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ARTICLE

The role of ICTs in intersectoral relationships between industry and services

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ABSTRACT

For decades, information and communication technologies (ICTs) have been incorporated into innovations and promoting great transformations in the world economy. This work analyzes the intersectoral relations between industrial activities, ICT and services in the main economies of the world to understand the role that ICT plays in the economy, the relationship between companies and the changes that occurred in 2000, 2007 and 2014. We use the analysis of two indicators: (i) value added, to evaluate the dimension of said activities and (ii) total density, to evaluate the links between them. The results show that, in more advanced economies, the indicators between ICTs and other activities are denser and are directly related to the development of more sophisticated services, located in the stages of the value chains that generate a larger share of the value added.

KEYWORDS: Information and communication technologies; Industry; Services; Intersectoral relations

1. Introduction

Information and communication technologies (ICTs) provide significant transformations in the economy. They were fundamental for the emergence of global value chains (GVCs) in the 20th century and continue to influence these chains through new technological developments such as the Internet of Things, cloud computing, big data, among others (NORDAS; KIM, 2013; WORLD TRADE ORGANIZATION, 2019). According to the Organisation for Economic Co-Operation and Development (2017), the ICTs industry is the backbone of today's society and what we call the digital economy. Without them, it is nearly impossible entering most value chains (WORLD TRADE ORGANIZATION, 2019).

This work aims to contribute to the literature on the interdependence between the manufacturing and services sectors (ANDREONI; GREGORY, 2013; ANDREONI; CHANG; LABRUNIE, 2021), specifically how ICTs play a relevant role in the productive structure of countries. The discussion about complementarity often starts on deindustrialization and the consequent increase of the services sector's share in the economic growth of countries.

According to Nassif and Morceiro (2022), natural deindustrialization is a phenomenon that follows an inverted U-shaped curve; that is, as a country's per capita income increases, the industrial share of GDP in the total GDP increases up to a certain level. Beyond this level, the industry share begins to decline, while the services sector spearheads economic growth instead. This is considered standard deindustrialization, being generally limited to developed countries. Developing countries might be affected by premature deindustrialization: before developing the industrial sector, the services sector begins to increase its share of their GDP growth, leaving not only a poorly developed industrial structure but also low manufacturing capacity in these economies.

According to Andreoni and Gregory (2013), the theoretical explanation for the increase in the participation of services during economic growth is related to factors on the demand side. That is, as income increases,

families spend more on services and less on manufactured goods; this applies to both developed and developing countries. Developed countries, such as Australia, Canada, and the United States, are used as examples of how productivity and job creation can be sustained through the services sector (ANDREONI; GREGORY, 2013). In developing countries, the Indian experience is used to show a new pattern of structural change supported by services-led growth. However, these explanations ["service-oriented view", cf. Andreoni and Gregory (2013)] pay little attention to the fact that developing countries, due to premature deindustrialization, lose capabilities that would allow them to address demand-related changes.

Andreoni and Gregory (2013) analyzed the symbiotic interdependencies between manufacturing and services. According to them, the ability of a country to develop its service sector depends on the structural and technological composition of the manufacturing sector. That is, services differ from each other in terms of complexity and technological intensity. Therefore, having a sophisticated industrial base is relevant. Similarly, Andreoni, Chang and Labrunie (2021) emphasize that new technologies related to ICTs are capable of generating productivity increases and value aggregation gains, but manufacturing remains the primary learning ground for industrialization.

In light of this discussion, the aim of this work is to analyze and quantify the interlinkages between industrial and service activities to demonstrate their mutual dependence. The objective is to compare the evolution of the links between the service sector and manufacturing across selected countries and periods. The intention is not to discuss whether more sophisticated services linked to ICTs lead to higher productivity or whether they depend on a more developed manufacturing sector. This is a theme that is already addressed in the literature. Our aim is to emphasize the mutual dependence between higher technological content services and industry.

To achieve this, we analyze the intersectoral relationships between the two activities in the world's major economies for the years 2000, 2007 and 2014, seeking to identify the main links between them.

We adopt Szapiro (2012)'s hypothesis regarding the relevance of the ICTs sector for national economic development: the more advanced a country's economic structure, the stronger its links with the ICTs sector will be. In addition, ICTs drive the development of more sophisticated services, which in turn imply stages in the value chains that create a greater share of value added in the production of a good (CASTELLACCI, 2008; BALDWIN, 2013); that is, they create better jobs with better salaries.

This work is divided into five sections, in addition to this introduction. Section 1 lays down the ICT complex, presenting the different activities, differences in terms of value added and skills demanded. Section 2 details the methodological procedures and metrics employed. Section 3 evaluates the value added of the selected countries and activities. Section 4 evaluates the network density indicator. Finally, the conclusion presents the final considerations on the results obtained.

2. The role of services in GVCs: the importance of ICTs

It is widespread in the literature that the second half of the twentieth century was accompanied by strong changes in the global productive structure, thanks to the diffusion of ICTs and globalization. It caused deep impacts on the social and economic landscape. This process intensified in the 1970s and 1980s. More and more the relationship between industry and services became prominent to economic development. The services sector had become the most relevant one in most economies in terms of value added and employment, according to Confederação Nacional da Indústria (2023).

A series of radical innovations were gradually introduced into the economy, initially with the semiconductor industry and, later, with the software and telecommunications sectors, which spread rapidly since the 1990s. As a result, new services based entirely on information and

communication have emerged, as well as improvements in existing ones (CASTELLACCI, 2008).

Influenced by these events, Castellacci (2008) highlights that the service sector has experienced rapid growth, being currently responsible for the largest value added, employment and trade shares in most countries. Provided by more advanced service activities as a result of ICTs emergence and diffusion, these new sectorial dynamics show that there has been a growing interdependence and a greater exchange between industry and services.

Low (2013) points out this integration between services and industry as a trait of value chains in the sense that services and industry are interdependent in the process from product design to support for the final consumer. In this context, services have often been seen as the "glue" that unites value chains, ensuring that they work smoothly. In addition, services are part of many production processes that make them a marketable input (LOW, 2013).

In this way, the globalization and the evolution of ICTs in the 1970s and the 1980s redefined and gave a new meaning to the service sector, which has become fundamental and complementary to the industry. Since services have become a highly dynamic and sophisticated sector, they have been influenced not only by changes in preferences in final demand but also by changes in the firm's internal organization, structural changes in international trade patterns and technological advances (FORNARI; GOMES; HIRATUKA, 2017; CASTELLACCI, 2008; KON, 2007; GREENHALGH; GREGORY, 2001).

Although, on one hand, services account for approximately two-thirds of GDP and less than a quarter of total trade in goods in many developed countries, on the other, they contribute more than 50% to the value added formation in many of these countries (ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, 2013). This shows how services contribute significantly to manufactured goods production processes (ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, 2013).

The Organisation for Economic Co-Operation and Development (2017) report points out that the main technological advances and innovations have always been accompanied by extensive transformations in the labor market in the sense that the diffusion of digital technologies increases the demand for jobs with "nonroutine tasks" (usually related to complex tasks performed by qualified labor) at the expense of employment with "routine tasks" (less complex tasks, easy to standardize, normally performed by less qualified labor).

In the midst of these changes, services began to have an even more heterogeneous and diverse character. Some authors proposed taxonomies to classify the various types of existing services. Among the various aspects that these typologies incorporate, our study has a special interest in the capacity of services to absorb and create innovation, their relationship with other sectors of the economy, in particular, how they integrate with industry and their relevance to GVCs. In short, its relevance in the economic system.

The taxonomy proposed by Castellacci (2008) divides services into three groups: the first is knowledge-intensive services (or with high technological content), which gives support to the knowledge base of most innovations from all other sectors. They are the suppliers of specialized knowledge and technical solutions such as software, R&D, engineering and consultancy. The second group is supporting infrastructure services, which represent physical infrastructure activities such as logistics and network infrastructure services such as finance and telecommunications. The third group includes personal services, which are services with low technological content that acquire technology and knowledge from other sectors. According to Castellacci, knowledge-intensive services and network infrastructure services are more dynamic than the others because they are closer to the ICTs paradigm.

There are other taxonomies. Confederação Nacional da Indústria (2023), for example, divides the service sector into two categories: cost-related services and value added services. The first includes functions that affect production costs such as logistics and transport,

storage, repairs and maintenance, credit and financial services, travel, accommodation, food, and distribution, among others. In the second category, there are the functions that contribute to add value, differentiate and customize products (design, engineering, consulting, software, specialized technical services, sophisticated IT services, marketing, among others) and, therefore, raise their market price, increase labor productivity and return on capital.

The Confederação Nacional da Indústria (2023) classification also brings a hierarchical organization of global production: developed countries are associated with value added services, where knowledge and innovation are intimately linked. Developing countries, however, are associated with cost-related services, having sectors with less technological sophistication and less innovation.

Among the various types of services that exist, as seen above, certain categories contribute positively to the competitiveness of the industry and to better performance in GVCs. More advanced or more sophisticated services are those with greater incorporation of knowledge. This category of services is, therefore, the one where most of the value added generated in the value chain is found (CASTELLACCI, 2008; BALDWIN, 2013; CONFEDERAÇÃO NACIONAL DA INDÚSTRIA, 2023).

The growing integration between services and industry is a feature that was favored by the process of globalization and the advancement of ICT. According to Castellacci (2008), this integration occurs as the evolution of the industry drives the development of advanced services, which, in turn, contribute to the growth of the industry. This relationship favors the competitiveness of the firm both locally and internationally and thus positively affects industrial performance in global value chains. This phenomenon has altered the ways in which companies enter and remain in GVCs since more advanced services are essential, as they contribute to increasing industrial productivity (CONFEDERAÇÃO NACIONAL DA INDÚSTRIA, 2023).

In this context, the Organisation for Economic Co-Operation and Development (2017) highlights the relevance of ICT-services for international trade in an increasingly digital world, together with

financial services and distribution and logistics services, as they help to increase productivity, trade and competitiveness across the economy, both in manufacturing and in the services sector itself.

Diegues and Roselino (2019) argue that ICTs have a focal role in the development of nations and companies in the Industry 4.0 era. The third industrial revolution brought the evolution of the services sector in which technology-intensive activities emerged, since many of these services are related to ICT. Among them, information and telecommunication services are highlighted by the authors, as they argue that these services are the essential infrastructure for the development of economies in this new paradigm.

The main factor in these changes was the increasing digitalization of the economy. it led to a technological convergence starting in the 1990s. It changed the limits of ICTs, enabling the integration of different markets and sectors. This process occurs when structural changes combine previously distinct markets. With regard to ICTs, it fostered convergence between the semiconductor industries, electronic equipment manufacturing, telecommunications services, software development and content production (ARAUJO; SOUZA, 2014; OLIVEIRA, 2016).

In this sense, for Fransman (2010), ICTs have become an "ecosystem" formed by equipment configured in networks that provide platforms on which internet providers use to provide content and applications. According to the author, it is a dynamic industry that supplies the essential mechanism for economic and social development, both nationally and globally. Szapiro (2012) also argues in the same direction, pointing out that ICTs are responsible for providing the information and communication infrastructure without which economies cannot develop. Therefore, the greater the degree of development of this industry (or ecosystem) in a given country, the greater its potential economic and social development.

The dynamic and evolutionary process of ICT is intrinsically related to the industrial and service activities of the sector itself and has spread throughout the world, influencing structural changes toward an industry increasingly specialized in the development of services,

especially services of high technological content (SZAPIRO, 2012). Thus, Araújo and Souza (2014, p. 9) draw attention to the fact that the effects of ICT on the economy and society are due not only to the significant volume of investments in R&D but also to the transversal effects on the productivity of other economic activities.

In this way, more than tools that facilitate processes and reduce transaction costs, ICTs lead to the integration of technologies and organizations, structures and firms' internal processes and support for learning, which consequently leads to knowledge creation (reinforcing the important role of information). In this way, ICTs also become the activity that induces and assists in innovative production processes, and forms of internal or external business organization in the most diverse areas of economic activity (TIGRE; PINHEIRO, 2019).

From this review, the positive cross-cutting economic effects of ICTs are clear. Next, we will show the methodological procedures to evaluate the intersectoral relations ICT has in the economic structures that were analyzed.

3. Methodological procedures

We used two indicators to analyze intersectoral relations between industrial, service and ICT activities: value added and network density. The data used are from the input-output tables from the World Input-Output Database (2023). The database covers 43 countries and 56 sectors classified according to the International Standard Industrial Classification (ISIC rev. 4). We used the tables for the years 2000, 2007 and 2014 (which are the most recent series and with compatible statistics). To avoid excessive information, three years were selected among those available: the oldest, the one before the 2008 crisis and the most recent one. Monetary values were deflated by the OECD Producer Price Index, for 2010.

In line with the scope of our work, the intersectoral relations analysis is applied to the most relevant economies in ICTs, selected

according to the value added from the input-product tables of World Input-Output Database (2023) – greater share of ICT value added in relation to the worldwide value added. According to these criteria, Germany, China, South Korea, United States, France, Great Britain, India, Japan and Taiwan were selected. Together, these countries were responsible for approximately 68% of ICT value added in 2014. In addition to the countries mentioned, this study includes Brazil in the sample under evaluation. According to the adopted criterion, Brazil appears in 12th place.

Among the sectors (56) defined by WIOD, we considered six aggregates: (1) ICT considered in three segments, i) ICT-industry[1], ii) ICT-telecommunications and iii) ICT-services; (2) industry without ICT-industry; (3) services (i) of low technological intensity and (ii) of medium/high technological intensity. Thus, the aggregation of services according to technological content follows an attempt to combine the classifications proposed by Castellacci (2008) and Confederação Nacional da Indústria (2023).

We carry out our research in two stages. In the first one, a descriptive analysis of the value added is made (taken as a proxy for the productive structures). In the second one, the total and partial density indicator is calculated using the network analysis method. This indicator makes it possible to analyze and compare domestic structures and different economies based on intersectoral relations. Such a method allows us to identify the differences in the productive structures, either by the indication of diversification/specialization in certain activities (value added) or through the densities of these activities, highlighting, therefore, the most relevant links between the sectors (FORNARI; GOMES; HIRATUKA, 2017). For the application of this method, it was decided to limit the number of intersectoral relations, considering only intermediate flows starting at US$100 million, eliminating less

[1] For the purpose of consistency, the term "ICT-industry" was used instead of "ICT-manufacturing" here. It should be noted that the terms "manufacturing" and "industry" are being used interchangeably in this context.

relevant flows and facilitating the result analysis. This filter represents less than 1% of intermediate flows in the US and China, for example.

Density is measured by the ratio $m/(n.(n-1))$, where n is the number of nodes (sectors) and m is the number of links between nodes in the network (GOYAL, 2007). The value of the density of a network varies in the range [0, 1], and the closer the density is to 1, the greater the number of connections between sectors of the economy. Total density, relative to the links in a network, can also be understood as the contribution (sum of the number of links) of each node in a network, that is, the sum of the "partial" densities, each taken in proportion of possible links in the network.

Due to our interest in the relations between industrial, services and ICT activities, the partial density is calculated for each pair of aggregates (k, j), with $k \neq j = i$ (industry without ICT-industry), *ls* (low technology services), *hs* (medium/high technology services), *ICTi* (ICT-industry), *ICTt* (ICT-telecommunications) and *ICTs* (ICT-services)—through the sum of the densities of all sectors included in it. Under these conditions, total density can be described as follows:

$$\begin{aligned} Total\ density = & \frac{M(ICTi,i)}{n(n-1)} + \frac{M(ICTi,ls)}{n(n-1)} + \frac{M(ICTi,hs)}{n(n-1)} + \\ & \frac{M(ICTt,i)}{n(n-1)} + \frac{M(ICTt,ls)}{n(n-1)} + \frac{M(ICTt,\ hs)}{n(n-1)} + \frac{M(ICTs,\ i)}{n(n-1)} + \\ & \frac{M(ICTs,ls)}{n(n-1)} + \frac{M(ICTs,hs)}{n(n-1)} \end{aligned} \quad (1)$$

where:

n: number of aggregates/sectors;

$\frac{M(k,j)}{n(n-1)}$: Partial density for aggregate (k,j), as defined above.

3.1 ICTs and national structures

Table 1 shows the relative and absolute share in millions of US dollars in value added (VA) of the main ICT producer countries and Brazil, according to the six aggregates we adopted.

3.1.1 Industry and ICT-manufacturing

According to Table 1, in industry (I), which aggregates all branches of manufacturing present in World Input-Output Database (2023), except ICTs (ICT-I), some changes are evident in the analyzed period. The main one to be highlighted is the evolution and consolidation of China as the main industry in the world. In the 2000s, China was already the fourth country among those with the largest share (7%) of industrial value added. In 2007, the Chinese share almost doubled (12.7%), making the country the second main country in this activity. In 2014, the Chinese industrial performance continued, surpassing the US, to become the leading country with 25.2% of the value added share of the industry.

On the other hand, traditional industrial economies remained in leadership positions. Aside from China's entry into the industrial scene, the US, Japan, and Germany remained highly important in manufacturing. Altogether, the four countries accounted for more than 50% of industrial value added since 2000 (57%, 50% and 55% in 2000, 2007 and 2014, respectively).

In addition to China, South Korea and India expanded their share in industrial value added. In 2014, they both surpassed France and Great Britain, becoming the fifth and sixth industrial economy. However, the gap that separates them from the four main countries (China, USA, Japan and Germany) is considerable. In the case of Brazil, as well as Taiwan, those countries have retained similar portions of the industrial value added in recent years, getting closer to developed countries that "lost" relevance (France and Great Britain) on the world stage.

This analysis points to the well-known advance of Asian countries, especially China, toward the strengthening of industrial activities and

TABLE 1
Absolute and relative share of value added in selected countries by sectoral aggregation: 2000, 2007 and 2014*

Country	Industry (I)						Services (LS + HS)						Low technology services (LS)						Medium / High technology services (HS)					
	2000		2007		2014		2000		2007		2014		2000		2007		2014		2000		2007		2014	
	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%
Germany	279,503	7.2	610,465	8.0	804,168	6.5	392,821	5.1	866,691	5.4	1,105,372	4.3	234,185	4.9	531,545	5.3	680,178	4.2	158,635	5.7	335,146	5.6	425,193	4.5
Brazil	66,212	1.7	160,094	2.1	260,664	2.1	123,430	1.6	350,021	2.2	696,978	2.7	80,864	1.7	220,458	2.2	444,535	2.8	42,566	1.5	129,563	2.2	252,443	2.6
China	272,213	7.0	973,060	12.7	3,096,054	25.2	213,417	2.8	794,980	5.0	3,017,628	11.8	157,224	3.3	545,631	5.5	1,903,198	11.9	56,193	2.0	249,349	4.2	1,114,429	11.7
South Korea	87,897	2.3	208,056	2.7	337,173	2.7	104,369	1.4	262,037	1.6	397,452	1.6	64,246	1.3	142,168	1.4	217,110	1.4	40,122	1.4	119,868	2.0	180,342	1.9
USA	1,010,444	25.9	1,510,128	19.7	2,036,714	16.6	2,640,901	34.6	4,409,037	27.6	6,313,067	24.7	1,452,216	30.1	2,326,307	23.3	3,302,934	20.6	1,188,685	42.4	2,082,731	34.8	3,010,133	31.5
France	124,040	3.2	241,333	3.1	266,349	2.2	283,097	3.7	665,757	4.2	877,723	3.4	181,215	3.8	409,671	4.1	525,857	3.3	101,882	3.6	256,087	4.3	351,866	3.7
Great-Britain	144,466	3.7	240,901	3.1	283,068	2.3	348,747	4.6	878,063	5.5	1,028,710	4.0	211,798	4.4	457,530	4.6	539,751	3.4	136,949	4.9	420,533	7.0	488,959	5.1
India	50,932	1.3	161,259	2.1	304,657	2.5	94,118	1.2	313,474	2.0	733,573	2.9	73,530	1.5	245,013	2.5	572,157	3.6	20,588	0.7	68,461	1.1	161,416	1.7
Japan	649,913	16.7	731,297	9.5	830,638	6.8	1,134,255	14.9	1,292,510	8.1	1,490,794	5.8	752,789	15.6	811,532	8.1	975,383	6.1	381,466	13.6	480,978	8.0	515,411	5.4
Taiwan	42,514	1.1	58,653	0.8	85,094	0.7	87,155	1.1	122,195	0.8	183,399	0.7	60,522	1.3	85,582	0.9	130,101	0.8	26,633	1.0	36,614	0.6	53,298	0.6
*World***	*3,899,241*	*100.0*	*7,664,135*	*100.0*	*12,301,834*	*100.0*	*7,630,190*	*100.0*	*15,963,768*	*100.0*	*25,558,843*	*100.0*	*4,826,751*	*100.0*	*9,971,203*	*100.0*	*16,014,156*	*100.0*	*2,803,439*	*100.0*	*5,992,564*	*100.0*	*9,544,687*	*100.0*

Country	ICT (I+T+S)						ICT Industry (ICT-I)						Telecommunications (ICT-T)						ICT services (ICT-S)					
	2000		2007		2014		2000		2007		2014		2000		2007		2014		2000		2007		2014	
	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%	USD	%
Germany	64,435	5.1	150,032	5.9	190,186	4.7	21,558	4.6	47,130	6.1	50,541	4.1	21,866	4.7	44,106	4.4	38,485	2.6	21,011	6.5	58,796	7.8	101,160	7.6
Brazil	15,816	1.3	41,271	1.6	74,529	1.9	2,137	0.5	4,877	0.6	8,648	0.7	7,881	1.7	20,865	2.1	31,707	2.2	5,798	1.8	15,529	2.0	34,174	2.6
China	37,912	3.0	186,129	7.3	593,539	14.7	20,977	4.5	94,325	12.2	291,450	23.5	14,794	3.2	78,555	7.8	232,642	16.0	2,141	0.7	13,249	1.7	69,447	5.2
South Korea	31,513	2.5	75,007	3.0	114,455	2.8	23,200	5.0	57,267	7.4	96,786	7.8	3,421	0.7	7,300	0.7	7,271	0.5	4,892	1.5	10,440	1.4	10,399	0.8
USA	454,246	36.2	707,798	27.9	1,037,060	25.8	171,674	36.8	210,913	27.2	298,273	24.0	178,041	38.4	281,804	28.1	362,706	24.9	104,531	32.3	215,080	28.4	376,080	28.4
France	46,794	3.7	106,496	4.2	117,387	2.9	10,845	2.3	16,409	2.1	15,261	1.2	14,587	3.1	38,942	3.9	35,300	2.4	21,362	6.6	51,145	6.7	66,827	5.0
Great-Britain	59,989	4.8	129,892	5.1	158,485	3.9	13,114	2.8	14,677	1.9	20,854	1.7	22,509	4.9	45,899	4.6	51,215	3.5	24,365	7.5	69,316	9.1	86,416	6.5
India	11,654	0.9	47,898	1.9	115,181	2.9	909	0.2	3,507	0.5	5,678	0.5	5,151	1.1	14,857	1.5	25,773	1.8	5,594	1.7	29,535	3.9	83,730	6.3
Japan	222,328	17.7	238,253	9.4	305,872	7.6	99,399	21.3	98,713	12.7	104,678	8.4	62,999	13.6	66,637	6.6	103,757	7.1	59,930	18.5	72,902	9.6	97,438	7.4
Taiwan	27,473	2.2	55,093	2.2	98,097	2.4	20,261	4.3	45,332	5.8	84,993	6.8	5,505	1.2	6,402	0.6	8,028	0.6	1,707	0.5	3,358	0.4	5,077	0.4
*World***	*1,254,618*	*100.0*	*2,535,796*	*100.0*	*4,024,433*	*100.0*	*466,809*	*100.0*	*775,210*	*100.0*	*1,242,429*	*100.0*	*464,079*	*100.0*	*1,002,447*	*100.0*	*1,456,354*	*100.0*	*323,730*	*100.0*	*758,139*	*100.0*	*1,325,649*	*100.0*

Source: Authors' elaboration based on World Input-Output Database (2023).
*Values in billions of dollars deflated by PPI from OECD. 2010 as base year. **World total considers the sum of the 43 countries included in the WIOD database.

after developed economies transferred these activities to this region. However, these changes are restricted almost exclusively to China and do not extend to other countries.

At the same time, Table 1 shows that the ICT-industry, which refers to the manufacture of computer, electronic and optical products, moves strongly toward the Asian region over the analyzed period. The participation of China, South Korea, and Taiwan is growing but in smaller proportions than those of the other manufacturing sectors. In addition, China, Japan, South Korea and Taiwan accounted for approximately 50% of the VA of all ICT-manufacturing in 2014.

It should be noted that in the 2000s, this industry was concentrated in only two countries, the United States and Japan, which together accounted for almost 60% of the total value added. In 2014, ICT-manufacturing remained very concentrated; however, China took over Japan's place, therefore both countries had approximately 1/4 of the sector's value added.

In relation to the other countries, Germany is the European country with the largest share of value added from that region, while France and Great Britain, as well as Brazil and India, make up the countries with the smallest portions of value added in ICT-manufacturing throughout the period. Except for India, all of these countries have a lower share of global ICT-I value added than other industrial sectors.

Some points are worth mentioning. The United States is the main leader when looking at the ICT segments as a whole, without exception. In addition, the United States has lost much of its share in the value added of Industry (I) and the ICT-industry (ICT-I), approximately -35% between 2000 and 2014, although it still preserves a substantial part of these manufacturers. China, however, increased its participation in both industrial segments, living up to its title of "factory of the world". For industry in general, the Chinese economy has almost ¼ of ICT-manufacturing and has positioned itself closer to the US leadership.

Germany, on the other hand, despite the sharp growth of the Asian region, has maintained its participation in value added after

a small reduction, remaining as one of the main economies of the world in both industrial segments. This seems to be an indication of its adaptive productive structure in an ongoing changing world.

Japan, although losing its leading place in value added in all the analyzed aggregates, has its largest participation in ICT-manufacturing, in 2014 (8.4%). This fact denotes its ICTs' strategic potential, since it has large companies, such as Canon and Ricoh in the area of hardware, equipment and components (ICT-industry), NTT Docomo and KDDI in the area of telecommunications and Softbank Corporation that initially started as a software distribution company and is currently a multinational holding company in the technology industry, among many others. Most of these companies have a greater focus on the Japanese and Asian markets, all of which are among the global leaders in ICT and among those that invest the most in R&D[2].

3.1.2 Medium- and high-technology services

Low-tech services (LS) generally include some nontradable services and those that can be considered supporting production activities, such as repair and maintenance of machinery and equipment, wholesale and retail, terrestrial transport services and postal services. Altogether, even though low technology services require less qualified work, they add important monetary value due to their diversity. For example, in 2014, they exceeded 70% of the high-tech services and 20% of the entire industry sector combined.

It is important to note that China and the US concentrate 1/3 of the global value added in these services, but, with the exception of China, the developed economies (USA, Japan, Germany, France and Great Britain) maintained a higher share of value added every year observed. This suggests that these services are more consolidated in these countries - see Table 1 (LS). In this case, they may demand or reinforce other activities.

[2] For more information see European Commission (2018).

Table 1 also presents the medium/high technology (HS) services, which include services such as research and development (R&D), advertising and market research, engineering and architecture activities, financial services, legal and accounting, consultancy, and management activities, among others. These services are closely related to the industry, requiring their goods to complete their respective services. They can mirror the technological power of countries. As mentioned in section 1, these services are linked to the stages of the value chains that receive different value added shares because they are activities with greater technological content, that is, they incorporate and/or require distinctive skills when compared to the other stages of the value chains.

It is in these activities that the differences between developed countries such as the US, Japan, Germany, Great Britain and France becomes clear, although these shares have decreased over time and reveal some weaknesses of others (Korea, Taiwan and India), even though the relative percentages have slightly increased in the period. Even China, which has considerably increased its share of value added – from approximately 2% in the 2000s to approximately 11% in 2014 – has not yet managed to match the United States (31% in 2014) as it did in the activities discussed above, see Table 1 (HS).

Among developing economies, India (from 0.7% to 1.7%), Brazil (from 1.5% to 2.6%) and South Korea (from 1.4% to 1.7%) showed significant growth in their participation in the global value added. However, these shares remain low compared to other countries. Thus, also considering that the global value added in services of medium/high technological intensity has almost quadrupled in the period, the data suggest that specialization of advanced economies persists in these services and a better positioning of these countries in their activities in the GVCs. Only China, once again, does not fit the pattern neatly.

A distinguishing feature of developed economies is that, in general (except for Japan), they have greater shares in the value added of medium/high technology services than in the low-technology ones, unlike other nations (except for South Korea). This seems to

be a confirmation of the structural differences resulting from the transformations that have been occurring, subdividing the third phase of the development stage (item 1): the prevalence of the industry is followed by the ascendancy of services of low technological intensity and, later, of high technology services.

3.1.3 Telecommunications and ICT-services

Telecommunications represent the pivotal network infrastructure for most ICT-services. These services are mostly offered on a regional basis; that is, the largest companies in the industry are concentrated on different continents, operating mainly in the regions in which they operate. Examples include AT&T in America, Deutsch Telekom, Vodafone in Europe, Orange in part of Europe and Africa and NTT Docomo and China Telecom in Asia.

In this sense, the data in Table 1 (ICT-Telecommunications) suggest that countries/regions that have a more consolidated network infrastructure have greater portions of the value added in telecommunications. Thus, countries such as the US, Japan, the European countries (together) and, recently, China stand out in this area, reinforcing this argument. China quadrupled its participation in the sector between 2000 and 2014, and significant growth in its local network infrastructure seems to have supported the performance of the ICT-industry (more than quadrupled), ICT-services (multiplied by seven) and high-technology services (approximately five times higher).

Additionally, observing Table 1 (ICT-Services) - computer programming services, consultancy and information services, which are considered knowledge-based services and, therefore, of high technological content – we note a difference between developed countries and the others in their participation in the sector's value added. Between 2000 and 2007, the developed countries had the largest share of value added, a difference that was reduced in 2014 with the growth of the participation of India and, also, of China, surpassing

French participation. Even so, the US, Germany, Japan and Great Britain remain the main countries in this services category.

It is noteworthy that it is in ICT-services that developed economies have their largest share among the other categories that make up ICTs. They are also higher than the percentages of high technology services (HS) (except the US - 28% and 31%, respectively) and low technology (LS). Thus, it is possible to note that developed countries have sought to specialize in these activities to the detriment of industrial ones (ICT-industry), manifesting, on the one hand, the tendency of ICT to become increasingly service intensive and, on the other hand, the relevance of these activities as suppliers of basic technologies and enablers of the current innovation processes of the other activities of the global economy.

3.1.4 ICT analysis

Looking at ICT as a whole in Table 1 (ICT I + T + S), it can be seen that the US, Japan, Germany, Great Britain (smaller proportion than the rest of the group due, mostly, to the significant losses in ICT-I) and China (performance dampened by the small increase in ICT-S) operate more intensely in the sector, while France India, South Korea, Taiwan and Brazil have less participation. Chinese advances are shown to be one of the main changes in ICT over time. This result is mainly due to the growing Chinese dominance of the value added of the ICT-industry (on a par with the US) and its consolidation as a producer and exporter of ICT goods in the world (SZAPIRO, 2012; ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT, 2017), which were achieved to the detriment of the decrease in shares from advanced countries.

Although China has more than tripled its share of value added in the industry, the country's holdings in the ICT segments have more than quintupled. The "worst" performance of participation in value added was in ICT-services (5.2% of the total in 2014), raised by means of a sevenfold increase over the percentage of 2000 – below

the US, Germany, Japan, Great Britain and India. This result seems to explain, on one hand, the impressive Chinese effort and, on the other hand, that the country has not yet achieved some of competencies in knowledge-intensive activities, even when the US is removed from the sample. However, it must be recognized that China has directed its strategy of specialization toward a more diversified and technologically advanced production structure.

Although the United States has shown a drop in its share of value added in the sector (from approximately 1/3 to ¼), it remains a leader in ICT, maintaining in this economy both an industrial base (similar to the Chinese in value added), telecommunications (more than 50% higher than Chinese) and, mainly, services (five times higher). In this sense, the recognition that the US maintained primacy both in the industrial area and in the ICT-services (as well as in the services of medium/high technological content, as shown above) can be a revealing result of its strategy compatible with the ones (here called "new") stages of economic development based on service competencies differentiated by the demanded competencies. In summary, the US has not only made progress in ICT-services and high value added technologies but has also not "given up" on ICT-manufacturing.

On the other hand, the relative evolution of the value added of developing countries deserves two highlights. Brazil, in general one of the smallest relative shares in the analyzed aggregates, achieved the main performances (value added) in low (SB – most important with 2.8% of the world total in 2014), medium/high (SA; 2.6%) technological content and ICT-services (ICT-S; 2.6%), higher than the total for industry (I; 2.1%). The participation of the ICT-industry was reduced in the period (ICT-I; from 2.1% in 2000 to 0.7% in 2014), reflecting the strong deindustrialization of knowledge-intensive industries, with domestic demand being supplied by imports (MORCEIRO, 2018). In these terms, it seems to be a paradoxical case. However, if India is taken as a counterpoint, this feature seems to unravel. Considering its gigantic population and structural problems of great magnitude, in most of the activities analyzed, India achieved better results than

Brazil (except in medium-high technology services – in the period there was an increase in its participation of more than twice, against 70% of the Brazil). India was in a worse situation than Brazil in 2000, but it has since surpassed Brazil in 2014. In short, Brazil apparently missed opportunities.

Japan is an interesting case. The country has a similar performance to that of the US, with generalized losses in the shares of global value added in different aggregates, but with greater intensity (reduction of approximately 60%) in every period considered. However, the country retained part of its share in the aggregates observed. Even so, this country remains among the global leaders when compared to other countries in all analyzed aggregates.

The Japanese case can be, with a few additional considerations, applied to other advanced countries. The losses in the share of the global value added, total or for each particular aggregate, are explained mainly by the Chinese emergence. In other words, the world has changed due to the "China effect".

3.2 Analysis of intersectoral relations

The density indicator shows the activities that have the highest number of links with other aggregates. As already mentioned, if the density of an aggregate – which varies in the interval [0, 1] – is closer to the upper limit, the greater the number of relations with the others. Thus, this indicator makes it possible to do both identify and highlight (rank) the most relevant aggregates, as well as to compare the different national structures (if the aggregate is structurally more or less rooted in the country).

3.2.1 Analysis by country

Table 2 shows that the countries with above average density (bold) in ICT activities are Germany, China, United States, France (except

TABLE 2
Total density and share (%) of aggregates in total density according to selected countries: 2000, 2007 and 2014

Country	Total Density			ICT-I, I			ICT, I			ICT, LS			ICT, HS		
	2000	2007	2014	2000	2007	2014	2000	2007	2014	2000	2007	2014	2000	2007	2014
	Density [0.1]			Share (%)											
Germany	**0.073**	**0.099**	**0.088**	18.3	16.0	15.2	39.2	**45.4**	41.4	30.8	29.4	32.4	**30.0**	**25.2**	**26.2**
Brazil	0.028	0.051	0.051	8.7	15.5	12.0	26.1	**43.0**	39.5	**34.8**	29.9	**33.5**	**39.2**	**26.3**	**26.3**
China	**0.060**	**0.087**	**0.102**	**29.5**	**23.1**	**20.3**	**58.9**	**54.7**	**53.2**	29.5	28.0	30.5	12.2	16.8	16.7
South Korea	0.038	0.070	0.066	**24.1**	**27.9**	**28.6**	**41.7**	39.2	37.0	28.9	27.9	30.5	**30.5**	**33.1**	**33.3**
USA	**0.127**	**0.128**	**0.129**	16.3	16.2	15.6	**47.1**	**47.2**	**47.3**	26.9	27.2	26.9	25.9	**25.7**	**25.5**
France	**0.062**	**0.081**	0.063	12.8	7.5	4.8	30.5	32.4	28.1	31.5	**33.9**	**35.8**	**37.4**	**30.9**	**36.8**
Great-Britain	**0.066**	**0.077**	**0.086**	10.2	7.9	10.6	27.8	33.1	39.0	**39.8**	**37.0**	**32.6**	**32.4**	**29.9**	**28.4**
India	0.017	0.032	0.049	**28.6**	**24.5**	**21.0**	**60.7**	**52.8**	**55.6**	25.0	**30.2**	27.2	14.3	17.0	17.3
Japan	**0.104**	**0.102**	**0.102**	18.2	18.5	**18.0**	**48.2**	**48.2**	**46.7**	**32.4**	31.5	32.9	19.4	20.2	20.4
Taiwan	0.018	0.023	0.023	**37.9**	**32.4**	**32.4**	37.9	32.4	32.4	**37.9**	**43.2**	**43.2**	24.1	18.9	24.3
Average	*0.059*	*0.075*	*0.076*	*20.5*	*19.0*	*17.9*	*41.8*	*42.8*	*42.0*	*31.7*	*31.8*	*32.6*	*26.5*	*24.4*	*25.5*

Source: Authors' elaboration based on World Input-Output Database (2023).
Note: The markings (bold) highlight values above the average. The sum of the percentages of the last three columns totals 100%. ICT represents the sum of ICT-I. ICT-S. and ICT-T.

in 2014), Great Britain and Japan over the entire period observed. This implies that the ICTs in these countries are more connected and integrated with the national productive structure than others. This first result confirms a previous observation: China has achieved a spot among these relevant ICT actors.

The characteristic evolution of Chinese density (70%) is highlighted when compared to other countries – null (USA, Japan and France) or less (Germany, 20%; Great Britain, 30%). China (0.102 in 2014) increased the relationship between ICTs and other activities, reaching a level similar to Japan (0.102) and only lower than the US (0.129). This Chinese achievement is best explained by the strong connection (approximately 50%) between ICT-manufacturing and industry in general (ICT, I) and, to a lesser extent (approximately 30%), with low-technology services (ICT, LS). Thus, the densities of these two aggregates represent approximately 80% of the country's total density. This sets China apart from the US.

Although Japan's density has experienced a slight decrease (translated as decrease in links between activities), it has a production structure comparatively integrated with ICTs and similar to that of China, that is, strong connections between ICTs and industrial activities (ICT-I) and with low technological intensity services (ICT-LS). However, it differs from China in the more intense relations between ICTs and services with medium-high technological content (ICT-HS).

In summary, if China has advanced to the point of reaching an ICT structure similar to that of Japan (unchanged since 2000), it has not yet proportionally developed relations with higher value added (HS) services. On the other hand, despite competition from China in ICT, especially in industry, Japan seems to have preserved the relationships of its structure - in particular, ICT-I but also ICT-HS.

Despite not having a total density as expressive as the three previous countries, Germany (0.088 in 2014) and Great Britain (0.086 in 2014) had considerable growth in the links of ICT that mirror slightly different forms of (re)structuring. Germany preserved ICT's relations

with industry (ICT-I) and with low and, in particular, medium-high technology services (above the sample average). Britain does not differ in aggregate terms that sustain the changes but in the intensity of how they have been affected. The country increased the densities of ICTs with the industry (ICT-I), despite the low connection between ICT-I with the industry in general (I), less than that of the Germans. It also preserved at high levels (greater than the Germans) the links between ICTs and services. France appears to be an enhanced version of the latter case.

The United States is the country with the highest density of ICTs in the three periods analyzed. Possibly because of its high level, the density shows modest growth over the period. It is possible to distinguish between the ICT structures from the US, China and Korea, especially due to differences in density with industrial links. However, this distinction becomes a more difficult task when comparing the US with Germany, for example. In other words, if the ICT structures of the most advanced countries in the sample are more similar, how can we explain the US?

We know that the structure of an economy is denser, or less frayed, if there is a greater number of links between the activities or aggregates analyzed. However, suppose an economy is very much based on a single activity and that this activity has high partial density and the others have low density. Thus, the total density is influenced by this activity, but there is a weak contribution from the other aggregates, that is, there is an "imbalance" between the activities (partial densities). In other words, the structure of this economy is not yet "complete". It is in this context that the partial densities of the US should be analyzed.

The US differs from the other economies analyzed because they present a significant part of partial densities at similar levels, that is, there is a greater balance between the contribution of different aggregates, and, concomitantly, there is a greater number of aggregates contributing to total density. For example, the relationships (ICT-I, I), (ICT-T, I), (ICT-S, I) contribute to the total density with a percentage

close to 15% each. Note that these examples show links between different segments of ICT with industry, covering just under half of ICT links. The other half of the links (density) is associated, equally homogeneously, with the two service aggregates.

3.2.2 Hierarchical and structural changes

Several countries showed a change in the proportion in which each aggregate contributes to the total density. In particular, the links between ICTs and industry (ICT-I) appear to be diminishing to the benefit of links with service activities, both in the direction of low-tech services and for medium/high-tech services. This transition, although not widespread, is largely influenced by the increased links between ICT-services and other economic activities.

This result suggests that developed countries, especially European ones (Great Britain, France and Germany), have specialized in service activities, in particular, medium/high technology services. South Korea also seems to be moving in this direction, but without giving up the industry, especially the ICT-industry (ICT-I), unlike the Europeans.

Table 3 summarizes the results of total density and ranks countries through links between ICTs and other activities. This classification is compatible with the one obtained through the value added shown in the previous section (Table 1). In addition, the highlights are (i) the repositioning of China, (ii) the hegemony of the US and (iii) the increase in total density in most countries.

The advanced countries stand out for their higher value added (see previous item) and for the denser relations between aggregates and ICTs. The discrepancy in the density of the US with other countries, highlighting the country's leadership in the ICT sector, is another element of the scenario that has remained unchanged. Despite the efforts of the observed developing countries, India (one of the largest exporters of ICT-services worldwide), Brazil and Taiwan remain among the countries with the lowest ICT densities in their national production structures.

TABLE 3
Total densities in ICTs - 2000, 2007 and 2014

Ranking	Country	Total Density	Country	Total Density	Country	Total Density
	2000		2007		2014	
1	USA	**0.127**	USA	**0.128**	USA	**0.129**
2	Japan	**0.104**	Japan	**0.102**	Japan	**0.102**
3	Germany	**0.073**	Germany	**0.099**	Germany	**0.102**
4	Great-Britain	0.066	Great-Britain	0.087	Great-Britain	0.088
5	France	0.062	France	0.081	France	0.086
6	China	0.060	China	0.077	China	0.066
7	South Korea	0.038	South Korea	0.070	South Korea	0.063
8	Brazil	0.028	Brazil	0.051	Brazil	0.051
9	Taiwan	0.018	Taiwan	0.032	Taiwan	0.049
10	India	0.017	India	0.023	India	0.023

Source: Authors' elaboration based on World Input-Output Database (2023).

4. Conclusion

This study analyzed the relationships between industrial and service activities and ICTs. The assessment of intersectoral relations in ICT in the main national economies in this industry allowed us to understand how ICTs interact with the national structures of different countries, comparing them and identifying which activities each country seeks to or has specialized in.

The methods of analysis, value added and network density, sought to understand the role played by ICTs from the year 2000 to 2014. The contributions of each method made it possible to show how ICTs are structured in each country of the sample and the respective specializations, the changes that happened in the period and how ICTs interact with the different national productive structures.

Both indicators used show that the main change in ICTs were the emergence of China as one of the most relevant countries in this

sector, together with the United States, Japan and Germany. If this result seems to indicate that the changes in the period (2000 to 2014) were limited to China's entry into a select group, other results from this study confirm both the Asian region as the center of ICT-manufacturing, as well as the specialization of developed countries in services of medium/high technological intensity in ICTs. Still, the US held 1/3 of the added value of these services, in 2014.

Another change that occurred in the period was the increase in the relationship between telecommunications and ICT-services with industrial and service activities, since in most countries, the relations between ICT-manufacturing and the production structure were already stronger. The increase in relations in the area of telecommunications and ICT-services has intensified without a drop in relations in ICT-manufacturing in most cases. This result portrays structural change that has occurred in the entire economic system and not just in individual countries.

Manufacturing is fundamental to the functioning of the ICT ecosystem, as it is from there that the necessary infrastructure for the development of sophisticated services originates, which are disseminated throughout the economy. ICT-manufacturing supplies the ecosystem itself with the technologies necessary to provide telecommunications and information services. This justifies the fact that this industry is extremely strong in spending on research and development.

It can also be said that the provision of advanced services, supported by an efficient and large physical infrastructure, together with telecommunication services, is the main way in which ICTs are absorbed by other activities of the economic system today. It is through this relationship that productivity increases occur in the sector itself and in the rest of the economy. In other words, innovations resulting from advances in ICTs are disseminated in the economy through the diversity of services that make up the sector, reinforcing those with high technological content.

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