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UPSKILLING AND DISTRIBUTIONAL CHANGES IN THE ELECTRONICS GLOBAL VALUE CHAIN

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Abstract.*The electronics industry has one of the most complex global production chains in the international economy. Using data from the World Input–Output Database for the period 2000–14, this article traces individual contributions to the value chain in order to observe how financial turmoil has affected its evolution over timeand to map international interactions. The authors point to a rise in offshoring until the outbreak of the global financial crisis of 2007–08, as China and other Eastern Asian economies became an essential node of value creation. They* *also detect a deep transformation of production technologies, accompanied by a process of upskilling.*

Keywords: *global value chain, upskilling, offshoring, electronics industry, functional upgrading, WIOD.*

1.Introduction

Increasingly, global value chains are becoming the main drivers of international trade. The internationalization of production is generating intricate cross-border flows, to the point that it is not possible to understand competitive performance in global markets without considering the international configuration of its production activities. In recent years, the international fragmentation of industrial production has given rise to highly complex processes (Timmer et al. 2014; Baldwin and Venables 2013).

Goods and services are produced by combining inputs from different countries to achieve export competitiveness. The supply-chain trade has become a sophisticated process of valueadded generation in which each member of the chain acquires inputs and adds value in the form of wages and capital income, which in turn constitute the costs of the next stage of production. As a consequence, this trade'simpact on the labour market is highly significant (Baldwin andLopez-Gonzalez 2015).

Technology now plays an important role in this new configuration of international production. In fact, the effects of technology and the influence of trade on the level and structure of employment are often very similar and difficult to untangle (WTO 2017). The progressive opening of economies to international trade is inducing a process of upskilling, intensifying the demand for high-skill workers (Helpman 2016) and making emerging technologies skillbiased asthey tend to be better complementedby the most skilled workers (Acemoglu 1998; Autor, Katz and Krueger 1998).

This skill bias of world trade has been confirmed both in advanced and developing economies and ininter- and intra-industry trade (Epifani and Gancia 2008). However, the polarization of employment (Goos and Manning 2007), the reduction of the skill premium in many countries (Parro 2013) and the evidence of routine-biased technical change linked to the emerging digital technologies (Autor,Levy and Murnane 2003) raise questionsregarding the future composition of employment in high-technology industries.

The manufacture of computer, electronic and optical products is a paradigmatic case of fragmentation on a global scale, appropriate for investigating changes in the distribution of value and employment. Through a network analysis based on vertical trade, Ferrarini (2011) previouslyanalysedthe interactions in this industry, identifying three majorglobal production nodes: Asia, the countries of the North American Free Trade Agreement (NAFTA) and Europe.

However, the fact that a product is marketed from a particular country does not mean that itseconomy captures the greatest part of the income generatedor that the companies located in ithave the capacity to govern the value chain (Gereffi 1999). The information contained in the World Input–Output Database (WIOD) provides a deeper understanding of the nature of the interactions in this network because the changing participation of countries in the value chain can be inferred and traced (Timmer et al. 2015).

The aim of this study is threefold. First, to improve understanding of the international interactions in this value chain. Second, to identify any distributional changes in the wake ofthe Great Recessiontriggered by the global financial crisis of 2007–08, including shifts in the composition of labour. Third, to shed some light on upgrading processes.

This articleis organized as follows. The second section presentsa literature review, describing the principal actors in the industry and recent developments in its global value chain. The third section describes our statistical and data collection methods, including a description of the WIOD database. We present and discuss ourresults in the fourth section, while the fifth provides a network visualization of the industry to reveal the intensity and changes of the main interactions. The sixth section concludes.

2. Literature review

2.1. Main actors

The electronics industry has one of the most complex global production chains in the international economy since many companies, of different dimensions and in different locations,take part in the value chain. This widediversity occurs because the main products and processes can mostly be formalized, codified, standardized and computerized. The interoperability between components leads to the fragmentation of production into separate stages or functions. Modularity allows the product structure to be modified, and thisopens up new opportunities for the organization of the industry. In this way, both the design and logistics of each production stage can be implemented by distinctcompanies located in different geographic locations (De Backer and Miroudot 2014).

The value chain has become increasingly fragmented and global in naturebecause modularization makes it easier to undertake production activities at great distances when transport costs are small (Sturgeon and Memedovic 2011). Most electronic components and final products are characterized by a high value-to-weight ratio, which facilitates agile and comparatively economical transport over long distances. The use of digital technologies to monitor the production process has also facilitated the coordination of the different production stages, even when they are located in geographically distant locations.

Three major types of actors are involved in electronics global production chains. Sturgeon and Kawakami (2011) differentiate between lead companies (also known as brand companies), contract manufacturers and platform companies. The lead companies are essentially responsible for research, design, brand management, intellectual property, marketing, advertising and customer services. They seek to capitalize on the value chain through their superior technological capacity, brand development and financial assets. In practice, these companiesoften have extensive market power over their suppliers and capture most of the value created in the international production networks.

As value shifts from manufacturing-related stages to pre- and post-production services, in a pattern known as the “smile curve”, lead companies seekto retain the bulk of the value generated under their direct control. This process, has a direct influence on the geographical location of each stage of the production process (Mudambi 2008; Shin, Kraemerand Dedrick 2012; Baldwin,Ito and Sato 2014). Since knowledge-based assets have become the most important source of value, the business strategies of brand companies are oriented towards the control and appropriation of the returns on these assets.

Lead companies must compete in a wide range of segments and markets because the expansion of the industry has been accompanied by a great diversification. This market complexity has led to the emergence of a wide and very entangled ecosystem, nurtured by many companies with diverse attributes. Most of the lead companies in this industry are located in the United States, Western Europe, Japan or the Republic of Korea, although some brand companies have emerged in China and Taiwan (China) in recent years.

Contract manufacturers (or subcontractors) produce for lead companies and sometimes also provide design services. Their presence is extremely important in the industryand has a long historical tradition, since the modularity of the value chain allows a technical division of labour between design and manufacturing operations at multiple points in the value chain. At present, very few lead companies carry out the assembly of their products in their own production facilities.

We can differentiate between varioustypes of subcontractors, providing electronic manufacturing or product design services. The complementarity ofthese suppliers, workingin different locations, has led to a rapid geographic expansion in both segments to the point that they are currently responsible for the vast majority of the procurement of electronic components. This significant increase in production capacity and the expertise achieved over time are making it easier for lead companies in the industry to implement global production strategies through more complex subcontracting networks.

Lastly, although lead companies have sufficient capacity to define the structure of the production system in most segments, other types of participants have emerged. Some companies, primarily dealing in personal computers and mobile phones, have succeeded in integratingtheir technology – such as software or hardware – in the products of other companies. Known as platform leaders,these companies haveenough technological capacity and market power to capture a more significant portion of the value generated in the chain than the lead companies (Imai and Shiu 2011). They even have the capacity to decide the location of the critical nodes of the global value chain. Most of these companies have headquarters located in Europe or in the United States.

2.2. Evolution of the global value chain

Several authors (Feenstra and Hamilton 2006; Sturgeon and Kawakami 2011) point out that the evolution of the global value chain in the electronics industry has been characterized by a progressive acquisition of competencies by outsourcing companies and the emergence of a variety of strategies and business models.

The rapid transition to global offshoring, with a huge transfer of production capacity abroad, is furtherdefined by a process of consolidation and integration of the global production base and by the scaling upof some of the main suppliers. In fact, the level of production fragmentation reached by the leading companies in the United States, Europe and Japan highlights this structural change. Most of the brand companies have very little production capacity in their domestic markets, being essentially gearedtowards providinghigh-value-added intermediate products. Instead, they rely onglobal support from their suppliers. To meet these requirements, most contract manufacturers have expanded their activities in the closest regional areas through new investments, sometimes even through the acquisition of other suppliers.

Thus, most majorsubcontracting companies offer global coverage. In the case of Asian countries, this involves a large volume of low-cost production or, alternatively,in the case of medium-income economies, such as Mexico or Eastern Europe, meeting the demand for more sophisticated products. In addition to providing international partners with value, these subcontracting companies are able to respond to the growing demand inthe biggest emerging markets, such as China, Brazil and India, through the use of local suppliers. Lastly, they can also operate with lead companies in the global market to jointly offer the highest quality products in the most profitable market niches.

The Great Recessionacted asa catalyst for restructuring among brand and subcontractor firms, in the context of falling prices. The will of lead firms to rationalize their organization andconsolidate their supplier base has opened up new upgrading opportunities and trajectories for contract manufacturers (Gereffi and Lee 2016). These suppliers increasinglyprovide lead firms with design, engineering and prototyping services, as well as technological development. They are gaining new capabilities, expanding their outsourcing activities and growingorganically, becoming strategic partners to leadfirms, investing themselves on a global scale and introducing new business models (Raj-Reichert 2018).

The search for organizational rationalization, in particular, has led brand companies to focus on a small number of technologically capable and strategically located suppliers. The immediate consequence of thishasbeen largelyto shut smaller companies with less manufacturing expertise out of this complex value chain (Lee and Gereffi 2015). Such rising polarization between the suppliers located in the main productionhubs and those left outsideresults in an uneven distribution of upgrading opportunities.

As long ascompanies continueseeking efficiency and productivity gains, many electronic goods willnot be produced by the top brands. On the contrary, the recent trend is forboth production suppliers and design services to take on a substantial part of the risks and costs related to the business activity. This transition model has a relevant impact on the income distribution along the value chain (Pawlicki 2016).

The use of temporary work agencies is allowing manufacturers to adjust more easily to changes in demand, but these agencies are negatively affecting working conditions in the global value chain (Andrijasevic and Sacchetto 2017). Agencieshave also undergonemajor transformations, with a significant diversification of operations, going beyond the traditional leasing of workers to directly taking on the organization of recruitment, international migration, transportation and housing of workers. This shifting model makes it easier forbrand companies and contract manufacturers to maximize the short-term utilization of labour in the main production hubs and it also reinforces the polarization of activities between the lead firmsand contract and component manufacturers located in these high-density locations,and the actors located in the slimmer nodes of the network.

Lastly, although in most segments the lead firms capture the lion's share of the value created within the chain, platform leadershave dominated the branches of personal computers and mobile phone handsets (Sturgeon and Zylbergerg 2016), even retaining tight control over the innovative trajectory of that part of the industry. However, as the case of the Taiwanese chipmaker MediaTek shows, the growth of demand for less sophisticated products in emerging economies has made the entrance of domestic platforms leaders to the smartphone businesspossible, reshaping the value chain and extracting a large share of the value created through the supply of chipsets and complementary services (Chuang 2016). The emergence of key suppliers, platform leaders and local brands in these domestic market-oriented production networks is challenging the dominance of the incumbent global brands.

3. Methodology and data collection

3.1. Description of the WIOD

The WIOD project produces a publicly available statistical database and provides the underlying data sources and methodology with complete transparency.[1] This database enablesthe study of the electronics global value chain based on the flow of value between countries and itsdecomposition into capital and labour.

The starting point of this study is the second releaseof the WIOD (2016), which includes a set of input–output tables for 43countries and the "rest of the world" category,whichaccount for 85 per cent of world GDP. It includes55industries in the primary, secondary and tertiary sectors, connected by bilateral international trade flows, considering themovera period of 15 years (2000–14). In this way, a broad summary of the transactions in the global economy between

[1] See http://www.wiod.org/home.

the industries and the end users is available forthe countries analysed. World Input–Output Tables (WIOT) are compiled from each country's official statistics and are expressed in millions of dollars. We can therefore consider the WIOD as a time series of WIOT, and the latteras a set of national input–output tables connected to each other by bilateral international trade flows.

3.2. The value added of final production

The study of the electronics industry is based on the methodology developed byTimmer et al. (2015). This methodology proposes an operating guide for the WIOD in the analysis of international trade. In order to calculate the value added of final production (VA), we have followed the steps indicated in their article, which, in turn, uses the detailed process described in Johnson and Noguera (2012) as its reference. Themethodology is based on the use of the decomposition technique introduced by Leontief (1949). We thus calculated the value-added vector involved in the value chain ($VA_{i,j,a}$) for industry$i$, country j and year a using the following expression:

$$VA_{i,j,a} = VAR_a \cdot (Id - M_a)^{-1} \cdot F_{i,j,a} \tag{1}$$

where VAR_a is a diagonal matrix of dimensions SN x SN containing the ratio between value added and production for each industry and for each country per year a, M_a is the matrix of the intermediate input coefficients for year a obtained directly from the corresponding global input–output table, and the matrix $(Id - M_a)^{-1}$ is the Leontief inverse. Lastly, $F_{i,j,a}$represents the sum of all final production associated with private final consumption (domestic and foreign) and the investment of industry i and country j for year a. It is a vector of dimension SN x 1 that only has a single value different from zero, which corresponds to industry i and country j.

From the vector $VA_{i,j,a}$we can calculate the value of the final output of industry i of country j for a given year a, $VPF_{i,j,a}$, by adding all the components of the vector (Los, Timmer and de Vries 2015):

$$VPF_{i,j,a} = \sum_{k=1}^{SN} VA_{i,j,a}(k) \quad (2)$$

If we now addonly the values corresponding to all the industries of country l, we obtain the valueadded generated in country l by industry i of country j:

$$VPF_{i,j,a}^{l} = \sum_{k=1}^{S} VA_{i,j,a}(l_k) \quad (3)$$

where l_k represents the k-th component of country l in vector $VA_{i,j,a}$. The percentage of valueadded generated in country l can be obtained by dividing this value by the value of the final production referred toabove:

$$PVPF_{i,j,a}^{l} = \frac{VPF_{i,j,a}^{l}}{VPF_{i,j,a}} \cdot 100 \quad (4)$$

In the case that $l=j$, then the valueadded generated in the home country is discussed. To know the valueadded generated by industry i of country j in year a for a set of countries (region), we simply add all the components of vector $VA_{i,j,a}$corresponding to all of the industries from all of those countries.[2]

[2] The WIOD includes a specific treatment for re-exports (Timmer 2012), which considers imports as intermediate consumption of the processing country. However, the different implementation of this policy in each national WIOT requires great caution.

4. Results and discussion

This methodology provides information about the geographical distribution of the value added of a specific industry, according to the country of completion. In our case, the analysis will be carried out for the electronics industry during the period 2000–14, the years for which the most recent WIOD update is available. In order to infer the effects of the economic crisis on the evolution of the valueadded generated and its geographical distribution, we analysed two different periods. We selected 2007 as the turning point as this corresponds to the peak of the production cycle in the industry.

Information has been selected and analysed for the sixteen topproducing countries. Using formula (2), table 1 indicates that they represent 76.5 per centof the changes observed during the period under analysis and almost 80 per centof the value added of final production at the end of the same period.

Using formula (4) to calculate the national value-added content generated in each of the countries of completion in table 2, we can confirm that the impact of the international fragmentation of production has been considerable. At the end of the period, more than a quarter of the value added generated in the production chain is transferred outside of the country of completion. Only a few economies with large domestic markets are able to retain a markedly predominant national share ofvalue added.

Table 1. Evolution of the value added of the final production of computer, electronic and optical products, 2000–14 (millions of US$)

	2000	2007	2014	2000–07	2008–14	2000–14
Brazil	14462.59	28363.97	38191.49	13901.37	9827.52	23728.90
China	130447.24	600089.79	1583060.73	469642.56	982970.94	1452613.49
Czechia	1669.76	14597.49	14587.74	12927.73	-9.75	12917.98
France	42442.19	40128.24	30010.82	–2313.95	–10117.43	–12431.38
Germany	71188.32	124912.85	97179.67	53724.53	–27733.18	25991.35
United Kingdom	50559.24	42775.90	39677.63	–7783.33	–3098.28	–10881.61
India	6572.47	20070.32	27826.32	13497.86	7756.00	21253.86
Indonesia	5923.71	13277.03	21787.84	7353.31	8510.81	15864.13
Japan	358158.92	287164.55	251752.29	–70994.37	–35412.25	–106406.63
Mexico	53454.30	72117.32	61781.30	18663.02	–10336.02	8327.00
Poland	2373.84	10955.20	12541.27	8581.37	1586.07	10167.43
Russian Federation	5885.36	33296.10	39793.40	27410.74	6497.30	33908.04
Republic of Korea	113872.31	231602.13	312095.00	117729.82	80492.87	198222.69
Switzerland	20918.52	44026.90	70747.84	23108.38	26720.94	49829.32
Taiwan, China	93203.12	152069.45	206935.46	58866.34	54866.00	113732.34
United States	527883.00	431071.00	387091.00	–96812.00	–43980.00	–140792.00
Total	1499014.88	2146518.25	3195059.80	647503.37	1048541.55	1696044.93
World production	1825762.17	2799997.29	4042397.97	974235.12	1242400.68	2216635.80
Participation (%)	82.10	76.66	79.04	66.46	84.40	76.51

Source: Authors’compilation from WIOD data, 2016 release.

Despite the growth of international outsourcing, electronic production still maintains a high domestic bias in most economies. In 2014, the countries analysed on averageretained more than 73 per cent of the value added from production in the country of completion. Trade and transport costs and specific obstacles to the international fragmentation of production mayexplain the persistence of high domestic value-added quotas, as Venables and Baldwin (2010)indicate. However, the impact of economic geography on the location of some high value-added-specific activities is probably more decisive, as some tasks are geographically concentrated in locations where they benefit fromsignificant economic complementarities, limiting the incentives of offshoring.

The severe economic crisis of the late 2000s has affected international fragmentation strategies in the electronics industry. In particular, we note that the regression of value added generated outside national borders has been significant since 2007. While the fragmentation process was very intense during the upward phase of production activity, the economic downturn has slowed this process (Timmer et al. 2016) with data suggestinga move back towards a greater concentration of value added within domestic economies.

In this general context, the intensity of imports indicator for the global computers industry decreased from 48.7 to 43.9 per centbetween 2008 and 2014.This trend is especially pronouncedin the case of China’s economy where the share of domestic production increased by 14 percentage points during the period of economic decline (table 2). This is a shared phenomenon, albeit with less intensity in some other major producing countries, such as Germany, Switzerland, Taiwan (China) and the United States. In the particular case of China’s economy, there is evidence of a growing trend in domestic demand towards electronic products, which are completed in the country and generally have a lower intensity of imports than the final products acquired abroad, resulting in an increase in the domestic content of the value generated.

Table 2. Distribution of value added according to the country of completion, domestic participation, 2000–14 (percentages)

	2000	2007	2014	2000–07	2007–14	2000–14
Brazil	62.67	79.23	64.08	16.56	–15.15	1.41
China	70.64	60.34	74.31	–10.30	13.97	3.67
Czechia	48.77	34.24	32.49	–14.53	–1.75	–16.28
France	72.66	77.87	72.06	5.21	–5.82	–0.60
Germany	73.00	72.63	75.06	–0.36	2.42	2.06
United Kingdom	66.85	72.55	71.33	5.69	–1.22	4.47
India	72.42	70.36	72.49	–2.06	2.13	0.07
Indonesia	74.86	73.21	60.79	–1.65	–12.42	–14.07
Japan	89.52	83.72	78.88	–5.80	–4.84	–10.65
Mexico	40.31	31.83	29.82	–8.48	–2.01	–10.50
Poland	61.16	47.87	39.25	–13.29	–8.62	–21.91
Russian Federation	84.53	88.45	85.41	3.91	–3.03	0.88
Republic of Korea	64.81	68.83	64.14	4.02	–4.70	–0.67
Switzerland	73.69	76.16	77.79	2.47	1.63	4.09
Taiwan, China	50.56	55.77	60.08	5.21	4.31	9.52
United States	87.71	89.83	90.89	2.12	1.06	3.18
Total	78.44	71.25	73.52	–7.18	2.27	–4.91

Source: Authors’ compilation from WIOD data, 2016 release.

However, these general trends conceal large differences in behaviour among the major producing countries. In fact, they occur in the context of a profound restructuring of the industry. The two economies leading production at the beginning of the period (the United States and Japan) have suffered a marked fall in value generation, while the Chinese and Korean economies have emerged as the main sources of value in the industry. However, contrary to the intense offshoring process that accompanied the decline in Japanese production, the productive adjustment in the United States has not been detrimental to domestic participation in value added (tables 1 and 2).

4.1. Regional analysis

Given thatproductive fragmentation and the subsequent economic crisis have profoundly reconfigured the international distribution of value added, it seems appropriate to analyse the evolution of the main players separately. Only China,Brazil,Germany, the Russian Federation, Switzerland andTaiwan (China)have been able to improve national participation significantly while increasing their volume of production. The improvement in production is, in most economies, the result of a greater concession of value added to its partners in the network.

The analysis of changes in regional contributions to the global value chain confirms that the epicentre of restructuring is located in the East Asian economies. Table 3 shows that the bulk of the value chain is maintained at the regional level, since a significant part of the production fragmentation has been made in favour of regional partners, which capture 2.87 percentage points of the 5.41 percentage point fall in the value held domestically. The influence of the regional economies is maintained or broadened in the case of industries that reduce their production (Japan) as well as those that increase production (China, Indonesia, the Republic of Korea and Taiwan (China)). The profound restructuring of the industryhas not adversely affected the magnitude of the joint influence wielded by the region, which retained more than 82 per centof the valueadded generated in its final production in 2014. In general, Asian electronics companies have been able to combine their growing opportunities to participate in value chains with increased incomes for the set of activities in the industry, as pointed out by Kiyota, Oikawa and Yoshioka (2016).

However, this result is the consequence of a remarkable rearrangement of the participation of different Asian countries. Table 4 shows the changes in the distribution of the value added of production completed in Japan and China. On the one hand, it confirms that regional economies are the main beneficiaries of the intense decentralization in the Japanese economy. Its Asian partners improved their share in the value chain by 5.4 percentage points. On the other hand, it reveals that the increasing absorption of value by Chinese companies in their final production is not to the detriment of their Korean and Taiwanese associates. The changes in the Asian economic region may have also favoured relations of complementarity and the consolidation and expansion of brands (Samsung or Hon Hai, among others), lead companies and product design firms in these two Asian economies. In contrast, the contribution of Japanese, European and North American companies to the value chain of the Chinese electronics industry has decreased significantly.

Table 3. Computer, electronic and optical products: Regional distribution of value added in South East Asia, 2000–14 (percentages)

	2000	2007	2014	2000–07	2007–14	2000–14
China	10.72	14.77	8.81	4.05	–5.96	–1.90
Indonesia	9.70	8.28	16.31	–1.42	8.03	6.61
Japan	2.65	5.25	8.07	2.61	2.82	5.42
Republic of Korea	12.88	11.72	16.34	–1.16	4.62	3.46
Taiwan, China	19.17	19.20	19.17	0.02	–0.02	0.00
Regional participation	7.61	12.49	10.49	4.88	–2.00	2.87
Domestic participation	77.78	66.43	72.38	–11.36	5.95	–5.41

Source: Authors' compilation from WIOD data, 2016 release.The rise of Asian emerging economies as new markets has reinforced the regional links within the global value chain (Barrientos, Gereffi and Rossi 2011). This growing flow of commercial interactions between companies has facilitated the participation of local companies and improved their chances of engaging in high-value-added activities, because of the lower entry barriers and the less stringent product and process standards. Thus, the changing pattern of international trade and the effervescent Asian markets are helping new places and actors to join this network of production, offeringnew employment opportunities for medium and high-skilled labour.

Table 4. Changes in distribution of value added of production completed in Japan and China, 2000–14 (percentages)

	Japan	China
China	3.96	3.67
Taiwan, China	0.84	0.63
Australia	0.49	0.20
Russian Federation	0.47	0.16
Republic of Korea	0.42	0.87
Indonesia	0.21	–0.09
Germany	0.17	–0.26
United Kingdom	0.04	–0.33
France	0.01	–0.43
United States	–0.98	–1.71
Japan	–10.65	–3.32
Rest of the world	5.03	0.61

Source: Authors' compilation from WIOD data, 2016 release.

The Chinese electronics industry also has other specific features revealing a change in roles during the economic crisis. Table 5 shows the changes in the Chinese industry's share in the valueadded of the final production of its main trading partners. We observed how the participationof the Chinese industry rose significantly during the phase of economic deceleration. This greater presence is foundboth in the production completed by its regional partners as well as in the distribution of value added acrossthe global industry as a whole, even in economies with a predominance of national content (Japan, the Russian Federation and the United States). The growing presence of the Chinese electronics industry in the production completed in non-regional economies, such as Brazil, Czechia,Mexico and Poland is highly significant. This productive transformation is therefore based on an organizational strategy on a global scale.

The Chinese electronics industry has benefited from the intense process of production fragmentation, capturing a growing portion of income. During the upward phase of production and international trade, the Chinese industry was able to substantially improve its production activity in exchange for concessions in the domestic content of the production completed in the country. Subsequently, it also expanded its contribution to local final production (Koopman, Wang and Wei 2012).

Table 5. Distribution of value added in computer, electronic and optical products according to country of completion: Changes in the participation of the Chinese electronics industry (percentages)

Country of completion	2000–07	2007–14	2000–14
Brazil	1.35	6.16	7.50
China	–10.30	13.97	3.67
Czechia	8.50	5.69	14.19
France	0.66	1.79	2.45
Germany	1.70	0.96	2.66
United Kingdom	0.98	2.90	3.88
India	2.42	2.25	4.67
Indonesia	1.77	5.85	7.62
Japan	1.54	2.42	3.96
Mexico	5.35	5.79	11.14
Poland	2.75	6.44	9.19
Russian Federation	0.65	1.01	1.66
Republic of Korea	2.68	5.34	8.02
Switzerland	0.56	0.72	1.28
Taiwan, China	3.68	4.23	7.91
United States	0.61	0.83	1.45

Source: Authors' compilation from WIOD data, 2016 release.

This process is likely to be the consequence of both the emergence and consolidation of large local companies (such as Lenovo) in the electronics market and the greaterparticipation of domestic suppliers in the production completed in the country (Koopman, Wang and Wei 2008). This would seem to confirm an increased ability among Chinese companies to supply upstream products for internal consumption (Kee and Tang 2016), which would in turn restructure the specialization of the partners in the Asian hub. As Sztulwark and Juncal (2014) indicate regarding consumer electronics, while Taiwanese firms progressively abandon manufacturing to concentrate on the product development stage, China is the regional economy that continuously expands its share in the value chain to new links.

Thus, the significant increase in Chinese participation may be explained by factors that are complementary to its advantages in labour costs. In the telecommunications equipment branch of the industry, these factors would appear to be based on the consolidation of large brands in the Chinese capital goods industry. In the production of computer equipment and consumer electronics, however, the emergence of certain brands is thought to have led toa progressive displacement of domestic production towards more technologically intensive segments with higher value added (Nogueira de Morais 2012). The improvement in the country's value added would indicate the success of its technological absorption process and corresponds to both the development of more sophisticated components and the formation of lead companies (Zhang and Zhang 2015).

Although several previous studies that focused on specific products in the electronics industryhad identified the United Statesand Japan as the economies that capture most of the distributed income (Dedrick, Kraemer and Linden 2010; Linden, Kraemer and Dedrick 2009), a more aggregated analysis indicatesthat China and its regional allies (mainly the Republic of Korea and Taiwan (China)) are becoming the key players in the industry's production and innovation system (Sturgeon andKawakami 2011). Basing its analysis on vertical integration, the Organisation for Economic Co-operation and Development (OECD 2012)confirmed that the East Asia hub plays a dominant global role in the industry. Significant evidence is the increasing participation of the Korean and Taiwanese electronics industriesin the domestic value of their non-regional partners, which replicates the behaviour observed in Chinese companies. After the global financial crisis, the influence of the Asian economies becomesparticularly relevant for the industry in Latin America and Eastern Europe (table 6).

Asia's strength is based both on significant intra-regional relations and on strong links with American and, to a lesser extent, European economies. Given the integrated nature of the electronics industry on a global level, leading firms in emerging economies are not only global suppliers, but also potentially dominant competitors.

The situation is very different in the case of the North American economies, with a significant decrease in regional links. In the United States, domestic content has increased its participation in the final production share of the industry, reaching the highest value in the sample of countries. Therefore, the loss of leadership byUScompanies in the global electronics industry can be explained by a decrease in the international fragmentation of their production and a reduction of the valueadded generated. Throughout the period under analysis, just the companies located in China managed to significantly improve their contribution to final production in the United States. However, NAFTA partners and the European economies lost participation in the value chain of US firms (table 7).

In contrast, while the domestic content of production improved in the United States, the Mexican electronics industry exhibited radically different behaviour, with a very significant drop in national content of final production,representingless than 30 per centof the total value generated by 2014 (see table 2). This would confirm the vertical specialization pattern in Mexico, with a decreasing contribution of domestic value to its exports.

Table 6. Distribution of value added in computer, electronic and optical products according to country of completion: Changes in the participation of Korean and Taiwanese electronic industries, 2000–14 (percentages)

Country of completion	Republic of Korea	Taiwan (China)
Poland	3.76	0.19
Brazil	3.30	0.49
Hungary	2.58	0.19
Mexico	2.11	1.22
Czechia	1.40	0.12

Source: Authors’ compilation from WIOD data, 2016 release.

The low salary levels found inLatin America, its industrial experience and its improvement of labour skills make it one of the preferred destinations for the completion of electronic products from SouthEast Asia. This effect could then potentially be distributed within NAFTA economies. However, although the Mexican electronic industry was the recipient of new inflows of foreign direct investment and some local companies were involved in a process of economic upgrading and higher value products during this period, many of the techniques that support these changes are still developed outside the region and many local firms are not able to adapt to these new requirements (Sturgeon andKawakami 2011). Ashortage of knowledge and resources are thought to limit the capacity of the Mexican economyto increase the employment of high-skilled workers and the domestic value of production.

Table 7. Computer, electronic and optical products completed in the United States: Changes in the distribution of value added, 2000–14 (percentages)

	2000–07	2007–14
United States	2.12	1.06
China	0.61	0.83
Germany	0.05	–0.18
Canada	–0.03	–0.43
Mexico	–0.06	–0.08
United Kingdom	–0.06	–0.13
France	–0.11	–0.08
Taiwan, China	–0.33	–0.06
Republic of Korea	–0.52	0.08
Japan	–1.27	–0.36
Rest of the world	–0.39	–0.66

Source: Authors' compilation from WIOD data, 2016 release.

A more detailed analysis of changes in the distribution of value added in the electronics industry (table 8) shows that China and, to a lesser extent, the Republic of Korea and Taiwan (China) are the main beneficiaries of the production fragmentation process completed in Mexico. They obtain a preferential position in the value chain of the Mexican electronics industry, to the detriment of domestic, US and Japanese companies.

We find a similar scenario in Brazil's industry. The distribution of value added has also undergonea deep reconfiguration, with a loss of influence amongthe companies located in the United Statesand Japan because of the increasing participation of their Chinese and Korean competitors (table 9). Mexico and Brazil could stand as paradigmatic cases of the emergingmodels for companies participating in global value chains. As Sturgeon and Van Biesebroeck (2011) pointed out, the speed of technological change in the electronics industryand the dynamism of the market offer new opportunities for lagging economies to participate in a globally integrated industry. Because of their specific advantages and the characteristics of their domestic market, emerging-market firms can thrive and obtain certain market dominance despite a lack of technological leadership (Grimes and Sun 2016).

Table 8. Computer, electronic and optical products completed in Mexico: Changes in the distribution of value added (percentages)

	2000–14
China	11.14
Republic of Korea	2.11
Taiwan, China	1.22
Germany	0.47
Canada	0.35
Japan	–2.27
Mexico	–10.50
United States	–10.86
Rest of the world	8.33

Source: Authors' compilation from WIOD data, 2016 release.

However, although the Brazilian electronics industry has been struggling to occupy a more productive place in the global value chain, the financial crisis has worsened its domestic industry and market's reliance on imports, and has severely narrowed the local production of electronic components and communication equipment, which are increasingly outsourced through contract manufacturers in order to remain adaptive to rapidly changing market conditions (Sturgeon et al. 2013). This process limits the developmentof domestic content and the opportunities for functional upgrading.In particular, the development of a significant local industry is restricted by direct competition fromhigh-volume Asian factories.

Table 9. Computer, electronic and optical products completed in Brazil: Changes in the distribution of value added (percentages)

	2000–14
China	7.50
Republic of Korea	3.30
Brazil	1.41
Taiwan, China	0.49
United Kingdom	–0.45
Germany	–0.82
Japan	–2.50
United States	–9.91
Rest of the world	8.33

Source: Authors' compilation from WIOD data, 2016 release.

Lastly, as regards the electronics production in Europe, the accessionof Central and EasternEuropean economies to the European Union during this period strengthened the regional value chains througha growing participation of European partners. However, weobserve that the fragmentation of production is also increasing at a global level in all of the European economies. The participation of non-European countries in the generation of value added has also increased very quickly. As a consequence, the fragmentation has been particularly intense in Central and EasternEuropean economies, with a minor and decreasing domestic contribution to their final output(see table 10).

In fact, foreign direct investment from European and Asian brand companies in EasternEuropean countries is becoming a primary vehicle of integration in the electronics global value chain (Radosevic 2004). These small economies import large numbers of inputs from multinational companies involved in processes of vertical specialization and serve as a low-cost supply base for assembly and export to the main European markets (De Backer andMiroudot 2014). Their connection with the rest of the value chain is essentially based on a downstream linkage.

Table 10. Computer, electronic and optical products completed in Czechia and Poland: Changes in the distribution of value added, 2000–14 (percentages)

	Czechia			Poland		
	2000	2007	2014	2000	2007	2014
Domestic	48.77	34.24	32.49	61.16	47.87	39.25
EU-28	33.89	30.09	29.68	24.17	28.90	28.93
United States	5.28	3.53	3.59	3.43	2.45	2.51
Japan	2.41	6.57	2.20	1.70	2.10	1.52
Taiwan, China	1.69	2.36	1.82	1.41	1.22	1.60
China	0.92	9.42	15.11	0.77	3.52	9.96
Russian Federation	0.77	1.11	1.02	1.22	1.97	1.87
Republic of Korea	0.68	2.39	2.07	0.90	5.20	4.66
Rest of the world	5.59	10.29	12.02	5.24	6.77	9.70
Total	100.00	100.00	100.00	100.00	100.00	100.00

Source: Authors' compilation from WIOD data, 2016 release.

Over the period of study, there is clear evidence of a shift in offshoring locations from western European countries to their eastern neighbours. Eurofound (2016) points out that this process occurs in Europe due to the reduction of international fragmentation activities in the wake of the economic crisis, as the yield of new potential offshoring initiatives has decreased and efficiency-based targets have been reached.

While the participation share of regional partners remains at similar levels, the growth of offshoring activities is essentially global. In the upward phase of production, we detect a growing participation of EasternAsian economies. Afterwards, a reconfiguration of the value chain in favour of enterprises located in China emerges. Overthe whole period, the rising contribution of the Chinese economy to the value generated in the Eastern European industry is particularly pronounced.

Although regional interactions remained significant in Europe throughout the period and large European economies still retain a major share in the generation of value, a deep internal restructuring can be detected. Despite the fact that the continent's three main suppliers of electronic products at the beginning of the period – France, Germany and the United Kingdom

–retained more than 70 per centof the value generated in their final production at the end of the period, the economic crisis entailed a decrease in production and a reduction in domestic participation by the United Kingdom and France. The data also reveal the loss of influence by Japan's industry and the importance of China's role in the fragmentation of European production of electronic equipment (table 11).

Table 11. Computer, electronic and optical products completed in France, Germany and the United Kingdom: Changes in the distribution of the valueadded, 2000–14 (percentages)

	France		Germany		United Kingdom	
	2000–07	2007–14	2000–07	2007–14	2000–07	2007–14
Domestic	5.21	–5.82	–0.36	2.42	5.69	–1.22
EU-28	–2.12	1.69	1.14	–1.71	1.18	–0.47
United States	–2.08	0.31	–1.78	–0.68	–4.10	–0.37
Japan	–1.12	–0.11	–1.21	–0.69	–1.72	–0.59
Taiwan, China	–0.31	0.06	–0.20	–0.07	–0.50	0.03
China	0.66	1.79	1.70	0.96	0.98	2.90
Russian Federation	0.18	0.09	0.36	–0.06	0.22	0.04
Republic of Korea	–0.20	0.09	0.05	–0.46	–0.97	–0.06
Rest of the world	–0.23	1.90	0.31	0.28	–0.78	–0.26

Source: Authors' compilation from WIOD data, 2016 release.

Furthermore Switzerland, the Netherlands and some of the new European partners (mainly Poland and Czechia) are increasing their participation in the value chain of the main European producers. Meanwhile, we also observe a decline in the participationof the Irish, Swedish and Finnish industries. The adverse economic framework has thus accelerated the trend towards the reconfiguration of offshoring processesin the European regional scenario.Table 12 shows the changes in the distribution across European economies of the value added for products completed in France, Germany and the United Kingdom. In the case of products completed in the German industry, value added grows in Poland, the Netherlands and Czechia at the expense of the Southern European partners.

Table 12. Computer, electronic and optical products completed in France, Germany and the United Kingdom: Changes in the distribution of the valueadded across European economies, 2000–14 (percentages)

	France	Germany	United Kingdom
Austria	0.04	0.01	0.00
Belgium	–0.13	–0.15	–0.03
Czechia	0.17	0.15	0.18
Finland	–0.11	–0.11	–0.16
Hungary	0.06	0.05	0.09
Ireland	–0.19	–0.09	–0.27
Italy	0.03	–0.20	0.00
Netherlands	0.26	0.26	0.54
Poland	0.32	0.36	0.33
Portugal	0.07	–0.01	0.02
Spain	0.24	–0.07	0.03
Sweden	–0.10	–0.05	–0.35
Switzerland	0.21	0.03	0.13

Source: Authors' compilation from WIOD data, 2016 release.

4.2. Analysis of production technology

An analysis of production technology in the electronics industry during the 2000–14 period reveals changes in the functional and geographical distribution of value. The information has been calculated from WIODfigures by obtaining the contribution of each productive factor (X_{ij}^{a}) for each industry*i*, country *j* and year *a*, using the following expression:

$$X_{ij}^{a} = \frac{C_{ij}^{a}}{C_{i}^{a}} \tag{5}$$

where *C* is the value contributed to the global electronics industry byeach of the inputs produced in each country. From the perspective of the value added incorporated in final production, changes in production technology may also be the result of developmentsin the use of each input.

Table 13 displays the variations inthe production chain of the global electronics industry in the main resource-based branchesof activity between 2000 and 2014. We observe that the computer and electronic equipment industry increasingly depends on the intermediate products elaborated within the industry. In this regard, table 14 shows the progress of the Chinese industry in extracting a larger share of the value created to the detriment of itsJapanese and UScounterparts. A growing share of the value generated in the electronics global value chain derives from the use of electronic components, electrical equipment and metal products manufactured in China.

Table 13. Changes in the contribution of the main resource-based sectors of activity to the valueaddedof computer, electronic and optical products, 2000–14 (percentages)

Computer, electronic and optical products	6.94
Manufacture of electrical equipment	0.69
Financial services	0.68
Manufacture of basic metals	0.63
Manufacture of fabricated metal products	–0.99
Legal and accounting activities	–1.26
Administrative and support service activities	–1.30

Source: Authors' compilation from WIOD data, 2016 release.

Lastly, in order to analyse how changes in production technology are affecting the factorial distribution of value, we also use the database containing the WIOD Socio-Economic Accounts (2014 release), which provide information about the different levels of labour qualification duringthe period 1995–2009.

In particular, we analyse changes in the evolution of employment, the composition of skills and the distribution of income. We find an intense redistribution of employment in favour of China and other emerging economies, together witha process of upskilling in the industry. The relative share of high-skilled workers has grown in leading and emerging economies even when the level of employment has fallen (figure 1).

Table 14. Changes in the contributions to the value added of computer, electronic and optical products, 2000–14 (percentages)

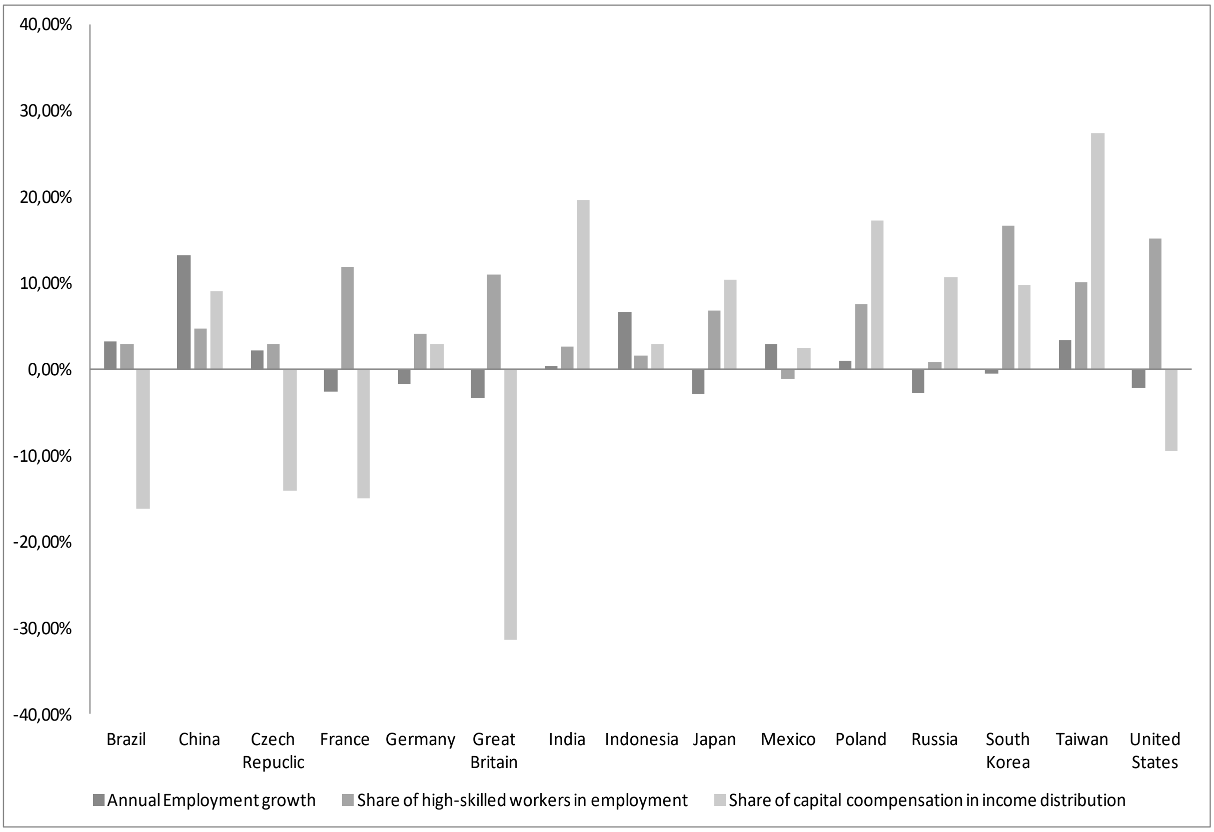
Industry branch	Country	Weight variation
Computer, electronic and optical products	China	21.22
Manufacture of electrical equipment	China	2.25
Manufacture of basic metals	China	1.12
Computer, electronic and optical products	Taiwan, China	0.99
Manufacture of rubber and plastic products	China	0.97
Manufacture of chemicals and chemical products	China	0.95
Financial services	China	0.94
Manufacture of machinery and equipment	China	0.65
Computer, electronic and optical products	Republic of Korea	0.55
Scientific research and development	China	0.46
Manufacture of electrical equipment	United States	–0.56
Computer, electronic and optical products	United Kingdom	–0.58
Computer, electronic and optical products	Mexico	–0.76
Administrative and support service activities	United States	–0.76
Manufacture of electrical equipment	Japan	–0.92
Manufacture of fabricated metal products	United States	–0.97
Legal and accounting activities	United States	–1.67
Computer, electronic and optical products	Japan	–6.81
Computer, electronic and optical products	United States	–11.08

Source: Authors' compilation from WIOD data, 2016 release.

Our findings confirm that, in most emerging economies, the offshoring of assembly activities hasnot necessarily resultedin a fall indomestic jobs and a substitution effect, butrather in a change of position along the value chain that would result in a rising demand forhigh-skilled and high-paying jobs (Lee and Jung 2015).

In particular, we identify agreaterdemand for more skill-intensive tasks among the Asian economies (table 15). Skills measured by educational attainment are obviously connected with functional upgrading,that is, the development of new functions in the value chain to increase the skill content and the contribution of high-skilled workers. This evolution could be the consequence of an increasing specialization of China in higher value-added activities (Chen et al. 2018). Table 14 shows the increasing participation of Chinese firms in the supply of financial and research and development services to the industry. As Hollweg (2019) states, a rising use of skill-intensive inputs increases the complexity of global supply chains and the skill-biased nature of trade.

Figure 1.Evolution of employment, skillpremium and income distribution: Electronics industry, 1995–2009 (percentages)



Source: Authors' compilation based on data from the WIOD Input-Output Tables (2016 release) and theSocio-Economic Accounts(2014 release).

Table 15. Changes in the hours worked, according to the skills of persons engaged, 1995–2009(millions)

	Highskills	Mediumskills	Lowskills
Brazil	72798	379792	–90383
China	3393731	14677616	13106019
Czechia	14067	70978	–6377
Germany	–26662	–241553	–153874
France	11046	–109129	–159886
United Kingdom	–13129	–140473	–256255
Indonesia	10196	74674	105106
India	99957	–108,96	133884
Japan	–168813	–1006453	–420415
Republic of Korea	314961	–137121	–318562

	Highskills	Mediumskills	Lowskills
Mexico	30567	740502	–131769
Poland	29621	14797	–3461
Russian Federation	–56378	–848105	–144778
Taiwan, China	254435	353535	2313
United States	62764	–1466474	–271649
Sample-15	4029161	12253626	11389913

Source: Authors' compilation based on data from the WIOD Input-Output Tables (2016 release) and theSocio-Economic Accounts(2014 release).

The rise of regional demand would also be likely tohave an employment-enhancing effect (De Vries et al. 2016). However, each Asian economy seems to follow a different path. China appears to undergoa substantial upgrading process, reflected in the relative growth of high-skilled labour, whereas the industry has also created job opportunities for their large low-skilled workforce. The process of upskilling manifests itself more clearly in theRepublic of Korea or in Taiwan (China); meanwhile, functional upgrading in Indonesia seems to move at a slower pace.

The emerging economies in LatinAmerica appear to facea number ofconstraints in following this path. In terms of creating valueadded, the local economy is still benefiting more from purely domestic production for the internal market than from exports (Castillo andSzirmai 2016). As long as the local industry has much stronger linkages with the rest of the domestic economy, the scope forexporting companies to bring aboutfunctional upgrading and a major growth of high-skilled labour remains limited.

This skill-biased process is also found in the leading economies in this industry,alongside the substitution of human labour by capital, with distributional consequences. In the case of Germany or Japan, the process has improved the participation of capital gains in income distribution, while the share of labour compensation has been preserved in the United States, France andthe United Kingdom, albeitat the expense of the destruction of thousands of low- and medium-skilled jobs and a growing segmentation of employment opportunities.

However, upskilling isnot necessarily tantamount tofunctional upgrading, which would imply that it is integrated into the job or tasks that a person is carrying out and the quality of education. Thus, obtaining results on functional specialization alonecouldcomplement more qualitative future research.

Furthermore, these changes in the geographical distribution of jobs do not imply a general improvement in the share of labour compensation. A greaterparticipation of high-skilled workers has probably prompted aconversion of productivity gains in wage increasesin some of the major producers. However, in most countries, the transformation of the electronic industry has sharply enhanced the capital share in the distribution of income despite the growth in employment. Upskilling opportunities, if any, seem to be scarcer for low-skilled workers.

Although the evidence of upskilling and a greater relative demand for high-skilled labour can reflect a process of economic and functional upgrading, they do not necessarily promote social upgrading and the enhancement of employment quality in the industry. The case of Foxconn in Asia and Eastern Europe provides evidence of this shortfall (Raj-Reichert 2015; Chan, Ngai and Selden 2015; Pun et al. 2016). As Raj-Reichert (2013) describes, although self-regulatory private standards and codes of conduct are recently trying to improve the health and safety conditions of workers in this global value chain, production-line workers continue to suffer from poor working conditions.

The recent changes in the distribution of power relationships in the industry could also be behindthe shortage of social upgrading. On the one hand, the increasing dependency of brands on contract manufacturers does not necessarily improve labour conditions along the value chain. In fact, there is a wide variation in the composition of the labour force and the methods of managing this labour from both a social and legal perspective. Each node in this global network seems to be deeply rooted within the social and institutional characteristics of each location, allowing lead companies to use them to ensureconflict-free management, and giving risetogrowing segmentation in salaries and labour regulation (Sacchetto and Andrijasevic 2015 and2016). This results in a surge of management dualism and discrepancies among workers as regards salaries, social benefits and employment security (Smith and Zheng 2016).

On the other hand, the upskilling of suppliers located in the main production hubs could stimulate their functional upgrading into the value chain. However, power asymmetries cannot be ignored here either, because the value captured bythese global contract manufacturers is still extremely small compared to the gains of the brand firms and other high-end component suppliers in Japan, the Republic of Korea or Taiwan (China), which also have strong research and development capabilities. Narrow margins and rapidly changing demand requirements are likely tohamper their ability to improve the labour conditions of their workers (Gereffi and Lee 2016).

5. Mapping the electronics industry trade between countries

Ouranalysis is completed by constructing a network that can graphically show both the proximity between the countries with high trade levels and the degree of activity created in the country of origin. To this end, we define an index using the matrix of coefficients of the intermediate inputs obtained directly from the corresponding global input–output table.

For year a and countries $h$and j ($h\neq j$), the index of trade intensity (ITI) between the countries induced by industry$i$is defined as follows:

$$ITI_{h,j,a} = \sum_{k=1}^{S} M_a(l_k^j, l_i^h) + \sum_{k=1}^{S} M_a(l_k^h, l_i^j) \qquad (6)$$

where $M_a(l_k^j, l_i^h)$ represents the value of intermediate inputs inyear *a* placed in the *k*-th row of country *j* and the *s*-th column of country *h* in the matrix of coefficients, and $M_a(l_k^h, l_i^j)$ the value placed in the *k*-th row of country *h* and the *s*-th column of country *j*. This index is symmetric:[3]

$$ITI_{h,j,a} = ITI_{j,h,a} \tag{7}$$

Table 16 shows the 50 highest values for each year, representing around 5 per centof the total numberof relationships. The displayed data reveal a significant rise in the ITI among China, the Republic of Korea, Taiwan (China) and Japan. This networked interaction not only grows faster than the connections between NorthAmerican economies or within the European Union, but it also spreads across third economies, not detailed in the WIOD matrix.

In addition, we focus on the case *h* = *j*, which corresponds to the degree of activity, generated by industry*i*in country *h*, and is defined as follows:

$$ITI_{h,h,a} = \sum_{k=1}^{S} M_a(l_k^h, l_i^h) \tag{8}$$

Using these indices, we can then apply an edge-weighted spring-embedded algorithm to represent the complexity of the relationships between countriesgraphically in a networked map (Ferrarini 2013). This algorithm is founded on a directed system of forces where network nodes (that is, countries) are compared to electrons that repel each other, and where the connection between each pair ofcountries *h* and *j* (in our case, measured with the $ITI_{h,j}$index) is treated like a rope attached to both of them (Kamada and Kawai 1989). The layout algorithm places the positions of the nodes ona two-dimensional map in such a way that the sum of forces in the network are minimized.The algorithm is implemented using Cytoscape.[4] Although it is

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[3] From the data for the 43 countries and the "Rest of the world", we consider the 946 possible interactions between them.

[4] For more information about this software, see https://cytoscape.org/.

mainly used in the field of molecular biology and genomics, this software has also been employed in social sciences (see, for example, Hidalgo et al. 2007; Ferrarini 2013).

Table 16. Highest ITI values for the computer, electronics and optical products industry per year(millions of US$)

	Year 2000			Year 2007			Year 2014	
Country *h*	Country *j*	ITI*hj*	Country *h*	Country *j*	ITI*hj*	Country *h*	Country *j*	ITI*hj*
ROW	USA	31498.87	ROW	CHN	104512.48	ROW	CHN	164378.65
ROW	JPN	22992.03	TWN	CHN	32670.13	KOR	CHN	57751.87
ROW	TWN	21596.70	ROW	TWN	28727.98	TWN	CHN	52763.65
USA	MEX	21126.87	ROW	JPN	26940.22	ROW	TWN	38581.58
ROW	CHN	16712.66	ROW	USA	26230.73	ROW	KOR	33885.45
USA	JPN	11152.38	KOR	CHN	25933.86	ROW	JPN	26819.23
USA	KOR	10865.92	JPN	CHN	22224.72	ROW	USA	24848.84
ROW	KOR	10865.32	ROW	KOR	21170.35	JPN	CHN	23757.58
TWN	JPN	10220.21	USA	MEX	19505.07	USA	MEX	18255.71
USA	CAN	9716.27	ROW	DEU	13354.22	TWN	JPN	13028.72
USA	TWN	9681.86	TWN	JPN	12368.51	KOR	JPN	11547.54
KOR	JPN	9463.31	KOR	JPN	10343.83	ROW	DEU	11223.33
ROW	DEU	7369.66	USA	CHN	9747.38	TWN	KOR	10903.92
ROW	GBR	7004.11	TWN	KOR	9136.54	USA	CHN	10806.22
TWN	KOR	5629.22	DEU	CHN	6696.94	ROW	NLD	10501.52
JPN	CHN	4600.00	ROW	GBR	6369.20	ROW	MEX	7537.11
ROW	FRA	4044.64	ROW	IRL	6323.31	MEX	CHN	7068.99
USA	DEU	3836.96	USA	CAN	6112.32	ROW	CHE	6420.71
USA	GBR	3619.26	USA	KOR	5776.30	DEU	CHN	6403.74
TWN	CHN	3477.19	ROW	FRA	5696.37	USA	KOR	6007.43
USA	IRL	3331.57	USA	JPN	5313.13	ROW	FRA	5011.63
KOR	CHN	3253.90	USA	TWN	5199.58	ROW	GBR	4808.66
FRA	DEU	3038.76	MEX	CHN	4855.43	ROW	RUS	4594.06
IRL	GBR	2916.36	ROW	MEX	4699.00	ROW	IDN	4512.49
ROW	IRL	2879.95	IRL	GBR	4416.08	USA	CAN	4494.60
GBR	DEU	2564.21	ROW	IND	4298.79	NLD	CHN	4162.17
USA	CHN	2563.84	USA	DEU	4077.12	ROW	IND	3823.16
ROW	MEX	2348.66	USA	IRL	3860.69	ROW	IRL	3696.01
JPN	DEU	2094.38	FRA	DEU	3740.80	USA	NLD	3647.31
MEX	JPN	1959.26	MEX	KOR	3703.10	USA	TWN	3451.23
USA	FRA	1912.31	ROW	CHE	3578.87	NLD	DEU	3339.66
TWN	DEU	1881.28	HUN	DEU	3555.90	USA	JPN	3302.06
GBR	FRA	1837.12	ROW	ITA	3449.08	ROW	BRA	3079.79
ROW	CAN	1826.54	ROW	HUN	3233.70	MEX	KOR	3013.97
ROW	ITA	1752.64	MEX	JPN	3208.94	DEU	CHE	2918.36
ITA	DEU	1732.03	DEU	CHE	3102.57	CHN	BRA	2706.26

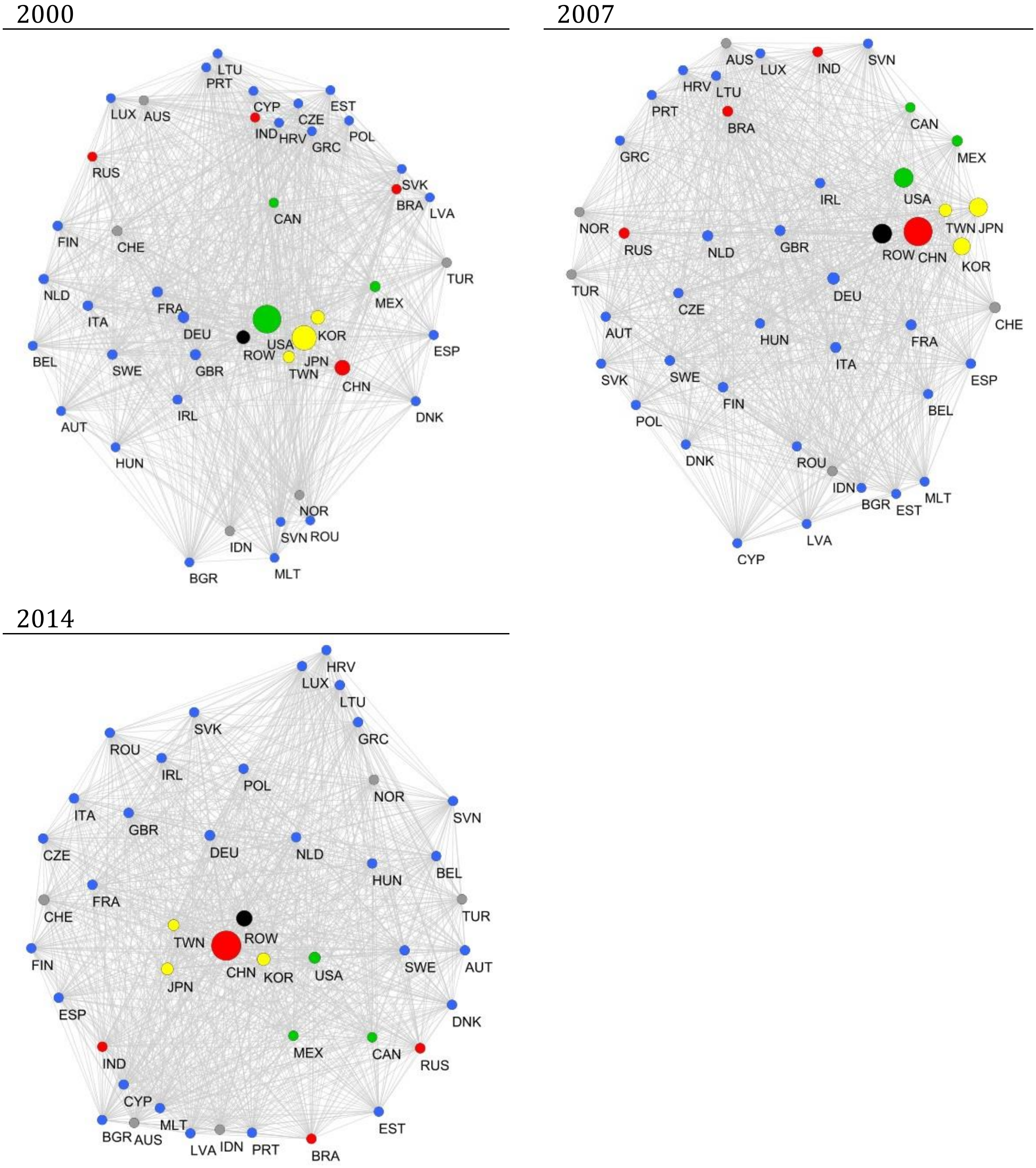
	Year 2000			Year 2007			Year 2014	
Country *h*	Country *j*	ITI*hj*	Country *h*	Country *j*	ITI*hj*	Country *h*	Country *j*	ITI*hj*
ITA	FRA	1641.91	IRL	CHN	3080.95	KOR	BRA	2683.52
ROW	CHE	1620.62	ROW	RUS	2945.32	ROW	CAN	2651.82
USA	BRA	1545.50	ROW	NLD	2917.15	FRA	DEU	2607.41
DEU	CHE	1532.89	GBR	DEU	2849.04	KOR	DEU	2572.09
KOR	DEU	1385.02	ITA	DEU	2800.97	DEU	CZE	2562.14
DEU	AUT	1306.17	DEU	CZE	2790.48	ROW	ITA	2551.32
KOR	GBR	1251.35	ROW	CAN	2655.54	USA	DEU	2505.36
HUN	DEU	1238.55	JPN	DEU	2642.88	ITA	DEU	2458.60
ROW	SWE	1238.20	KOR	DEU	2540.45	HUN	DEU	2435.68
JPN	GBR	1164.60	ROW	IDN	2425.82	CZE	CHN	2364.81
USA	ITA	1138.00	DEU	AUT	2415.68	GBR	CHN	2265.45
SWE	GBR	1104.14	TWN	DEU	2243.76	ROW	TUR	2234.65
MEX	KOR	1102.24	NLD	DEU	2221.68	GBR	DEU	2186.59
USA	SWE	1100.06	ROW	SWE	2161.13	ROW	SWE	2167.16

Note: Country names indicated using ISO 3166-1 alpha-3 code.

Source: Authors' compilation based on data from the WIOD Input-Output Tables (2016 release) and theSocio-Economic Accounts(2014 release).

In figure 2, each country is represented by a sphere. The dimension of each sphere corresponds to the relative value of the domestic index $ITI_{h,h}$. The maps help to visualise the evolution of interactions, the growing centrality of the Chinese industry and the changes in relative position of the main producing economies in relation to the new reference nodes.

Figure 2. Evolution of the networked map of the electronics industry



Notes: Country names indicated using ISO 3166-1 alpha-3 code.

Source: Authors' compilation based on data from the WIOD Input-Output Tables (2016 release) and theSocio-Economic Accounts(2014 release).

6. Conclusions

Through the analysis of WIOD data for the period 2000–14, we have describethe way in whichproductive fragmentation and the Great Recession have deeply reconfigured the international distribution of value added in the electronics industry. While the offshoring process was very intense during the upward phase of production from 2000 to 2007, the data suggest that the economic downturnresulting from the global financial crisis of 2007–08 has forced most of the leading actors in the industry to reduce their activity, whileretaining most of the value in their domestic industries. This finding would confirm the downturn of complex global value chains, also in the electronics industry (World Bank 2017).

This evolution takes place in the context of an intense restructuring of the industry. The analysis of changes in the regional contribution to the global value chain confirms that the epicentre of the transformation is located in the East Asian economies. The participation of the Chinese industry rose significantly during the economic deceleration and the adjustment of production. The whole Asian hub has emerged as the main source of value generation and it has gained size and influence by reinforcing itsregional ties and byexpanding production links with LatinAmerican and EasternEuropean economies.

This extensive restructuring has also induced significant changes in the labour market and the distribution of income. An intense redistribution of employment is detected in favour of China and other emerging economies. Our findings suggest that the progress of the Chinese electronics industry in extracting a larger share of globalvalue derives from the increasing use of electronic components, electrical equipment and metal products manufactured domestically.

The labour requirements and the skill composition of the workforce have also changed in the electronics industry, revealing a perceptible process of upskilling throughout the whole network. As functional upgrading is closely connected with the improvement in the use of technology, knowledge and skills, the growing contribution of emerging economies could be the consequence of their engagement in new and more complex activities within the value chain.

Significantly, the relative share of high-skilled workers has grown in leading and emerging economies even when employment levels have fallen. However, a rising demand for more skill-intensive tasks does not necessarily imply better working conditions. The skill-biased process in leading economies has essentially been based on automation and the destruction of low- and medium-skilled jobs. This growing segmentation of employment meansthat only a handful of countries are able to improve the share of labour compensation in income.

Despite the significant growth of employment in SouthEast Asian industries, capital incomes have gained ground in the distribution of income. The pressures to reduce costs and increase flexibility couldlead to management dualism in relation to employment conditions. If that were the case, outsourcing mightbe accompanied by the use ofirregular workers and casual contracts to respond quickly to changes in the market, whereby any upskilling would not lead to social upgrading. The need to promote cross-border intervention to exercise more power and control over labour governance seems to be crucial in order to transform upskilling and functional upgrading opportunities into animprovement in the rights and entitlements of workers and the quality of employment.

In concluding, we consider it necessary to address two important limitations of this study. First, upskilling is a complexprocess that is not fully covered here and which would requirea complementary analysis ofthe evolution of salaries according to the skill content of jobs. Second, it would be wrong to assume that labour market structure and performance are only affected by technological developments or the business cycle. This articlehas not contemplated the latent influence of local policies and institutions on the development of the value chain.We leave this task to future research.

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