used in the literature on multinational firms' decisions regarding the relationship with their suppliers (integrate or outsource) as proxies of the services provided by the headquarter (i.e. headquarter intensity). Seminal papers in the literature of the determinants of intra-firm trade, such as Antràs (2003) and Antràs and Helpman (2004), use capital intensity as a proxy of headquarter intensity, based on the assumption that capital investment can only be provided by the headquarter. In subsequent papers, (Antràs and Helpman (2004) and Yeaple (2006)) headquarter intensity also includes R&D, advertising and managerial skills. Skill intensity is also considered (Antràs and Chor (2013)).

[33] The index of routineness has proved to be a good indicator of subsequent offshoring to low-income locations in some papers (Ebenstein et al. (2014)). This index has not been used in this analysis because it is based on occupational task data that is then matched to the industries available under the Census Industry Classification (CIC). This would require to convert our data to a more aggregated classification, which will yield a more limited number of observations. Besides, it is unclear how to make the cross-walk between the CIC classification and the HS.

millions of US dollars) and capital intensity is total capital expenditure over total payroll, in million dollars. Data on factor intensities is calculated from the NBER-CES Manufacturing Industry database. This dataset is the result of "the joint effort between the National Bureau of Economic Research (NBER) and U.S. Census Bureau's Center for Economic Studies (CES)". Data is available for the 473 six-digit 1997 NAICS (North American Industry Classification System) industries. TFP growth is also available in the NBER CES database. It is based on a five-factor production function: capital, production worker hours, non-production workers, non-energy materials and energy. According to the methodology, TFP growth is calculated as the difference between the growth rate of output and revenue-share weighted average of the growth rates of each of the five inputs.

We use US data on factor intensities because of the availability of information. Another reason that justifies the use of US data is that, since it is a large and diverse economy, estimates based on US data are likely to be representative. The use of US data as being representative of other countries' data is a usual approach in the literature.[34] Because this analysis includes other variables that are available under the Input-Output (IO) classification, the NAICS 6 digit codes are mapped to 6-digit IO2002 industries using a correspondence provided by the Bureau of Economic Analysis (BEA).[35] Although the concordance between these two classifications is a straightforward many-to-one mapping for the manufacturing industries, not all NAICS industries were listed at the six-digit level of disaggregation, so some 4 or 5 digit codes had to be broken down into its 6-digit components using the original NAICS classification.[36] The concordance between NAICS codes and IO2002 leaves us with 279 manufacturing industries.

Data on R&D intensity is taken from Antràs and Chor (2013). The data is originally computed by Nunn and Trefler (2013) from the ORBIS database.[37] These authors calculate it for the IO 1997 industries, and Antràs and Chor (2013) provide the data under the IO2002 classification using a crosswalk from IO1997 and IO2002 through the NAICS industry codes. R&D intensity is computed as the logarithm of R&D

[34] See for instance Romalis (2004) or Nunn and Trefler (2013), who use U.S. factor intensities assuming that they are correlated with the factor intensity of production in other countries.
[35] http://www.bea.gov/industry/xls/2002DetailedItemOutput.xls
[36] For instance, NAICS code 31121, "Flour milling and malt manufacturing", was split into its six-digit industries 311211, 311212 and 311213.
[37] The ORBIS database is a database of Bureau Van Dijck (BvDEP). It is a commercial database which contains information on over 200 million companies or business records around the world.

expenditures over total sales ($log = (0.001 + R\&D/Sales)$).[38] These data is available for the US and "World" for two different periods: an average for 2000-2005 and 1998-2006. The data in Antràs and Chor (2013) is available for 274 manufacturing industries. In order to get a perfect merge between our dataset of factor intensities from the NBER-CES Manufacturing database and the data for R&D intensity from Antràs and Chor (2013), we apply the same treatment to some IO codes and create the synthetic code 31131X to merge IO codes 311313 and 31131A and 33641X for the IO codes 336411-336414 and 33641A. This leaves us with 274 industries.

Our relocation and pure relocation indices are calculated for nearly 5,000 products using 6-digit data from BACI. However, given that the variables we are interested in are available under a different classification, we construct our relocation indices for the Input-Output industries, applying a correspondence between the 6-digit HS product codes and the IO2002 classification. To do so, we take the crosswalk in Antràs et al. (2012), which is based on the classification provided by the BEA. However, the correspondence in the former is based on the 10-digit HS products. At this level of disaggregation, each HS product matches into a single IO industry. At the 6-digit level however, some HS products map into multiple IO industries. The correspondence in Antràs et al. (2012) provides weights to assign to each IO industry the value of the corresponding 6-digit product.

The *PRODY* and *ciPRODY* indices are calculated for 299 six-digit IO 2002 industries (294 when industries 311313 and 31131A are grouped under code 31131X, and industries 336411 to 336414 under code 33641A). Data on factor intensities and R&D are only available for manufacturing industries (that is, industries with code starting in 3). Only 265 out of the 299 (260 out of 294) for which we calculate the relocation indices are manufacturing industries. Thus, we end up with a sample of 260 industries when we combine all datasets, which is reduced to 257 in the econometric specifications after dropping 3 industries that appear as outliers in the variables TFP growth and US R&D intensity.

Now we turn to the econometric analysis of the relationship between international production relocation and its potential drivers. In our specifications, industry-specific

[38] The 0.001 is added to the ratio to avoid dropping industries with zero reported R&D expenditures in the ORBIS dataset.

relocation and pure relocation indices are regressed on skill (s/l) and capital intensity (k/l), R&D expenditures, TFP growth and initial product sophistication. We define these measures as an average over different periods (1998-2006, 1995-1997) or include the rate of growth during the preceding period (1991-1996) instead of their levels. Equations (13) and (14) regress the control variables on the relocation index (R) and pure relocation index (PR), respectively.

$$R_k^{0,T} = \beta_0 + \beta_1 \log\left(\frac{s}{l}\right) + \beta_2 \log\left(\frac{k}{l}\right) + \beta_3 \log\left(0.001 + \frac{R\&D}{Sales}\right) + \beta_4 TFP + \beta_5 logPRODY_k + u_k, \quad (13)$$

$$PR_k^{0,T} = \beta_0 + \beta_1 \log\left(\frac{s}{l}\right) + \beta_2 \log\left(\frac{k}{l}\right) + \beta_3 \log\left(0.001 + \frac{R\&D}{Sales}\right) + \beta_4 TFP + \beta_5 logPRODY_k + u_k, \quad (14)$$

We run industry regressions using several variations of the specifications in (13) and (14). Results are reported in Tables 8 and 9, respectively. Columns (1) to (2) in Table 8 report results using an average of the skill and capital intensity measures for the period 1998-2006. Columns (3) to (4) show results of using the initial values of these factor intensity measures (1995-1997). In columns (5) and (6) we consider the rate of variation of these measures during the preceding period instead of their levels, to see if changes in factor intensities during the preceding 5-year subperiod are relevant in explaining subsequent relocation.[39] We consider the two different measures of R&D intensity available in Antràs and Chor (2013) dataset: one is based on US manufacturing firms' data and the other is constructed using data on firms' worldwide. We also include a measure of TFP growth for two different periods (1998-2006 and 1995-1997). The same specifications are run in Table 9.

[39] We have also used skill and capital intensity in monetary units (wages and capital expenditures). Results are very similar to those reported in Tables 8 and 9.

Table 8. Determinants of Relocation, 1996-2006.

	Dependent variable: Relocation index 1996-2006					
	(1)	(2)	(3)	(4)	(5)	(6)
log(s/l) 1998-2006	0.002	0.000				
	(0.004)	(0.004)				
log(k/l) 1998-2006	-0.003	-0.003				
	(0.002)	(0.002)				
log(R&D/sales), World 1998-2006	0.004***		0.003**		0.004***	
	(0.001)		(0.001)		(0.001)	
log(R&D/sales), US 1998-2006		0.003***		0.003***		0.003***
		(0.001)		(0.001)		(0.001)
TFP growth 1998-2006	0.123*	0.118			0.120*	0.115
	(0.068)	(0.072)			(0.068)	(0.070)
Initial log(s/l)			0.003	0.001		
			(0.004)	(0.004)		
Initial log(k/l)			-0.002	-0.002		
			(0.002)	(0.002)		
TFP growth 1995-1997			0.033	0.036		
			(0.064)	(0.064)		
Δ log(s/l) 1991-1996					-0.006	-0.011
					(0.016)	(0.015)
Δ log(k/l) 1991-1996					-0.018	-0.019
					(0.011)	(0.011)
log initial PRODY	-0.011***	-0.010***	-0.012***	-0.011***	-0.011***	-0.011***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Constant	0.131***	0.113***	0.134***	0.119***	0.119***	0.110***
	(0.041)	(0.039)	(0.042)	(0.041)	(0.040)	(0.038)
Observations	257	257	257	257	257	257
R^2	0.080	0.083	0.066	0.071	0.092	0.101

Notes: Results from estimating equation 13 using OLS. The dependent variable is the Relocation index over 1996-2006. Robust standard errors are in parentheses. Columns (1) and (2) include an average of the industry factor intensity variables over 1998-2006. Columns (3) and (4) include initial industry factor intensities, corresponding to an average over the years 1995-1997. Columns (5) and (6) introduce the variation in factor intensities over the 5-year preceding period 1991-1996.
Significance levels: *** 1-percent, ** 5-percent, * 10-percent.

Table 9. Determinants of Pure Relocation, 1996-2006.

	Dependent variable: Pure Relocation index 1996-2006					
	(1)	(2)	(3)	(4)	(5)	(6)
log(s/l) 1998-2006	0.003	0.001				
	(0.004)	(0.004)				
log(k/l) 1998-2006	-0.002	-0.002				
	(0.002)	(0.002)				
log(R&D/sales), World 1998-2006	0.004***		0.003***		0.004***	
	(0.001)		(0.001)		(0.001)	
log(R&D/sales), US 1998-2006		0.003***		0.003***		0.004***
		(0.001)		(0.001)		(0.001)
TFP growth 1998-2006	0.122*	0.116			0.122*	0.116*
	(0.067)	(0.071)			(0.067)	(0.070)
Initial log(s/l)			0.004	0.002		
			(0.004)	(0.004)		
Initial log(k/l)			-0.002	-0.001		
			(0.002)	(0.001)		
TFP growth 1995-1997			0.029	0.032		
			(0.062)	(0.062)		
Δ log(s/l) 1991-1996					-0.007	-0.012
					(0.015)	(0.015)
Δ log(k/l) 1991-1996					-0.014	-0.015
					(0.011)	(0.011)
log initial *PRODY*	-0.010**	-0.009**	-0.011***	-0.010**	-0.010**	-0.009**
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Constant	0.118***	0.098**	0.122***	0.104**	0.107***	0.095**
	(0.043)	(0.041)	(0.044)	(0.042)	(0.041)	(0.039)
Observations	257	257	257	257	257	257
R^2	0.082	0.084	0.068	0.072	0.090	0.099

Notes: Results from estimating equation 14 using OLS. The dependent variable is the Pure Relocation index over 1996-2006. Robust standard errors are in parentheses. Columns (1) and (2) include an average of the industry factor intensity variables over 1998-2006. Columns (3) and (4) include initial industry factor intensities, corresponding to an average over the years 1995-1997. Columns (5) and (6) introduce the variation in factor intensities over the 5-year preceding period 1991-1996. Significance levels: *** 1-percent, ** 5-percent, * 10-percent.

Results are almost identical for the relocation (Table 8) and pure relocation indices (Table 9). The coefficients on skill and capital intensity are small in magnitude and are imprecisely estimated. They are not statistically significant in any of the specifications. The only variables that seem to play a role in predicting future relocation are the initial *PRODY* and R&D intensity. The TFP growth is positive and significant in some specifications, but only at the 10-percent. The initial level of a product's sophistication, as captured by the initial *PRODY*, is negative and statistically significant at the 1 or 5-percent level in all specifications. However, the negative coefficient of the initial *PRODY* may arise as a consequence of mean reversion, since instrumenting this variable with a lag changes the sign of the coefficient. R&D intensity is significant at the 5-percent or 1-percent in all specifications. This suggests that sectors with a higher investment in R&D are more likely to experience *upward* relocations (i.e., towards higher income countries), whereas sectors with lower R&D intensity are more likely to undergo *downward* relocations (i.e., towards lower income countries).

The industry-level regressions have failed to provide evidence for the importance of factor intensities in explaining subsequent production relocation. The results presented in this section suggest that the variables on factor intensities, capital and skill intensity, are not predictive of future relocation. However, we do not suggest that they are irrelevant. A plausible explanation is that the level of aggregation of the data is not adequate for this kind of analysis. As we have seen in Section 4, relocation processes are better captured with highly disaggregated trade data.

Hence, the results presented in this section do not support the hypothesis that relocation processes can be predicted based on the variables presented here, with the exception of R&D intensity. Thus, future production relocation appears mostly as an unpredictable phenomenon on the basis of the variables here considered. Only R&D investment is positively correlated with subsequent relocation: industries that invest more (less) in R&D are more likely to experience *upward* (*downward*) relocations.

7. CONCLUSIONS

The process of international relocation of production across country income groups has been a central feature of economic globalization. This chapter explores the broad figures of this process over the years 1996-2006 and 1963-1999 and provides an assessment of the sign and intensity of production relocation over the two sample periods, at an aggregate level and at the product and sector level. The analysis also attempts to characterize the dynamic empirical properties of international relocation processes based on the analysis of intra-distribution dynamics and the long-run distribution that arises as a result of production relocation across countries with different income levels.

We find that, from an aggregate perspective, the intensity of international relocation of production has remained surprisingly constant over the 1996-2006 period. The same analysis over the years 1963-1999 reveals a slightly lower intensity compared to the analysis based on the 6-digit level data for the more recent period, but it is very similar when both periods are compared using a common level of product disaggregation. However, the apparent stability in the intensity of production relocation over the two sample periods masks considerable relocation at the product level. A more formal analysis using a model of distribution dynamics confirms substantial mobility in products *PRODYs'*, which reflect the existence of *upward* and *downward* relocations, as captured by products' transitions to different states. The lower and upper states of the distribution show more persistence, whereas in the other three intermediate states the probability of transiting out of that category is higher. The mobility indices used to summarize the intra-distribution dynamics reflect higher mobility in the more recent period (1996-2006) compared to the previous one (1963-1999). However, we cannot conclude that mobility has been higher in the more recent period, since the results obtained for these two periods are not strictly comparable because of the different disaggregation levels.

Regarding the evolution of the overall distribution, the long-run scenario based on the ergodic distribution is very similar to the initial and final distribution in both sample periods. That is, despite the mobility observed, with products undergoing *upward* and *downward r*elocations (as captured by the products' transitions across country income groups), the external shape of the distribution does not change significantly. This result confirms the conclusions obtained with the analysis based on the index of dispersion, which provided evidence on the constant intensity of production relocation.

The fact that the ergodic distribution is equal to the initial distribution and that distributions are almost identical over a 40-year period and a 10-year period provides evidence that production relocation appears as a stochastic stationary process which is time-invariant. This chapter does not develop a formal model to explain the kind of shocks that might lead to this stationary distribution, but the (informal) interpretation of this result is that international trade tends to a moving equilibrium driven by innovation and standardization. These technological product shocks lead to a continuous process of international relocation by affecting factor intensities that change countries' comparative advantage. As a result of these shocks (innovation and standardization), products experience *upward* and *downward* relocations. Countries may adapt to the loss of some industries by changing their specialization towards products more in line with their comparative advantage. This reorientation in export specialization acts as some sort of compensating mechanism. As a result, despite the continuous relocation processes, world trade tends to a stationary distribution, with products roughly equally distributed across income groups.

The analysis of the dynamics at the sector level reveals substantial heterogeneity and important relocation processes. During the period 1996-2006, at the six-digit level, we find that product relocation is only very weakly (negatively) correlated with the product's initial sophistication index. The same result is obtained for the 1963-1999 period. Thus, the fact that a product is currently an export of low- (high-) income countries is of no real help in predicting whether the product will relocate in the future towards higher or lower income producers. Similarly, at the sector level, we find industries with high initial sophistication relocating towards higher-income countries (e.g., pharmaceuticals and chemicals), as well as industries relocating towards lower-income countries (e.g., machinery and motor vehicles). Conversely, we find industries with low initial sophistication moving upwards along the exporters' income ladder (e.g., miscellanea), as well as industries moving downwards (e.g., textiles).

This apparent unpredictability is somewhat confirmed with the industry regressions that consider other variables as potential drivers of subsequent production relocation, such as capital and skill intensity, R&D or TFP growth, although these results have to be interpreted with caution due to data aggregation. The cross-industry regressions have failed to provide evidence for the importance of factor intensities as potential determinants of relocation. The only variable that seems to play a role in predicting subsequent relocation is R&D intensity. This leaves little room for industrial policies aimed at promoting specific industries that have better chances of moving up along the exporters' income ladder and for regional policies aimed at anticipating the dangers of future relocations of local industries towards lower-income areas. An interesting question that arises then is how the relocation processes analyzed in this chapter have influenced the economic performance across countries. The analysis of the impact of international production relocation on countries’ growth is conducted in Chapter 5.

8. APPENDIX

Table A1. List of countries used in the analysis for the 1995-2007 period.

ISO3	Country name	ISO3	Country name
AGO	Angola*	FRA	France
ALB	Albania	GAB	Gabon
ARE	United Arab Emirates	GBR	United Kingdom
ARG	Argentina*	GEO	Georgia*
ARM	Armenia	GHA	Ghana
AUS	Australia	GIN	Guinea
AUT	Austria	GMB	Gambia, The
AZE	Azerbaijan*	GNB	Guinea-Bissau*
BDI	Burundi	GRC	Greece
BEN	Benin	GTM	Guatemala
BFA	Burkina Faso	GUY	Guyana
BGD	Bangladesh	HKG	Hong Kong SAR, China
BGR	Bulgaria	HND	Honduras
BHR	Bahrain	HRV	Croatia
BIH	Bosnia and Herzegovina	HUN	Hungary
BLR	Belarus*	IDN	Indonesia
BLX	Benelux	IND	India
BOL	Bolivia	IRL	Ireland
BRA	Brazil	IRN	Iran, Islamic Rep.
BTN	Bhutan	ISR	Israel
CAF	Central African Republic	ITA	Italy
CAN	Canada	JOR	Jordan
CHE	Switzerland	JPN	Japan
CHL	Chile	KAZ	Kazakhstan*
CHN	China	KEN	Kenya
CIV	Cote d'Ivoire	KGZ	Kyrgyz Republic *
CMR	Cameroon	KHM	Cambodia
COG	Congo, Rep.	KOR	Korea, Rep.
COL	Colombia	KWT	Kuwait
CRI	Costa Rica	LAO	Lao PDR
CYP	Cyprus	LBN	Lebanon
CZE	Czech Republic	LBR	Liberia *
DEU	Germany	LKA	Sri Lanka
DJI	Djibouti	LTU	Lithuania
DNK	Denmark	LVA	Latvia
DOM	Dominican Republic	MAR	Morocco
DZA	Algeria	MDA	Moldova *
ECU	Ecuador	MDG	Madagascar
EGY	Egypt, Arab Rep.	MEX	Mexico
ERI	Eritrea	MKD	Macedonia, FYR
ESP	Spain	MLI	Mali
EST	Estonia	MNG	Mongolia
ETH	Ethiopia	MOZ	Mozambique
FIN	Finland	MRT	Mauritania
FJI	Fiji	MUS	Mauritius

* Outliers in GDP that are excluded from the construction of the indices

Table A1 (*cont*). List of countries used in the analysis for the 1995-2007 period.

ISO3	Country name	ISO3	Country name
MWI	Malawi	SLV	El Salvador
MYS	Malaysia	SVK	Slovak Republic
NER	Niger	SVN	Slovenia
NGA	Nigeria	SWE	Sweden
NIC	Nicaragua	SYR	Syrian Arab Republic
NLD	Netherlands	TCD	Chad*
NOR	Norway	TGO	Togo*
NPL	Nepal	THA	Thailand
NZL	New Zealand	TJK	Tajikistan *
OMN	Oman	TKM	Turkmenistan*
PAK	Pakistan	TTO	Trinidad and Tobago
PAN	Panama	TUN	Tunisia
PER	Peru	TUR	Turkey
PHL	Philippines	TZA	Tanzania
PNG	Papua New Guinea	UGA	Uganda
POL	Poland	UKR	Ukraine *
PRT	Portugal	URY	Uruguay*
PRY	Paraguay	USA	United States
ROM	Romania	UZB	Uzbekistan
RUS	Russian Federation*	VEN	Venezuela, RB*
RWA	Rwanda *	VNM	Vietnam
SAU	Saudi Arabia	YEM	Yemen, Rep.
SDN	Sudan	ZAF	South Africa
SEN	Senegal	ZAR	Congo, Dem. Rep.
SGP	Singapore	ZMB	Zambia
SLE	Sierra Leone*		

* Outliers in GDP that are excluded from the construction of the indices

Table A2. List of countries used in the analysis for the 1962-2000 period.

ISO3	Country name	ISO3	Country name	ISO3	Country name
ARG	Argentina*	GIN	Guinea	NPL	Nepal
AUS	Australia	GNB	Guinea-Bissau	NZL	New Zealand
AUT	Austria	GRC	Greece	PAK	Pakistan
BDI	Burundi	GTM	Guatemala	PAN	Panama
BEN	Benin	HKG	Hong Kong SAR, China	PER	Peru
BFA	Burkina Faso	HND	Honduras	PHL	Philippines
BLX	Benelux	IDN	Indonesia	PRT	Portugal
BOL	Bolivia	IND	India	PRY	Paraguay
BRA	Brazil	IRL	Ireland	ROM	Romania
CAF	Central African Republic	IRN	Iran, Islamic Rep.*	SEN	Senegal
CAN	Canada	ISR	Israel	SGP	Singapore
CHE	Switzerland	ITA	Italy	SLE	Sierra Leone*
CHL	Chile	JAM	Italy	SLV	El Salvador
CHN	China	JOR	Jordan*	SWE	Sweden
CIV	Cote d'Ivoire	JPN	Japan	SYR	Syrian Arab Republic*
CMR	Cameroon	KEN	Kenya	TCD	Chad
COG	Congo, Rep.*	KOR	Korea, Rep.	TGO	Togo
COL	Colombia	LKA	Sri Lanka	THA	Thailand
CRI	Costa Rica	MAR	Morocco*	TTO	Trinidad and Tobago
CYP	Cyprus*	MDG	Madagascar	TUN	Tunisia
DNK	Denmark	MEX	Mexico	TUR	Turkey
DOM	Dominican Republic	MLI	Mali	TWN	Taiwan
ECU	Ecuador	MOZ	Mozambique	TZA	Tanzania
EGY	Egypt, Arab Rep.	MRT	Mauritania	UGA	Uganda
ESP	Spain	MUS	Mauritius	URY	Uruguay
ETH	Ethiopia	MYS	Malaysia	USA	United States
FIN	Finland	NER	Niger	VEN	Venezuela, RB
FRA	France	NGA	Nigeria*	ZAF	South Africa
GBR	United Kingdom	NLD	Netherlands	ZAR	Congo, Dem. Rep.
GHA	Ghana	NOR	Norway	ZMB	Zambia*

* Outliers in the output gap

Table A3. Correspondence between the original sections of the HS and our sectoral classification.

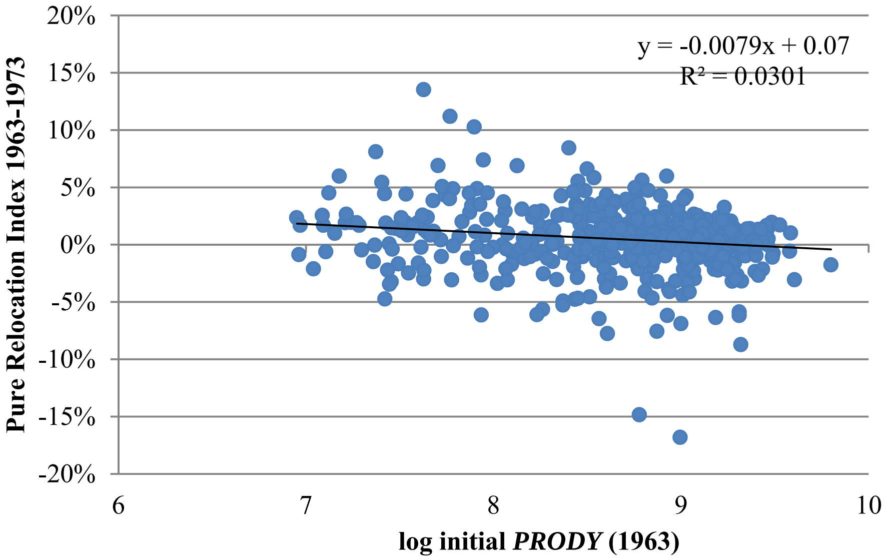
Original sections (HS)	Section Name	Sectors in our classification	Sector Name
Section I	Animal products	Section I	Animal products
Section II	Vegetable products	Section II	Vegetable products
Section IV	Food, beverage and tobacco	Section IV	Food, beverage and tobacco
Section V	Minerals	Section V	Minerals
Section VI	Products of the chemical or allied industries	Section VI, exc. chap. 30 Section VI. Chap. 30	Chemicals exc. Pharmaceuticals Pharmaceuticals
Section VII	Plastics	Section VII	Plastics
Section IX Section X	Wood Paper	Sections IX & X	Wood and paper
Section XV	Base metals and articles thereof	Section XV, exc. chap. 72 & 73 Section XV. Chap. 72 & 73	Metals and manufactures, exc. Iron Iron and manufactures thereof
Section XVI	Machinery	Section XVI. Chap. 84 Section XVI. Chap. 85	Machinery and mechanical appliances Electrical equipment
Section XVII	Transport equipment	Section XVII, exc. chap. 87 Section XVII. Chap. 87	Transport equipment, exc. Motor vehicles Motor vehicles
Section XVIII	Instruments	Section XVIII	Instruments
Section III Section XIV Section XIX Section XXI	Animal or vegetable fats and oils Pearls Arms Works of art	Sections III, XIV, XIX & XXI	Miscellanea
Section VIII Section XI Section XII	Leather Textiles Footwear	Sections VIII, XI & XII	Leather, textiles and footwear
Section XIII Section XX	Manufactures of stones and others Furniture and other manufactures	Sections XIII & XX	Furniture and other manufactures and stones

Table A4. Correspondence between the original sections of the SITC Rev.2 and our sectoral classification.

Original section (SITC)	Section Name	Sectors in our classification	Sector Name
Section 0	Food and live animals	Section 0	Food and live animals
Section 1	Beverages and tobacco	Section 1	Beverages and tobacco
Section 2	Crude materials, inedible, except fuels	Section 2	Crude materials, inedible, except fuels
Section 3	Mineral fuels, lubricants and related materials	Section 3	Mineral fuels, lubricants and related materials
Section 4	Animal and vegetable oils, fats and waxes	Section 4	Animal and vegetable oils, fats and waxes
Section 5	Chemicals and related products, n.e.s.	Section 5 excl. div. 54 & 58	Chemicals exc. Pharmaceuticals and Plastics
		Section 5. Div.54	Pharmaceuticals
		Section 5. Div.58	Plastics
Section 6	Manufactured goods classified chiefly by material	Section 6 exc. div. 61, 63, 64, 65 & 67	Manufactured goods excl. leather, textiles, wood and paper, iron and steel
		Section 6 Div.61, 65 & Section 8 Div.84, 85	Leather, textiles and footwear
		Section 6. Div.63 & 64	Wood and paper
		Section 6. Div.67	Iron and steel
Section 7	Machinery and transport equipment	Section 7 excl. div. 76 to 79	Machinery and mechanical appliances
		Section 7. Div.76 & 77	Electrical equipment
		Section 7. Div.78	Road vehicles
		Section 7. Div.79	Other transport equipment
Section 8	Miscellaneous manufactured articles	Section 8 exc. div. 84, 85, 87 & 88	Miscellaneous manufactured articles excl. apparel, footwear and instruments
		Section 8. Div.87 & 88	Instruments
Section 9	Commodities and transactions not classified elsewhere in the SITC	Section 9	Commodities and transactions not classified elsewhere in the SITC

Figure A1. Initial *PRODY* and Pure Relocation Index (*PR*) for the 1963-1999 period. 10-year subperiods. 4-digit products

a) 1963-1973



b) 1973-1983

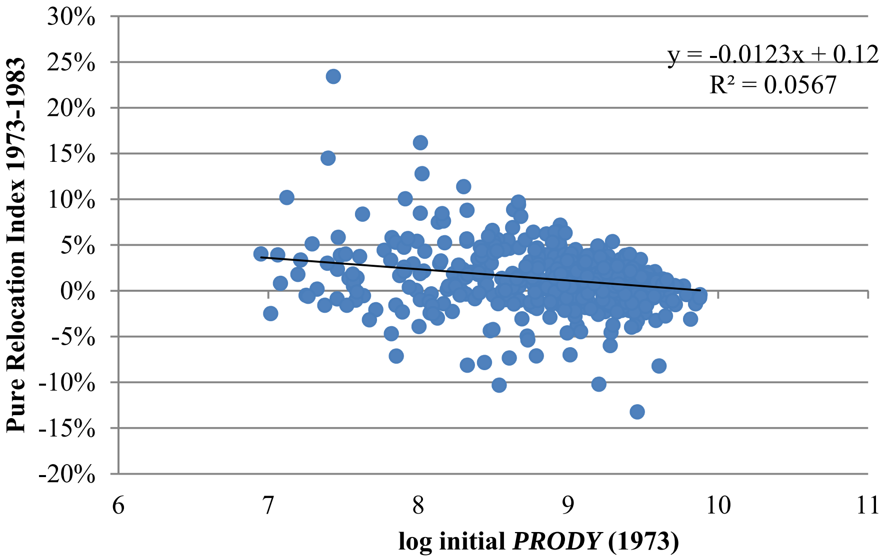
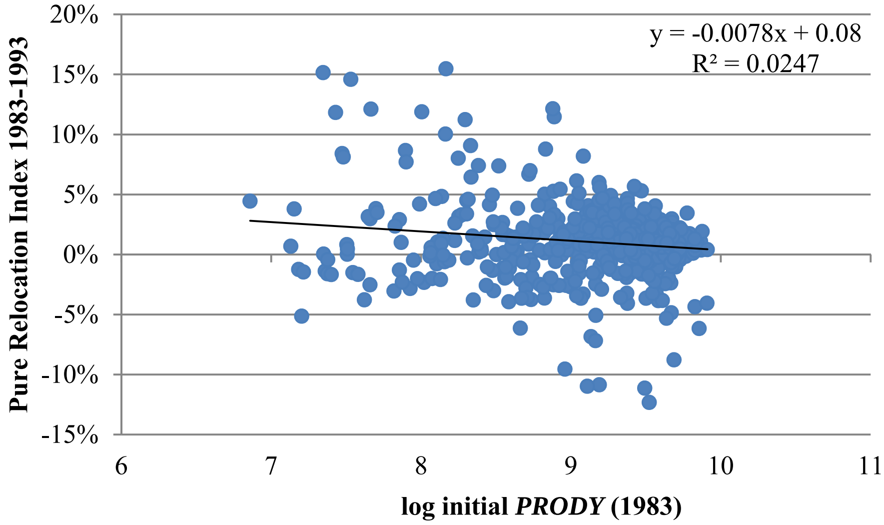
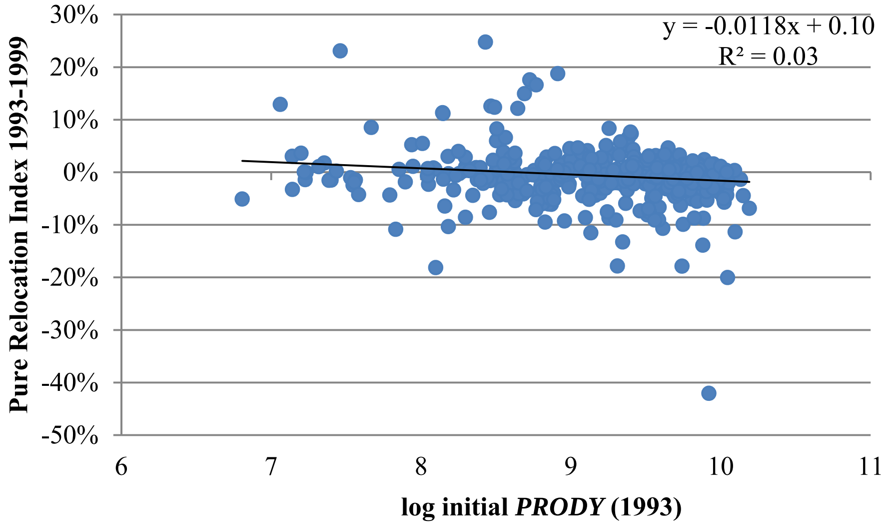


Figure A1 (*cont*). Initial *PRODY* and Pure Relocation Index (*PR*) for the 1963-1999 period. 10-year subperiods. 4-digit products

c) 1983-1993



d) 1993-1999



Chapter 5:

INTERNATIONAL RELOCATION OF PRODUCTION AND GROWTH

Abstract

The process of international relocation of production from high to low-income countries is a central feature of economic globalization and, potentially, an important determinant of the recent dynamics of output and employment across countries. However, this phenomenon and its impact on countries' economic performance have not been analysed systematically across a large sample of countries. This chapter contributes to the analysis of this process. Using trade data on around 5,000 products and more than 100 countries, this chapter examines how international relocation has affected cross-country growth between 1995 and 2007. We find that countries that were specialized at the beginning of the period in products that, on average, relocated towards lower-income (higher-income) economies over the following years exhibited significantly lower (greater) growth over the period. This impact is robust and economically important: a difference of one standard deviation in the country's relocation impact index resulted in a difference of about 1 percentage point in the country's average annual growth.

1. INTRODUCTION

International relocation of production from high to low-income countries has been a key feature of the increase in economic globalization over the last decades. Stimulated by the fall in transportation costs, the revolution in the information and communication technologies (ICT) and the reduction in tariffs and other barriers to trade, the nature of production and international trade has undergone substantial changes. The ensuing extraordinary increase in international trade has not kept constant the composition of each country's exports, but has involved a great deal of international relocation of production. Goods that were mostly exported by advanced countries are now exported by developing countries.

In the mid-nineties, exports of high income countries accounted for 78% of total exports, whereas exports of low income countries represented less than 7%.[40] In 2007, those countries doubled their share in world trade up to nearly 14%, whereas the share of the advanced countries fell to 63%. In the same vein, the share of low-income countries accounted for just 6% of high income countries' imports and in 2007, this share reached 15%. In parallel with these events, the relative share of the manufacturing sector in the advanced countries decreased, with the subsequent job losses and an increase in wage inequality. In the US, more than three million employments were lost in manufacturing during this period and in the European Union, job losses in this sector amounted to two million.[41] This turmoil in labour markets of advanced countries has led to the impression that globalization and international trade have raised wage inequality by moving jobs abroad.

Although some studies consider that other shocks, such as skill biased technical change might have played a more important role (Acemoglu (2002), Acemoglu and Autor (2011), Goos, Manning and Salomons (2014)), international production relocation is likely to have considerably influenced the dynamics of output and employment across countries. The importance of this phenomenon has motivated numerous studies on specific industries, regions and countries (e.g., Feenstra and Hanson (1996, 1999); Gereffi (1999); Bernard, Jensen and Schott (2006); Lall, Albaladejo and Zhang (2004);

[40] Countries are classified in income groups according to the World Bank definition in 1995.

[41] Data for US is based on the Current Employment Statistics survey by the Bureau of Labor Statistics. For the European Union, we have calculated the changes in manufacturing employment in the EU-15 during the period 1998-2007 using the Labour Force Survey from Eurostat.

Marin (2006); Sturgeon, Van Biesebroeck and Gereffi (2008); Autor, Dorn and Hanson (2013); Ebenstein et al. (2014), Timmer et al. (2015); Acemoglu et al. (2016); Pierce and Schott (2016)). For instance, Bernard, Jensen and Schott (2006) found that imports from low-income countries negatively affected US firms' outcomes in terms of plant survival and employment growth. Autor, Dorn and Hanson (2013) estimate that one-quarter of the aggregate decline in US manufacturing employment is explained by import competition from China. In Pierce and Schott (2016), they find a link between US employment decline and the change in US trade policy that granted China a permanent most-favored-nation (MFN) status, eliminating potential tariff increases on Chinese imports. Although there is a substantial body of research, there is not a systematic analysis of the impact of international relocation processes across countries. This is the gap that this work intends to fill. Using data for the 1995-2007 period on around 5,000 products and more than 100 countries, this chapter studies the process of international relocation of production between richer and poorer countries and the impact it has had on cross-country growth.

The first analysis of the dynamics of the reorganization of production across countries at different levels of development is the *product life-cycle theory* described in Vernon (1966). In this seminal paper, Vernon (1966) argued that most new goods are initially manufactured in the country where they are first developed, with innovations taking place in developed countries. However, as the demand for a product expands, a certain degree of standardization takes place. At an advanced stage of standardization, the less-developed countries become attractive locations that offer competitive advantages in terms of cost-saving. At this stage of the product cycle, part or all of the production shifts to less developed countries, where wages are lower. International production relocation due to the product-cycle has been reinforced in recent times by production fragmentation and offshoring. Production processes are broken into separate stages, and tasks with different factor intensities are relocated to different countries according to comparative advantage, giving rise to a huge increase in trade of intermediate products and to the emergence of global supply chains (Feenstra (1998), Hummels, Ishii and Yi (2001), Johnson and Noguera (2012a), Koopman, Wang and Wei (2014)).

To the extent of our knowledge, there are no studies considering the aggregate impact of the international relocation process on cross-country growth. This is the area in which this work aims to contribute. For that purpose, country impact indices are defined, based on the product relocation indices developed in Chapter 4. Recall that the product indices defined in the previous chapter are a weighted average of the exporting countries' GDP pc. Then, the change over time in the average per capita GDP of the exporting countries is used as a measure of the product's international relocation across countries at different stages of development. Note that an increase (reduction) in the product's index implies that the average exporter is now a richer (poorer) country and hence, indicates that its production has relocated towards more advanced (less developed) countries. Based on these indices, we construct country measures of the intensity with which the relocation process has affected the particular export basket of each country.

The *relocation impact indices* used in this chapter capture the extent to which a country's export basket is composed of products whose production has relocated towards richer or poorer countries. Using these latter country measures, the impact of international relocation on the countries' economic growth is estimated. We find that countries that were specialized in 1996 in products that, on average, experienced a relocation process towards lower-income (higher-income) economies over the following years, exhibited lower (greater) growth over the 1996-2006 period. The impact is statistically significant, robust and economically important.

The empirical regularities found in this work could potentially be explained by different mechanisms. The analysis points to product shocks leading to innovation and standardization as two drivers of international relocation of production and intend to link them to differences in cross-country growth. Technological shocks can increase or reduce product sophistication. For instance, the intensification of innovation and skill-biased technical change raise sophistication in a product category, thereby increasing the relative productivity of knowledge and skills (Nelson and Phelps (1966), and Acemoglu (2002)). Conversely, standardization reduces product sophistication and, thus, the relative requirement of knowledge and skills. Hence, if the sophistication of a product increases, then its production will relocate towards the countries with higher human capital or a previous specialization in that product (i.e., these countries will increase their revealed comparative advantage (*RCA*) in that product). On the contrary, standardization leads to relocation towards countries with lower human capital and no previous specialization in the good. These shocks affect countries' per capita GDP:

higher standardization increases competition from low-wage countries and reduces the productivity of the product-specific knowledge and skills (it reduces the value of product-specific knowledge), thereby harming the relative growth of the countries previously specialized in the product.[42]

Consequently, countries initially specialized in products exhibiting relocation towards lower-income countries are likely to show lower relative income growth. The reverse correlation is expected in the case of a positive shock (innovation) leading to a relocation trend towards higher-income countries. The empirical strategy in this chapter also controls for the existence of country shocks that could affect countries' GDP pc without products undergoing any relocation. To isolate country shocks from product shocks and avoid the potential correlation between the relocation impact indices and country growth due to country shocks, we employ an instrumental-variables strategy that consists of excluding from the calculation of each country's indices all the data relative to the country.[43] Thus, each country's instrument is affected by the product shocks in which the country is specialized, but not by country specific shocks.

The policy implications derived from this chapter's results are not straightforward. Product categories experience technological shocks that change comparative advantage across country income groups: increasing innovation (standardization) in a particular product category raises (reduces) the comparative advantage and growth prospects of countries with greater generic human capital and better economic institutions, as well as of countries with greater product-specific human capital and knowledge in the category experiencing the shock. The analysis of the potential drivers of relocation conducted in the fourth chapter suggests that these shocks appear to be largely unpredictable: it is not obvious which will be the specific industries, products, and tasks more intensively migrating towards lower-income countries over the next decade and which ones will stay in high-income countries. Consequently, it is unclear how governments could implement industrial (or regional) policies that anticipate and take advantage of future

[42] The assumption that products require a specific set of inputs and capabilities in the framework described above is also related to the literature of complexity and the product space developed in Hidalgo et al. (2007) and Hidalgo and Hausmann (2009). They show that the level of complexity of a country's economy predicts the types of products that countries will be able to develop in the future. This suggests that the new products a country develops depend substantially on the capabilities already available in that country. Thus, the productive structure of countries evolves by spreading to nearby products in the product space.

[43] Our identification strategy is related to that used by Autor, Dorn and Hanson (2013), who replace US imports from China by imports from China to other high-income markets.

relocation shocks. Nonetheless, as it is often suggested, general policies that raise the country's generic human capital and improve its institutional environment can increase their flexibility to favorably adjust to technology shocks that change the comparative advantage of countries.

The chapter is organized as follows: section 2 includes a review of the related literature and provides a framework that will help to interpret the empirical work; section 3 introduces the indices used to measure product relocation and its impact on countries, depending on their specialization. Section 4 presents the results and section 5 concludes.

2. RELATED LITERATURE

The work in this chapter relates to different literatures. First, it relates to models of the product cycle (Vernon (1966)) and models of technology diffusion (Krugman (1979), Dollar (1986), Jensen and Thursby (1986), Grossman and Helpman (1991a, b), Antràs (2005), Acemoglu et al. (2012)), which provide a theoretical framework for the phenomenon of international relocation. Second, this chapter is also related to the empirical literature that studies the impact of globalization and exposure to international trade on countries' economic performance (Bernard, Jensen and Schott (2006); Autor, Dorn and Hanson (2013); Ebenstein et al. (2014); Pierce and Schott (2016), among others).

The dynamics of the spatial reorganization of production across countries at different levels of development seem to fit the *product life-cycle theory* described in Vernon (1966), although this phenomenon has been reinforced in recent times by production fragmentation and the slicing of value chains. The analysis of the product life-cycle theory and the nature and limitations of offshoring have been extended in several directions by many authors (Krugman (1979), Dollar (1986), Jensen and Thursby (1986), Grossman and Helpman (1991a, b), Antràs (2005), Acemoglu et al. (2012), and Baldwin and Evenett (2015)).

The first attempt to formalise the concept of the product cycle was carried out by Krugman (1979). He developed a general-equilibrium model in which the pattern of trade is determined by a continuing process of innovation and technology transfer. Innovation takes place in rich countries (the North) in the form of production of new goods, which are exported to less developed countries (the South). New products can be produced by South only after a lag. This lag in the adoption of technology by South is what gives rise to trade: the North exports new products and imports old ones.[44] Relative wages are constant, with a positive differential in developed countries derived from its ability to exploit new technology, which gives those countries a temporary monopoly position in new goods. However, changes in the rates of innovation and technology transfer can alter income distribution between regions: if rich countries want to maintain a wage differential and earn higher incomes and grow, they need to continuously improve the type of goods they produce.

Krugman's work has been extended by Dollar (1986) and Jensen and Thursby (1986, 1987). Dollar (1986) constructs a model of North-South trade that combines the product cycle approach in Vernon (1966) and Krugman (1979) with factor price equalization. As in Krugman, the rate of product innovation is exogenous, and it is the factor that enables workers in the North to earn a premium over wages in the South. However, in the absence of innovation, international factor mobility (transfer of technology and capital), together with rapid growth of the labor force in the South, will put downward pressures over wages in the North, leading to factor price equalization.

Contrary to Krugman and Dollar, who take the introduction of new products in the North as an exogenous rate, Grossman and Helpman (1991a) construct a model where the length of the cycle and the speed in the introduction of new products are determined endogenously. Acemoglu et al. (2012) emphasize the interaction between innovation and standardization, with these two forces affecting growth. Innovation takes the form of the creation of new goods that, initially, can only be produced by skilled workers. Then, a process of standardization follows so that new goods are adapted to be produced by unskilled workers. Thus, standardization alleviates the pressure on high-skill workers, thereby stimulating further innovation, but at the same time, the anticipation of standardization may discourage innovation because if reduces the potential profits from new products. Contrary to the approaches in Krugman and Grossman and Helpman, they do not focus in the interactions between advanced and less developed countries. In their model, innovation and standardization lead to a different use of skilled and

[44] In the model, the technical progress takes the form of the availability of new products rather than an increase in productivity in the manufacturing of old goods; technology transfer turns new goods into old goods.

unskilled labor. Although Acemoglu et al. (2012) focus on a closed economy setup, product shocks take the form of standardization and innovation as in our work. These product shocks, by affecting factor intensities, change countries' comparative advantage and lead to international relocation of production.

Innovation and technology transfer are the drivers of the product-life cycle models described above and both play an important role in the pattern of world trade and its changes over time. In recent times, the decline in transport cost, the ICT revolution and greater trade liberalization have accelerated the spatial reorganization of production. Production processes are increasingly fragmented across countries, slicing up the value chains (Feenstra (1998), Hummels, Ishii and Yi (2001), Johnson and Noguera (2012), Timmer et al. (2013, 2014), Koopman, Wang and Wei (2014)). As a consequence, if trade mostly entailed an exchange of goods, now it involves value added in different locations, leading to a new paradigm characterized by trade in tasks[45] (see for instance Grossman & Rossi-Hansberg (2006, 2008)). The possibility of unbundling the different stages of the production of a good magnifies each country's comparative advantage, since it allows for a deeper specialization (Baldwin & Evenett (2015)).

However, in spite of lower wages in developing countries and falling transport and coordination costs, there are some factors that limit the extent to which an activity can be moved abroad without incurring in excessive costs. Among the factors that may offset the profitability of producing goods abroad, Antràs (2005) emphasizes that the incomplete nature of contracts limits the extent to which production processes can be fragmented across borders.[46] In his model, the presence of incomplete contracts gives rise to product cycles as a result of a trade-off between the lower costs of Southern manufacturing and the potential incomplete-contracting distortions associated with it. Nunn (2007) empirically tests how contract enforcement determines investment and trade decisions, and finds that the average contract intensity of production and of exports is positively correlated with contract enforcement.[47] On the other hand, Baldwin

[45] Although the analysis in this chapter is conducted on a product basis, data at the 6-digit level allows us to capture part of the fragmentation process, since it is based on highly disaggregated trade data that also includes parts and components.

[46] There is a large literature that focuses on the effect that contract enforcement has on the decisions of multinational firms (see for instance Grossman and Helpman 2005; Antràs 2003; Antràs and Helpman 2004).

[47] Marin (2006) also points to the improved contracting environment in Eastern Europe as one of the factors that has increased the attractiveness of this region as a location for European firms.

and Evenett (2015) point out that some activities benefit from co-location and the agglomeration of skills and tasks. According to these authors, innovation and globalization generate opposing tendencies: reduction in trade barriers and lower transport and coordination costs make it feasible to split production to take advantage of the big wage differences between countries, but agglomeration of skills and tasks in some activities leads to higher productivity and specialization advantages.[48] Thus, not every activity is at risk of moving across borders.[49]

All in all, international relocation of production from high to low-income countries is a process which has had an important impact on the economic performance of countries over the past decades. This topic has attracted considerable attention, giving rise to an extensive literature that discusses the impact of international relocation on the labor market and how it affects wages and income (see for instance, Feenstra and Hanson (1996, 1999); Amiti and Wei (2005); Grossman and Rossi-Hansberg (2008); Autor, Dorn and Hanson (2013); Timmer, Stehrer and de Vries (2013) and Ebenstein et al. (2014); Pierce and Schott (2016) among others; or Crinò (2009) for a review of the literature analyzing the effects of offshoring on labour market and wages). Another strand in the literature analyses the impact of relocation on specific sectors or countries (Gereffi (1999); Lall, Albaladejo and Zhang (2004); Marin (2006); Bernard, Jensen and Schott (2006); Sturgeon, Van Biesebroeck and Gereffi (2008); Pavlínek and Ženka, (2010), Timmer et al. (2015)).

The previous empirical literature has explored different avenues to measure a country's exposure to globalization. For instance, Feenstra and Hanson (1996, 1999) estimate, using a two-step procedure, the impact of trade on wages using the foreign outsourcing of intermediate inputs (i.e., the share of imported intermediate inputs over total inputs). Their results suggest that foreign outsourcing, together with technical change, have contributed to the increase of wage inequality. Bernard, Jensen and Schott (2006) study the impact of low-wage countries imports in the outcome of US manufacturing plants (in terms of firm exit, survival and employment growth). Using US plant data, they find

[48] Actually, these are some of the factors that have been identified by the economic geography literature as forces leading to agglomeration (see for instance Krugman (1991) and Redding (2010)).

[49] Other factors preventing offshoring to take place have to do with malfeasance by counterparties (quality of products, treatment of staff or subcontractors or under-bidding for contracts). It is also worth mentioning the political sensitivities and social pressures to keep production close to the end markets (Sturgeon, Van Biesebroeck and Gereffi, 2008).

that an industry's exposure to imports from low-wage countries is negatively related to the probability of plant survival and to employment growth in the plant (although the effect is smaller for the most capital-intensive plants in the industry). They also find evidence that U.S. manufacturing plants adjust their product mix in response to competition from low-wage countries.

Using data on US local labour markets, Autor, Dorn and Hanson (2013) relate changes in Chinese import penetration on changes in US employment, wages, labour-force participation rates and also changes in public transfer benefits. They find that local labour markets that are exposed to rising Chinese imports experienced increased unemployment, decreased labour-force participation and increased use of disability and other transfer benefits, as well as lower wages during the period 1990-2007. In Ebenstein et al. (2014), they define offshore activity in each industry using the total employment of foreign affiliates among multinational U.S. firms. With this measure, they examine the impact of globalization (offshoring and trade) on U.S. workers' wages and find that individuals who perform routine tasks are more affected by competition overseas, since they are engaged in activities that can be easily performed elsewhere. Pierce and Schott (2016) find a link between the sharp decline in US manufacturing and the conferral of permanent normal trade relations (PNTR) on China. This change in US policy removed the uncertainty associated with annual renewals of this status by permanently setting US tariffs on Chinese imports at the Most Favored Nation's levels. The impact of this trade policy is estimated using the difference between the level to which tariffs would have risen and the actual tariff rate that was locked in by PNTR. Their results show that industries more affected by the change in US policy experienced larger employment declines, along with increases in the volume of US imports from China and in the number of US firms importing from China. Results also suggest that firms adjust their production processes or product mix in response to increased import competition, by reallocating towards more capital-intensive plants, which are more in line with US comparative advantage.

The studies mentioned above document a negative effect of import competition from low-wage countries on income and employment. While very interesting approaches, the previous research is limited to specific sectors, countries or regions. The aim of this chapter is to contribute to fill this gap by estimating the cross-country aggregate growth impact of international relocation of production. Our empirical approach to estimate the impact of this process on countries' GDP per capita is straightforward: first, a measure of a product's international relocation across countries with different income levels is defined. Then, based on these indices, country measures are calculated to address the intensity with which this process has affected each country, depending on its initial specialization. This approach allows us to study this phenomenon over a wide sample of countries and to provide an assessment of the economic impact of international relocation.

3. METHODOLOGY

3.1. Measuring production relocation

The indices used in this chapter to measure production relocation are based on the changes in the average income of the exporting countries. The average income is calculated using the exporters' revealed comparative advantage (RCA) in a product as weights, as in Hausmann, Hwang and Rodrick (2007) (henceforth HHR). HHR calculate the sophistication of a good by means of an index called *PRODY,* which is a weighted average of the exporting countries' GDP per capita. Specifically, the *PRODY* index of good *k* in period *t* is defined as:

$$PRODY_k^t = \sum_{c=1}^{C} \frac{RCA_{ck}^t}{\sum_{c=1}^{C} RCA_{ck}^t} GDPpc_c^t, \tag{1}$$

where $RCA_{ck}^t = \omega_{ck}^t / \omega_{Wk}^t$ is the revealed comparative advantage of country c in product k at period t (ω_{ck}^t and ω_{Wk}^t are the value-shares of product k in country c's exports and world trade, respectively), C is the number of countries and $GDPpc_c^t$ is the per-capita GDP of country c in constant PPP terms. Thus, the *PRODY* index is a weighted average of the exporting countries' GDP per capita, where the weights are given by the countries' specialization in the product.

Note that if the production of a good moves from rich to developing countries, the good's *PRODY* decreases. Conversely, an increase in a good's *PRODY* indicates that its average exporter is now a more developed country. Note that the change over time in a product's *PRODY* has two potential components: the change in the exporting countries' *RCA* and the change in their per capita GDP. The first component can be interpreted as the *pure relocation* effect because it only depends on the shift of production across countries with different income levels (e.g., lower income countries may increase their *RCA* in the product, while higher income countries decrease their *RCA*), whereas the second component does not involve a migration of production. To measure the first component, we define a variant of the *PRODY* index that we call the *constant income-PRODY*, denoted by *ciPRODY*, which is computed using per capita GDPs of the immediately preceding period and final-period *RCAs*:

$$ciPRODY_k^{0,T} = \sum_{c=1}^{C} \frac{RCA_{ck}^T}{\sum_{c=1}^{C} RCA_{ck}^T} GDPpc_c^0 \qquad (2)$$

3.2. Measuring the impact of production relocation

3.2.1. Product shocks impact

To capture the impact of product shocks on country *c* (i.e., changes in products' *PRODY*), we define the country *c*'s product-shocks impact index between periods 0 and T, denoted by $PSI_c^{0,T}$, as:

$$PSI_c^{0,T} = \log\frac{EXPY_c^{0,T}}{iEXPY_c^0} = \log\frac{\sum_k PRODY_k^T\,\omega_{ck}^0}{\sum_k PRODY_k^0\,\omega_{ck}^0}. \qquad (3)$$

Note that, as we keep constant the shares ω_{ck}^0 in country *c*'s exports, this index only depends on the change in the *PRODYs*. A high (low) value of the product-shock impact index *PSI* means that the country's export basket is made up of products whose production, on average, has moved towards higher (lower) income countries.

However, there is a potential problem with the interpretation of *PSI* as a measure of the impact of product shocks. Note that if a country is sufficiently large in the context of world trade, country-specific shocks changing this country's per capita GDP can significantly affect the *PRODY*s of the products it exports, thereby affecting the *PSI* index. Consequently, $PSI_c^{0,T}$ and country *c*'s growth would be positively correlated not because of the product shocks affecting country *c*'s export basket but because of country *c* specific shocks. To deal with this potential problem, we calculate specific *PRODY*s for each country that are constructed excluding all the data relative to the country (i.e., we exclude the information on this country's exports and GDP per capita). Then, we use these country specific *PRODY*s to construct instruments for the country's product-shocks index *c*'s. Specifically, we define the country *c*'s specific *PRODY* for good *k* (which is denoted by adding a '*csp'* prefix) as:

$$cs\_PRODY_{k,-c}^{t} = \sum_{i \neq c}^{C} \frac{RCA_{i-c,k}^{t}}{\sum_{c=1}^{C} RCA_{i-c,k}^{t}} GDPpc_{i}^{t}, \tag{4}$$

where $RCA_{i-c,k}^{t}$ is the country *i*'s revealed comparative advantage in good *k* calculated by excluding country *c*'s exports from world trade. Then, the *PSI* index using country-specific *PRODY*s is:

$$csp\_PSI_{c}^{0,T} = \log \frac{\sum_k cs\_PRODY_{k,-c}^{T}\, \omega_{ck}^{0}}{\sum_k cs\_PRODY_{k,-c}^{0}\, \omega_{ck}^{0}}. \tag{5}$$

The $csp\_PSI_{c}^{0,T}$ index is not affected by country-*c* specific shocks as country-*c* specific shocks do not affect the $cs\_PRODY_{k,-c}^{t}$ indices and the country-*c* export shares ω_{ck}^{0} are kept constant. However, product shocks to country *c*'s exports do affect the $cs\_PRODY_{k,-c}^{t}$ indices as they impact on all the remaining exporters of *k* and, therefore, they are captured by the $csp\_PSI_{c}^{0,T}$ index. The csp_PSI indices are used as instruments for the PSI indices in the econometric analysis so as to identify the impact of product shocks on each country's growth.

3.2.2. Pure relocation impact

Next, we assess the specific impact of the product shocks that lead to international production relocation, i.e., to changes in revealed comparative advantage across country income groups. To do so, we first define an index based on the *ciPRODYs* described in section 3.1. The *ciEXPY* index is calculated as:

$$ciEXPY_{c}^{0,T} = \sum\nolimits_{k} ciPRODY_{k}^{0,T} \omega_{ck}^{0} \tag{6}$$

Then, we define country *c*'s *pure relocation impact* index between periods 0 and T, $PRI_{c}^{0,T}$, as:

$$PRI_{c}^{0,T} = \log \frac{ciEXPY_{c}^{0,T}}{iEXPY_{c}^{0}} = \log \frac{\sum_k ciPRODY_{k}^{0,T}\, \omega_{ck}^{0}}{\sum_k PRODY_{k}^{0}\, \omega_{ck}^{0}}$$

$$= \log \left(\sum_{c=1}^{C} \frac{RCA_{ck}^{T}}{\sum_{c=1}^{C} RCA_{ck}^{T}} GDPpc_{c}^{0} \Big/ \sum_{c=1}^{C} \frac{RCA_{ck}^{0}}{\sum_{c=1}^{C} RCA_{ck}^{0}} GDPpc_{c}^{0} \right) \tag{7}$$

The *PRI* index captures changes in revealed comparative advantage across country income groups and averages these changes using each product share in the country's exports. Moreover, as before, we must keep in mind the possibility of the *PRI* indices capturing not only relocation shocks but also country-specific shocks. If a country is sufficiently large, country-specific shocks could also significantly affect the *ciPRODY*s of its exports by affecting the country's *RCAs*, thereby influencing the *PRI* measure. Consequently, the potential correlation between $PRI_c^{0,T}$ and country *c*'s growth could be due to country-*c* specific shocks instead of to relocation shocks to the country's export basket. Hence, as before, country specific *PRODY*s and *ciPRODYs* (which are constructed excluding all the data relative to each country) are used to construct instruments for each country's pure relocation index and use these instruments in two-stage least squares (2SLS) regressions (see the Appendix for the specific formulas of the instruments).

3.3. Data.

To construct the *PRODY* and *ciPRODY* indices, we use the data in BACI (Base pour l'Analyse du Commerce International, Gaulier and Zignago (2010)), which is a database provided by CEPII (Centre d'Études Prospectives et d'Informations Internationales). The original data in BACI come from the United Nations Statistical Division (COMTRADE database), over which an harmonization procedure is applied for reconciling the data reported by the exporting and importing countries in order to generate a single figure consisting of each bilateral flow in FOB values. We use the Harmonized System (HS)-1992 classification, which comprises more than 5,000 goods at the 6-digit level.

Data on GDP per capita, measured in 2005 prices PPP, come from the World Bank's World Development Indicators (WDI). For the regression analysis in section 4, we consider four alternative measures of institutional quality from the World Bank's World Governance Indicators: rule of law, regulatory quality, government effectiveness, and corruption control. Our main measure for human capital is years of schooling from Barro and Lee (2013). We conduct robustness checks also using the percentage of population over 25 years with the complete secondary education (denoted as *secondary*), also from Barro and Lee (2013), and the index of human capital per person from Penn World Tables 8.1 (denoted as PWT; Feenstra, Inklaar, and Timmer (2015)), which is based on Barro and Lee and returns to education from Psacharopoulos (1994). Capital intensity is defined as the country's capital stock per person engaged in production, which is also obtained from PWT 8.1. As additional controls, we also consider the share of oil exports in total exports from PWT 8.1, and population and land area from the World Bank's WDI. Given that BACI do not report separate trade flows for Belgium and Luxembourg, we had to merge the data of these two countries for the other variables here mentioned (GDP per capita, human capital, capital intensity, institutional quality measures, population and area).[50]

To calculate the *PRODYs*, we look for a consistent sample of countries offering trade information over all the reference period (1996-2006) and having a population of at least 500,000 inhabitants. As emphasized in HHR (2007), it is essential to use a consistent sample of countries to avoid index changes due to a changing composition of the sample. Moreover, since non-reporting is likely to be correlated with income, constructing *PRODY* using a different set of countries at different points in time could introduce serious bias into the index. A group of 141 countries report trade data over all the reference period, but GDP (which is used in the construction of the *PRODY* indices) shows a number of potential outliers that appear to be the result of important shocks on some countries, especially in the 90s, such as civil wars, large ethnic conflicts or the traumatic dismemberment from the Soviet Union, as well as the discovery of natural resources. Including these countries in the calculations of the *PRODY* can distort the indices and the subsequent econometric analysis.

To check for potential outliers in our sample, we identify the countries whose value for initial output gap deviated more than three times the interquartile range from the sample median of the corresponding variable. The initial output gap is calculated as actual GDP over Hodrick-Prescott filtered GDP at the beginning (1995-1997) and the end of the period (2005-2007) in the cross-section regressions, as well as 2000-2002 in the case of the 5-years panel. The initial output gap outliers are Liberia, Tajikistan, Azerbaijan, Ukraine, Georgia, Rwanda, Kyrgyz Republic, Belarus, Moldova, Turkmenistan and Guinea Bissau; output gap outliers in the period 2000-2002 are Liberia and Chad, and Liberia and Azerbaijan in 2005-2007. Thus, the initial set of 141 countries providing

[50]Except for GDP per capita, which is calculated as the sum of each country’s GDP divided by the sum of the population, the data for “Belgium-Luxembourg” is constructed as weighted average, where the weights are given by each country’s share in total population.

trade data over all the reference period (1996-2006) and having a population of at least 500,000 inhabitants is reduced to a consistent sample of 129 countries. This is the sample used in the construction of the *PRODYs* for the whole period (1996-2006) and the 5-year periods (1996-2001 and 2001-2006). Nonetheless, results of the regression analysis will also be presented using the whole sample of 141 countries in the construction of the *PRODYs* as a robustness test, to show that results are not driven by the exclusion of the output gap outliers (see Tables A5.1 to A5.3 in the Appendix).

The *PRODYs* are calculated using average trade data of three years to attenuate the potential distorting effect of atypical values that may arise from unusual exports in a given year. Therefore, we calculate initial *PRODYs* averaging trade data for 1995-1997 and final *PRODY*s averaging data for 2005-2007 (and analogously for the *ciPRODYs*). For the intermediate period, average data for 2000-2002 is used. The *EXPY* and the relocation impact indices are constructed using the *PRODYs* and the information on product export shares in each country from BACI. These indices are also calculated using average trade data. Our analysis ends in 2007 to avoid the impact of the Great Recession. Because we average three years to calculate the initial and final values of the *PRODYs* used to build our *PSI* and *PRI* indices (i.e., we average the values for 1995-1997 and 2005-2007), the dependent variable is growth between 1996 and 2006 (except in the final table of panel regressions in which we consider two 5-year periods: 1996-2001 and 2001-2006).

The sample of 129 countries used to construct the *PRODY*s after excluding the output gap outliers is reduced to 110 countries when we introduce human and physical capital variables in the regression analysis in next section. Furthermore, the variables *PSI* and *PRI* show a number of potential outliers. To check for potential outliers in our sample, we apply the same criterion as for the output gap and we sequentially identify the countries whose value for *PSI* and *PRI* deviate more than three times the interquartile range from the sample median of the corresponding variable.

We apply this criterion to the indices used in the cross-country growth regressions, as well as to those used in the panel regressions. We also identify the outliers in the indices that are used as instruments (the *csp-PSI* and the *csp-PRI*). The decision to exclude the outliers in the instruments is justified by the fact that the indices of products with few exporters may be distorted. If a product has few exporters and some of them have a very different level of development, the resulting index might not be adequately reflecting the sophistication (characteristics) of the export basket of that country, as measured by the country specific *EXPY* indices.

According to this criterion, in cross-country regressions the *PSI* outliers are Gambia, Central African Republic, Sierra Leone, Gabon, Mauritania and Cameroon. When the *PRI* is introduced, Democratic Republic of Congo becomes and additional outlier. The outliers in the *csp-PSI* (Cameroon, Gambia and Sierra Leone) are also outliers in *PSI*, so the number of observations in OLS and IV estimates is the same. In IV regressions using the *csp-PRI* instrument, South Africa is also identified as an outlier. In turn, in panel growth regressions, the *PSI* or *PRI* outliers are Gambia and Sierra Leone in both sub-periods, plus Bahrain, Cameroon, Gabon, Sudan, and Democratic Republic of Congo in the first period (1996-2001), and Burundi, Benin, Mozambique, and Mauritania in the second period (2001-2006). Additional outliers in the *csp-PSI* and *csp-PRI* instruments are Central African Republic in 1996-2001, and Democratic Republic of Congo and Ghana in 2001-2006.

The list of countries can be found in the Appendix (Table A1). The table includes the list of 141 countries which report trade data over all the reference period and identifies the different outliers (output gap, *PSI* and *PRI* outliers), a group of oil countries[51] as well as those countries for which data on some of the variables used in the regression analysis (human capital, capital intensity or exports of oil) is not available.

[51] According to PWT database, oil countries are OPEC countries and any other country in which energy exports accounts for at least one-third of total exports.

4. RELOCATION AND GROWTH

4.1.Econometric procedure

We now proceed to the econometric analysis of the relationship between international product relocation and economic growth within the framework of growth regressions (Barro and Sala-i-Martin (2003)). In our specifications, GDP per capita growth is regressed on initial per-capita GDP, our product-shocks and relocation impact indices, and a vector of controls X_c^0, that includes human and physical capital and measures of institutional quality. In addition, we also include in the equations the HHR (2007)'s measure for country initial export sophistication.[52] This measure is included in levels as well as interacted with per capita GDP to account for the possibility that the growth impact of export sophistication decreases with income. Country *c*'s export sophistication at time 0, denoted by $iEXPY_c^0$, is a weighted average of the *PRODY*s using as weights the share of each product in country c's exports at time 0: $iEXPY_c^0 = \sum_k PRODY_k^0 \omega_{ck}^0$.

Denoting the error term by u_c, our econometric specifications are the following:

$$\frac{1}{T}\log\frac{GDPpc_c^T}{GDPpc_c^0} = \beta_0 + \beta_1\log(GDPpc_c^0) + \beta_2\log(iEXPY_c^0) + \beta_3 X_c^0 + \beta_4 PSI_c^{0,T} + u_c, \quad (8)$$

$$\frac{1}{T}\log\frac{GDPpc_c^T}{GDPpc_c^0} = \beta_0 + \beta_1\log(GDPpc_c^0) + \beta_2\log(iEXPY_c^0) + \beta_3 X_c^0 + \beta_4 PRI_c^{0,T} + \beta_5\left(PSI_c^{0,T} - PRI_c^{0,T}\right) + u_c. \quad (9)$$

We use OLS and 2SLS to estimate several variations of the preceding equation. For instance, the interaction between $\log(iEXPY_c^0)$ and $\log(GDPpc_c^0)$ is also included, as in the complexity approach in Hausmann and Hidalgo (2009), and run some panel data regressions that include year fixed effects. The already described instruments used for *PSI* and *PRI* in the 2SLS estimations are explained in detail in the Appendix A2.

[52] The original initial export sophistication index, as defined in HHR (2007), which we denote by $hhrEXPY_c^0$, is somewhat different from our $iEXPY_c^0$ as it mixes two components: the actual countries' initial sophistication and the impact of product shocks on the initial sophistication along the subsequent period. Formally, HHR (2007) define the *EXPY* index of country *c*'s export sophistication at time 0 as $hhrEXPY_c^0 = \sum_k PRODY_k^T \omega_{ck}^0$. Thus, the *hhrEXPY* combines data from two different periods: product shares in country *c*'s exports ω_{ck}^0, which refer to the initial period 0, and $PRODY_k^T$ indices, which refer to the final period T. More specifically, HHR construct the *PRODY* measures using 6-digit trade data for the 1999-2001. Then, they use these *PRODY*s to construct their initial *EXPY* measures used in their growth regressions for the 1991-2003 and 1994-2003 periods.

4.2.Descriptive statistics

Table 1 reports the main variables' descriptive statistics and correlations. The correlation matrix can be found in the Appendix (Table A3). The number of observations is 103 because we have excluded the outliers in the *PRI* and *PSI* index. Figure 1 shows the high correlation between the *PSI* and *PRI* indices, which is 0.8 (see Table A3). Figures 2 and 3 show the scatterplots of initial GDP per capita against the *PSI* and *PRI* indices. As we can see from these figures, we do not observe a pattern of correlation between initial GDP per capita and the *PSI* or *PRI* indices. On the other hand, poorer countries exhibit larger dispersion of the indices. Figures 4 and 5 show the correlations between the *PSI* and *PRI* indices and GDP per capita growth, respectively.

Table 1. Descriptive statistics

Statistic	Mean	Median	Std. Dev.	Min	Max	Obs
per capita GDP	10,986.5	7,009.0	10,747.7	414.7	42,981. 9	103
initial EXPY	10,646.4	11,295.40	4,389.0	2,702.7	18,269.7	103
Product-shocks impact (*PSI*)	0.16	0.16	0.06	0.00	0.32	103
Pure Relocation Impact (*PRI*)	-0.08	-0.09	0.05	-0.23	0.10	103

Figure 1. Product-shocks impact (*PSI*) and pure relocation impact (*PRI*) across countries.

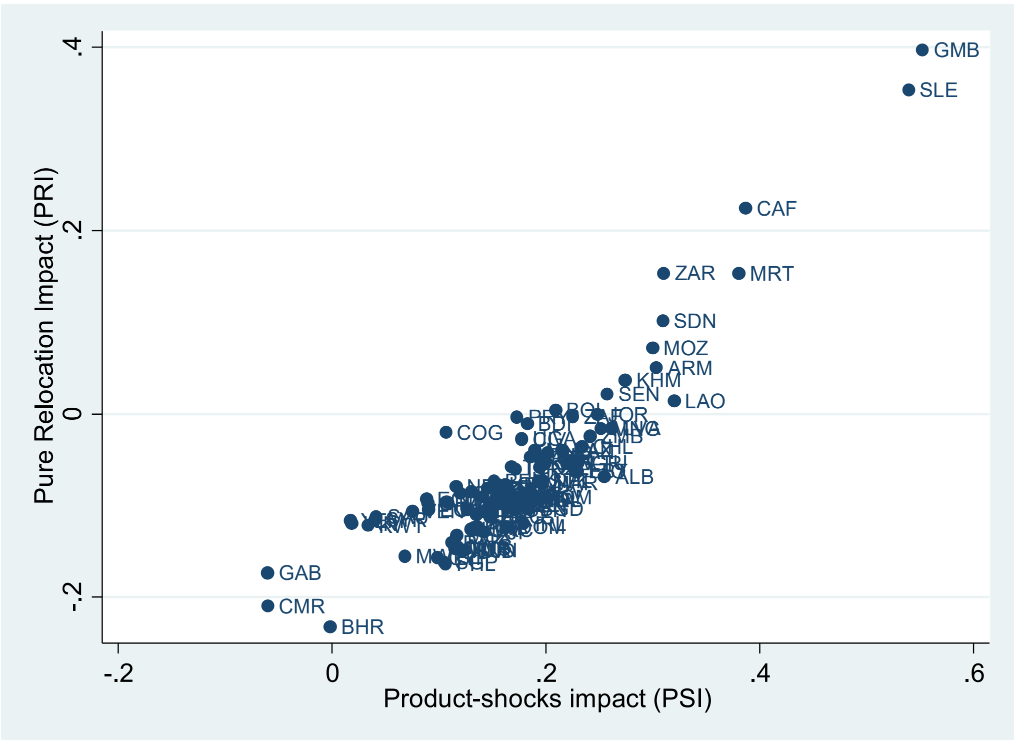


Figure 2. Initial per capita GDP and Product Shocks Impact (*PSI*)

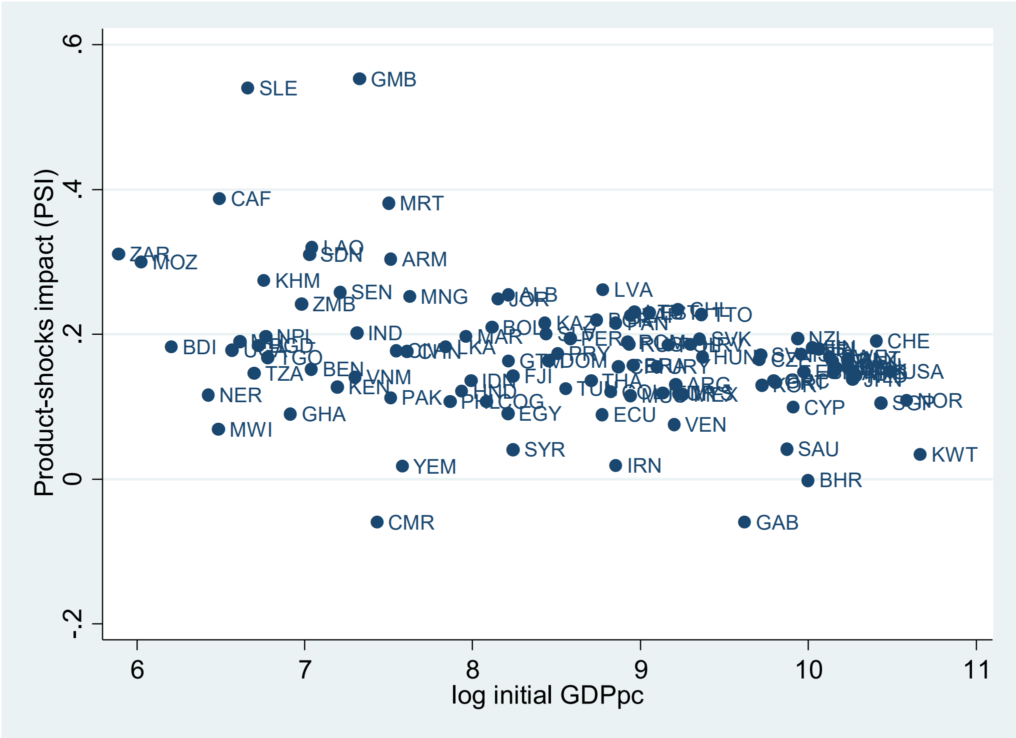


Figure 3. Initial per capita GDP and Pure Relocation Impact (*PRI*)

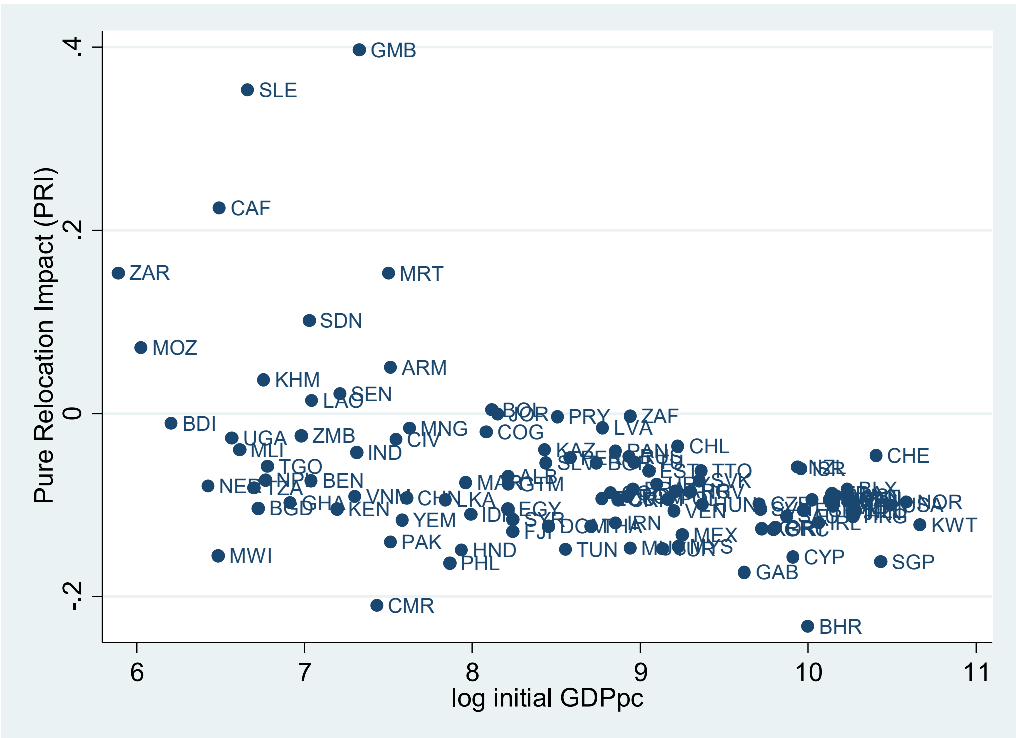


Figure 4. Product shocks impact (*PSI*) and per capita GDP growth

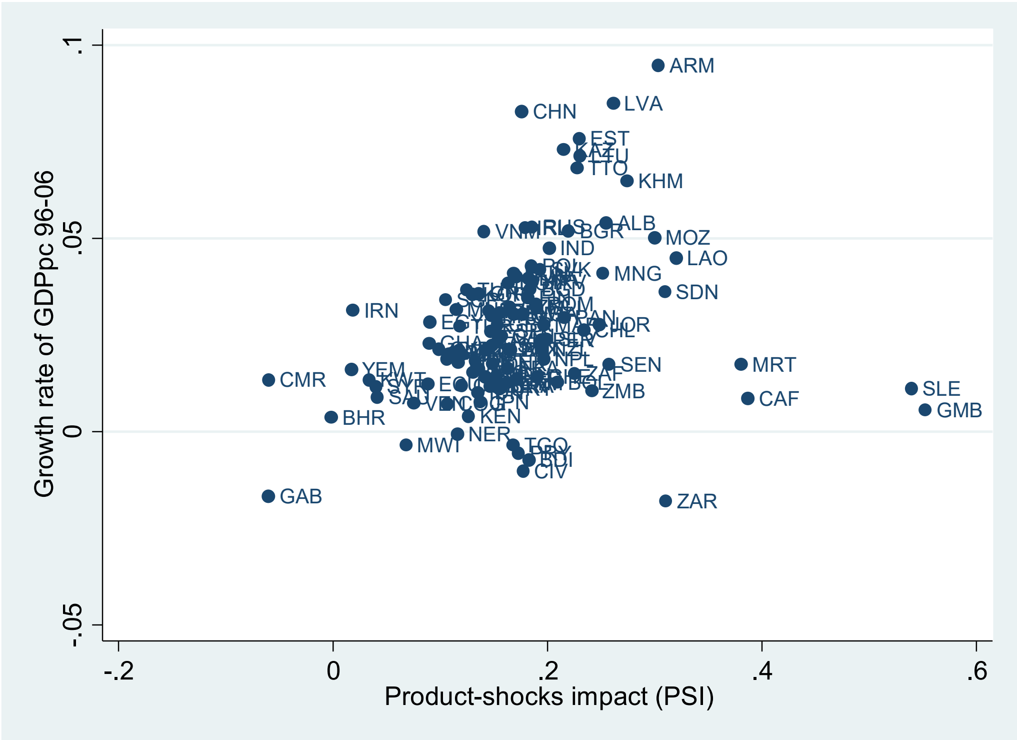
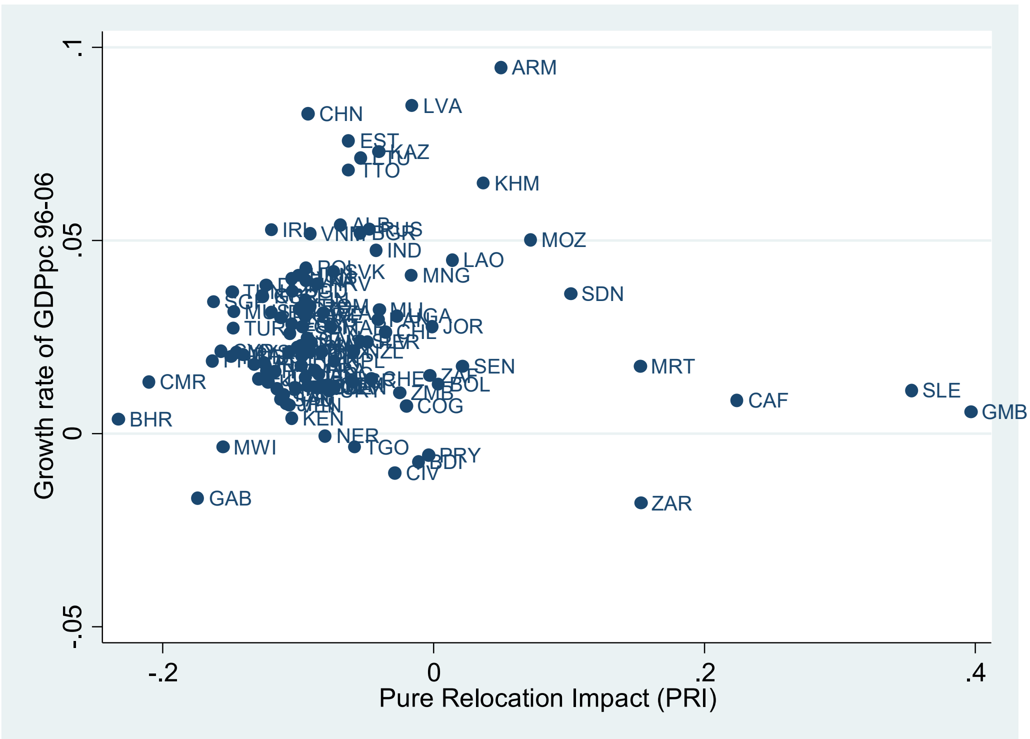


Figure 5. Pure Relocation Impact (*PRI*) and per capita GDP growth



4.3.Results

4.3.1. Product-shocks impact

Table 2 reports the OLS estimates of equation 8. Robust standard errors are reported in parenthesis. The variable of interest is the product shocks impact index (*PSI*). Except in the specification in column (1), we always include the standard controls in growth regressions, with the addition of initial export sophistication (as in HHR); namely, initial per capita GDP, human capital (as measured by the average number of school years), capital intensity (as measured by physical capital per worker), institutional quality (as measured by the rule of law index), and initial *EXPY*. Not including human and physical capital in the specification in column (1) allows testing the model for a larger sample (13 countries have data for all the variables included in this specification except human and physical capital). The share of oil in exports is always included because there is a large set of countries for which the evolution of oil prices has a strong impact on their economic performance.

In columns (4) to (6), we also include controls for the country's population and area, as well as an interaction between initial export sophistication and per capita GDP (col. 5), as in Hausmann and Hidalgo (2009). The estimation in column (3) and the subsequent ones exclude from the sample the six *PSI* outliers. In all the regressions, the product-shocks impact index *PSI* is positive and significant at the 1-percent level. Its coefficient and statistical significance tends to increase as we exclude potential outliers and include additional controls. The estimation in column (6) shows results for a sample that excludes oil countries. Figure 6 shows the component-plus-residual plot for our preferred specification (column 4).

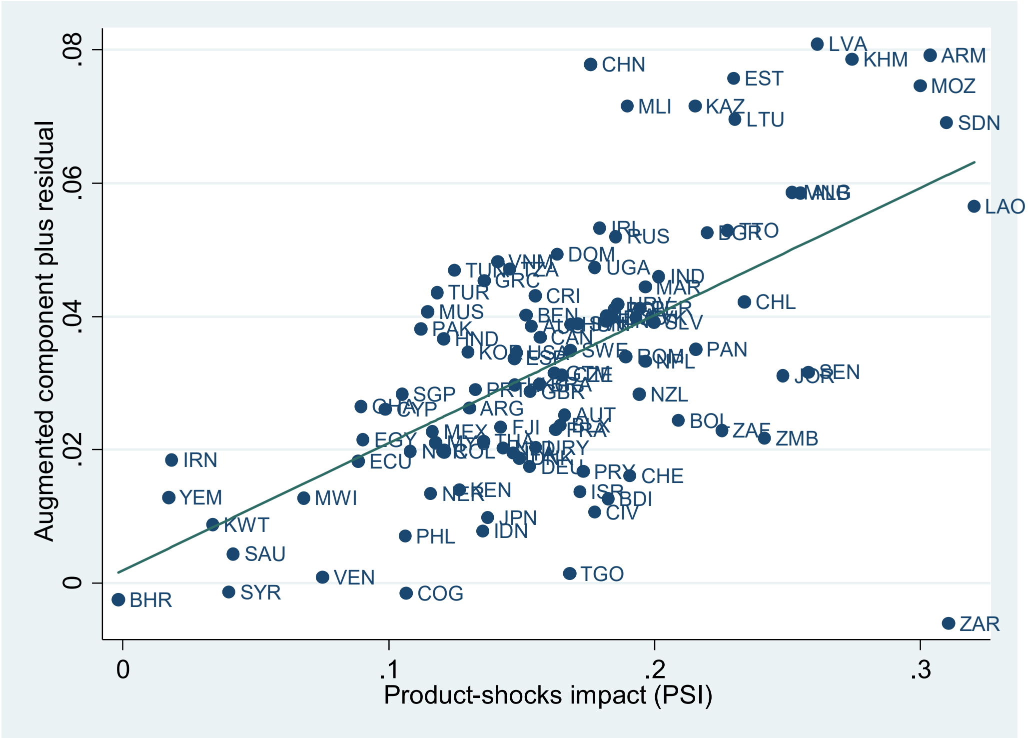
As in most of the previous literature, initial export sophistication (initial *EXPY*) and human capital are also positive and statistically significant, whereas initial GDP per capita is negative. In column (5) we include an interaction between initial *EXPY* and GDP per capita and find a negative coefficient, which indicates that the effect of initial export sophistication decreases with the country's development. The share of oil exports is positive and statistically significant when we include all the controls and exclude outliers. The coefficients on population and area tend to have opposite signs with similar absolute coefficients, thereby suggesting that the relevant variable is population density, which would have a positive impact on growth.

Table 2. Impact of product shocks on cross-country growth. OLS estimates

	Dependent variable: Growth rate of GDP per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
Product-shocks impact (*PSI*)	0.072***	0.085***	0.170***	0.189***	0.204***	0.166***
	(0.027)	(0.029)	(0.039)	(0.041)	(0.035)	(0.049)
log initial *EXPY*	0.032***	0.029***	0.024***	0.024***	0.088**	0.026**
	(0.009)	(0.008)	(0.008)	(0.008)	(0.039)	(0.011)
log initial GDPpc	-0.009**	-0.014***	-0.011**	-0.013***	0.067	-0.011**
	(0.004)	(0.005)	(0.005)	(0.004)	(0.046)	(0.005)
log iEXPY*log gdppc0					-0.009*	
					(0.005)	
log Human Capital (years sch)		0.016***	0.011**	0.010**	0.007	0.010*
		(0.005)	(0.005)	(0.005)	(0.005)	(0.006)
log Capital Intensity		-0.001	-0.001	0.001	0.001	-0.002
		(0.003)	(0.003)	(0.003)	(0.003)	(0.005)
Rule of law		0.002	0.002	0.002	0.006*	0.004
		(0.003)	(0.002)	(0.002)	(0.003)	(0.003)
Export share of oil	-0.001	0.009	0.018*	0.027**	0.030***	0.029
	(0.008)	(0.010)	(0.010)	(0.011)	(0.009)	(0.033)
log Population				0.002	0.003	0.001
				(0.002)	(0.002)	(0.002)
log Area				-0.003***	-0.003***	-0.003***
				(0.001)	(0.001)	(0.001)
Constant	-0.203***	-0.146***	-0.146***	-0.139***	-0.738**	-0.118**
	(0.057)	(0.053)	(0.048)	(0.049)	(0.352)	(0.057)
Excluding pcGDP outliers	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding *PSI* outliers	*No*	*No*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	123	110	104	104	104	90
R^2	0.184	0.312	0.371	0.409	0.449	0.367

Notes: Results from estimating equation 8 using OLS. The dependent variable is the annual average growth rate of GDP per capita over 1996-2006. Robust standard errors are in parentheses. Output gap outliers are excluded. The excluded *PSI* outliers starting in column (3) are Gambia, Central African Republic, Sierra Leona, Gabon, Mauritania and Cameroon. See the body text for the criteria used to identify potential outliers. Column (6) also excludes the main oil producers. Significance levels: *** 1-percent, ** 5-percent, * 10-percent.

Figure 6. Partial relationship between *PSI* and subsequent GDP pc growth



Notes: The vertical axis measures the GDP per capita growth to be explained by the *PSI* index:

$$\frac{1}{T}\log\frac{\widehat{GDPpc_c^T}}{GDPpc_c^0} - (\hat{\beta}_0 + \hat{\beta}_1 \log(GDPpc_c^0) + \hat{\beta}_2 \log(iEXPY_c^0) + \hat{\beta}_3 X_c^0),$$

with the coefficient estimates taken from Table 2, column (4). The horizontal axis measures the value of the *PSI* index.

Table 3 reports 2SLS estimates using as instruments the indices constructed with country-specific *PRODYs* (see the Appendix for the details). The first-stage regressions confirm that these instruments are good predictors of the instrumented variables with very large F statistics (see Table A4 in the Appendix). The regressions in Table 3 are run using the same set of controls and samples as those used in Table 2. The IV estimates of the coefficients on *PSI* show somewhat smaller positive values than the OLS estimates and are not statistically significant in the largest sample. Its significance and coefficient increases after excluding the *PSI* outliers.

Table 3. Impact of product shocks on cross-country growth. IV estimates

	Dependent variable: Growth rate of GDP per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
Product-shocks impact (*PSI*)	0.048	0.047*	0.134**	0.151***	0.148***	0.139**
	(0.031)	(0.026)	(0.052)	(0.055)	(0.054)	(0.063)
log initial EXPY	0.027***	0.024***	0.020**	0.020**	0.069**	0.021**
	(0.010)	(0.008)	(0.008)	(0.008)	(0.035)	(0.010)
log initial GDPpc	-0.008**	-0.014***	-0.010**	-0.013***	0.048	-0.011**
	(0.004)	(0.005)	(0.005)	(0.005)	(0.040)	(0.005)
log iEXPY*log gdppc0					-0.007	
					(0.004)	
log Human Capital (years sch)		0.017***	0.012***	0.012**	0.010*	0.011**
		(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
log Capital Intensity		-0.001	-0.000	0.001	0.001	-0.002
		(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
Rule of law		0.003	0.002	0.002	0.005*	0.004
		(0.003)	(0.002)	(0.002)	(0.003)	(0.002)
Export share of oil	-0.004	0.005	0.016	0.023**	0.023**	0.031
	(0.009)	(0.009)	(0.010)	(0.011)	(0.011)	(0.031)
log Population				0.002	0.002	0.001
				(0.002)	(0.002)	(0.002)
log Area				-0.003**	-0.003***	-0.003**
				(0.001)	(0.001)	(0.001)
Constant	-0.162***	-0.101*	-0.105**	-0.104**	-0.555*	-0.080
	(0.060)	(0.053)	(0.048)	(0.048)	(0.311)	(0.054)
Excluding pcGDP outliers	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding *PSI* outliers	*No*	*No*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	123	110	104	104	104	90
R^2	0.173	0.292	0.361	0.399	0.430	0.360

Notes: Results from estimating equation 8 using 2SLS. The dependent variable is the average growth rate of GDP per capita over 1996-2006. The variables log(*iEXPY*) and *PSI* are instrumented using the country specific PRODY variables log(*csp-iEXPY*) and *csp-PSI* (see the body text and the Appendix for details). Robust standard errors are in parentheses. The excluded *PSI* outliers starting in column (3) are Gambia, Central African Republic, Sierra Leona, Gabon, Mauritania and Cameroon. See the body text for the criteria used to identify potential outliers. Column (6) also excludes the main oil producers. Significance levels: *** 1-percent, ** 5-percent, * 10-percent.

As explained before, the instruments used in the 2SLS estimates are constructed by excluding from the *PRODY* indices all the data relative to the country (i.e. data on the country's exports and GDP per capita is excluded). This approach allows us to deal with country-specific shocks that may affect the value of the *PRODY* of the products it exports, if the country is sufficiently large in the context of world trade. However, there might be some shocks correlated within countries belonging to the same region. In such cases, omitting the country from the construction of its own index would not solve this problem. Thus, to deal with these potential spatially correlated shocks, we run the regressions in Tables 2 and 3 adding dummies by continent. Results are shown in Tables 4 (OLS) and 5 (IV).

Table 4. Impact of product shocks on cross-country growth. Robustness, OLS estimates

	Dependent variable: Growth rate of GDP per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
Product-shocks impact (*PSI*)	0.060***	0.075***	0.158***	0.170***	0.181***	0.133**
	(0.023)	(0.027)	(0.038)	(0.042)	(0.037)	(0.052)
log initial *EXPY*	0.018**	0.013	0.011	0.014*	0.083**	0.014
	(0.009)	(0.009)	(0.008)	(0.008)	(0.039)	(0.010)
log initial GDPpc	-0.011***	-0.013**	-0.009**	-0.012**	0.076	-0.010
	(0.004)	(0.005)	(0.004)	(0.005)	(0.049)	(0.006)
log iEXPY*log gdppc0					-0.009*	
					(0.005)	
log Human Capital (years sch)		0.014***	0.009**	0.009*	0.006	0.008
		(0.005)	(0.005)	(0.005)	(0.005)	(0.006)
log Capital Intensity		-0.001	-0.001	0.001	0.000	-0.002
		(0.003)	(0.003)	(0.003)	(0.003)	(0.005)
Rule of law		0.003	0.002	0.003	0.006*	0.005
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Export share of oil	0.010	0.015	0.020*	0.026**	0.027**	0.037
	(0.009)	(0.011)	(0.011)	(0.013)	(0.011)	(0.035)
log Population				0.001	0.001	-0.000
				(0.002)	(0.002)	(0.003)
log Area				-0.002	-0.002	-0.002
				(0.001)	(0.001)	(0.002)
Constant	-0.074	-0.025	-0.045	-0.050	-0.700*	-0.010
	(0.055)	(0.057)	(0.054)	(0.057)	(0.360)	(0.071)
Dummies by continent	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding pcGDP outliers	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding *PSI* outliers	*No*	*No*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	123	110	104	104	104	90
R^2	0.324	0.408	0.448	0.462	0.504	0.431

Notes: Results from estimating equation 8 using OLS. The dependent variable is the annual average growth rate of GDP per capita over 1996-2006. Robust standard errors are in parentheses. Output gap outliers are excluded. All regressions include dummies by continent (Africa, America, Europe, Asia and Oceania). The excluded *PSI* outliers starting in column (3) are Gambia, Central African Republic, Sierra Leona, Gabon, Mauritania and Cameroon. See the body text for the criteria used to identify potential outliers. Column (6) also excludes the main oil producers. Significance levels: *** 1-percent, ** 5-percent, * 10-percent.

Table 5. Impact of product shocks on cross-country growth. Robustness, IV estimates

	Dependent variable: Growth rate of GDP per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
Product-shocks impact (*PSI*)	0.036	0.038*	0.116**	0.124**	0.115**	0.091
	(0.024)	(0.022)	(0.047)	(0.051)	(0.051)	(0.061)
log initial EXPY	0.012	0.007	0.005	0.007	0.063*	0.005
	(0.009)	(0.008)	(0.008)	(0.008)	(0.033)	(0.010)
log initial GDPpc	-0.010**	-0.013**	-0.009*	-0.011**	0.059	-0.008
	(0.004)	(0.005)	(0.005)	(0.005)	(0.041)	(0.006)
log iEXPY*log gdppc0					-0.008*	
					(0.004)	
log Human Capital (years sch)		0.015***	0.011**	0.011**	0.009*	0.009*
		(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
log Capital Intensity		-0.000	-0.000	0.001	-0.000	-0.002
		(0.003)	(0.003)	(0.003)	(0.003)	(0.004)
Rule of law		0.003	0.002	0.003	0.005	0.004
		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Export share of oil	0.008	0.011	0.018*	0.022	0.020	0.039
	(0.009)	(0.011)	(0.011)	(0.013)	(0.013)	(0.034)
log Population				0.000	0.000	-0.001
				(0.002)	(0.002)	(0.002)
log Area				-0.001	-0.001	-0.001
				(0.002)	(0.002)	(0.002)
Constant	-0.003	0.039	0.016	0.014	-0.509*	0.058
	(0.057)	(0.055)	(0.051)	(0.054)	(0.305)	(0.065)
Dummies by continent	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding pcGDP outliers	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding *PSI* outliers	*No*	*No*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	123	110	104	104	104	90
R^2	0.313	0.390	0.434	0.449	0.479	0.417

Notes: Results from estimating equation 8 using 2SLS. The dependent variable is the average growth rate of GDP per capita over 1996-2006. The variables log(iEXPY) and *PSI* are instrumented using the country specific PRODY variables log(*csp*-iEXPY) and csp-*PSI* (see the body text and the Appendix for details and first-stage regressions). Robust standard errors are in parentheses. Output gap outliers are excluded. All regressions include dummies by continent (Africa, America, Europe, Asia and Oceania). The excluded *PSI* outliers starting in column (3) are Gambia, Central African Republic, Sierra Leona, Gabon, Mauritania and Cameroon. See the body text for the criteria used to identify potential outliers. Column (6) also excludes the main oil producers. Significance levels: *** 1-percent, ** 5-percent, * 10-percent.

The OLS estimates in Table 4 show that controlling for spatially correlated shocks by adding continent dummies does not alter the results: the *PSI* index is statistically significant at the 1-percent level, although the coefficients are somewhat smaller as compared with Table 2. On the contrary, the *PSI* index in Table 5 (IV estimates) is only significant at the 5-percent level when the *PSI* outliers are excluded. It is not significant in the specification in column (6) that excludes the oil countries. A potential explanation for the low statistical significance of the *PSI* index in the estimations with some of the samples is that this index is capturing a number of different types of product shocks (relocation shocks as well as demand and other non-relocation product shocks). Because the growth impact of these shocks can be different (and could even be negatively correlated), synthesizing them into a single index can lead to a low estimated coefficient and significance. In the next subsection, we check this hypothesis by running regressions that separate the *pure* relocation shocks from the *other* product shocks and find that they indeed have a different, independent impact that is always highly significant in both cases.

4.3.2. Pure relocation impact

We now analyze the growth impact of the *pure* relocation shocks using the *PRI* index. The specifications always include the difference *PSI-PRI* between the two indices to capture the impact of *other* product shocks and reduce the risk of omitted variable biases. Table 6 displays OLS estimates, whereas Tables 7 and 8 display 2SLS estimates. These tables report the results using the same combinations of controls and samples as in Tables 2 and 3 (except that we now consider also the *PRI* outliers, together with those corresponding to *PSI*).

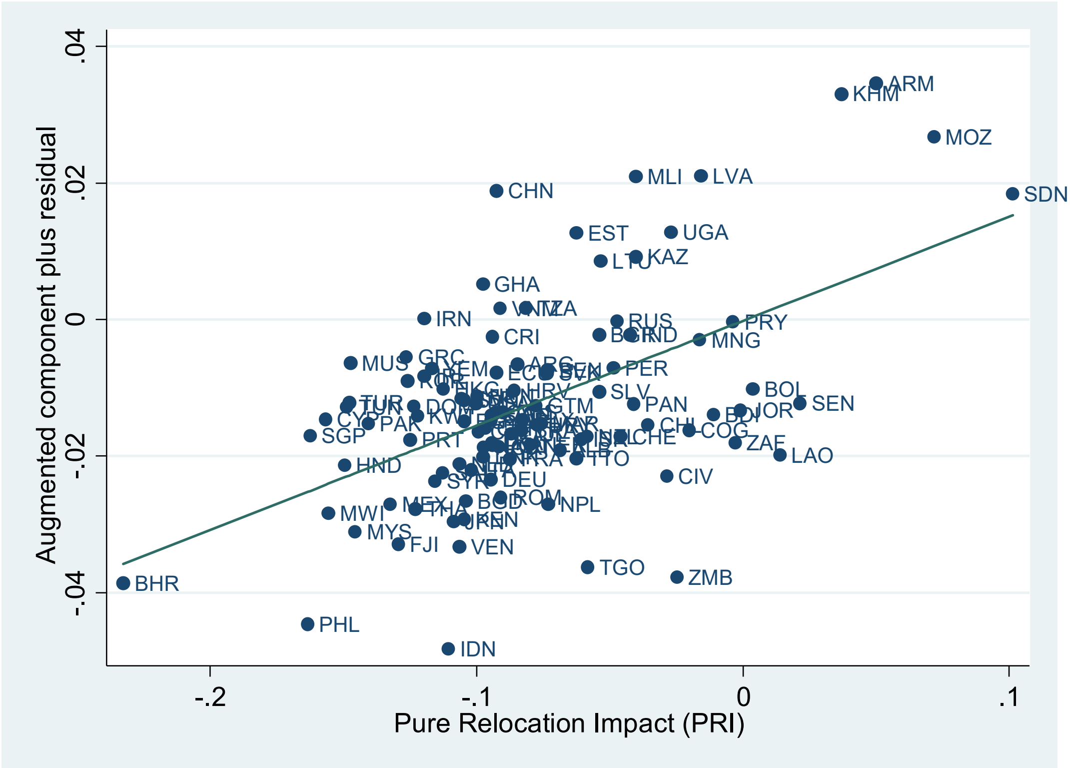
Results in Table 6 show that the *PRI* index is always significant at the 1-percent level, with a coefficient that keeps increasing as we exclude the outliers and include additional controls. The estimated coefficient ranges from 0.052 to 0.153. Figure 7 shows the component-plus-residual plot for this latter estimation, where it is apparent that the results are not driven by any possible remaining outliers.

Table 6. Impact of pure relocation on cross-country growth. OLS estimates

	Dependent variable: Growth rate of GDP per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
Pure Relocation Impact (*PRI*)	0.052***	0.078***	0.134***	0.153***	0.153***	0.149***
	(0.018)	(0.018)	(0.033)	(0.035)	(0.035)	(0.041)
Other product shocks (*PSI-PRI*)	0.484***	0.484***	0.471***	0.462***	0.462***	0.475***
	(0.048)	(0.056)	(0.060)	(0.065)	(0.065)	(0.077)
log initial EXPY	0.017**	0.017**	0.017**	0.016**	0.017	0.016**
	(0.008)	(0.007)	(0.007)	(0.007)	(0.024)	(0.008)
log initial GDPpc	-0.008***	-0.009**	-0.010**	-0.011**	-0.008	-0.009*
	(0.003)	(0.004)	(0.004)	(0.004)	(0.028)	(0.005)
log iEXPY*log gdppc0					-0.000	
					(0.003)	
log Human Capital (years sch)		0.009**	0.008*	0.008*	0.008*	0.008
		(0.004)	(0.004)	(0.004)	(0.005)	(0.005)
log Capital Intensity		-0.004*	-0.002	-0.001	-0.001	-0.003
		(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
Rule of law		0.002	0.002	0.003	0.003	0.004*
		(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Export share of oil	0.053***	0.054***	0.053***	0.056***	0.056***	0.060**
	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)	(0.029)
log Population				0.002	0.002	0.001
				(0.001)	(0.001)	(0.001)
log Area				-0.002	-0.002	-0.002*
				(0.001)	(0.001)	(0.001)
Constant	-0.177***	-0.148***	-0.150***	-0.146***	-0.162	-0.132**
	(0.047)	(0.046)	(0.047)	(0.046)	(0.219)	(0.055)
Excluding pcGDP outliers	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding *PRI* and *PSI* outliers	*No*	*No*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	123	110	103	103	103	89
R^2	0.520	0.598	0.600	0.609	0.609	0.579

Notes: Results from estimating equation 9 using OLS. The dependent variable is the average growth rate of GDP per capita over 1996-2006. Robust standard errors are in parentheses. Output gap outliers are excluded. The excluded *PRI* and *PSI* outliers starting in column (3) are Cameroon, Central African Republic, Democratic Republic of Congo, Gambia, Gabon, Mauritania and Sierra Leona. See the body text for the criteria used to identify potential outliers. Column (6) also excludes the main oil producers. Significance levels: *** 1-percent, ** 5-percent, * 10-percent.

Figure 7. Partial relationship between *PRI* and subsequent GDP pc growth



Notes: The vertical axis measures the GDP per capita growth to be explained by the *PRI* index:

$$\frac{1}{T}\log\frac{\widehat{GDPpc_c^T}}{GDPpc_c^0} - (\hat{\beta}_0 + \hat{\beta}_1\log(GDPpc_c^0) + \hat{\beta}_2\log(iEXPY_c^0) + \hat{\beta}_3 X_c^0 + \hat{\beta}_5(PSI_c^{0,T} - PRI_c^{0,T}),$$

with the coefficient estimates taken from Table 6, column (4). The horizontal axis measures the value of the *PRI* index.

Tables 7 and 8 display the 2SLS estimates. In the specifications in Table 8 we consider the alternative measures of institutional quality (regulatory quality, government effectiveness, and control of corruption) and human capital. The coefficients of the *PRI* index in the IV estimates are higher than in the OLS estimates. We find that the growth impact of pure relocation is always positive and significant at the 1-percent level.

The impact of international relocation shocks on growth appears to be sizable. The estimated coefficient of the *PRI* in Table 7 ranges between 0.053 and 0.195, with the highest point estimate for the coefficient on the *PRI* index found in the specification that excludes the group of oil exporters (column 6 in Table 7). Considering the value of 0.186 on our preferred specification and sample in column 4 of Table 7, taking a country from the 1st quartile (-0.111) to the 3rd quartile (-0.054) along the distribution of the *PRI* index implies an increase in the annual rate of growth of about 1.05 percentage points. Similarly, an increase of the size of one standard deviation in the *PRI* index (0.052) increases the annual rate of growth by 0.97 percentage points. Thus, countries that were specialized at the beginning of the period in product categories showing a relocation process towards low-wage (advanced) economies over the following years, exhibited significantly lower (greater) growth over the period.

Table 7. Impact of pure relocation on cross-country growth. IV estimates

	Dependent variable: Growth rate of GDP per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
Pure Relocation Impact (*PRI*)	0.053***	0.060***	0.161***	0.186***	0.185***	0.195***
	(0.020)	(0.018)	(0.048)	(0.053)	(0.052)	(0.060)
Other product shocks (*PSI-PRI*)	0.359***	0.348***	0.314***	0.304***	0.295***	0.288***
	(0.059)	(0.063)	(0.068)	(0.070)	(0.069)	(0.076)
log initial EXPY	0.015*	0.016**	0.016**	0.015**	0.031	0.013
	(0.008)	(0.007)	(0.007)	(0.007)	(0.026)	(0.008)
log initial GDPpc	-0.006**	-0.010**	-0.010**	-0.012***	0.007	-0.011***
	(0.003)	(0.005)	(0.004)	(0.004)	(0.030)	(0.004)
log iEXPY*log gdppc0					-0.002	
					(0.003)	
log Human Capital (years sch)		0.012***	0.010**	0.011**	0.010**	0.012***
		(0.004)	(0.004)	(0.004)	(0.005)	(0.005)
log Capital Intensity		-0.003	-0.000	0.001	0.001	0.001
		(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
Rule of law		0.003	0.002	0.002	0.003	0.003
		(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Export share of oil	0.038***	0.040***	0.037***	0.042***	0.041***	0.056**
	(0.010)	(0.009)	(0.009)	(0.009)	(0.009)	(0.027)
log Population				0.003	0.003	0.003
				(0.002)	(0.002)	(0.002)
log Area				-0.003**	-0.003**	-0.003**
				(0.001)	(0.001)	(0.001)
Constant	-0.144***	-0.112**	-0.115**	-0.115**	-0.257	-0.087*
	(0.050)	(0.046)	(0.045)	(0.045)	(0.237)	(0.050)
Excluding pcGDP outliers	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding *PRI* and *PSI* outliers	*No*	*No*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	123	110	102	102	102	88
R^2	0.486	0.567	0.566	0.576	0.575	0.529

Notes: Results from estimating equation 9 using 2SLS. The dependent variable is the average growth rate of GDP per capita 1996-2006. The variables *log(iEXPY), PRI,* and *PSI-PRI* are instrumented using the country specific PRODY variables *log(csp-iEXPY), csp-PRI* and *csp-PSI-PRI* (see the body text and the Appendix for details). Robust standard errors are in parentheses. Output gap outliers are excluded. The excluded *PRI* and *PSI* outliers starting in column (3) are Cameroon, Central African Republic, Democratic Republic of Congo, Gambia, Gabon, Mauritania, Sierra Leona and South Africa. See the body text for the criteria used to identify potential outliers. Column (6) also excludes the main oil producers. Significance levels: *** 1-percent, ** 5-percent, * 10-percent.

Table 8. Impact of pure relocation on cross-country growth. Robustness, IV estimates

	Dependent variable: Growth rate of GDP per capita				
	(1)	(2)	(3)	(4)	(5)
Pure Relocation Impact (*PRI*)	0.181***	0.184***	0.184***	0.191***	0.184***
	(0.051)	(0.053)	(0.053)	(0.053)	(0.052)
Other product shocks (*PSI-PRI*)	0.298***	0.306***	0.298***	0.294***	0.306***
	(0.065)	(0.069)	(0.070)	(0.069)	(0.068)
log initial EXPY	0.014**	0.014**	0.015**	0.014**	0.011*
	(0.007)	(0.007)	(0.007)	(0.006)	(0.006)
log initial GDPpc	-0.015***	-0.013***	-0.011***	-0.010***	-0.011***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
log Human Capital (years sch)	0.011***	0.011**	0.011**		
	(0.004)	(0.004)	(0.004)		
log Capital Intensity	0.002	0.001	0.001	0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)
Export share of oil	0.049***	0.044***	0.039***	0.038***	0.045***
	(0.011)	(0.010)	(0.009)	(0.010)	(0.009)
log Population	0.003*	0.003	0.003	0.003	0.003**
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
log Area	-0.003**	-0.003**	-0.003**	-0.003**	-0.003**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Regulatory Quality	0.006**				
	(0.003)				
Government Effectiveness		0.003			
		(0.002)			
Control of Corruption			0.000		
			(0.002)		
Rule of law				0.002	0.002
				(0.002)	(0.002)
log Human Capital (BL)				0.006**	
				(0.002)	
log Human Capital (PWT)					0.032***
					(0.010)
Constant	-0.092**	-0.104**	-0.124***	-0.112***	-0.097**
	(0.043)	(0.044)	(0.045)	(0.043)	(0.045)
Excluding pcGDP outliers	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding *PRI* and *PSI* outliers	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	102	102	102	102	102
R^2	0.588	0.579	0.572	0.566	0.587

Notes: Results from estimating equation 9 using 2SLS. The dependent variable is the average growth rate of GDP per capita 1996-2006. The variables log(*iEXPY*), *PRI*, and *PSI-PRI* are instrumented using the country specific PRODY variables log(*csp-iEXPY*), *csp-PRI* and csp-*PSI-PRI* (see the body text and the Appendix for details). Robust standard errors are in parentheses. Output gap outliers are excluded. The excluded *PRI* and *PSI* outliers starting in column (1) are Cameroon, Central African Republic, Democratic Republic of Congo, Gambia, Gabon, Mauritania, Sierra Leona and South Africa. See the body text for the criteria used to identify potential outliers. Column (6) also excludes the main oil producers. Significance levels: *** 1-percent, ** 5-percent, * 10-percent.

Overall, the other variables and controls included in the regressions have the expected signs and are statistically significant, although regulatory quality is the only measure for institutional quality that turns out to be statistically significant at the 5% level (though the estimated value and significance of the pure relocation impact in the regression using this measure of institutions is almost identical to the other estimations). The difference *PSI-PRI* between our two indices, which captures the impact of *other* product shocks (i.e., shocks not leading to production relocation), is always positive, significant at the 1-percent level, and with a coefficient that is significantly different than the one on the *PRI* index. However, we do not pursue the analysis of this estimate as the nature of these shocks are subject to different interpretations, while our goal including this variable in the regression is to reduce the risk of omitting a relevant variable in the specification.

Tables 9 and 10 report the results using the same combinations of controls and samples as in Tables 6 and 7 but include dummies by continent to control for potential spatially correlated shocks. Results in Tables 9 and 10 are very similar to those in the corresponding tables (Table 6 and Table 7, respectively). Although slightly lower, the magnitude of the coefficients is very similar. As in Table 6, the estimates for the *PRI* in Table 9 are significant at the 1-percent in all the specifications and the coefficient ranges between 0.048 when we use the whole sample and 0.144. The IV estimates in Table 10 are significant at the 1-percent (5-percent when we use the more complete sample (col.1)), with a coefficient that varies between 0.043 and 0.158.

Table 9. Impact of pure relocation on cross-country growth. Robustness, OLS estimates

	Dependent variable: Growth rate of GDP per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
Pure Relocation Impact (*PRI*)	0.048***	0.073***	0.133***	0.142***	0.144***	0.138***
	(0.018)	(0.018)	(0.033)	(0.035)	(0.035)	(0.042)
Other product shocks (*PSI-PRI*)	0.435***	0.452***	0.433***	0.430***	0.426***	0.438***
	(0.050)	(0.058)	(0.061)	(0.065)	(0.065)	(0.081)
log initial EXPY	0.012	0.011	0.010	0.010	0.022	0.012
	(0.008)	(0.007)	(0.007)	(0.007)	(0.026)	(0.009)
log initial GDPpc	-0.009***	-0.008*	-0.008**	-0.010*	0.005	-0.010
	(0.003)	(0.004)	(0.004)	(0.005)	(0.031)	(0.006)
log iEXPY*log gdppc0					-0.002	
					(0.003)	
log Human Capital (years sch)		0.010**	0.008*	0.008*	0.008*	0.008
		(0.005)	(0.005)	(0.005)	(0.005)	(0.006)
log Capital Intensity		-0.004*	-0.002	-0.001	-0.001	-0.003
		(0.002)	(0.002)	(0.003)	(0.003)	(0.004)
Rule of law		0.002	0.002	0.002	0.003	0.005*
		(0.002)	(0.002)	(0.002)	(0.002)	(0.003)
Export share of oil	0.052***	0.053***	0.051***	0.053***	0.053***	0.065**
	(0.009)	(0.008)	(0.008)	(0.008)	(0.008)	(0.032)
log Population				0.001	0.001	0.001
				(0.002)	(0.002)	(0.002)
log Area				-0.001	-0.001	-0.001
				(0.001)	(0.001)	(0.001)
Constant	-0.123**	-0.097*	-0.093*	-0.094*	-0.204	-0.085
	(0.051)	(0.050)	(0.050)	(0.052)	(0.241)	(0.068)
Dummies by continent	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding pcGDP outliers	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding *PRI* and *PSI* outliers	*No*	*No*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	123	110	103	103	103	89
R^2	0.542	0.618	0.626	0.628	0.629	0.596

Notes: Results from estimating equation 9 using 2SLS. The dependent variable is the average growth rate of GDP per capita 1996-2006. The variables log(*iEXPY*), *PRI*, and *PSI-PRI* are instrumented using the country specific PRODY variables log(*csp-iEXPY*), *csp-PRI* and csp-*PSI-PRI* (see the body text and the Appendix for details). Robust standard errors are in parentheses. Output gap outliers are excluded. All regressions include dummies by continent (Africa, America, Europe, Asia and Oceania). The excluded *PRI* and *PSI* outliers starting in column (3) are Cameroon, Central African Republic, Democratic Republic of Congo, Gambia, Gabon, Mauritania, Sierra Leona. See the body text for the criteria used to identify potential outliers. Column (6) also excludes the main oil producers. Significance levels: *** 1-percent, ** 5-percent, * 10-percent.

Table 10. Impact of pure relocation on cross-country growth. Robustness, IV estimates

	Dependent variable: Growth rate of GDP per capita					
	(1)	(2)	(3)	(4)	(5)	(6)
Pure Relocation Impact (*PRI*)	0.043**	0.051***	0.144***	0.158***	0.154***	0.149***
	(0.018)	(0.017)	(0.045)	(0.051)	(0.050)	(0.057)
Other product shocks (*PSI-PRI*)	0.260***	0.280***	0.246***	0.242***	0.227***	0.201**
	(0.068)	(0.075)	(0.080)	(0.081)	(0.079)	(0.100)
log initial EXPY	0.007	0.006	0.006	0.006	0.033	0.004
	(0.008)	(0.007)	(0.007)	(0.007)	(0.029)	(0.009)
log initial GDPpc	-0.008**	-0.009**	-0.009**	-0.011**	0.023	-0.011**
	(0.003)	(0.005)	(0.004)	(0.005)	(0.034)	(0.005)
log iEXPY*log gdppc0					-0.004	
					(0.004)	
log Human Capital (years sch)		0.012***	0.011**	0.011**	0.010**	0.011**
		(0.004)	(0.004)	(0.004)	(0.004)	(0.005)
log Capital Intensity		-0.002	-0.000	0.001	0.001	0.000
		(0.002)	(0.002)	(0.003)	(0.003)	(0.003)
Rule of law		0.003	0.001	0.002	0.003	0.004
		(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
Export share of oil	0.034***	0.036***	0.032***	0.037***	0.034***	0.058*
	(0.011)	(0.010)	(0.011)	(0.011)	(0.011)	(0.031)
log Population				0.002	0.002	0.001
				(0.002)	(0.002)	(0.002)
log Area				-0.002	-0.001	-0.002
				(0.001)	(0.001)	(0.002)
Constant	-0.053	-0.021	-0.026	-0.029	-0.276	0.014
	(0.060)	(0.054)	(0.055)	(0.058)	(0.268)	(0.076)
Dummies by continent	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding pcGDP outliers	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding *PRI* and *PSI* outliers	*No*	*No*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	123	110	102	102	102	88
R^2	0.494	0.577	0.579	0.582	0.582	0.531

Notes: Results from estimating equation 9 using 2SLS. The dependent variable is the average growth rate of GDP per capita 1996-2006. The variables log(*iEXPY*), *PRI*, and *PSI-PRI* are instrumented using the country specific PRODY variables log(*csp-iEXPY*), *csp-PRI* and csp-*PSI-PRI* (see the body text and the Appendix for details and first-stage regressions). Robust standard errors are in parentheses. Output gap outliers are excluded. All regressions include dummies by continent (Africa, America, Europe, Asia and Oceania). The excluded *PRI* outliers starting in column (3) are Cameroon, Central African Republic, Democratic Republic of Congo, Gambia, Gabon, Mauritania, Sierra Leona and South Africa. See the body text for the criteria used to identify potential outliers. Column (6) also excludes the main oil producers. Significance levels: *** 1-percent, ** 5-percent, * 10-percent.

As it has been shown in the previous chapter (Chapter 4), the 1996-2006 period has been characterized by a decrease in the income level of the average exporter, indicating a relocation trend towards lower income countries. As a result, the *PRI* indices of most countries appear to be negative. Hence, international relocation of production, although it is a phenomenon that could go in either a positive or a negative direction (positive as a result of innovation in some product categories and negative as a result of standardization), appears to have had a negative influence on most countries during this period. Obviously, some countries have been more negatively affected than others, due to their initial specialization: countries like Mexico, Philippines, Turkey or Malaysia have large negative *PRI* indices.

In the case of Mexico, exports of electrical equipment, motor vehicles and machinery and mechanical appliances (chapters 85, 87 and 84) represented 23.8%, 17.1% and 11.6%, respectively, of total Mexican exports in 1996. Excluding petroleum oils, which was the first product exported by Mexico in that year (accounting for 9.6% of Mexican exports), the top 10 products exported by Mexico are goods belonging to those industries. Together, these products accounted for 26% of Mexican exports, and all of them have undergone a *downward* relocation, as reflected by the pure relocation indices.

In the case of Philippines, the negative impact of relocation can also be attributed to its specialization: 38.6% of its exports are concentrated on products of the electrical equipment industry (chapter 85), 16.6% on machinery and mechanical appliances (chapter 84) and 14% on textiles, leather and footwear (chapters 8, 11 and 12). All of them have experienced a *downward* relocation. Malaysia has also been affected by the *downward* relocation undergone by electrical equipment, and machinery and mechanical appliances, since more than half of its exports are concentrated on products of these industries. In the case of Turkey, the main exporting industry of the country is textiles (23.9%), which is the sector that exhibited the largest *downward* relocation, followed by metals and manufactures (8.3%).

On the other side, some countries have been less negatively affected by international production relocation. It is the case of some European eastern countries: Latvia, Lithuania and Estonia. These countries were specialized in pharmaceutical products (which accounted for around 1% and 1.5% of those countries' exports), and other products of the chemical industry (5.7% in Latvia's exports, 7.4% of Estonia's exports and up to 9.8% in Lithuania's), which have experienced an *upward* relocation. Although the share of these products in those countries' exports was not large enough to offset the negative effect caused by the *downward* relocation in other industries, their specialization in those products may have helped to mitigate that negative effect. In the end, the net effect depends on each country's specialization and its capacity and flexibility to adapt to the changing conditions in international trade.

4.3.3. Controlling for export diversification

This section addresses if the results presented so far are not driven by issues related to export diversification. Lederman and Maloney (2012) explore the effects of export concentration on economic welfare. To do so, they use the Herfindahl index as a measure of export concentration. Instead, we approach this question by excluding from the regressions a sample of low diversified countries, which are defined as those countries for which the export of a product accounts for more than 50% of its export basket in any of the periods used for the construction of the indices (1995-1997, 2000-2002 or 2005-2007).[53]

Low diversified countries may exhibit more volatility, and this can potentially affect the *PSI* or *PRI* indices. 21 countries out of the sample of 110 are selected by this filter: Burundi, Benin, Bahrain, Central African Republic, Congo, Rep., Gabon, Gambia, Iran, Kazakhstan, Kuwait, Mali, Malawi, Saudi Arabia, Sudan, Sierra Leone, Syria, Uganda, Venezuela, Yemen, Democratic Republic of Congo and Zambia. Thus, we end up with a sample of 89 countries, which is further reduced as *PSI* or *PRI* outliers are excluded.

For ease of exposition, we only report the results of our preferred specification and the specification that excludes oil countries. Results for the product-shocks impact index are presented in Table 11 and results for the pure relocation impact in Table 12. Columns (1) and (2) report OLS estimates, whereas columns (3) and (4) report IV estimates. The tables also include dummies by continent. As it can be seen in these tables, results are robust to the exclusion of low-diversified countries: the *PSI* index is positive and statistically significant at the 1-percent in the four specifications, as it is the case of the *PRI*.

[53] Lederman and Maloney (2012) find that including the Herfindahl Index of export concentration in the cross-country growth regressions of HHR (2007) eliminates the effect of EXPY on pc GDP growth, suggesting that export concentration is not good for growth.

Table 11. Impact of product-shocks on cross-country growth. Results excluding low diversified countries. OLS and IV estimates

	Dependent variable: Growth rate of GDP per capita			
	OLS	OLS	IV	IV
	(1)	(2)	(3)	(4)
Product-shocks impact (*PSI*)	0.193***	0.184***	0.131***	0.117***
	(0.035)	(0.038)	(0.042)	(0.045)
log initial EXPY	0.018*	0.016	0.013	0.008
	(0.011)	(0.013)	(0.010)	(0.012)
log initial GDPpc	-0.017***	-0.017**	-0.016***	-0.015**
	(0.006)	(0.007)	(0.006)	(0.007)
log Human Capital (years sch)	0.015***	0.014***	0.016***	0.015***
	(0.005)	(0.005)	(0.005)	(0.005)
log Capital Intensity	0.002	0.001	0.001	0.001
	(0.003)	(0.004)	(0.003)	(0.004)
Rule of law	0.002	0.003	0.002	0.003
	(0.003)	(0.004)	(0.003)	(0.003)
Export share of oil	0.045***	0.049	0.043***	0.049
	(0.011)	(0.036)	(0.013)	(0.035)
log Population	0.003	0.002	0.002	0.001
	(0.002)	(0.002)	(0.002)	(0.002)
log Area	-0.003***	-0.003**	-0.003**	-0.002*
	(0.001)	(0.001)	(0.001)	(0.001)
Constant	-0.085	-0.054	-0.017	0.024
	(0.071)	(0.086)	(0.067)	(0.082)
Dummies by continent	*Yes*	*Yes*	*Yes*	*Yes*
Excluding pcGDP outliers	*Yes*	*Yes*	*Yes*	*Yes*
Excluding *PSI* outliers	*Yes*	*Yes*	*Yes*	*Yes*
Observations	87	82	87	82
R^2	0.568	0.541	0.549	0.518

Notes: Results from estimating equation 8 using OLS (col. 1 and 2) and 2SLS (col. 3 and 4). The dependent variable is the average growth rate of GDP per capita over 1996-2006. The variables log(*iEXPY*) and *PSI* are instrumented using the country specific *PRODY* variables log(*csp-iEXPY*) and *csp-PSI* (see the body text and the Appendix for details). Robust standard errors are in parentheses. Output gap outliers are excluded. All regressions include dummies by continent (Africa, America, Europe, Asia and Oceania). The excluded *PSI* outliers are Gambia, Central African Republic, Sierra Leona, Gabon, Mauritania and Cameroon. See the body text for the criteria used to identify potential outliers. Columns (2) and (4) also exclude the main oil producers. Significance levels: *** 1-percent, ** 5-percent, * 10-percent.

Table 12. Impact of pure relocation on cross-country growth. Results excluding low diversified countries. OLS and IV estimates

	Dependent variable: Growth rate of GDP per capita			
	OLS	OLS	IV	IV
	(1)	(2)	(3)	(4)
Pure Relocation Impact (*PRI*)	0.139***	0.142***	0.138***	0.129***
	(0.045)	(0.048)	(0.045)	(0.046)
Other product shocks (*PSI-PRI*)	0.425***	0.451***	0.245***	0.229***
	(0.067)	(0.080)	(0.076)	(0.089)
log initial EXPY	0.016	0.016	0.013	0.010
	(0.011)	(0.012)	(0.010)	(0.011)
log initial GDPpc	-0.012*	-0.013*	-0.013**	-0.012*
	(0.007)	(0.007)	(0.006)	(0.007)
log Human Capital (years sch)	0.014**	0.013**	0.016***	0.016***
	(0.005)	(0.006)	(0.005)	(0.005)
log Capital Intensity	-0.002	-0.002	-0.001	-0.001
	(0.003)	(0.004)	(0.003)	(0.003)
Rule of law	0.002	0.004	0.001	0.002
	(0.003)	(0.003)	(0.002)	(0.003)
Export share of oil	0.053***	0.060*	0.045***	0.053
	(0.011)	(0.036)	(0.011)	(0.035)
log Population	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.002)	(0.002)
log Area	-0.001	-0.002	-0.002*	-0.002
	(0.001)	(0.001)	(0.001)	(0.001)
Constant	-0.120*	-0.121	-0.061	-0.028
	(0.069)	(0.086)	(0.068)	(0.087)
Dummies by continent	*Yes*	*Yes*	*Yes*	*Yes*
Excluding pcGDP outliers	*Yes*	*Yes*	*Yes*	*Yes*
Excluding *PRI* and *PSI* outliers	*Yes*	*Yes*	*Yes*	*Yes*
Observations	87	82	86	81
R^2	0.649	0.630	0.614	0.583

Notes: Results from estimating equation 9 using 2SLS. The dependent variable is the average growth rate of GDP per capita 1996-2006. The variables log(*iEXPY*), *PRI*, and *PSI-PRI* are instrumented using the country specific PRODY variables log(*csp-iEXPY*), *csp-PRI* and csp-*PSI-PRI* (see the body text and the Appendix for details). Robust standard errors are in parentheses. Output gap outliers are excluded. All regressions include dummies by continent (Africa, America, Europe, Asia and Oceania). The excluded *PRI* and *PSI* outliers are Cameroon, Central African Republic, Democratic Republic of Congo, Gambia, Gabon, Mauritania and Sierra Leona. South Africa becomes and additional outlier in IV estimates (columns (3) and (4)). See the body text for the criteria used to identify potential outliers. Columns (2) and (4) also exclude the main oil producers. Significance levels: *** 1-percent, ** 5-percent, * 10-percent.

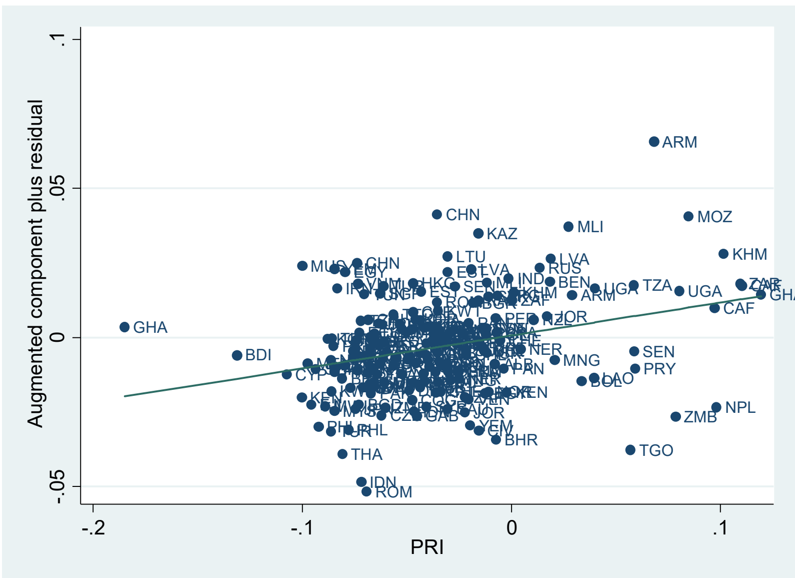
4.3.4. Pure relocation impact in 5-years panel data

Finally, Table 13 reports the results of estimating equation 9 using 5-years panel data (1996-2001 and 2001-2006) with time fixed effects and dummies by continent. Standard errors clustered by country are reported in parenthesis. Columns (1) to (4) in Table 13 report OLS estimates, whereas columns (5) to (8) report IV estimates. We exclude the main oil producers in columns (4) and (8) and only report estimates of the specifications that exclude *PRI* (and *PSI*) outliers.

The estimated coefficient for *PRI* in the OLS estimates ranges between 0.9 and 0.119. The coefficients are slightly lower than in the cross-country growth regressions over the 10-year period (see Table 9). The *PRI* is significant at the 1-percent in all the specifications. As before, Figure 13 shows the component-plus-residual plot after estimating our preferred specification (Table 13, col. 2). It becomes apparent that the results are not driven by outliers.

The coefficient for *PRI* in the IV estimates varies between 0.96 and 0.102. It is significant at the 5-percent in all the specifications. The magnitude of the coefficients is slightly lower than the ones in growth regressions over the 10 year period (see Table 10).

Figure 8. Partial relationship between *PRI* and subsequent GDP pc growth



Notes: The vertical axis measures the GDP per capita growth to be explained by the *PRI* index:

$$\frac{1}{T}\log\frac{\widehat{GDPpc_c^T}}{GDPpc_c^0} - \left(\hat{\beta}_0 + \hat{\beta}_1\log(GDPpc_c^0) + \hat{\beta}_2\log(iEXPY_c^0) + \hat{\beta}_3X_c^0 + \hat{\beta}_5\left(PSI_c^{0,T} - PRI_c^{0,T}\right)\right),$$

with the coefficient estimates taken from Table 13, column (2). The horizontal axis measures the value of the *PRI* index.

Table 13. Impact of pure relocation on cross-country growth. Panel growth regressions, 1996-2006. OLS and IV estimates.

	Dependent variable: Growth rate of GDP per capita							
	OLS	OLS	OLS	OLS	IV	IV	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Pure Relocation Impact (*PRI*)	0.115***	0.109***	0.110***	0.119***	0.096**	0.099**	0.097**	0.102**
	(0.039)	(0.038)	(0.037)	(0.042)	(0.048)	(0.048)	(0.048)	(0.044)
Other product shocks (*PSI-PRI*)	0.735***	0.740***	0.736***	0.818***	0.303***	0.299***	0.277***	0.363***
	(0.061)	(0.062)	(0.066)	(0.068)	(0.094)	(0.095)	(0.101)	(0.109)
log initial EXPY	0.007	0.007	0.012	0.003	0.002	0.003	0.025	-0.005
	(0.007)	(0.007)	(0.023)	(0.009)	(0.008)	(0.009)	(0.029)	(0.010)
log initial GDPpc	-0.008*	-0.007	-0.002	-0.005	-0.010**	-0.011*	0.015	-0.007
	(0.004)	(0.005)	(0.024)	(0.005)	(0.005)	(0.006)	(0.032)	(0.007)
log iEXPY*log gdppc0			-0.001				-0.003	
			(0.003)				(0.003)	
log Human Capital (years sch)	0.010**	0.010**	0.010**	0.009	0.015***	0.015***	0.014***	0.012**
	(0.005)	(0.005)	(0.005)	(0.006)	(0.005)	(0.005)	(0.005)	(0.006)
log Capital Intensity	-0.002	-0.003	-0.003	-0.004	-0.000	0.000	-0.000	-0.002
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)
Rule of law	0.002	0.002	0.002	0.004	0.002	0.002	0.003	0.004
	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Export share of oil	0.043***	0.041***	0.041***	0.065**	0.023**	0.023**	0.022*	0.065*
	(0.007)	(0.007)	(0.008)	(0.032)	(0.010)	(0.011)	(0.012)	(0.034)
log Population		-0.001	-0.001	-0.001		-0.000	-0.000	-0.000
		(0.001)	(0.001)	(0.001)		(0.002)	(0.002)	(0.002)
log Area		0.001	0.001	0.000		-0.000	-0.000	-0.001
		(0.001)	(0.001)	(0.001)		(0.001)	(0.001)	(0.001)
Constant	-0.054	-0.052	-0.097	-0.024	0.033	0.032	-0.166	0.082
	(0.047)	(0.048)	(0.200)	(0.065)	(0.054)	(0.055)	(0.260)	(0.068)
Observations	207	207	207	176	204	204	204	173
R^2	0.569	0.570	0.570	0.584	0.479	0.479	0.474	0.500

Notes: Results from estimating equation 9 using OLS and 2SLS. The dependent variable is the average growth rate of GDP per capita 1996-2006. The variables log(*iEXPY*), *PRI*, and *PSI-PRI* are instrumented using the country specific PRODY variables log(*csp-iEXPY*), *csp-PRI* and csp-*PSI-PRI* (see the body text and the Appendix for details). Robust standard errors are in parentheses. Output gap outliers are excluded. All regressions include dummies by continent (Africa, America, Europe, Asia and Oceania). The excluded *PRI* and *PSI* outliers are Gambia and Sierra Leona in both subperiods, plus Bahrain, Cameroon, Sudan and D.R. Congo in the first period, and Burundi, Benin, Mozambique and Mauritania in the second period. Additional outliers in the instruments are Central African Rep. and Ghana. See the body text for the criteria used to identify potential outliers. Columns (4) and (8) also exclude the main oil producers. Significance levels: *** 1-percent, ** 5-percent, * 10-percent.

5. CONCLUSIONS

The process of international relocation of production across country income groups has been a central feature of economic globalization. This chapter explores the consequences of this process over the 1996-2006 period on cross-country growth. We find that countries that were specialized in 1996 in product categories that, on average, relocated towards lower-income (higher-income) economies over the following years, exhibited significantly lower (greater) growth over the 1996-2006 period. This impact is statistically significant, robust, and economically important: a difference of one standard deviation in the country's pure relocation impact index resulted in a difference of about 1 percentage point in the country's average annual growth.

The period analyzed in this chapter (1996-2006) has been dominated by a general relocation trend towards lower-income countries. Thus, while international relocation of production could potentially have gone in either a positive or a negative direction (as a result of innovation and standardization, respectively), during this period the negative effect has been larger than the positive one for most countries, as a consequence of their specialization in products that have migrated towards lower-income countries. On the other hand, countries with a specialization in product categories that have experienced an *upward* relocation appear to have been better off than those specialized in products that exhibited a *downward* relocation. Hence, although in this period relocation has had a relative negative influence on many countries, this is only one of the effects of trade. On average, it is accepted that trade has an overall positive impact, but it can have some losers. The net effect of trade on each particular country ultimately depends on the country’s flexibility and capacity to adapt to the changing opportunities provided by comparative advantage and specialization.

Thus, what you export matters (at least) because products experience frequent shocks leading to the international relocation of production that have a notable impact on the countries' economic performance. Technical progress can change the productive sophistication of a good, thereby leading to a process of international relocation of production whose impact on each country depends on the country's initial specialization. As long as the production of each good involves product-specific knowledge and skills, countries initially specialized in the goods that relocate towards lower-income countries will tend to decrease their income. The opposite will be true for countries initially specialized in the goods experiencing innovation and relocation towards higher-income countries.

The analysis about the potential determinants of production relocation conducted in the previous chapter has revealed that this phenomenon largely appears as an unpredictable phenomenon. This apparent unpredictability leaves little room for industrial policies aimed at promoting specific industries that have better chances of moving up along the exporters' income ladder and for regional policies aimed at anticipating the dangers of future relocations of local industries towards lower-income areas. Still, the long run impact of the relocation processes is not only a matter of fate and good or bad luck. Policies promoting human capital, R&D, and a pro-business institutional environment are likely to help countries to adjust to the loss of industries relocating towards lower-wage countries, by becoming more attractive to innovative industries that are reinforcing operations in developed countries.

6. APPENDIX

Table A1. List of countries

ISO3	Country name	ISO3	Country name
AGO	Angola*	FRA	France
ALB	Albania	GAB	Gabon
ARE	United Arab Emirates**	GBR	United Kingdom
ARG	Argentina	GEO	Georgia***
ARM	Armenia	GHA	Ghana
AUS	Australia	GIN	Guinea*
AUT	Austria	GMB	Gambia, The+
AZE	Azerbaijan***	GNB	Guinea-Bissau***
BDI	Burundi	GRC	Greece
BEN	Benin	GTM	Guatemala
BFA	Burkina Faso*	GUY	Guyana**
BGD	Bangladesh	HKG	Hong Kong SAR, China
BGR	Bulgaria	HND	Honduras
BHR	Bahrain	HRV	Croatia
BIH	Bosnia and Herzegovina*	HUN	Hungary
BLR	Belarus***	IDN	Indonesia
BLX	Benelux	IND	India
BOL	Bolivia	IRL	Ireland
BRA	Brazil	IRN	Iran, Islamic Rep.
BTN	Bhutan*	ISR	Israel
CAF	Central African Republic+	ITA	Italy
CAN	Canada	JOR	Jordan
CHE	Switzerland	JPN	Japan
CHL	Chile	KAZ	Kazakhstan
CHN	China	KEN	Kenya
CIV	Cote d'Ivoire	KGZ	Kyrgyz Republic ***
CMR	Cameroon+	KHM	Cambodia
COG	Congo, Rep.	KOR	Korea, Rep.
COL	Colombia	KWT	Kuwait
CRI	Costa Rica	LAO	Lao PDR
CYP	Cyprus	LBN	Lebanon*
CZE	Czech Republic	LBR	Liberia ***
DEU	Germany	LKA	Sri Lanka
DJI	Djibouti*	LTU	Lithuania
DNK	Denmark	LVA	Latvia
DOM	Dominican Republic	MAR	Morocco
DZA	Algeria**	MDA	Moldova ***
ECU	Ecuador	MDG	Madagascar*
EGY	Egypt, Arab Rep.	MEX	Mexico
ERI	Eritrea*	MKD	Macedonia, FYR*
ESP	Spain	MLI	Mali
EST	Estonia	MNG	Mongolia
ETH	Ethiopia*	MOZ	Mozambique
FIN	Finland	MRT	Mauritania+
FJI	Fiji	MUS	Mauritius

*** Outliers in GDP that are excluded from the construction of the indices; + Outliers in *PRI* or *PSI*.
* Countries with no data for human capital; ** countries with no data for capital intensity or exports of oil.

Table A1 (*cont*). List of countries.

ISO3	Country name	ISO3	Country name
MWI	Malawi	SLV	El Salvador
MYS	Malaysia	SVK	Slovak Republic
NER	Niger	SVN	Slovenia
NGA	Nigeria*	SWE	Sweden
NIC	Nicaragua**	SYR	Syrian Arab Republic
NLD	Netherlands	TCD	Chad***
NOR	Norway	TGO	Togo
NPL	Nepal	THA	Thailand
NZL	New Zealand	TJK	Tajikistan ***
OMN	Oman*	TKM	Turkmenistan***
PAK	Pakistan	TTO	Trinidad and Tobago
PAN	Panama	TUN	Tunisia
PER	Peru	TUR	Turkey
PHL	Philippines	TZA	Tanzania
PNG	Papua New Guinea**	UGA	Uganda
POL	Poland	UKR	Ukraine ***
PRT	Portugal	URY	Uruguay
PRY	Paraguay	USA	United States
ROM	Romania	UZB	Uzbekistan*
RUS	Russian Federation	VEN	Venezuela, RB
RWA	Rwanda ***	VNM	Vietnam
SAU	Saudi Arabia	YEM	Yemen, Rep.
SDN	Sudan	ZAF	South Africa
SEN	Senegal	ZAR	Congo, Dem. Rep.+
SGP	Singapore	ZMB	Zambia
SLE	Sierra Leone+		

*** Outliers in GDP that are excluded from the construction of the indices; + Outliers in *PRI* or *PSI*.
* Countries with no data for human capital; ** countries with no data for capital intensity or exports of oil.

A2. Construction of the instrumental variables

As explained in the body text, to separate the impact of country-specific shocks from the impact of product shocks and identify the latter, we calculate specific *PRODYs* for each country that are constructed excluding all the data relative to the country (i.e., its exports and GDP per capita). Then, these country specific *PRODYs* are used to construct instruments for the country's *iEXPY*, *PSI*, and *PRI* indices.

This appendix provides the specific formulas used in the calculations. Specifically, the country *c*'s specific *PRODYs* for good *k* are defined as:

$$cs\_PRODY_{k,-c}^{t} = \sum_{i \neq c}^{C} \frac{RCA_{i-c,k}^{t}}{\sum_{c=1}^{C} RCA_{i-c,k}^{t}} GDPpc_{i}^{t},$$

$$cs\_ciPRODY_{k,-c}^{0,T} = \sum_{i \neq c}^{C} \frac{RCA_{i-c,k}^{T}}{\sum_{c=1}^{C} RCA_{i-c,k}^{T}} GDPpc_{i}^{0},$$

where $RCA_{i-c,k}^{t}$ is the country *i*'s revealed comparative advantage in good *k* calculated by excluding country *c*'s exports from world trade. Thus, these indices reflect the level of development of the countries other than *c* exporting product *k*. The formulas for the *EXPYs* and relocation impact indices constructed using the $cs\_PRODY_{k,-c}^{t}$ and $cs\_ciPRODY_{k,-c}^{0,T}$ (which are denoted as *csp* for country specific *PRODYs*) are the following:

$$csp\_iEXPY_{c}^{0} = \sum_{k} cs\_PRODY_{k,-c}^{0}\, \omega_{ck}^{0},$$

$$csp\_EXPY_{c}^{0} = \sum_{k} cs\_PRODY_{k,-c}^{T}\, \omega_{ck}^{0},$$

$$csp\_PSI_{c}^{0,T} = \log \frac{\sum_{k} cs\_PRODY_{k,-c}^{T}\, \omega_{ck}^{0}}{\sum_{k} cs\_PRODY_{k,-c}^{0}\, \omega_{ck}^{0}} = \log \frac{\sum_{k} csp\_EXPY_{c}^{0,T}}{\sum_{k} csp\_iEXPY_{c}^{0}},$$

$$csp\_PRI_{c}^{0,T} = \log \frac{\sum_{k} cs\_ciPRODY_{k,-c}^{T}\, \omega_{ck}^{0}}{\sum_{k} cs\_PRODY_{k,-c}^{0}\, \omega_{ck}^{0}} = \log \frac{\sum_{k} csp\_ciEXPY_{c}^{0,T}}{\sum_{k} csp\_iEXPY_{c}^{0}}.$$

Table A3. Correlation matrix

	pc GDP growth	log initial pcGDP	Rule of law	Human capital (years sch)	log capital intensity	Export share of oil	log population	log area	log initial *EXPY*	*PSI*	*PRI*	*PSI-PRI*
pc GDP growth	1											
log initial pcGDP	-0.03	1										
Rule of law	0.00	0.78	1									
Human capital (years sch)	0.23	0.76	0.62	1								
log capital intensity	0.02	0.92	0.76	0.77	1							
Export share of oil	-0.06	0.10	-0.22	-0.11	-0.02	1						
log population	-0.04	-0.11	-0.08	-0.13	-0.08	-0.02	1					
log area	-0.06	-0.20	-0.19	-0.18	-0.14	0.15	0.71	1				
log initial *EXPY*	0.10	0.89	0.68	0.69	0.83	0.18	0.07	-0.08	1			
PSI	0.52	-0.27	-0.10	0.02	-0.19	-0.48	-0.11	0.05	-0.28	1		
PRI	0.26	-0.43	-0.33	-0.24	-0.42	-0.09	-0.06	0.24	-0.42	0.80	1	
PSI-PRI	0.50	0.15	0.31	0.38	0.28	-0.67	-0.08	-0.25	0.14	0.53	-0.09	1

Table A4. First-stage regressions of estimations in Table 5 and Table 10.

	Product-shocks Impact (*PSI*)			Pure Relocation Impact (*PRI*)		
	(1)	(2)	(3)	(4)	(5)	(6)
csp_Product-shocks impact (*csp-PSI*)	0.883***	0.820***	0.766***			
	(0.088)	(0.114)	(0.136)			
csp_Pure relocation impact (*csp-PRI*)				0.863***	0.785***	0.706***
				(0.085)	(0.096)	(0.110)
csp_Other Product Shocks *(csp-PSI_PRI)*				0.025	0.119	0.112
				(0.213)	(0.180)	(0.168)
log *csp-iEXPY*	-0.002	0.002	0.004	-0.003	0.004	0.002
	(0.019)	(0.018)	(0.021)	(0.019)	(0.018)	(0.020)
log initial GDPpc	-0.029	-0.027	-0.018	-0.019	-0.014	-0.000
	(0.019)	(0.020)	(0.027)	(0.017)	(0.019)	(0.024)
log Human Capital (years sch)	0.008	0.012	0.012	-0.002	0.004	0.004
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
log Capital Intensity	-0.005	-0.004	-0.008	-0.007	-0.009	-0.016
	(0.011)	(0.012)	(0.014)	(0.011)	(0.011)	(0.013)
Rule of law	0.008	0.003	-0.000	0.005	0.001	-0.003
	(0.010)	(0.011)	(0.012)	(0.009)	(0.009)	(0.010)
Export share of oil	-0.007	-0.008	-0.039	-0.006	0.005	-0.028
	(0.024)	(0.025)	(0.044)	(0.027)	(0.024)	(0.028)
log Population			-0.011**			-0.012***
			(0.005)			(0.004)
log Area			0.007			0.010**
			(0.006)			(0.005)
Constant	0.336**	0.283**	0.324**	0.275*	0.157	0.191
	(0.140)	(0.128)	(0.127)	(0.153)	(0.135)	(0.124)
Dummies by continent	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding pcGDP outliers	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding *PSI* or *PRI* outliers	*No*	*Yes*	*Yes*	*No*	*Yes*	*Yes*
Observations	110	104	104	110	102	102
R^2	0.826	0.682	0.701	0.848	0.632	0.675
F-test	30.34	26.53	25.35	18.95	16.84	14.65

Notes: The first-stage regressions for *PSI* in the first three columns correspond to the estimations of equation 8 that are in columns 2, 3, and 4 of Table 5. The first-stage regressions for *PRI* in columns (4) to (6) correspond to the estimations of equation 9 that are in columns 2, 3, and 4 of Table 10. Robust standard errors are in parentheses. Significance levels: *** 1-percent, ** 5-percent, * 10-percent.

A5. Results without excluding output gap outliers from the construction of the *PRODYs*.

The tables presented in this section correspond to results of the regression analysis using the whole sample of 141 countries in the construction of the *PRODYs*, that is, without excluding those countries that appear as output gap outliers. As explained in Section 3.3, output gap outliers are countries whose value for initial output gap deviated more than three times the interquartile range from the sample median of the corresponding variable. This exercise is conducted as a robustness test to show that results are not driven by the exclusion of these countries. We only report results for our main variable of interest, the Pure Relocation Impact (*PRI*) index.

Table A5.1 reports the OLS estimates using equation 9. The *PRI* has a positive and statistically significant coefficient at the 5 and 1-percent level. The coefficients are slightly lower than the ones in Table 9. Tables A5.2 and A5.3 show the IV estimates. Results in Table A5.2 show that the *PRI* is positive and statistically significant at the 5-percent level (10-percent in the specification in column (7) that excludes the oil countries). Table A5.3 considers alternative measures of institutional quality and human capital. The *PRI* is significant at the 5-percent.

Table A5.1. Impact of pure relocation on cross-country growth. Robustness, OLS estimates

	Dependent variable: Growth rate of GDP per capita						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Pure Relocation Impact (*PRI*)	0.044**	0.053***	0.085**	0.119***	0.127***	0.129***	0.125***
	(0.017)	(0.016)	(0.036)	(0.031)	(0.034)	(0.034)	(0.041)
Other product shocks (*PSI-PRI*)	0.450***	0.394***	0.357***	0.421***	0.416***	0.412***	0.432***
	(0.055)	(0.056)	(0.061)	(0.059)	(0.063)	(0.063)	(0.080)
log initial EXPY	0.021**	0.019*	0.019*	0.012	0.013*	0.022	0.015
	(0.010)	(0.011)	(0.010)	(0.007)	(0.007)	(0.026)	(0.010)
log initial GDPpc	-0.014***	-0.014*	-0.014*	-0.009**	-0.010*	0.002	-0.009
	(0.004)	(0.008)	(0.007)	(0.004)	(0.005)	(0.032)	(0.006)
log iEXPY*log gdppc0						-0.001	
						(0.003)	
log Human Capital (years sch)		0.010**	0.010**	0.009*	0.009*	0.008*	0.008
		(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)
log Capital Intensity		-0.001	-0.000	-0.003	-0.002	-0.002	-0.005
		(0.004)	(0.004)	(0.002)	(0.003)	(0.003)	(0.004)
Rule of law		0.002	0.001	0.002	0.003	0.003	0.005
		(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
Export share of oil	0.051***	0.044***	0.042***	0.050***	0.053***	0.053***	0.060*
	(0.010)	(0.009)	(0.009)	(0.008)	(0.009)	(0.009)	(0.033)
log Population					0.001	0.001	0.001
					(0.002)	(0.002)	(0.002)
log Area					-0.001	-0.001	-0.002
					(0.001)	(0.001)	(0.001)
Constant	-0.166***	-0.132**	-0.125**	-0.102*	-0.104*	-0.194	-0.101
	(0.059)	(0.064)	(0.061)	(0.052)	(0.053)	(0.245)	(0.072)
Dummies by continent	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding *PRI* and *PSI* outliers	*No*	*No*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding pcGDP outliers	*No*	*No*	*No*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	135	116	109	103	103	103	89
R^2	0.548	0.540	0.530	0.612	0.614	0.615	0.584

Notes: Results from estimating equation 9 using OLS. The dependent variable is the annual average growth rate of GDP per capita over 1996-2006. Robust standard errors are in parentheses. All regressions include dummies by continent (Africa, America, Europe, Asia and Oceania). The excluded *PRI* and *PSI* outliers starting in column (3) are Dem. Rep. of Congo, Gambia, Central African Republic, Sierra Leona, Gabon, Mauritania and Cameroon. Columns (4) to (7) exclude the output gap outliers (Liberia, Rwanda, Moldova, Ukraine, Tajikistan, and Kyrgyz Republic). See the body text for the criteria used to identify potential outliers. Column (7) also excludes the main oil producers.
Significance levels: *** 1-percent, ** 5-percent, * 10-percent.

Table A5.2. Impact of pure relocation on cross-country growth. Robustness, IV estimates

	Dependent variable: Growth rate of GDP per capita						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Pure Relocation Impact (*PRI*)	0.038**	0.036**	0.086**	0.105**	0.115**	0.111**	0.088*
	(0.019)	(0.015)	(0.040)	(0.041)	(0.045)	(0.046)	(0.049)
Other product shocks (*PSI-PRI*)	0.312***	0.241***	0.158**	0.209***	0.204**	0.189**	0.154
	(0.078)	(0.077)	(0.080)	(0.081)	(0.081)	(0.081)	(0.100)
log initial EXPY	0.017	0.014	0.012	0.006	0.008	0.030	0.007
	(0.011)	(0.011)	(0.010)	(0.007)	(0.007)	(0.028)	(0.010)
log initial GDPpc	-0.013***	-0.015**	-0.014**	-0.010**	-0.012**	0.016	-0.010*
	(0.004)	(0.007)	(0.007)	(0.004)	(0.005)	(0.034)	(0.005)
log iEXPY*log gdppc0						-0.003	
						(0.004)	
log Human Capital (years sch)		0.012***	0.012***	0.012***	0.011**	0.011**	0.011**
		(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)
log Capital Intensity		-0.000	0.001	-0.001	-0.000	-0.000	-0.003
		(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)
Rule of law		0.002	0.000	0.002	0.002	0.003	0.003
		(0.002)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)
Export share of oil	0.040***	0.031***	0.027**	0.032***	0.036***	0.034***	0.054
	(0.012)	(0.012)	(0.013)	(0.011)	(0.012)	(0.012)	(0.033)
log Population					0.001	0.001	-0.000
					(0.002)	(0.002)	(0.002)
log Area					-0.001	-0.001	-0.001
					(0.001)	(0.001)	(0.001)
Constant	-0.099	-0.057	-0.036	-0.010	-0.011	-0.214	0.029
	(0.089)	(0.071)	(0.066)	(0.055)	(0.057)	(0.261)	(0.073)
Dummies by continent	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding *PRI* and *PSI* outliers	*No*	*No*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding pcGDP outliers	*No*	*No*	*No*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	135	116	109	103	103	103	89
R^2	0.524	0.511	0.484	0.552	0.556	0.552	0.505

Notes: Results from estimating equation 9 using 2SLS. The dependent variable is the annual average growth rate of GDP per capita over 1996-2006. The variables log(*iEXPY*), *PRI*, and *PSI-PRI* are instrumented using the country specific PRODY variables log(*csp-iEXPY*), *csp-PRI* and csp-*PSI-PRI* (see the body text and the Appendix for details). Robust standard errors are in parentheses. All regressions include dummies by continent (Africa, America, Europe, Asia and Oceania). The excluded *PRI* and *PSI* outliers starting in column (3) are Dem. Rep. of Congo, Gambia, Central African Republic, Sierra Leona, Gabon, Mauritania and Cameroon. Columns (4) to (7) exclude the output gap outliers (Liberia, Rwanda, Moldova, Ukraine, Tajikistan, and Kyrgyz Republic). See the body text for the criteria used to identify potential outliers. Column (7) also excludes the main oil producers.
Significance levels: *** 1-percent, ** 5-percent, * 10-percent.

Table A5.3. Impact of pure relocation on cross-country growth. Robustness, IV estimates

	Dependent variable: Growth rate of GDP per capita				
	(1)	(2)	(3)	(4)	(5)
Pure Relocation Impact (*PRI*)	0.105**	0.110**	0.111**	0.114**	0.108**
	(0.044)	(0.045)	(0.046)	(0.045)	(0.044)
Other product shocks (*PSI-PRI*)	0.193**	0.209***	0.201**	0.189**	0.212***
	(0.077)	(0.079)	(0.081)	(0.083)	(0.079)
log initial EXPY	0.005	0.006	0.008	0.007	0.004
	(0.007)	(0.007)	(0.007)	(0.008)	(0.007)
log initial GDPpc	-0.015***	-0.013***	-0.011**	-0.011**	-0.012***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
log Human Capital (years sch)	0.012***	0.012***	0.012***		
	(0.004)	(0.004)	(0.004)		
log Capital Intensity	0.001	0.000	-0.000	0.000	-0.001
	(0.003)	(0.003)	(0.003)	(0.003)	(0.002)
Export share of oil	0.043***	0.039***	0.034***	0.032**	0.040***
	(0.012)	(0.012)	(0.011)	(0.013)	(0.011)
log Population	0.001	0.001	0.001	0.001	0.002
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
log Area	-0.001	-0.001	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Regulatory Quality	0.008***				
	(0.003)				
Government Effectiveness		0.004			
		(0.003)			
Control of Corruption			0.001		
			(0.002)		
Rule of law				0.002	0.002
				(0.003)	(0.003)
log Human Capital (BL)				0.005**	
				(0.003)	
log Human Capital (PWT)					0.035***
					(0.010)
Constant	0.027	0.012	-0.014	-0.006	0.007
	(0.054)	(0.059)	(0.057)	(0.058)	(0.057)
Dummies by continent	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding *PRI* and *PSI* outliers	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Excluding pcGDP outliers	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Observations	103	103	103	103	103
R^2	0.570	0.561	0.553	0.534	0.572

Notes: Results from estimating equation 9 using 2SLS. The dependent variable is the annual average growth rate of GDP per capita over 1996-2006. The variables log(*iEXPY*), *PRI*, and *PSI-PRI* are instrumented using the country specific PRODY variables log(*csp-iEXPY*), *csp-PRI* and csp-*PSI-PRI* (see the body text and the Appendix for details). Robust standard errors are in parentheses. All regressions include dummies by continent (Africa, America, Europe, Asia and Oceania). The excluded *PRI* and *PSI* outliers starting in column (3) are Dem. Rep. of Congo, Gambia, Central African Republic, Sierra Leona, Gabon, Mauritania and Cameroon. Columns (4) to (7) exclude the output gap outliers (Liberia, Rwanda, Moldova, Ukraine, Tajikistan, and Kyrgyz Republic). See the body text for the criteria used to identify potential outliers. Column (7) also excludes the main oil producers.
Significance levels: *** 1-percent, ** 5-percent, * 10-percent.

Chapter 6:

CONCLUSIONS

CONCLUSIONS

This doctoral thesis focuses around two major changes that have taken place in the nature of production and international trade in the last decades. The first one is the fragmentation of production processes across borders and the subsequent emergence of global value chains (GVCs). The second one is the process of international relocation of production across countries at different levels of development. The three central chapters of this thesis are grouped around these two relevant aspects of international trade.

In the past decades, the production and exports of many manufacturing products has moved from advanced countries to lower-income countries. As a result, the share of developed countries in world income and trade has decreased, while the importance of lower-income countries in global production and exports has increased. More recently, stimulated by the fall in transport and coordination costs, production processes fragmented across borders, leading to the internationalisation of supply chains. These phenomena have changed the way in which countries participate and compete in world trade.

Global value chains and the value-added content of trade

The international fragmentation of production leads us to reassess what is the actual contribution of trade to an economy's well-being, in terms of income and employment. As explained in the introduction, since countries increasingly rely on imported inputs to produce their exports, a given amount of exports does not generate an equivalent amount of benefits to the producing economy. To tackle this issue, the value-added content of trade has to be estimated. New trade statistics that allow us to follow goods through the supply chain and allocate value-added to the country and industry of origin are needed.

Value added exports and its evolution are closely related to the way in which countries participate in GVCs. The **third chapter** of the thesis focuses on this question. Specifically, it addresses the participation of Spain in GVCs, comparing its main features with a selection of 20 exporting countries. To do so, gross exports are fully decomposed into several components following the methodology by Koopman, Wang and Wei (2014). The value added content of exports, as well as the different indicators of vertical specialization are obtained as linear components of the terms resulting from the KWW's (2014) gross exports decomposition. The analysis is conducted over the period 1995 and 2011 using the international input-output tables from WIOD.

The results show that the value-added content of Spanish gross exports has declined over the sample period: in 1995, its value added exports accounted for 79% of total exports and decreased by more than 9 percentage points to reach 70% in 2011. These values are similar to those of its main European partners (Germany, France and Italy). The decrease in the value added content of exports is a tendency that is also shared by the other economies included in the analysis, and is symptomatic of countries' increasing interconnectedness around GVCs: the gap between value-added and gross exports widens with the exports' content in imported intermediate inputs.

The evolution of the value added content of exports is closely linked to the participation in GVCs, measured through the vertical specialization indices that capture countries' *backward* and *forward participation*. Spain's *backward linkages* are more relevant than its *forward linkages*, since it participates in GVCs mainly as an importer of intermediate goods which are subsequently used in the production of its exports. The import content of exports (i.e., the foreign content) increased by 9 percentage points during the period analysed: in 1995, one unit of exports contained 20.6% of imported inputs, whereas in 2011, the foreign content was around 30%. On the other hand, its *forward participation*, which measures the share of Spanish intermediate inputs embodied in the exports of other countries, shows a more moderate development and is around 20% in the last years of the period analysed.

The analysis by sectors reveals substantial heterogeneity between manufacturing and services in their participation in GVCs. Manufacturing is very intensive in the use of imported inputs to produce exports, while services exhibit a greater *forward participation*. These factors lead to a very different capacity to generate value added, which is higher in the services sector. The industries within these two major sectors also exhibit significant differences in their participation in vertical trade and the subsequent ability to generate value added. The most intensive industry in the use of imported inputs is coke and refined petroleum products, with a 76% foreign value added content, followed by transport equipment, electrical and optical equipment and metallic products, with more than 30%. Transport equipment stands out as an important sector for the Spanish economy and its foreign sector, whose production and exports contain almost 40% of foreign value added. These shares reflect a high integration in global value chains.

The analysis from a trade in value added perspective provides evidence that gross trade statistics underestimate the importance of services. The share of the manufacturing sector, which accounts for 70% of gross exports, falls to 40% in value-added terms. On the contrary, services, whose share is around 20% in gross exports, accounts for 50% of total exports when value added flows are considered. This reallocation in trade shares is due to the fact that manufacturing exports incorporate inputs from the services sector, and thus, have a high content of services' value added. Actually, more than a third of the total value added generated in 2011 to meet manufacturing final demand comes from the services sector.

This result also contributes to shed light into the debate about increasing the share of the manufacturing sector in advanced economies, since the analysis reveals that services' contribution to value added is very relevant and this sector plays a crucial role in GVCs as inputs in the production and exports of manufacturing goods. Global production networks rely on transport, logistics, finance, communication, business and other services. Thus, a well-functioning services sector is a key issue to improve the competitiveness of Spanish exports.

The **third chapter** has explored Spain's involvement in GVCs. As a result of the country's participation in global production networks, the import content of exports in many sectors has increased. An immediate consequence of a higher import content of production and exports is that the effect of an increase in final demand on the domestic economy is lower, since part of the export revenues go abroad as payments for the imported inputs. This may compromise the role of the foreign sector as a driver of growth. However, involvement in global value chains and access to inputs that are produced more efficiently abroad can contribute positively to external competitiveness. Importing intermediates can help to increase domestic value added, since it allows a country to specialize in the part of the value chain where production is more efficient. Exploring the real impact of participating in GVCs is a question that deserves further research in the future.

International relocation of production: dynamics and economic impact

The **fourth and fifth chapters** explore different aspects related to the process of international relocation of production across country income groups. The **fourth chapter** focuses on the dynamics of international relocation of production and provides an assessment of the sign and intensity of this process over the years 1996-2006 and 1963-1999, at an aggregate level and at the product and sector level. The analysis also attempts to characterize the dynamic empirical properties of international relocation processes based on the analysis of intra-distribution dynamics and the long-run distribution that arises as a result of production relocation across countries with different income levels.

The results of this analysis reveal that production has moved, on average, towards lower income countries during the periods analysed. The mean of the relocation and pure relocation indices is around -1%, which indicates that the average exporter's income has decreased by 1% per year. On the other hand, the intensity of international relocation of production has remained surprisingly constant over the 1996-2006 period, as well as during the period 1963-1999, as measured by the index of dispersion. However, despite the apparent stability in the intensity of production relocation over the two sample periods, there is considerable relocation at the product level. A more formal analysis using a model of distribution dynamics confirms substantial mobility in the products' *PRODYs*. The transition matrices reflect the existence of *upward* and *downward* relocations, as captured by products' transitions to different states. The mobility observed in the transition matrices is confirmed with the results that arise from the analysis of the dynamics at the sector level, which reveals substantial heterogeneity and important relocation processes.

Regarding the evolution of the overall distribution, the ergodic or long-run distribution is very similar to the initial and final distributions within and across both sample periods. That is, despite the mobility observed, with products undergoing *upward* and *downward* relocations, the initial and ergodic distributions are almost identical over a 40-year period and a 10-year period. This provides evidence that production relocation appears as a stochastic stationary process which is time-invariant. This result confirms the conclusions obtained with the analysis based on the index of dispersion, which provided evidence on the constant intensity of production relocation.

The chapter has not developed a formal model to explain the kind of shocks that might lead to this stationary distribution, but provides an informal interpretation of this result. It is suggested that technological product shocks (innovation and standardization) lead to a continuous process of international relocation by affecting factor intensities that change countries' comparative advantage. As a result of these shocks, products experience *upward* and *downward* relocations and international trade tends to a moving equilibrium driven by the interplay between innovation and standardization. Countries may react to the loss of some industries by reorienting their specialization towards products more in line with their comparative advantage. As a result, despite the continuous relocation processes, world trade tends to a stationary distribution, with products roughly equally distributed across income groups.

Regarding the study of the potential drivers of future relocation, several variables are considered. First, we have examined the role of initial product sophistication. Results show that during both sample periods, product relocation is only very weakly (negatively) correlated with the product's initial sophistication index at the product level. At the sector level, some industries with high initial sophistication exhibit a relocation trend towards higher-income countries, such as pharmaceuticals and chemicals, whereas other industries appear to have relocated towards lower-income countries (e.g., machinery and motor vehicles). Conversely, there are industries with low initial sophistication that appear to be moving upwards along the exporters' income ladder (e.g., miscellanea), as well as industries moving downwards (e.g., textiles).

Thus, the fact that a product is currently an export of low- (high-) income countries is of no real help in predicting the sign of future relocation. This result is confirmed with the industry regressions that consider other variables, such as capital and skill intensity, R&D or TFP growth, although these results have to be interpreted with caution due to data aggregation. R&D intensity is the only variable that seems to play a role in predicting subsequent relocation: it is statistically significant and positively correlated with future relocation. This suggests that industries that invest more in R&D are more likely to relocate towards higher-income countries.

After the analysis of the broad trends observed in production relocation in the last decades at the product level, the **fifth chapter** explores how this phenomenon has affected countries' economic performance. This process has been a central feature of economic globalization in the last decades and potentially, an important determinant of the dynamics of output and employment across countries. While there are numerous studies documenting the impact of import competition on countries' economic performance, they are focused on specific countries. Hence, the impact of this phenomenon across countries has not been systematically analysed. This chapter contributes to the literature by providing an assessment of the impact of relocation on cross-country growth using a large sample of countries.

The work in this chapter provides a straightforward way to measure production relocation and its impact: based on highly disaggregated trade data, the indicators measure the extent to which products have relocated across countries with different income levels. Then, to measure the impact of this phenomenon across countries, country impact indices are defined. These indices capture to extent to which the export basket of a country is made up of products whose production has relocated towards higher or lower income countries. These indices are regressed on annual average GDP per capita growth, controlling for the standard covariates in growth regressions. Dummies by continent are also included to control for spatially correlated shocks.

The econometric analysis is conducted with cross-sectional data over the period 1996-2006 and also with panel data over two subperiods (1996-2001 and 2001-2006). The different specifications have been estimated by OLS and 2SLS. In the latter, the country-specific indices have been used as instruments, as explained in the chapter. The results obtained reveal that countries that were specialized in 1996 in product categories that, on average, relocated towards low-income (high-income) economies over the following years, exhibited significantly lower (greater) growth over the 1996-2006 period. This impact is statistically significant, robust, and economically important: a difference of one standard deviation in the country's pure relocation impact index resulted in a difference of about 1 percentage point in the country's average annual growth.

Thus, a country's export specialization matters, at least, because products experience frequent shocks leading to the international relocation of production that have a notable impact on the countries' economic performance. Technological shocks, such as innovation and standardization, can change the productive sophistication of a good. These shocks change products' factor intensities, thereby leading to a process of international relocation of production. The impact on each country depends on the country's initial specialization. As long as the production of each good involves product-specific knowledge and skills, products experiencing innovation or increasing technical sophistication are more likely to relocate towards higher-income countries. Thus, countries initially specialized in the goods that experience an *upward relocation* (i.e., towards higher-income countries) will tend to increase their income. On the contrary, countries initially specialized in the goods experiencing standardization and relocation towards lower-income countries will experience a decrease in their income.

The analysis in the fourth chapter about the potential drivers of production relocation has revealed that this phenomenon appears mostly as an unpredictable phenomenon. Thus, the room for implementing industrial policies aimed at preventing the dangers of future relocations is limited, as well as for policies aimed at promoting specific industries that have better chances of moving up along the exporters' income ladder. However, the long run impact of the relocation processes is not only a matter of good or bad luck. Policies promoting human capital, R&D investment, and a pro-business institutional environment increase the attractiveness of countries as locations of innovative industries. This kind of horizontal policies is likely to help countries to adjust to the loss of industries relocating towards lower-wage countries and attract new activities.

Concluding remarks

The changes that have been described in the different chapters of this doctoral thesis have led to a new international competitive environment. Countries need to adapt to these changing conditions and, in this context, the analyses in the different chapters emphasize the role of a country's specialization: in a world with continuous international relocation of production and GVCs, countries' specialization trade patterns become more relevant. From a trade in value added perspective, as in the analysis conducted in the third chapter, specialization matters because it determines the ability to generate value added, since some activities contribute more than others to this purpose. On the other hand, the fifth chapter also stresses the importance of countries' specialization: since products experience shocks that lead to relocation and have an impact on countries' economic performance, the type of products that a country exports is also relevant. Production fragmentation and the emergence of global value chains have accentuated this phenomenon: the slicing of production processes and their relocation across borders amplifies the possibility of specializing in different segments of the value chain.

Results in the fifth chapter reveal that international production relocation has had, on aggregate, a relative negative effect on the economic growth of those countries specialized in goods whose production has migrated towards lower income countries. This could be an argument for the advocates of protectionist trade policies, which are increasing as a reaction to globalization. Certainly, some workers in advanced countries are worse-off due to import competition from lower wage countries, as it is shown, for instance, in the work by Pierce and Schott (2016). However, as it is shown in the analysis conducted in the third chapter, countries are increasingly interconnected around global production networks and depend on imports to produce their exports. In this context, imposing tariffs and other trade barriers to protect a country’s employment and wealth will be detrimental to both firms and households and is not a long-run solution to countries’ competitiveness problems. These types of measures are more likely to be counterproductive and end up harming economic growth. The response to production relocation and its potential negative impact is not turning to protectionism, but involves the reorientation of countries’ specialization towards products more in line with their comparative advantage and activities that allow to obtain more added value.

RESUMEN

Este último capítulo presenta un resumen en castellano de los tres capítulos centrales incluidos en esta tesis doctoral para cumplir con la normativa de la Universitat de València, ya que ninguno de los capítulos está escrito en una lengua oficial de la Universitat[54]. Se resumen a continuación los principales objetivos, la metodología utilizada y los resultados y conclusiones obtenidas.

En las últimas décadas se han producido una serie de cambios que han alterado la naturaleza de la producción y el comercio internacional. Por un lado, los países emergentes y en desarrollo han aumentado notablemente su participación en la renta y el comercio mundial. A principios de los años 90, el peso de los países desarrollados en la producción y el comercio internacional representaba el 60% y el 80%, respectivamente, mientras que el peso de los países de renta baja y media baja estaba en torno al 20% de la producción mundial y el 10% de las exportaciones. En 2015, la importancia económica de estos países ha aumentado hasta alcanzar el 41% de la producción y el 25% de las exportaciones. Esta relocalización internacional de la producción ha sido un aspecto clave en el incremento de la globalización económica en las últimas décadas.

Por otro lado, la reducción de los costes de transporte, la revolución de las tecnologías de la información y las comunicaciones (TIC) y la mayor liberalización de los intercambios comerciales han transformado la estructura de la producción y el comercio, propiciando la fragmentación internacional de los procesos productivos. Estos cambios tienen su reflejo en un incremento de las exportaciones de bienes intermedios, que ya representan dos tercios del comercio total. El mundo está cada vez más interconectado y los bienes y servicios que intervienen en los procesos productivos ya no se obtienen en un único país. Las empresas reparten sus actividades entre diferentes países, creando auténticas cadenas de producción mundiales. En estas cadenas globales de valor (CGV) las distintas etapas del proceso productivo se localizan en distintos países, en función de su ventaja comparativa.

En este contexto, el principal objetivo de esta tesis doctoral es analizar las implicaciones que estas transformaciones de la producción y el comercio han tenido sobre los patrones de especialización de los países, así como su impacto en el desempeño económico de

[54] Artículo 7.2 del Reglamento sobre depósito, evaluación y defensa de la tesis doctoral, aprobado por el Consejo de Gobierno del 28 de junio de 2016.

estos. El análisis que se aborda en los distintos capítulos gira en torno a las siguientes preguntas: ¿cómo ha cambiado la relocalización internacional de la producción y la aparición de las cadenas globales de valor el modo en que los países participan en el comercio internacional? ¿Cuáles son las implicaciones de estos cambios para los patrones de especialización comercial de los países y cómo ha afectado a su desempeño económico? ¿Qué tendencias se observan en la participación de los países en las CGV? ¿Qué dinámica siguen los procesos de relocalización?

Estas preguntas centran el análisis que se realiza en los tres capítulos principales de la tesis, si bien el estudio de distintos aspectos relacionados con los dos fenómenos mencionados (la fragmentación de la producción y la formación de CGV por un lado, y la relocalización internacional de la producción, por otro) se aborda de manera separada. En el **tercer capítulo** se analiza la participación de la economía española en las cadenas globales de valor desde una perspectiva comparada, utilizando el nuevo marco estadístico de la medición del comercio en valor añadido. Esta aproximación estadística permite estimar el contenido en valor añadido del comercio, así como atribuir el valor de la producción de bienes y servicios al país e industrias de origen. El **cuarto capítulo** analiza la dinámica de la relocalización internacional de la producción entre países de distintos grupos de renta desde una perspectiva agregada, así como a nivel de productos y sectores. El análisis se basa en datos de comercio estándar con un elevado nivel de desagregación. Por último, el **quinto capítulo** examina el impacto que los procesos de relocalización estudiados en el capítulo anterior han tenido sobre el crecimiento económico de los países.

Fragmentación internacional de la producción y cadenas de valor globales

El análisis del **tercer capítulo** se realiza desde la perspectiva del comercio en valor añadido, que requiere el uso de tablas input-output internacionales, mientras que el cuarto y quinto se basan en datos de comercio internacional convencionales. El motivo por el que el análisis de estos fenómenos no puede realizarse conjuntamente se debe a que las estadísticas disponibles para abordar estos temas, así como las técnicas de análisis necesarias, son distintas. La fragmentación internacional de la producción y la aparición de las CGV requieren nuevas estadísticas, complementarias a las tradicionales, capaces de medir la complejidad de las cadenas globales de producción. En la medida en que la producción se lleva a cabo en distintos países, los bienes y servicios cruzan las fronteras varias veces en diferentes etapas del proceso productivo. En cada etapa, el productor utiliza bienes intermedios, a los que puede añadir valor antes de volver a exportarlos. Este valor añadido, que equivale a la remuneración de los factores productivos empleados en el país exportador, forma parte del coste de los bienes intermedios utilizados en la siguiente fase, haciendo que las estadísticas de comercio convencionales incurran en una contabilización múltiple. El mismo capital, trabajo e inputs intermedios son contabilizados cada vez que cruzan una frontera incorporados en los bienes exportados. Estas cifras brutas pueden sobrevalorar la dimensión del comercio y distorsionar su importancia económica y su impacto sobre la renta y el empleo. Por otro lado, el sesgo estadístico que se produce al atribuir al último país de la cadena de producción el valor total del bien producido puede conducir a conclusiones erróneas acerca de la competitividad de los países y las fuentes de los desequilibrios comerciales y, por tanto, llevar a diagnósticos erróneos y a aplicar medidas contraproducentes (OECD-WTO (2012)).

El panorama de cambios descrito plantea importantes desafíos a los instrumentos empleados tradicionalmente para medir la competitividad de las economías. Las exportaciones brutas o la cuota de participación en los mercados mundiales no reflejan necesariamente la capacidad de los países de generar rentas y empleo. La fragmentación de los procesos productivos a escala internacional y la consiguiente dependencia de los insumos importados para la producción de exportaciones hacen que cada vez pueda ser mayor la desconexión entre estas y la generación de renta y empleo asociada al comercio exterior, ya que parte de los ingresos obtenidos por las ventas se filtran al exterior. Cuanto mayor sea el contenido de las exportaciones en *inputs* importados, menor es el valor añadido generado en la economía doméstica y por tanto, una parte mayor de los ingresos por exportaciones se destina a remunerar factores productivos empleados en el extranjero. De ahí la importancia de disponer de indicadores que capten el valor añadido contenido en las exportaciones, ya que esta variable guarda una relación directa con las ganancias asociadas al comercio (en términos de renta y empleo) y permite valorar en qué medida participa un país en las ventas generadas en las cadenas de producción mundiales.

La medición directa del valor añadido del comercio es una tarea muy complicada, ya que para ello sería necesario disponer de registros detallados a nivel de empresa acerca del origen –y el uso- de los bienes importados. Salvo para algunos casos de estudio concretos, en los que se ha podido rastrear el origen y el uso de los inputs utilizados en el proceso (como el caso del Ipod (Dedrick et al., 2010)), no existe esta información directa. Ante la ausencia de estos registros, la medición del valor añadido se estima a partir de Tablas Input-Output (TIO) internacionales. A nivel nacional, estas tablas se elaboran por los institutos nacionales de estadística dentro de la Contabilidad Nacional. Se trata de un conjunto de matrices que sirven para representar el funcionamiento de un sistema económico y permiten analizar las relaciones entre los distintos sectores de una economía. Para construir una base de datos que recoja también las interrelaciones entre distintas economías, es necesario enlazar las tablas nacionales con datos de comercio bilateral, lo cual requiere esfuerzos muy importantes de compilación y homogeneización de la información.

En los últimos años se han hecho avances significativos en esta dirección, gracias a dos iniciativas de gran calado: la creación de la World Input-Output Database (WIOD), un consorcio fundado por la Unión Europea bajo el VII Programa Marco, compuesto por distintos institutos de investigación europeos, y la alianza entre la Organización para la Cooperación y el Desarrollo Económico (OCDE) y la Organización Mundial del Comercio (OMC). El resultado de estas colaboraciones ha sido la creación de ambiciosas bases de datos, basadas en fuentes estadísticas oficiales, que permiten el análisis del valor añadido del comercio y el cálculo de nuevos indicadores, propuestos en la literatura especializada desarrollada también en los años recientes. La base de datos WIOD, publicada por primera vez en 2012, ofrece una serie de tablas input-output internacionales desde 1995 hasta 2011 (la actualización de 2016 cubre el periodo 2000-2014), mientras que la base de datos elaborada por la OMC-OCDE, Trade in Value Added (TiVA database), ofrece una serie de indicadores relacionados con el comercio en valor añadido para el periodo 1995-2011 (actualización de diciembre 2016) [55], basados en las tablas input-output de la OCDE. Hay que advertir que, dada la dificultad de elaborar este tipo de estadísticas, las bases de datos acumulan un retraso de varios años, pero en cualquier caso han cambiado sustancialmente el panorama de la información estadística disponible para analizar las tendencias estructurales más relevantes de la economía internacional.

[55] Antes de esta actualización, la base de datos TiVA de la OECD-OMC cubría únicamente los años 1995, 2000, 2005 y 2008-2011 (actualización de octubre 2015).

El objetivo del **tercer capítulo** es analizar el patrón de especialización productiva y comercial de la economía española desde la perspectiva de la literatura sobre comercio en valor añadido y especialización vertical, haciendo uso de las tablas input-output internacionales. Este análisis se aborda desde una perspectiva comparada, poniendo a la economía española en relación con los principales exportadores mundiales, entre los que se encuentran los países de su entorno geográfico y económico más cercano –las grandes economías europeas-, así como otros países de referencia (Estados Unidos, China, Japón…). Con este análisis se pretende responder a las siguientes cuestiones: ¿cuál es el grado de integración de la economía española y sus sectores en las CGV? ¿Cuál es el contenido en valor añadido de las exportaciones españolas y su evolución? ¿Favorece su especialización la generación de valor añadido? ¿Es relevante la especialización industrial para la generación de valor añadido a través de la exportación?

Para ello, se analizarán los distintos componentes de las exportaciones brutas siguiendo la metodología propuesta por Koopman, Wang y Wei (2014), en adelante KWW. Estos autores desarrollan un marco conceptual y matemático formal que integra la literatura de especialización vertical y comercio en valor añadido y permite descomponer las exportaciones brutas, distinguiendo los componentes de valor añadido en función de su origen (doméstico y extranjero), así como los términos que han sido contabilizados varias veces en las estadísticas oficiales. La contribución más novedosa de este trabajo consiste en la aplicación de estos nuevos instrumentos a la economía española, que se analizará desde una perspectiva comparada. El estudio del comercio internacional con esta nueva óptica permite valorar mejor las interdependencias entre economías y precisar el papel del sector exterior español como motor de la economía.

La base de datos utilizada en este trabajo es la World Input-Output (WIOD) database. Esta fuente estadística ofrece una serie anual armonizada de tablas input-output globales para el período 1995-2011. La información está disponible para 41 países (40 más un agregado estimado que representa al resto de países no incluidos en la base de datos) con un nivel de desagregación de 35 sectores. A diferencia del trabajo de KWW, que utilizan la base de datos Global Trade Analysis Project (GTAP) y centran su análisis en el año 2004, este trabajo cubre el período de expansión y crisis que va desde 1995 a 2011. Al interés de trabajar con una serie temporal que permite contemplar la evolución de los distintos componentes de las exportaciones brutas en términos de valor añadido se suma que, al disponerse de algunos años posteriores a 2009, se podrá valorar cómo se ha recuperado el comercio después del año en el que se produjo el último colapso del comercio mundial.

La medición del contenido en valor añadido del comercio se basa en el análisis de las interdependencias sectoriales introducido por Leontief (1936). La ecuación fundamental del marco input-output, $x = (I - A)^{-1}y$, muestra los requerimientos totales de bienes intermedios necesarios para producir una unidad de demanda final. Con *N* países y *S* sectores, esta expresión se puede expandir para configurar un modelo input-output interregional:

$$\begin{bmatrix} X_{11} & X_{12} & \dots & X_{1N} \\ X_{21} & X_{22} & \dots & X_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ X_{N1} & X_{N2} & \cdots & X_{NN} \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} & \dots & B_{1N} \\ B_{21} & B_{22} & \dots & B_{2N} \\ \dots & \dots & \ddots & \dots \\ B_{N1} & B_{N2} & \dots & B_{NN} \end{bmatrix} \begin{bmatrix} Y_{11} & Y_{12} & \dots & Y_{1N} \\ Y_{21} & Y_{22} & \dots & Y_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ Y_{N1} & Y_{N2} & \cdots & Y_{NN} \end{bmatrix} \quad (1)$$

La matriz **X** en el lado izquierdo de la ecuación muestra la descomposición de la producción bruta de cada país en función del país de destino. La matriz B es la inversa de Leontief y la matriz Y es la matriz de demanda final.

El valor añadido doméstico generado en la producción bruta de un país se puede obtener multiplicando la matriz **X** de la expresión anterior por una matriz $\hat{V}$ que contiene los coeficientes de valor añadido directo por unidad de producción:

$$\begin{bmatrix} \hat{V}_1 & 0 & \dots & 0 \\ 0 & \hat{V}_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \hat{V}_N \end{bmatrix} \begin{bmatrix} X_{11} & X_{12} & \dots & X_{1N} \\ X_{21} & X_{22} & \dots & X_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ X_{N1} & X_{N2} & \cdots & X_{NN} \end{bmatrix}$$

$$= \begin{bmatrix} \hat{V}_1 \sum_j^N B_{1j} Y_{j1} & \hat{V}_1 \sum_j^N B_{1j} Y_{j2} & \dots & \hat{V}_1 \sum_j^N B_{1j} Y_{jN} \\ \hat{V}_2 \sum_j^N B_{2j} Y_{j1} & \hat{V}_2 \sum_j^N B_{2j} Y_{j2} & \dots & \hat{V}_2 \sum_j^N B_{2j} Y_{jN} \\ \dots & \dots & \ddots & \dots \\ \hat{V}_N \sum_j^N B_{Nj} Y_{j1} & \hat{V}_N \sum_j^N B_{Nj} Y_{j2} & \dots & \hat{V}_N \sum_j^N B_{Nj} Y_{jN} \end{bmatrix} \quad (2)$$

El resultado es la matriz de valor añadido en la producción $\mathbf{\hat{V}BY}$, de dimensiones *SN* x *N*. Los elementos en la diagonal principal representan el valor añadido generado que absorbe la demanda doméstica; los elementos situados fuera de la diagonal se corresponden con el valor añadido absorbido por la demanda en el extranjero, i.e., las exportaciones de valor añadido.

Así pues, las exportaciones de valor añadido (VA) del país i pueden expresarse como la suma de 3 componentes, siguiendo a Johnson y Noguera (2012a):

$$VA\ Exports_i = \sum_{j\neq i}^{N} VX_{ij} = V_i \sum_{j\neq i}^{N} B_{ii}\, Y_{ij} + V_i \sum_{j\neq i}^{N} B_{ij}\, Y_{jj} + V_i \sum_{j\neq i}^{N} \sum_{t\neq i,j}^{N} B_{ij} Y_{jt} \tag{3}$$

El primer término refleja el valor añadido en las exportaciones de bienes finales; el segundo el valor añadido en las exportaciones de bienes intermedios que serán utilizadas para la producción de bienes destinados a consumo final en el país importador, y el tercero corresponde a las exportaciones de bienes intermedios que se utilizan en el país importador para producir bienes finales que serán exportados. Este último término refleja las exportaciones *indirectas* de valor añadido.

La ratio entre las exportaciones de VA y las exportaciones brutas constituye una medida del contenido en VA de estas últimas. Siguiendo la terminología acuñada por Johnson y Noguera (2012a), esta ratio se denomina *VAX* ratio. A su vez, las exportaciones brutas totales de un país pueden definirse como:

$$E_{i^*} = \sum_{j\neq i}^{N} E_{ij} = \sum_{j\neq i}^{N} (A_{ij} X_j + Y_j). \tag{4}$$

Estas pueden descomponerse en varios componentes siguiendo el trabajo de KWW (2014):

$$\begin{aligned} uE_{i^*} = &\{V_i \sum_{j\neq i}^{N} B_{ii}\, Y_{ij} + V_i \sum_{j\neq i}^{N} B_{ij}\, Y_{jj} + V_i \sum_{j\neq i}^{N} \sum_{t\neq i,j}^{N} B_{ij} Y_{jt}\} \\ &+ \{V_i \sum_{j\neq i}^{N} B_{ij}\, Y_{ji} + V_i \sum_{j\neq i}^{N} B_{ij} A_{ji} (I - A_{ii})^{-1}\, Y_{ii}\} + V_i \sum_{j\neq i}^{N} B_{ij} A_{ji} (I - A_{ii})^{-1}\, E_{i^*} \\ &+ \{\sum_{t\neq i}^{N} \sum_{j\neq i}^{N} V_t B_{ti} Y_{ij} + \sum_{t\neq i}^{N} \sum_{j\neq i}^{N} V_t B_{ti} A_{ij} \big(I - A_{jj}\big)^{-1} Y_{jj}\} + \sum_{j\neq i}^{N} V_t B_{ti} \big(I - A_{jj}\big)^{-1} E_{j^*} \end{aligned} \tag{5}$$

Pueden distinguirse dos grandes bloques dentro de las exportaciones brutas: el contenido doméstico (los 6 primeros términos) y el contenido extranjero (los 3 últimos términos). Esta descomposición constituye un marco conceptual formal que integra la literatura de especialización vertical y comercio en valor añadido y permite identificar y calcular los distintos indicadores propuestos en la literatura: las exportaciones de valor añadido (dentro del contenido doméstico, las exportaciones de VA son los 3 primeros términos), la especialización vertical (*VS*), la especialización vertical desde el punto de vista del exportador (*VS1*) y el contenido doméstico retornado (*VS1**).

El concepto de especialización vertical *VS*, definido como el contenido en importaciones de las exportaciones, constituye una medida del contenido extranjero de éstas. Este índice refleja los vínculos *hacia atrás* de un país en la cadena de suministros, y puede expresarse como la suma de los últimos tres componentes de (5):

$$\begin{aligned} VS_i &= \sum_{t\neq i}^{N}\sum_{j\neq i}^{N} V_t B_{ti} Y_{ij} + \sum_{t\neq i}^{N}\sum_{j\neq i}^{N} V_t B_{ti} A_{ij}\left(I - A_{jj}\right)^{-1} Y_{jj} + \sum_{i\neq j}^{N} V_t B_{ti}\left(I - A_{jj}\right)^{-1} E_{j^*} \\ &= \sum_{i\neq j}^{N} V_j B_{ji} E_{i^*} \end{aligned} \tag{6}$$

La especialización vertical desde el punto de vista del exportador puede medirse a través del índice *VS1*. Este índice mide las exportaciones de bienes intermedios que son utilizados por otros países para producir sus exportaciones, y representa los vínculos *hacia delante* en la cadena de suministros:

$$\begin{aligned} VS1_i &= V_i \sum_{j\neq i}^{N} B_{ij} E_{j^*} = V_i \sum_{j\neq i}^{N}\sum_{t\neq i,j}^{N} B_{ij} Y_{jt} + V_i \sum_{j\neq i}^{N}\sum_{t\neq i,j}^{N} B_{ij} A_{jt} X_t + V_i \sum_{j\neq i}^{N} B_{ij} Y_{ji} \\ &+ V_i \sum_{j\neq i}^{N} B_{ij} A_{ji} X_i \end{aligned} \tag{7}$$

Un tercer concepto de especialización vertical lo constituye el índice *VS1**, que refleja el contenido doméstico retornado. Definido originalmente en el trabajo de Daudin et al. (2011), este índice es un subconjunto de *VS1* y representa la parte del valor añadido exportado que vuelve a la economía doméstica incorporado en las importaciones:[56]

[56] La expresión en (8) generaliza la definición propuesta por Daudin et al. (2011), ya que incluye no solo el contenido doméstico incorporado en las importaciones de bienes finales, sino también el que contienen las importaciones de bienes intermedios.

$$VS1^*{}_i = \sum_{j \neq i}^{N} V_i B_{ij} E_{ji} = V_i \sum_{j \neq i}^{N} B_{ij} Y_{ji} + V_i \sum_{j \neq i}^{N} B_{ij} A_{ji} X_i \qquad (8)$$

Otro de los indicadores utilizados en la literatura sobre comercio en valor añadido y que se aplica en el tercer capítulo es el índice *global value chain income* (*GVCI*), de Timmer et al. (2013). Expresado en notación compacta, $GVCI = \hat{v}\,(I - A)^{-1}y$, el indicador *GVCI* representa el valor añadido generado necesario para satisfacer un determinado nivel de demanda final. Se trata de un vector que recoge los flujos de valor añadido generados por todos los sectores-país implicados directa e indirectamente en el proceso productivo de un determinado producto final. Este indicador se corresponde con la matriz de VA en la producción bruta de la expresión (2). Se trata de un concepto más amplio que las exportaciones de VA, ya que también refleja el VA en la producción de los bienes que se consumen en el mercado doméstico.

Relocalización internacional de la producción

El **cuarto y quinto capítulo** de la tesis doctoral se centran en el estudio de la relocalización internacional de la producción. Este proceso, que se ha intensificado en los últimos años debido a la fragmentación internacional de los procesos productivos y la consiguiente aparición de las CGV, ha sido un elemento clave en la globalización económica de las últimas décadas, con importantes implicaciones para el desempeño económico de los países. La relevancia de este fenómeno ha dado lugar a una amplia literatura, centrada en los procesos experimentados en determinadas industrias, como el textil, la electrónica o el sector del automóvil (véase por ejemplo Gereffi (1999), Lall, Albaladejo and Zhang (2004), Sturgeon, Van Biesebroeck, Gereffi (2008), Timmer et al. (2015)), o en el impacto que la relocalización ha tenido en determinados países o regiones (Feenstra and Hanson (1996, 1999); Bernard, Jensen and Schott (2006); Autor, Dorn and Hanson (2013); Ebenstein et al. (2014); Acemoglu et al. (2016); Pierce and Schott (2016)).

A pesar de la abundante literatura centrada en este fenómeno, la relocalización internacional de la producción no se ha analizado de manera sistemática para todos los sectores, ni se ha estimado su impacto agregado sobre el crecimiento económico de los países. Por tanto, la contribución del cuarto y quinto capítulos a la literatura es doble. El **cuarto capítulo** analiza las tendencias en la relocalización internacional de la producción entre países de distintos grupos de renta a nivel agregado y también por productos y sectores. El **quinto capítulo** analiza el impacto de la relocalización sobre el crecimiento económico, con el objetivo de determinar cómo los procesos estudiados en el cuarto capítulo han afectado al desempeño económico de los países en el periodo reciente.

El análisis que se realiza en estos dos capítulos sugiere que la dinámica de la relocalización de la producción viene determinada por la interacción entre dos tipos de shocks de producto: la innovación y la estandarización. Esta es la idea central en la teoría de ciclo de vida del producto desarrollada por Vernon (1966), así como en los modelos de difusión de tecnología (Krugman (1979), Dollar (1986), Jensen and Thursby (1986), Grossman and Helpman (1991a, b), Acemoglu, Gancia and Zilibotti (2012)). Estos shocks, i.e., innovación y estandarización, afectan a la intensidad factorial de la producción y conducen a cambios en las ventajas comparativas reveladas (*VCR*): dado que la producción de cada bien requiere distintos grados de sofisticación o complejidad, un aumento en la sofisticación de un producto conllevará una relocalización de su producción a países que dispongan de las habilidades necesarias para producirlo (aquellos con mayor capital humano o una especialización previa en ese bien); esos países aumentarán su *VCR* en ese producto. En cambio, la estandarización desplazará la producción hacia países con menores dotaciones de capital humano y sin especialización previa en ese bien. De este modo, al afectar a las intensidades factoriales, la innovación y la estandarización cambian las *VCR* de los países, conduciendo así a la relocalización de la producción.

El cuarto y el quinto capítulo basan su análisis en datos de comercio convencionales. A pesar de que, como se ha señalado anteriormente, estos datos pueden resultar menos adecuados para analizar ciertos fenómenos (como aproximar el valor añadido del comercio), las bases de datos de comercio bilateral (UN Comtrade o BACI (CEPII)) permiten trabajar con una desagregación que distingue más de 5.000 productos. Aunque en los últimos años se ha hecho un gran avance en el terreno de las estadísticas que permiten estimar el contenido en valor añadido del comercio, con el desarrollo de importantes bases de datos IO internacionales, hasta el momento con estas tablas solo es posible distinguir un número limitado de sectores. En este caso, los datos estándar de comercio internacional resultan más adecuados debido al elevado nivel de desagregación disponible en estas estadísticas, que hace posible valorar el fenómeno de la relocalización de la actividad a nivel de producto. Además, como se muestra en el cuarto capítulo, los análisis son sensibles al nivel de desagregación utilizado.

Dinámica de la relocalización internacional de la producción

El análisis que se desarrolla en el **cuarto capítulo** permite responder a las siguientes preguntas: ¿cuál ha sido la dirección e intensidad de la relocalización en las últimas décadas? ¿Se ha intensificado este fenómeno en los últimos años? ¿Qué tipo de proceso estocástico siguen los procesos de relocalización? ¿En qué sectores ha sido más intenso? ¿Es posible anticipar qué industrias se relocalizarán en los próximos años? El análisis cubre dos periodos temporales, 1962-2000 y 1995-2007. Para el periodo 1962-2000 se utiliza la base de datos "the NBER-World Trade Flows database", de Feenstra et al. (2005). Esta fuente ofrece datos de comercio internacional a un nivel de desagregación de 4 dígitos siguiendo la Clasificación Uniforme de Comercio Internacional (CUCI Rev. 2). Para el periodo más reciente (1995-2007), la base de datos utilizada es BACI (CEPII), que ofrece datos con un nivel de desagregación de 6 dígitos del Sistema Armonizado (HS1992). Se estudia la dinámica de la relocalización en ambos periodos para determinar si este proceso se ha intensificado en la última década.

Para dar respuesta a las preguntas planteadas en este capítulo, se definen índices de relocalización de la producción a nivel de producto. En primer lugar, se calculan indicadores que reflejan el nivel de renta per cápita promedio de los exportadores de un determinado bien. Para el cálculo de la renta pc promedio, el PIB pc de los exportadores se pondera en función de la ventaja comparativa revelada (VCR) de cada país en la producción del bien k, siguiendo a Hausmann, Hwang y Rodrik (2007) (en adelante HHR). Concretamente, HHR calculan la sofisticación de un producto con un índice denominado *PRODY*. El *PRODY* del bien k en el periodo t se define como:

$$PRODY_k^t = \sum_{c=1}^{C} \frac{RCA_{ck}^t}{\sum_{c=1}^{C} RCA_{ck}^t} GDPpc_c^t, \tag{9}$$

donde RCA_{ck}^t es la ventaja comparativa revelada del país c en el bien k en el periodo t, y $GDPpc_c^t$ es la renta pc del país c en t.

A continuación, el índice de relocalización se define como la variación en la renta pc promedio de los exportadores de un producto. El objetivo de este índice es capturar el grado en que la producción se ha relocalizado entre países con distintos niveles de renta. Dado que la renta pc tiende a aumentar con el paso del tiempo, el *relocation index* entre 0 y T ($R_k^{0,T}$) se define como la diferencia entre el crecimiento del *PRODY* de un producto *k* y el crecimiento de la renta pc mundial:

$$\begin{aligned} R_k^{0,T} &= \frac{1}{T}\log\left(\frac{PRODY_k^T}{PRODY_k^0}\right) - g_w^{0,T} \\ &= \frac{1}{T}\log\left(\sum_{c=1}^{C}\frac{RCA_{ck}^t}{\sum_{c=1}^{C} RCA_{ck}^t} GDPpc_c^t \Bigg/ \sum_{c=1}^{C}\frac{RCA_{ck}^0}{\sum_{c=1}^{C} RCA_{ck}^0} GDPpc_c^0\right) - g^{0,T}. \end{aligned} \tag{10}$$

Una variación positiva (negativa) del $R_k^{0,T}$ indica que la renta del exportador promedio de *k* ha aumentado (disminuido) entre 0 y T. Hay que señalar que la variación del *PRODY* tiene dos componentes: los cambios en la *VCR* de los exportadores y los cambios en sus PIB pc. El primer término (la variación de las *VCR*) puede interpretarse como el término que mide la *relocalización pura*, puesto que únicamente depende de los cambios en la localización de la producción entre países con distintos niveles de renta pc, mientras que el segundo componente (la variación del PIB pc) no implica ningún cambio en la localización de la producción. Por tanto, para aislar el efecto de la variación de la renta pc, se define una variante del *PRODY* que fija el nivel de renta pc del año inicial. A este índice se le denomina *constant income-PRODY* (*ci-PRODY*):

$$ciPRODY_k^{0,T} = \sum_{c=1}^{C}\frac{RCA_{ck}^T}{\sum_{c=1}^{C} RCA_{ck}^T} GDPpc_c^0. \tag{11}$$

A partir de este índice se define el *pure* relocation index ($PR_k^{0,t}$):

$$\begin{aligned} PR_k^{0,T} &= \frac{1}{T}\log\left(\frac{ciPRODY_k^{0,T}}{PRODY_k^0}\right) \\ &= \frac{1}{T}\log\left(\sum_{c=1}^{C}\frac{RCA_{ck}^T}{\sum_{c=1}^{C} RCA_{ck}^T} GDPpc_c^0 \Bigg/ \sum_{c=1}^{C}\frac{RCA_{ck}^0}{\sum_{c=1}^{C} RCA_{ck}^0} GDPpc_c^0\right) \end{aligned} \tag{12}$$

Como se puede ver en (12), los cambios en la *VCR* son la única fuente posible de los cambios en este índice. Por tanto, su evolución se usa para determinar la dirección de la relocalización de la producción: una variación positiva del índice indica que los países de renta alta han aumentado su *VCR* en el producto *k* (*upward relocation*), mientras que una variación negativa indicaría que la producción se ha movido hacia países de renta baja (*downward relocation*).

La intensidad de la relocalización se mide a partir de un índice de dispersión. En este caso, se usa la desviación media absoluta (MAD, por su acrónimo en inglés) ponderada por el peso de cada producto en el comercio mundial (la fórmula es la misma para los índices $PR_k^{0,T}$):

$$MAD(R^{0,T}) = \sum_{k=1}^{K} \left| R_k^{0,T} - \left(\sum_{k=1}^{K} R_k^{0,T} * \frac{\omega_{Wk}^{0} + \omega_{Wk}^{T}}{2} \right) \right| \frac{\omega_{Wk}^{0} + \omega_{Wk}^{T}}{2}. \qquad (13)$$

Una mayor dispersión en los *relocation indices* refleja una relocalización más intensa entre grupos de renta.

La intensidad y el signo de la relocalización también se estudian utilizando un modelo basado en las cadenas de Markov. Esta aproximación empírica permite examinar los cambios en la distribución de los *PRODY* a lo largo del tiempo así como la persistencia o movilidad de la distribución. El análisis se basa en la estimación de las matrices de transición. Para estimar estas matrices, el conjunto de valores de los *PRODY* se divide en un número finito de categorías o celdas, tal que $k \in \{1, \dots, K\}$. Las transiciones de los productos entre las distintas celdas reflejan la probabilidad de que los productos experimenten relocalizaciones *hacia arriba* o *hacia abajo*.

Sea P^* la matriz de transición de probabilidad invariante, tal que $\lambda_{t+\tau} = P^* \lambda_t$, donde λ_t es un vector de probabilidades de dimensión *K*x1 que denota la probabilidad de que un producto esté en una celda determinada en *t*. Las entradas de la matriz, p_{ij}, reflejan la probabilidad de que un producto que empieza en la celda *i* se mueva a la celda *j*. cada fila de la matriz es un vector de probabilidades de transición que suma uno.

A partir de estas matrices, es posible inferir cuál es la distribución de largo a la que tienden los índices *PRODY* de los productos, si los patrones de relocalización que muestran las matrices de transición evolucionaran de ese modo indefinidamente. La distribución ergódica o de largo plazo se obtiene tomando el límite $\tau \rightarrow \infty$ en la expresión $\lambda_{t+\tau} = (P^*)^{\tau} \lambda_t$. Este tipo de análisis nos permite identificar el tipo de proceso estocástico que sigue la relocalización.

Finalmente, en el cuarto capítulo también se exploran los determinantes potenciales de la relocalización, con el objetivo de determinar si es posible anticipar, en base a algunas características del sector, qué industrias van a relocalizarse en el futuro. Se consideran distintas variables, como la sofisticación inicial del producto, la intensidad en trabajo cualificado y en capital, el crecimiento de la productividad total de los factores (PTF) y la intensidad en I+D. Estas medidas se incluyen como variables independientes en la regresión de los índices de relocalización (*R* and *PR*), para valorar si son factores relevantes a la hora de explicar la relocalización:

$$R_k^{0,T} = \beta_0 + \beta_1 \log\left(\frac{s}{l}\right) + \beta_2 \log\left(\frac{k}{l}\right) + \beta_3 \log\left(0.001 + \frac{R\&D}{Sales}\right) + \beta_4 TFP + \beta_5 logPRODY_k + u_k, \qquad (14)$$

donde (s/l) es la intensidad en trabajo cualificado, (k/l) es la intensidad en capital, $\log\left(0.001 + \frac{R\&D}{Sales}\right)$ representa el gasto en I+D, PTF es el crecimiento de la PTF y el *PRODY* captura el nivel de sofisticación inicial. Esta misma regresión se hace con el índice *PR* como variable dependiente.

Impacto económico de la relocalización internacional de la producción

Por último, el **quinto capítulo** se centra en el impacto agregado que los procesos de relocalización estudiados en el capítulo anterior han tenido sobre el crecimiento económico de los países. El análisis del quinto capítulo se centra en el periodo 1995-2007, usando datos de comercio a 6 dígitos de la base de datos BACI (CEPII). El análisis finaliza en el año 2007 para evitar el impacto de la Gran Recesión. El objetivo de este trabajo es determinar el impacto agregado que la relocalización internacional de la producción ha tenido en el crecimiento económico de los países, en función de su especialización inicial. Para responder a esta cuestión, se definen unos índices de impacto de la relocalización para cada país, basados en los índices de producto calculados en el capítulo anterior. Estos índices de impacto capturan en qué medida la cesta de exportaciones de un país está formada por productos cuya producción se ha desplazado, en promedio, hacia país relativamente ricos o pobres durante el periodo analizado. Del mismo modo que en el cuarto capítulo, se definen dos tipos de índices de relocalización: un índice, basado en la variación de los *PRODY*, que captura los shocks de producto, denominado *product-shocks impact index (PSI)* y un índice que captura la relocalización pura, el *pure relocation impact index* (*PRI)*, basado en los *ci-PRODYs*.

Matemáticamente, el *PSI* se construye como:

$$PSI_c^{0,T} = \log \frac{\sum_k PRODY_k^T \, \omega_{ck}^0}{\sum_k PRODY_k^0 \, \omega_{ck}^0}, \tag{15}$$

donde ω_{ck}^0 son las cuotas que representa cada producto *k* en las exportaciones totales del país *c*. Obsérvese que las cuotas ω_{ck}^0 se mantienen constantes. Por tanto, las variaciones del índice *PSI* entre 0 y T únicamente dependen de las variaciones de los *PRODYs*. Un valor alto (bajo) del *product-shocks impact index* (*PSI)* indica que la cesta de exportaciones del país *c* está compuesta por bienes cuya producción se ha desplazado, en promedio, hacia países de renta alta (baja).

El *PSI* captura los cambios que se producen bien por variaciones en las *VCR* de los países exportadores, o bien por cambios en los PIB pc que no conllevan ninguna relocalización. Para calcular el impacto de la relocalización pura, se define el índice *PRI*:

$$\begin{aligned} PRI_c^{0,T} &= \log \frac{\sum_k ciPRODY_k^{0,T} \, \omega_{ck}^0}{\sum_k PRODY_k^0 \, \omega_{ck}^0} \\ &= \log\left(\sum_{c=1}^{C} \frac{RCA_{ck}^T}{\sum_{c=1}^{C} RCA_{ck}^T} GDPpc_c^0 \Bigg/ \sum_{c=1}^{C} \frac{RCA_{ck}^0}{\sum_{c=1}^{C} RCA_{ck}^0} GDPpc_c^0 \right) \end{aligned} \tag{16}$$

Dado que la renta pc se mantiene constante, este índice capta únicamente los cambios en los índices derivados de cambios en la *VCR* entre países pertenecientes a distintos grupos de renta. Estos cambios en las *VCR* se ponderan en función del peso que representa cada producto en las exportaciones del país.

Este capítulo también implementa una estrategia de variables instrumentales para controlar el hecho de que, si un país es lo suficientemente grande en el contexto del comercio internacional, los shocks específicos de este país que afecten a su PIB pc pueden transmitirse al valor de los índices *PRODY*. Si esto es así, las variaciones en el *PRODY* y en los índices *PSI* o *PRI* podrían estar recogiendo shocks específicos de país, no de producto. Para evitar este problema, se calculan unos índices *PRODY* específicos que excluyen toda la información relativa a un país del cálculo de los índices (i.e., se excluyen los datos de comercio y renta pc). Estos índices, denominados "country *c*'s specific *PRODY"* (a los que se añade el prefijo '*csp'*) se calculan de la siguiente manera:

$$cs\_PRODY_{k,-c}^{t} = \sum_{i \neq c}^{C} \frac{RCA_{i-c,k}^{t}}{\sum_{c=1}^{C} RCA_{i-c,k}^{t}} GDPpc_{i}^{t}, \tag{17}$$

donde $RCA_{i-c,k}^{t}$ es la *VCR* del país *i* en el bien *k* excluyendo las exportaciones del país *c* del comercio mundial, y $GDPpc_{i}^{t}$ es el PIB pc de los países distintos de *c* que exportan el producto *k*.

A continuación, estos "country-specific *PRODYs"* se utilizan para calcular los instrumentos para los índices de impacto de la relocalización a nivel de país. En el caso del *PSI*, el "country's product-shocks index" (*csp_PSI*) se define como:

$$csp\_PSI_{c}^{0,T} = \log \frac{\sum_{k} cs\_PRODY_{k,-c}^{T}\, \omega_{ck}^{0}}{\sum_{k} cs\_PRODY_{k,-c}^{0}\, \omega_{ck}^{0}}. \tag{18}$$

Tal como se define este índice en (18), éste no se ve afectado por los shocks del país *c*. El *csp_PSI* captura únicamente los shocks sobre el producto *k*, ya que estos tienen un impacto sobre el resto de exportadores de ese bien.

Del mismo modo, los shocks específicos de país podrían afectar a sus exportaciones y transmitirse a la *VCR* del país. Por tanto, para separar el impacto de estos shocks de país del impacto de shocks de producto que conducen a relocalizaciones de la producción, se definen también unos índices específicos para el *PRI:*

$$csp\_PRI_{c}^{0,T} = \log \frac{\sum_{k} cs\_ciPRODY_{k,-c}^{T}\, \omega_{ck}^{0}}{\sum_{k} cs\_PRODY_{k,-c}^{0}\, \omega_{ck}^{0}}. \tag{19}$$

El *csp_PSI* y *csp_PRI* se utilizan como instrumentos para el *PSI* y *PRI* respectivamente en el análisis econométrico.

El análisis econométrico de la relación entre la relocalización internacional de la producción y el crecimiento económico se realiza en el marco de las regresiones de crecimiento. El crecimiento de la renta pc es la variable dependiente en las regresiones, que incluyen como variables independientes la renta pc inicial, los índices de shocks de producto *(PSI)* y los de relocalización (*PRI)*, así como un vector de variables de control que incluye capital humano, capital físico y una serie de medidas de calidad institucional. Además, se añade la medida de sofisticación inicial de las exportaciones propuesta por HHR (2007), el $iEXPY$, en niveles y también su interacción con la renta pc, para controlar por el hecho de que el impacto de la sofisticación puede disminuir con el nivel de desarrollo. La sofisticación inicial de las exportaciones de un país se define como $iEXPY_c^0 = \sum_k PRODY_k^0 \omega_{ck}^0$.

Las especificaciones econométricas son las siguientes:

$$\frac{1}{T}\log\frac{GDPpc_c^T}{GDPpc_c^0} = \beta_0 + \beta_1\log(GDPpc_c^0) + \beta_2\log(iEXPY_c^0) + \beta_3 X_c^0 + \beta_4 PSI_c^{0,T} + u_c, \qquad (20)$$

$$\frac{1}{T}\log\frac{GDPpc_c^T}{GDPpc_c^0} = \beta_0 + \beta_1\log(GDPpc_c^0) + \beta_2\log(iEXPY_c^0) + \beta_3 X_c^0 + \beta_4 PRI_c^{0,T} + \beta_5\left(PSI_c^{0,T} - PRI_c^{0,T}\right) + u_c. \qquad (21)$$

Las ecuaciones (21) y (22) se estiman utilizando mínimos cuadrados ordinarios (MCO) y mínimos cuadrados en dos etapas (2SLS). Estas regresiones también se estiman con datos de panel.

Conclusiones

Los resultados obtenidos en el **tercer capítulo** confirman que la economía española está integrada en las cadenas globales de valor y participa activamente en el comercio vertical. El contenido en valor añadido de las exportaciones brutas (*VAX* ratio) ha disminuido en más de 9 puntos porcentuales durante el periodo de análisis: en 1995 las exportaciones de VA representaban un 79% de las exportaciones brutas, y han pasado a situarse por debajo del 70% en 2011. Estos valores y su evolución son similares al de sus principales socios europeos, y son propios de países pertenecientes a un área comercial integrada en la que hay un grado de producción compartida más elevado. En general, se trata de una tendencia compartida por la mayoría de economías incluidas en el análisis, lo cual es un reflejo de la creciente integración de los países en torno a las CGV, de la que también participa España.

Respecto a las características de su integración en las CGV, el análisis revela que en la economía española los vínculos *hacia atrás* (*VS*) son más relevantes que los vínculos *hacia delante* (*VS1*), dada su mayor propensión a importar para exportar. Su dependencia del exterior, medida por la intensidad en el uso de bienes intermedios producidos en el extranjero por unidad de demanda final, ha aumentado más de 9 puntos porcentuales desde 1995, situándose el valor añadido extranjero en 2011 cerca del 30% del valor añadido total. La evolución del índice *VS1*, que mide el porcentaje de inputs intermedios producidos en la economía española que incorporan las exportaciones de otros países, es más moderada, y se sitúa en promedio en los últimos años en un 20%.

El análisis por sectores revela diferencias notables entre manufacturas y servicios. Las ramas de la industria manufacturera son muy intensivas en el uso de inputs importados para producir exportaciones, mientras que los servicios destacan por sus mayores vínculos *hacia delante*. Todo esto se traduce en una capacidad muy distinta de generar valor añadido. Uno de los resultados más llamativos que se obtiene cuando el análisis del comercio se aborda en términos de valor añadido es el cambio en la importancia relativa de manufacturas y servicios: en términos brutos los servicios pesan cerca de un 21%, mientras que si los flujos se miden en valor añadido, este sector supone el 50% de las exportaciones, superando a las manufacturas (40%). Esto se debe a que las exportaciones de las distintas ramas manufactureras contienen inputs del sector servicios, que se exportan *indirectamente* a través de las exportaciones de bienes.

Este resultado aporta elementos al debate industria vs. servicios: es evidente que los servicios juegan un papel fundamental en las cadenas de valor globales, como *inputs* en la producción y exportaciones de bienes manufactureros. Por tanto, el énfasis no debe ponerse en incrementar el peso relativo de la industria frente a los servicios, ya que la primera incorpora una parte sustancial de valor añadido generado en el sector servicios, sino en la especialización en sectores que generen más valor añadido. Por otro lado, es necesario un funcionamiento eficiente del sector servicios para contribuir a mejorar la competitividad de las exportaciones españolas.

El análisis más detallado por ramas dentro de estos dos grandes sectores también muestra diferencias entre estas en el grado de participación en el comercio vertical y la distinta capacidad de generar valor añadido. La industria más intensiva en el uso de inputs importados es coquerías y refino de petróleo, con un contenido en valor añadido extranjero del 76%. Le siguen equipo de transporte, equipo eléctrico y óptico y productos metálicos, con más del 30%. Es destacable el caso de *equipo de transporte*, un sector relevante para la economía española, cuya producción y exportaciones contienen casi un 40% de valor añadido extranjero. Estos altos porcentajes evidencian un elevado grado de participación en las cadenas de valor globales.

La dependencia de las importaciones puede deberse a una utilización más eficiente de las ventajas de la división internacional del trabajo o bien responder a una carencia estructural de tecnología interna. En cualquier caso, a mayor contenido importador, menor es el efecto de un incremento de la demanda final sobre el valor añadido que se genera en la economía, ya que los efectos de arrastre se filtrarán al exterior. Esto limita el papel del sector exterior como elemento dinamizador y motor del crecimiento. No obstante, la participación en las cadenas de valor y el acceso a inputs producidos de manera más eficiente en el exterior puede contribuir positivamente a la competitividad exterior y estimular la generación de valor añadido doméstico, ya que permite una especialización en aquellos segmentos de la cadena de valor en los que la producción resulta más eficiente. Así pues, el énfasis debe ponerse tanto en aumentar las exportaciones como en la especialización en tareas de mayor valor añadido. La reasignación de factores podría llevar a unas mejoras de eficiencia que permitan incrementar la participación de algunos sectores de la economía en el comercio mundial. Este aspecto constituye una línea de investigación sobre la que cabe seguir profundizando en el futuro.

El **cuarto capítulo** se centra en el análisis de los procesos de relocalización que han tenido lugar en las últimas décadas, con el fin de determinar su signo e intensidad a nivel agregado y también por sectores, así como de caracterizar la dinámica externa e interna de su distribución e identificar el tipo de proceso estocástico que sigue la relocalización entre países pertenecientes a distintos grupos de renta. Además, se exploran los posibles determinantes de este fenómeno.

Los resultados que se obtienen en este capítulo revelan que la producción se ha desplazado, en promedio, hacia países de renta baja durante los periodos analizados. En cuanto a la intensidad de la relocalización, ésta se ha mantenido relativamente constante, como se desprende de la evolución del índice de dispersión y también del análisis de la forma externa de la distribución. El hecho de que la distribución ergódica sea muy similar a la distribución inicial y final de productos por grupos de renta, y prácticamente idéntica cuando se comparan los resultados durante un periodo de 40 años y uno de 10, apunta a que la relocalización de la producción sigue un proceso estocástico estacionario. Sin embargo, esta estabilidad esconde una notable movilidad interna que refleja la existencia de importantes procesos de relocalización a nivel de producto. El análisis por sectores también confirma que hay una elevada heterogeneidad sectorial en la dirección e intensidad de la relocalización.

En cuanto al análisis de los determinantes de la relocalización, los resultados obtenidos sugieren que la relocalización es, en gran medida, un fenómeno impredecible. La única de las variables consideradas en el análisis que parece tener un efecto sobre la relocalización posterior es la intensidad en I+D: las industrias que realizan una mayor (menor) inversión en I+D tienen más probabilidades de experimentar una relocalización *hacia arriba* (*hacia abajo*). El hecho de que la relocalización sea un fenómeno difícil de predecir limita las posibilidades de implementar políticas económicas que anticipen los riesgos de la relocalización. En cualquier caso, la aplicación de políticas generales que estimulen la inversión en I+D pueden ser útiles para prevenir la relocalización de productos hacia países de renta baja o contribuir a atraer nuevas actividades más sofisticadas.

Por último, el **quinto capítulo** examina el impacto que los procesos de relocalización han tenido en el crecimiento económico de los países durante el periodo reciente, dependiendo de su especialización inicial. Los resultados obtenidos en este capítulo indican que los países especializados al principio del periodo en productos cuya producción se ha desplazado, en promedio, hacia países de renta baja (alta) en los años posteriores, han tenido un crecimiento económico menor (mayor) durante el periodo 1996-2006. El impacto es estadísticamente significativo, robusto y relevante desde el punto de vista económico: una diferencia de una desviación típica en el índice que capta el impacto de la relocalización supone una diferencia de aproximadamente 1 punto porcentual en el crecimiento económico promedio.

Los cambios que se han producido en las últimas décadas en el comercio internacional son el contexto en el que se ha desarrollado esta tesis doctoral. Estos cambios han configurado el nuevo escenario competitivo internacional, un entorno cambiante al que los países han de adaptarse mediante su especialización productiva y comercial. En conjunto, el análisis realizado en los distintos capítulos pone en evidencia la importancia de la especialización. Desde la perspectiva del comercio en valor añadido, de esta especialización depende la capacidad de generar mayor o menor valor en las exportaciones. El análisis que se realiza en el quinto capítulo también apunta a la relevancia de la especialización: con frecuencia, los productos experimentan shocks que conducen a una relocalización de la producción según la ventaja comparativa de los países, y esto tiene un impacto notable en el desempeño económico de estos. La fragmentación de la producción y la aparición de las cadenas globales de valor han acentuado este fenómeno: la división de los procesos productivos amplía la posibilidad de especializarse en distintos segmentos de la cadena de valor.

Los fenómenos estudiados en esta tesis han sido claves en el incremento de la globalización económica. En los últimos años, como respuesta a la globalización y a sus efectos económicos, percibidos como negativos por una parte importante de la población, han surgido notables tendencias proteccionistas. Las manifestaciones más relevantes de estas tensiones son probablemente el Brexit y la elección de Donald Trump como presidente de los Estados Unidos, así como la aparición de partidos extremistas en buena parte de Europa. Posiblemente, Donald Trump represente la postura más beligerante contra el libre comercio, ya que considera que es la causa directa de la destrucción de empleos y riqueza en EEUU, y expresa habitualmente su firme propósito de poner trabas al comercio, mediante la renegociación de tratados comerciales o la imposición de elevados aranceles a la importación de determinados productos.

Si bien es cierto que en las últimas décadas se han producido relocalizaciones significativas de la producción entre países con distintos niveles de desarrollo, como se ha estudiado en el cuarto capítulo, y estas han tenido un efecto negativo en el crecimiento económico de algunos países, dependiendo de su especialización, como se estima en el quinto capítulo, la vuelta al proteccionismo no es la solución. Precisamente, el análisis del tercer capítulo refleja las crecientes interdependencias entre países en torno a las cadenas de producción globales. Los países dependen de las importaciones para producir sus exportaciones, y la especialización en aquellas actividades en las que cada país es más eficiente contribuye a aumentar su competitividad.

El comercio es global, y en este contexto, aumentar las barreras al comercio resultaría perjudicial, tanto para las empresas como para los consumidores. Además, en un entorno caracterizado por la presencia de las CGV, estas medidas tendrían un mayor efecto acumulado, ya que los bienes cruzan las fronteras varias veces en las distintas etapas del proceso productivo. La respuesta a la relocalización y a su potencial impacto negativo no pasa por la imposición de barreras al comercio, sino por la reorientación de la especialización hacia aquellas actividades más acordes a la ventaja comparativa del país y que le permitan obtener más valor añadido. En última instancia, el impacto neto de determinados procesos, como la relocalización internacional de la producción, depende de la capacidad y flexibilidad de los países de adaptarse a un entorno cambiante.

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