ARTICLE

Global productive flows in health: elements for building a map of health industrial complexes in the world[1]

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Global productive flows in health: elements for building a map of health industrial complexes in the world

ABSTRACT

It is based on the assumption that productive spatial circuits have global dynamics built on the articulation between places and regions of the different socio-spatial formations that make up the current world system. The establishment of these cross-border dynamics is achieved by imposing the hegemonic temporalities of global agents, specifically those that promote the use of instrumental simultaneity for the purposes of capitalist accumulation. In industrial production, this spatial practice of companies is achieved, among other ways, by the exchange of productive inputs between countries that have the same branches of industry, and in this article we are dealing with the branches that make up the health industrial complex. It is by analyzing these flows of productive inputs and finished products that it is possible to produce indicators and estimate the countries that own these complexes.

Keywords: Health industrial complex. Productive spatial circuit. Productive inputs. Health economy.

Fluxos produtivos globais da saúde: elementos para a construção do mapa dos complexos industriais da saúde no mundo

RESUMO

O artigo parte do pressuposto de que os circuitos espaciais produtivos apresentam dinâmicas globais, conforme assevera Milton Santos (1988), construídas pela articulação entre lugares e regiões das diferentes formações socioespaciais que constituem o atual sistema mundo. Essa dinâmica transfronteiriça se estabelece pela imposição das temporalidades hegemônicas dos agentes globais, especificamente aquelas que usam a simultaneidade instrumental para fins de acumulação capitalista. Na produção industrial, essa prática espacial das empresas se atinge, entre outros modos, pela troca de insumos produtivos entre países que detêm os mesmos ramos industriais, e aqui tratamos daqueles que constituem o complexo industrial da saúde. É por meio da análise desses fluxos de insumos produtivos e produtos acabados que se podem criar indicadores e estimar os países detentores de tais complexos.

Palavras-chave: Complexo industrial da saúde. Circuito espacial produtivo. Insumos produtivos. Economia da saúde.

Flujos globales de producción en salud: elementos para construir un mapa de los complejos industriales sanitarios del mundo

RESUMEN

Se basa en el supuesto de que los circuitos espaciales productivos tienen dinámicas globales construidas a partir de la articulación entre lugares y regiones de las diferentes formaciones socioespaciales que componen el actual sistema mundial. El establecimiento de estas dinámicas transfronterizas se logra a través de la imposición de las temporalidades hegemónicas de los agentes globales, específicamente aquellas que promueven el uso de la simultaneidad instrumental para los fines de la acumulación capitalista. En

la producción industrial, esta práctica espacial de las empresas se logra, entre otras formas, a través del intercambio de insumos productivos entre países que tienen las mismas ramas de la industria, y en este artículo nos ocupamos de las ramas que componen el complejo industrial sanitario. Es analizando estos flujos de insumos productivos y productos acabados que es posible elaborar indicadores y estimar los países que poseen estos complejos.
Palabras clave: Complejo industrial sanitario. Circuito espacial productivo. Insumos productivos. Economía sanitaria.

INTRODUCTION

The health industrial complex (HIC) is a network of industrial branches that manufacture a wide range of human healthcare products. These specialized industries, most often observed in a select group of countries with advanced technology and scientific research, generally produce high value-added goods. This is typically concentrated in countries with well-established industrial parks and robust knowledge production, demonstrating a high degree of interdependence in this technical division of labor.

While the United States (US) and the most industrialized European nations are primary examples, HICs may also be identified in Brazil, China, India, Indonesia, Japan, Mexico, and other countries, albeit with varying scales and production capabilities. A defining characteristic of these complexes is the diversity of branches, rather than the existence of one very strong branch with the other branches and sectors being weak or even non-existent.

Carlos Grabois Gadelha (2003) was responsible for introducing the concept, which he clearly defined in his article "O complexo industrial da saúde e a necessidade de um enfoque dinâmico na economia da saúde" [The health industrial complex and the need for a dynamic approach to the health economy], in which he proposed a systemic perspective encompassing all types of industry involved in the health economy, emphasizing their inseparability from health systems. In Brazil, this concept is particularly relevant due to the presence of a significant universal health system, SUS (Unified Health System), which allocates a substantial annual budget and serves as the country's largest consumer of health-related products and services.

Gadelha (2003, 2006, 2012) and the group of researchers who have focused on the issue of health industrial complexes have meticulously analyzed the importance of this group of specialized industries in Brazil. This paper aims to contribute by providing a preliminary overview of the countries that possess the industries comprising these complexes, as well as an understanding of their relative size within the international system of countries[3], based on the author's definition. While this initial analysis focuses on identifying the main countries with HICs, we do not however set out to investigate the broader scope of *Health Economic-Industrial Complexes* (HEICs), as defined by Gadelha in his later publications (2006, 2012, among others), which also encompasses companies linked to finance, health insurance, and a wide range of other services.

[3] This research is part of a broader study exploring the geopolitical role of health industrial complexes. Here, we have set out to present our initial steps and proposals for mapping the health production complexes in different countries, a crucial first step in this broader investigation.

Despite being a reality in many countries, the specialized international literature rarely mentions this notion neither to provide an overall idea of this group nor regarding the systemic relationship between the agents involved in relating the productive sectors, often very different from one another, with health services. When this occurs, the most common expression is the *medical-industrial complex*, to some extent denouncing the medicalization of society with a focus more directed toward large pharmaceutical laboratories (Relman, 1980; Salomon, 1998), but without the same agglutinating, systemic characteristic implied in the concept of the *health industrial complex*.

Thus, this article has rigorously adopted the concept of the *health industrial complex* (HIC) and its associated productive sectors, as originally proposed by Gadelha, in order to identify countries with this group of productive sectors, and to analyze the potential size variations among them. In light of this productive complex characterized by spatial production circuits and circles of cooperation in space (Santos, 1988; Antas Jr., 2019), HEICs have not been employed, since, consistent with the perspective of previous studies (Antas Jr., 2017, 2019, 2020), non-productive firms have been classified as circles of cooperation. Here, it is essential to focus solely on industrial production and capitalist cooperation among companies operating within different socio-spatial formations.

It is essential to note that this survey does not seek to provide a definitive definition or a precise hierarchy among the main countries and others. Instead, it is designed to explore the dynamics of these industries within the global flows that they generate, characterizing the productive spatial circuit. To achieve this, we have therefore developed a methodology based on specific indicators that will guide the analysis (Santos, 1988, 1996; Santos; Silveira, 2001).

THE HEALTH INDUSTRIAL COMPLEX WORLDWIDE: INDICATORS DEVELOPED TO GRASP THE ACTIONS AND DYNAMICS OF PRODUCTIVE SPATIAL CIRCUITS

A striking feature of the emergence of productive spatial circuits is the change in the regional edifice, with the onset of globalization and the emergence of informational networks that have increasingly given rise to all kinds of flows (Santos, 1988). Many economies that were more restricted to regional agglomerations, even those related to the entire sociospatial formation, began to incorporate informational networks, intensifying the relationships between places and regions spread throughout the world. This is to say, in the technical-scientific-informational period, the region comes to be conceived through horizontalities, understood as the materiality of technical systems in territories, and also by verticalities, constituted by informational networks (Santos, 1996).

This new spatial dynamic, encompassing all the articulated scales, has led to a dramatic intensification of the social, territorial, and technical division of labor. A direct consequence of this process has been the interpenetration of different sectors, previously more defined and circumscribed, which has ultimately made it difficult to identify the distinctions necessary for analysis, particularly in the case of productive spatial circuits. Thus:

> An activity will belong to a given circuit when its main input comes from the previous phase of the same circuit. Otherwise, it is considered

> that from that point on, a new circuit develops, to be studied separately (Santos, 1986, p. 125).

The problem of identifying this primary input, especially in the current technical-scientific and informational period, characterized by the ultra-specialization of industrial production and related applied sciences, is neither trivial nor unimportant, since it defines the boundaries of the object under analysis. In the case of the HIC, it has been previously mentioned that there is a proliferation of industrial sectors that incorporate laboratory experiments into production lines (Antas Jr., 2019), as exemplified by recent widely publicized breakthrough in mRNA technology, which led, for example, to the development of vaccines against COVID-19.

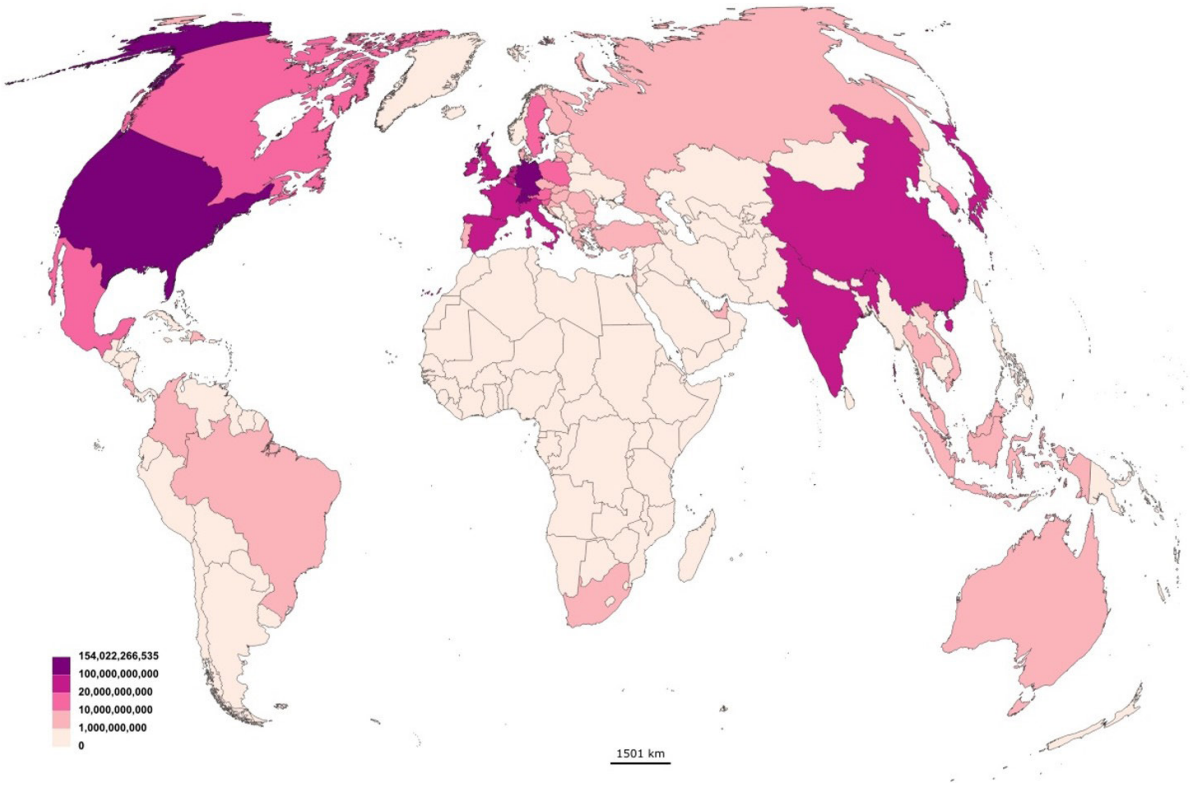
Besides the obvious question regarding the empiricism involved in this situation, additionally, there is a more prominent question: an analysis from the perspective grounded in the concept of productive spatial circuits, which provides a valuable lens through which to examine the sets of technical systems involved in scalar dynamics, and the diversity of economic and political agents involved in the construction of a global technical-scientific object - for example, the vaccine -, particularly those related to biotechnology. This complexity inherent in the production of magnetic resonance imaging machines, PET scans, among many other products stemming from this division of labor, is evident across various industrial branches focused on human health. This concept is deeply rooted in a larger theoretical framework, engaging in dialogue with it. Thus, the choices made in this context are closely tied to what contributes to explaining the interconnectedness between the world, region, and place.

From a theoretical standpoint, a worldwide analysis of HICs clearly underscores this issue, since it encompasses a broad spectrum of industrial sectors, including pharmaceutical laboratories, electro-electronic and mechanical industries, furniture and hospital supplies, as well as the manufacturing of orthoses and prostheses. Within these, there is also a wide variety of branches, often quite diverse. In other words, this industrial complex involves numerous productive spatial circuits that, nevertheless, maintain productive interconnections and global alliances, since the main focus is human health, in which all this economic apparatus is specialized.

This makes it challenging to create a comprehensive map of HICs worldwide, or of the countries where they exist, ranging from the major to the minor players. Map 1 offers a preliminary overview, based on the combined value of the sectors involved[4] in this industrial complex in the export of finished goods.

At first glance, Germany, the US, and Switzerland stand out as leading exporters, with exports totaling US$154 billion, US$125 billion, and US$104 billion, respectively. Indeed, this is further underscored by the fact that the first two countries have the most health industrial complexes, as evidenced by the overwhelming majority of quantitative data pertaining to this sector. In the case of Switzerland, further research is required to fully understand the composition of the HIC companies. The country's high value may be attributed

[4] This refers to the following industries: pharmaceuticals, vaccines, and reagents; blood products; medical equipment and devices; hospital furniture and consumables; prosthetics and orthotics. Further on, the composition of this health industrial complex will be detailed.



Map 1 – Exports of finished goods from the health industrial complex per country in 2022 (US$).
Data organization: Caroline Fernandes and Clara Penz. Cartography: Antas Jr., with Magrit-CNRS. Russian data refers to 2021, since Comtrade stopped reporting data from Russia as of 2022.
Source: United Nations Commodity Trade Statistics Database (Un Comtrade, 2024).

to the production of pharmaceuticals, vaccines, and reagents, since it hosts some of the largest pharmaceutical laboratories in the world, and the other three HIC sectors present proportionally lower values than the first two.

On the next level, between US$64 billion and US$20 billion, there are seven Western European countries (Belgium, Spain, France, Ireland, Italy, the Netherlands, and the United Kingdom) and four Asian countries (China, India, Japan, and Singapore). Even so, the least prominent, in the range between US$20 billion and US$2 billion, despite the large difference with the upper strata, also present expressive values and volumes.

Although the total finished goods exported by the HIC of each country is only one indicator of the size of any one complex, the most relevant data is the production capacity of this industrial park in each socio-spatial formation. However, this investigation is a subsequent step to that presented in this article. It is essential to first identify the countries that possess the group and diversity of industries characteristic of such a complex, and then analyze the factory production across the different national territories.

One crucial point to highlight is that these are sectors with a highly globalized production modus operandi. However, despite this, it is common to try to understand their characteristics solely through import and export relationships. However, total exports and imports do not reveal as much about global production dynamics as the decomposition of these values into productive inputs and finished goods. To capture the movement of the spatial productive circuits of the health industry worldwide, it is necessary to analyze the flows of productive

inputs, which thereby enables an understanding of the regional and local dynamics of the production of objects and technical systems aimed at human health[5].

When the imports of productive inputs is selected, most of which have a medium or high added value, it may be noted that a smaller number of countries are outstanding. Once again, the US and Germany emerge as leaders, with US$ 35 billion and US$ 22 billion, respectively. Following this, there is a range between US$ 10 and US$ 5 billion, with five European countries (Austria, Belgium, France, Italy, and Switzerland) and China. The next group, between US$ 5 and US$ 1.5 billion, is the most numerous, with 13 relevant countries in terms of health-oriented industrial production. Brazil is the main Latin American country within this group, with US$ 2.2 billion, and the 15th largest importer of inputs. Another important country in Latin America is Mexico.

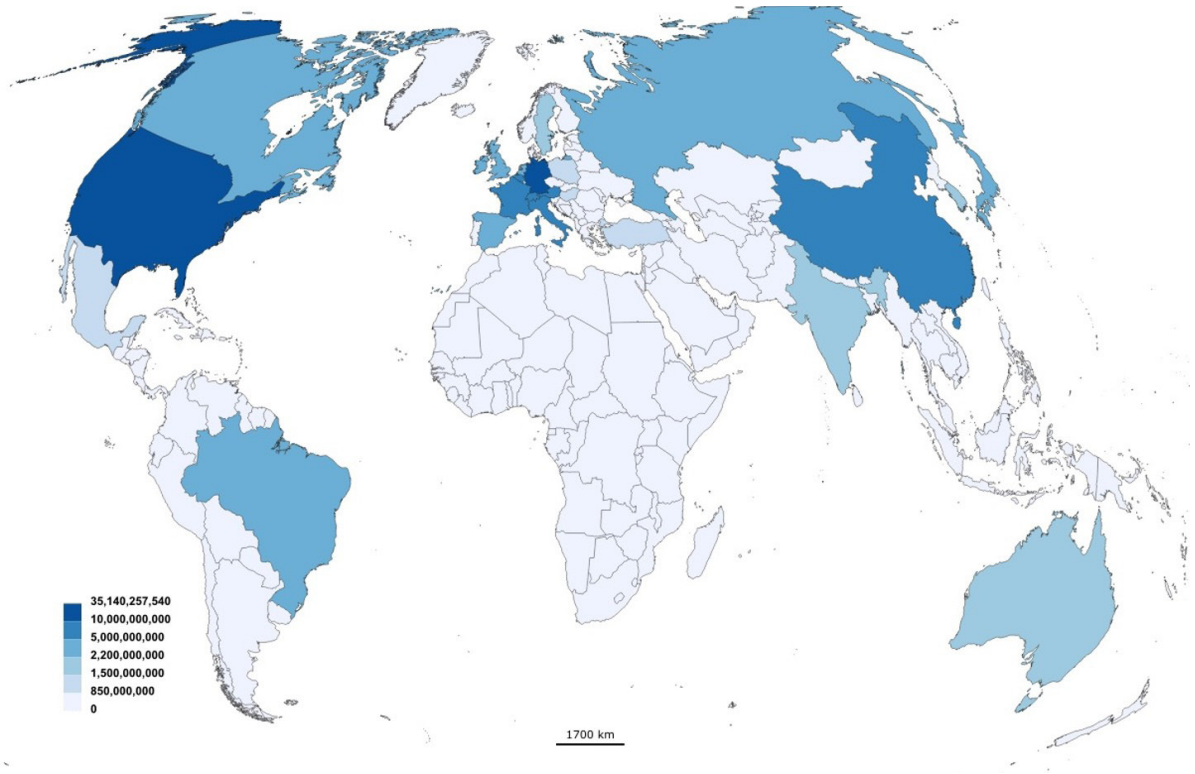
Analyzing the imports of productive inputs related to HICs is important because it reveals two prominent processes: (1) where the global corporations of the main companies that generate these flows of productive inputs are located and (2) strong evidence of countries that possess a HIC, insofar as these productive inputs enter countries destined for manufacturing plants installed in territories capable of accommodating very specific technological products in their production lines. In other words, the countries highlighted in Map 2 present important evidence that they have a significant specialized industrial park to import large volumes of productive inputs.

A GLOBAL INDUSTRIAL PRODUCTION?

The practice of capitalist cooperation in industrial production, technically associating different manufacturing plants in the same territorial division of labor, involving two or more countries simultaneously, did not become fully established during the first two decades that marked the technical-scientific and informational age (1980/1990). Indeed, it only began to transform into a spatial practice at the dawn of the twenty-first century, fueled by the cutting-edge advancements in information and communication technologies (ICT) and the more widespread and in-depth adoption of neoliberal policies by States.

From a technological standpoint, it was at this juncture that ICT began to integrate more deeply, even becoming indispensable, within the tools and machinery used in the production of high value-added industrial goods. Additionally, it demonstrated a consistent demand for technical and scientific innovations. Thus, the automotive and aerospace industries, as well as certain productive branches that make up the health industrial complex, are now closely intertwined with the ICT manufacturers themselves. Advancements in logistics have also played a crucial role. With improved precision, logistics systems now offer forecasting

[5] The starting point for collecting and processing data on customs platforms was to define the sectors and branches that make up the health industrial complex according to the Seade Foundation (Dias, 2016), which identified the codes of the National Classification of Economic Activities (CNAE) that involve the LARGE PRODUCTIVE FIELDS defined by Gadelha (2003). From there, we classified them into FINISHED GOODS and INDUSTRIAL INPUTS, according to the correspondence of the CNAE with the Harmonized System (HS) classification, which is standardized worldwide among customs platforms, and which in Brazil is known as the Mercosul Common Nomenclature (NCM), for which we used ComexStat and Comtrade, from the United Nations (UN). The initial classification was undertaken by ComexStat, which enables the final products to be divided into up to 8 digits (NCM8/SH8), to detect the number of inputs that make up each final product ready for consumption. In the case of the UN Comtrade platform, only access to SH6 was possible, affecting the accuracy of the inputs that make up the final products. For this reason, the finished products and productive inputs in the branches of the HOSPITAL FURNITURE AND CONSUMABLE MATERIALS sector were not divided, for which inputs only appear in NCM8/SH8. In the survey, 122 finished goods and 95 types of productive inputs were selected in all HIC companies.



Map 2 – Imports of productive inputs from the health industrial complex per country in 2022 (US$). Data organization: Caroline Fernandes and Clara Penz. Cartography: Antas Jr., with Magrit-CNRS. Russian data refers to 2021, since Comtrade stopped reporting data from Russia as of 2022.
Source: United Nations Commodity Trade Statistics Database (Un Comtrade, 2024).

and control of production inputs, facilitating technical integration across the points of a given corporate network.

With regard to neoliberal policy, the selective flexibilization of control over national borders for goods and industrial inputs is a significant factor. However, equally crucial have been the countless indirect subsidies and tax exemptions extended to corporations. Moreover, the diversification and sophistication of financial and legal services have greatly facilitated the viability of various elements, including the flow of capital between dispersed units around the world, the practice of accountability, and the system of accelerated dispute resolution, such as arbitration, among others.

Indeed, this expansion of the territorial division of labor in productive sectors between non-contiguous places, often involving different countries, has been primarily driven by technological advancements in the division of labor in these industrial branches, and which are highly dependent on scientific and informational innovations for manufacturing production stricto sensu and the institutionalization of the corporate financial and regulatory apparatus. This convergence of technology and politics has fostered and broadened the development of productive spatial circuits. By connecting places and regions, this fusion has facilitated a new spatial practice which is of great interest to big capital, since this interscalar articulation enables it to hegemonize national companies and institutional entities, especially those that are state owned (Antas Jr., 2020).

In short, productive spatial circuits are characterized by the global capitalist dynamics that involve specialized sectors of the economy. They are formed by the interconnectedness of places and regions situated within diverse sociospatial contexts. Global agents, such as corporations, impose hegemonic temporalities that create a sense of spatiotemporal simultaneity, facilitating capitalist accumulation and corporate strategies (Santos, 1997).

It is important to emphasize that this articulation is not homogeneous. It varies across different economic branches of the same sector (agriculture, industry, services) due to the use of different technical systems and technologies, as well as the economic ends for which they have been employed. Moreover, it is not homogeneous primarily because the sociospatial formations constitute distinct totalities.

This simultaneity implemented by different corporations with cross-border action in their modus operandi for capital accumulation is always a dynamic process of search. It never becomes fully established, as it frequently encounters conflicts with spatial practices and processes of national companies and the State. However, these conflicts do not necessarily occur simultaneously, as demonstrated by Roberto Lobato Corrêa (1992, 2006).

The fact is that, as a transnational corporation in a specific branch manages to establish a hegemonic temporal dynamic within a subspace of the sociospatial formation, coupled with other constituent temporalities of that formation, it increases control over the circulation and distribution of production, enabling everything from gains in productivity, by achieving technical objectives, through to a greater margin for speculation on the capital markets.

In specific branches of the HIC, this corporate practice is particularly pronounced, especially in the case of large pharmaceutical laboratories. However, it is also somewhat common in companies that produce high and medium technology medical equipment and devices (Antas Jr., 2019). Thus, the use of concrete simultaneities, i.e., intentionally constructed for specific purposes, is a highly effective strategy for corporations to hegemonize medium and large companies located in certain cities, as well as their regional business networks and alliances. The ability of industries to exert a dominant influence on the organization of time within a specific territorial division of labor differs from that of other sectors. For example, financial institutions may have the capacity to impose, in a more direct manner, the instrumentalization of money and credit circulation throughout the entire territory.

The central question is to understand how corporate groups achieve ubiquity, defined herein as the orchestrated manipulation of events by the agents involved, as previously explored (Antas Jr., 2020). It is understood that there are multiple answers, since the technological and organizational specificities of each type of industry, including their goods, demand a variety of discoveries and innovations (Antas Jr., 2020). Recognizing the diversity of responses acknowledges that the technological and organizational nuances of each industry, along with their products, necessitate a range of discoveries and innovations.

At the same time, some economic processes are common to all economic activity. In the context of globalization, the relationship between fixed assets and flows strategically distributed around the planet play a pivotal role in the teleological construction of ubiquity or, in other words, the instrumental use of the simultaneity of hegemonic actions built through information and communication technologies.

THE GLOBAL DYNAMICS OF PRODUCTIVE SPATIAL CIRCUITS IN HEALTH: CONTRIBUTIONS TO THE CONSTRUCTION OF A MAP OF THE GLOBAL HEALTH INDUSTRIAL COMPLEX.

When analyzing the major global pharmaceutical laboratories through productive spatial circuits, it became evident that corporate practices have significantly enhanced their capacity to finalize industrial products simultaneously at different points of the planet (Antas Jr., 2019). To accomplish this, there is an intense exchange of parts that already have a medium or high-added value that constitute the final product.

In these terms, this division of labor extends beyond the mere transformation of raw materials or low-value semi-finished goods into high-value-added products. This process results in a significant differential, reflecting the geographically unequal development typical of pre-globalization eras. Furthermore, the flows are not only confined between the US and certain European countries, but also extend to Asia – including the north, south, and southeast – and even some Latin American countries, with Brazil playing a prominent role within the previously mentioned productive spatial circuits.

The circulation of inputs and their productive consumption highlight significant corporate practices in the production of goods and, subsequently, in the spatial dynamics of each productive sector. Capitalist cooperation in the contemporary era of technological, scientific and informational advancement has dramatically expanded the arena of production. This trend was foreshadowed by Marx in the nineteenth century, who observed the growing interconnectedness of firms within the same sector. However, the context of globalization presents hegemonic companies with a worldwide stage on which to execute the spatial strategies, leveraging cooperative partnerships while simultaneously outcompeting or dominating their rivals.

Therefore, analyzing the exchange of inputs reveals the positions of the productive agents involved in manufacturing the same final product, i.e., the interaction of the flows of productive inputs that results in the simultaneous materialization of the commodity in various locations worldwide, often near its point of consumption. The technological development of logistics is fundamental for the entire industry. This territorial fluidity (Arroyo, 2005) allows these large companies to expand their reach globally, no longer focusing solely on local and regional benefits, as in the past. Instead, the primary goal is to establish a reticular logic of actions that enables simultaneity for hegemony in different markets (Antas Jr., 2020).

In the pharmaceutical industry, for example, the advancements of logistics have enabled unparalleled flexibility, which has contributed to the creation of hegemonic simultaneities insofar as they may transport events and experiences across vast distances. The pharmaceutical industry is increasingly reliant on the agility of the air transport system for the transportation of products, both finished and in parts[6], and it is precisely the transport sector where a significant growth in the exchange of large volumes has been most observed. This innovative sector has demonstrated its cutting-edge capabilities by

[6] Pharmaceutical companies that use air transport typically have higher-value-added drugs, which allows them to absorb the higher logistical cost. Additionally, they require deliveries to be made as quickly as possible, as these are perishable drugs, often with strict temperature control.

pioneering the production of mobile vaccine factories in shipping containers, as undertaken by Biontec/Pfizer, who successfully deployed such a complex technical object in South Africa to produce mRNA-based vaccines to combat COVID-19[7].

This analysis acts as a crucial indicator of the modus operandi of hegemonic globalization agents within productive spatial networks. It is possible to observe how capitalist collaboration links diverse regions and cities worldwide, serving the interests of corporate industrial production planning. It also highlights the dynamic nature of the circulation processes in the global political economy, demonstrating how they foster a productive logic unprecedented in the history of the mode of production. This involves the strategic coordination of hierarchical and complementary events between non-contiguous spaces, ultimately driving expanded capital accumulation.

> The instantaneity of information in a globalized world draws places closer together, enabling immediate knowledge of **simultaneous events** and creating a unitary relationship between places and events on a global scale [...].
>
> This interconnected event, despite all the differences between people and places, manifests in three ways in the contemporary territory: **a homologous event, a complementary event, and a hierarchical event**.
>
> In an agricultural region, this interconnected event is homologous. However, within the same city, dominated by the same industrial production, this homologous event may also be identified. In the relationships between the city and countryside, it is complementary, as well as in interurban relationships. There is also the hierarchical event, resulting from the ordering and information originating in one place and being realized in another, such as labor (Santos, 1996, p. 132-133. Our emphasis).

Beyond the simple exchange of productive inputs and finished goods, productive spatial circuits encompass a broader range of interactions. By examining the flow of product parts that circulate the entire world, passing through different cities with factories that make up the HIC, some of the key spatial dynamics are uncovered, such as the global relationship between the fixed productive assets of this complex.

Therefore, this organizational approach to data clarifies the role of technology in the global territorial division of labor and the role of the specific productive branch located in particular places. By analyzing flows it is possible to deduce the size and significance of the HIC in any given country. In essence, the flows of imports and exports of manufactured industrial inputs serve as reliable indicators of the presence, in a specific branch of the complex, of production plants in cities of different socio-spatial formations. These flows signify a complementarity in the technical and territorial division of labor.

Given the global prominence and influence of HICs, it is essential to identify which nations possess them and the preponderance of each one in the economic and geopolitical affairs. This was underscored by the COVID-19 pandemic, since these countries demonstrated

[7] "Germany's BioNTech has developed a vaccine factory made from shipping containers that it plans to ship to Africa as assembly kits to ease what the World Health Organization has described as huge disparities in global COVID-19 vaccine access" (Burger, 2022). The company has announced its intention to export the 'container factories' to Asian countries if this initial 'test' is successful.

their capacity for innovation and healthcare technology development, prioritizing the protection of their own populations while also negotiating cooperative arrangements with other nations to secure advantageous terms.

It is important to emphasize that the mere presence of health-related industries in a country is insufficient to indicate the presence of what is being discussed herein. Instead, a diverse range of industrial sectors, a strong capacity for both basic and applied research, highly specialized and complex hospital services, and robust financial, information, and regulatory systems are all critical components. In essence, a systemic organicity, or as stated by Viana, Silva and Elias (2007), a political economy of health, is essential within each national territory.

Although mapping HICs worldwide involves taking various factors into consideration, this article limits its scope to two key indicators: the volume of exports of finished goods and of imports of inputs for the health industry production.

The first indicator gauges a country's productive capacity by measuring the quantity it is able to produce for both the domestic and foreign markets, with the latter being effectively evaluated by the level of exports. The second indicator is based on the assumption that the technical division of labor, which exists in various countries and cities with manufacturing capabilities, will continue. This enables the size and significance of the HIC in each country to be estimated, defined by Gadelha (2003) in two sectors: (1) chemical and biotechnological based industries and (2) mechanical, electronic, and materials based industries, which are composed of industrial branches: in sector (1), pharmaceuticals, vaccines, reagents, and blood products, and in sector (2), medical equipment and devices, furniture, hospital consumables, prostheses, and orthoses. Table 1 presents the values exported and imported by this group of branches.

In order to identify those countries with HIC, the top 25 countries were selected for each list, although this measure alone is inconclusive: some countries may present significant values, but the majority may come from just one sector or even one branch. Often, pharmaceuticals, vaccines, and reagents make up almost the entire value, with the remaining branches being of little significance; in this case, the definition of HIC does not apply in the sense that it is used herein.

It may be observed that only four of the countries among the top 25 exporters of finished goods are not on the same list of the largest importers (United Arab Emirates, Slovenia, Hungary, and the Czech Republic), where Australia, Brazil, Russia, and Turkey appear.

In the case of Brazil, how may such a situation be explained? Due to the Unified Health System (SUS), which provides universal and free-of-charge healthcare for a population of approximately 215 million people, the consumption of complex products is very high. Despite significant domestic production[8], this consumption inhibits the export of finished goods (in this list, Brazil appears in 40th position). One fact that reinforces this statement is that Brazil is the 6th largest consumer market for pharmaceuticals in the world. While the country exported US$ 2.4 billion in finished goods and imported US$ 2.2 billion in productive inputs, the participation of industrial production related to the HIC in the 2022 GDP was US$ 23.3 billion, indicating that this production is primarily consumed domestically.

[8] According to the Annual Report on Social Information (Relação Anual De Informações Sociais, 2017 - **RAIS**), there were 7,089 production plants in Brazil's health industrial complex.

Table 1 – Top exporting countries of finished health products and top importing countries of industrial inputs in different business sectors linked to the HIC in 2022.

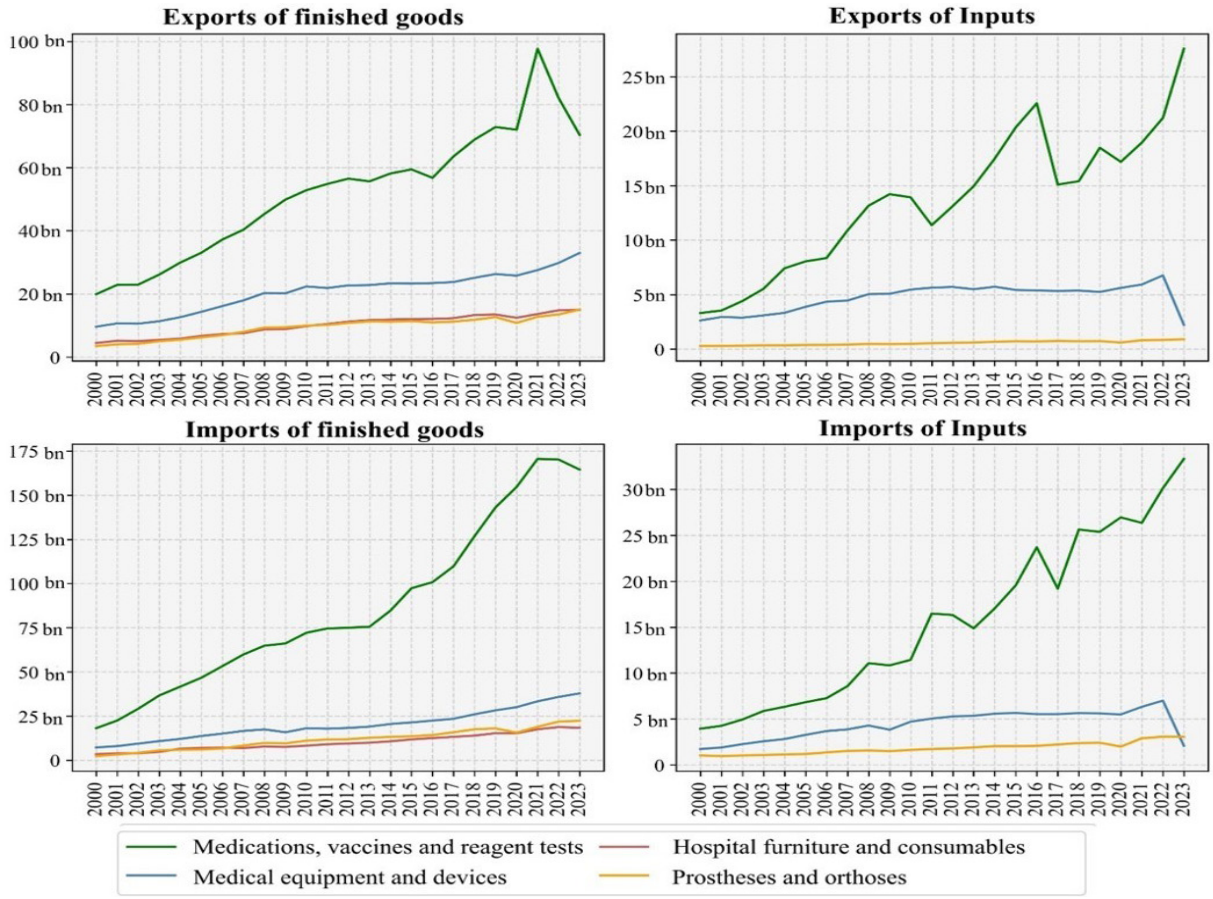
Exports of finished goods 2022			Imports of industrial inputs - 2022		
	Country	US$		Country	US$
1.	Germany	154,022,266,535	1.	United States	35,140,257,540
2.	United States	125,372,344,172	2.	Germany	22,079,890,033
3.	Switzerland	104,275,760,244	3.	Belgium	9,562,429,028
4.	Ireland	64,163,636,246	4.	France	9,554,184,077
5.	Italy	61,012,458,212	5.	Italy	8,965,610.603
6.	The Netherlands	60,126,911,844	6.	Switzerland	8,146,356,831
7.	China	58,657,508,508	7.	China	8,011,660,495
8.	France	58,540,400,982	8.	Austria	6,537,032,484
9.	Belgium	49,979,618,057	9.	Japan	4,368,252,404
10.	United Kingdom	38,375,104,884	10.	Spain	4,191,899,994
11.	Singapore	24,436,287,607	11.	The Netherlands	3,801,019,703
12.	India	22,465,526,839	12.	Ireland	3,608,480,355
13.	Japan	21,647,654,401	13.	United Kingdom	3,413,476,295
14.	Spain	21,417,013,763	14.	Canada	2,928,988,443
15.	Mexico	18,200,106,429	15.	Russia*	2,890,179,886
16.	Poland	16,705,086,858	16.	Brazil	2,203,528,457
17.	Canada	16,628,337,531	17.	South Korea	2,184,487,473
18.	Slovenia	15,977,360,146	18.	India	2,134,402,944
19.	South Korea	15,633,067,098	19.	Singapore	1,970,091,168
20.	Sweden	14,271,479,863	20.	Australia	1,756,044,329
21.	Austria	12,448,478,623	21.	Hong Kong	1,669,200,654
22.	Hong Kong	9,389,871,017	22.	Sweden	1,629,004,068
23.	Hungary	8,923,271,190	23.	Mexico	1,447,283,776
24.	República Tcheca	8,782,016,345	24.	Turkey	1,413,990,383
25.	U. Arab Emirates	8,289,605,680	25.	Poland	1,064,906,118

Group 1	Group 2	Group 3	transition + Group 2	transition + Group 3

*Russian data refers to 2021, since Comtrade stopped reporting data from Russia as of 2022. Data organization: Clara Penz; Table organization: Antas Jr.

Source: United Nations Commodity Trade Statistics Database (Un Comtrade, 2024).

It may be observed that Table 1 does not provide an exhaustive list of countries that possess a HIC, but rather indicates the most likely and classifies them into three relatively well-defined groups. However, it is also crucial to understand the specialized industrial structure of each country, since even those that appear on both lists may not have a diverse



Graph 1 – United States: Historical series of exports and imports of productive inputs and finished goods between 2000 and 2023.

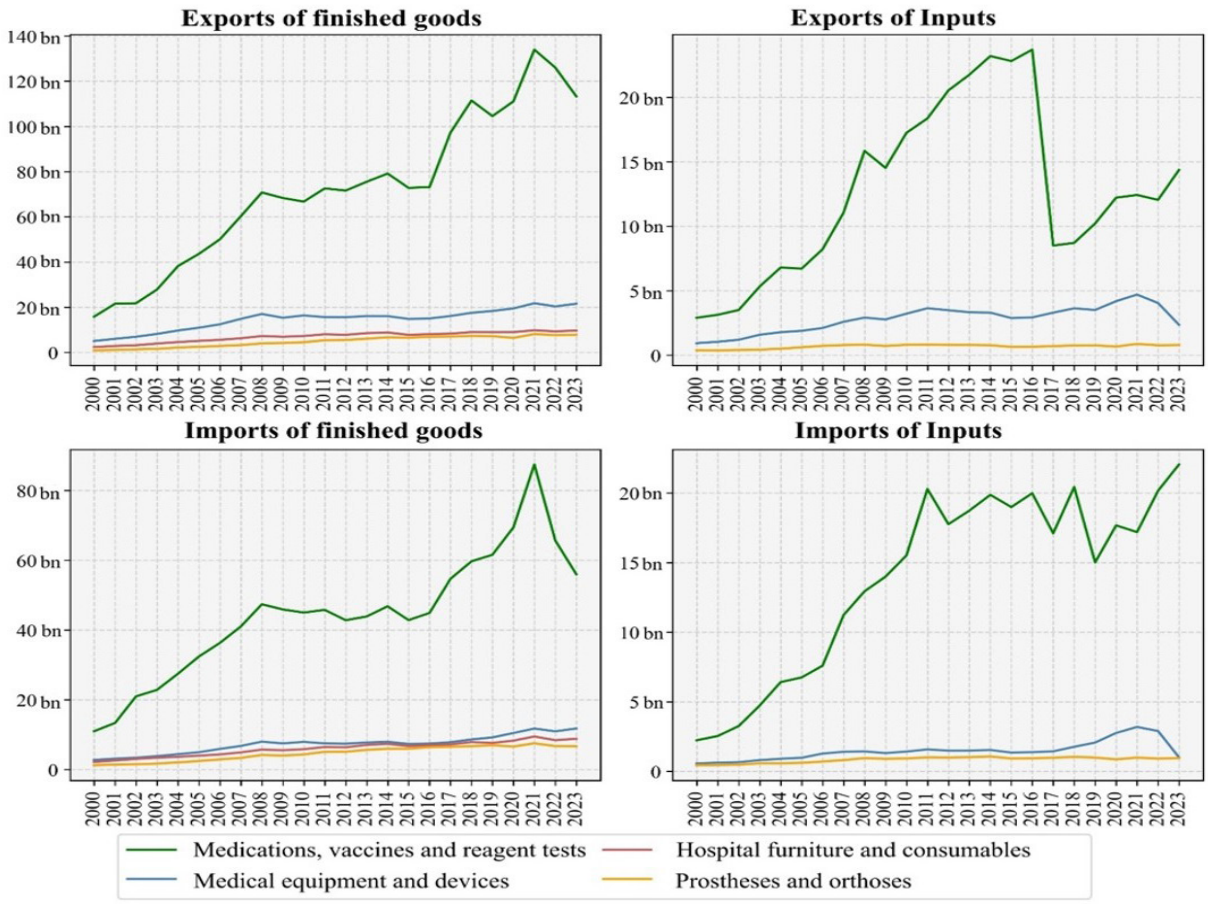
Data investigation and organization, and graph elaboration: Clara Penz.
Source: UN Comtrade (2024).

industrial complex. Some may excel in laboratory production but lack a broad range of other production branches, and the very importation of inputs might be concentrated in these same branches. In Graphs 1, 2, 3, and 4, it is possible to note how the HIC is composed in certain countries according to the major sectors.

These countries were selected to illustrate an initial classification of the HIC into three groups (Table 1), which in part clearly distinguishes them, although some are in a transitional phase, either because some countries in Group 3 are expanding, or because some in Group 2 have decreased their productive capacity over time, particularly over the last ten years. In the graphs for the US and Germany, it is understood that individually they belong to Group 1 of the HIC, since all indices are very high. Even so, it should be noted that the US has presented trade deficits for both finished goods ($142.6 billion) and productive inputs ($10 billion). Germany also has all equally high indices and presents a strong surplus among finished goods ($69 billion), but has a significant deficit of inputs, to the order of $6.5 billion[9].

In Group 2, it may be observed that China presents the same export and import profile, according to the order of importance of industrial branches, like the US and Germany, although

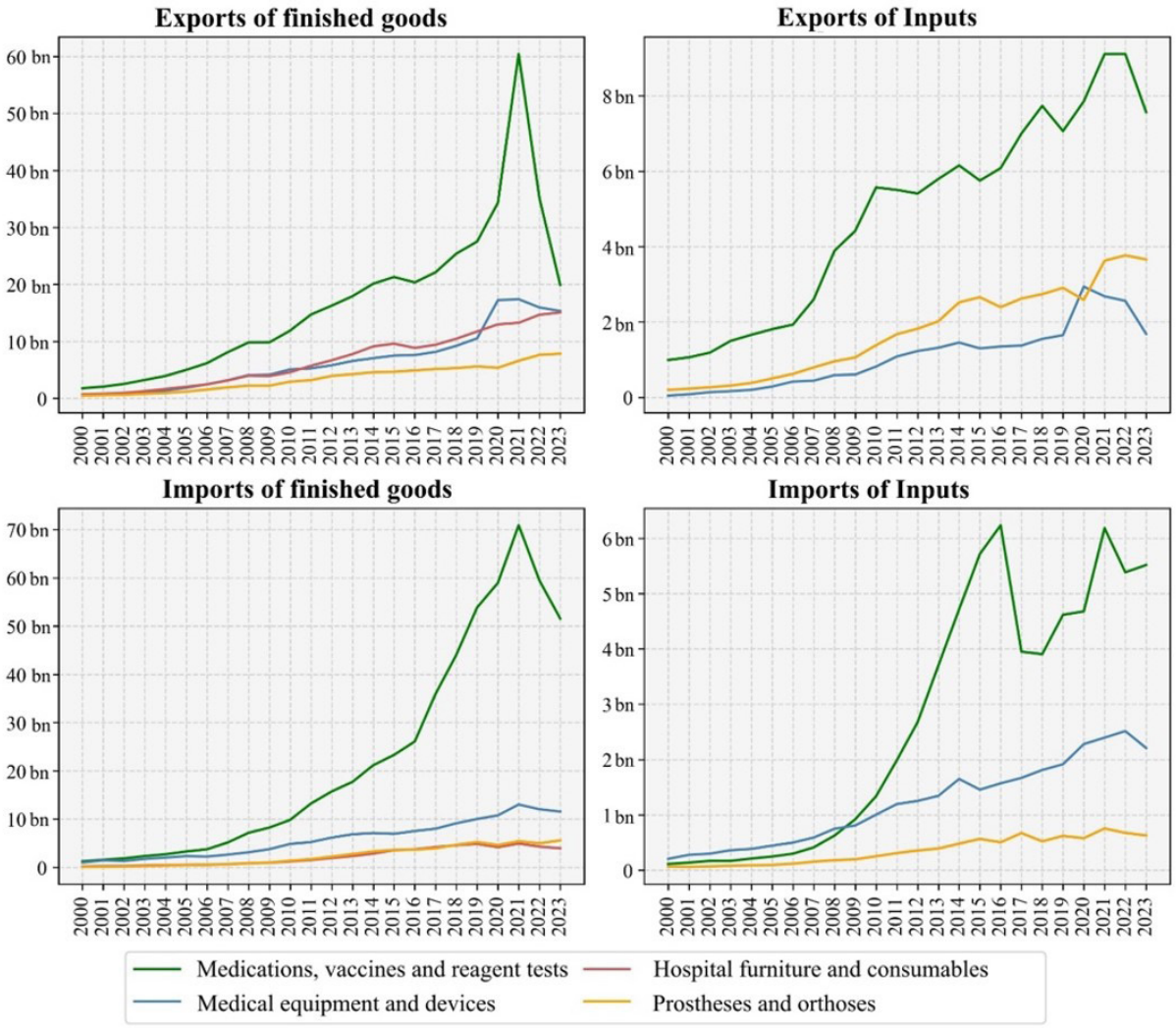
[9] While the focus of this analysis is on the export of finished goods and the import of inputs, it also accounts for the import of finished goods and the export of inputs.



Graph 2 – Germany: Historical series of exports and imports of productive inputs and finished goods between 2000 and 2023.
Data investigation and organization, and graph elaboration: Clara Penz.
Source: UN Comtrade (2024).

with much lower values. With exports of finished goods of around US$ 58 billion and imports of US$ 72.5 billion, there is a deficit of US$ 14.5 billion, after a peak of US$ 97.6 and US$ 94.2 billion during the pandemic and a surplus of US$ 3.5 billion. In Group 2, there would be between 9 and 12 countries, considering the position of those that appear in almost all lists of exports of finished goods and imports of industrial inputs. In this group, the case of Switzerland deserves a more in-depth analysis, since it is on the border between Groups 1 and 2. In 2022 it exported US$ 104.3 billion in finished goods and had a surplus of US$ 48.6 billion, but in which the pharmaceutical sector, vaccines, and reagents predominate, because it exported US$ 92 billion in the same year and imported US$ 42 billion in this same sector out of a total of US$ 48.7 billion of all the country's HIC imports. Furthermore, the case of inputs is at much lower levels than the US and Germany, and is more compatible with the group of Group 2.

Lastly, the Brazil graph also presents a profile of industrial sectors similar to the countries shown in the graphs of Groups 1 and 2, despite the large difference in values: it exported US$ 2.5 billion and imported US$ 12.8 billion in finished goods, with a deficit of US$ 10.3 billion, and exported US$ 482 million and imported US$ 1.7 billion in productive inputs in 2023, with a deficit of US$ 1.3 billion. Thus, it would be in Group 3, the most numerous, heterogeneous, and unstable, as it presents abrupt changes, in many cases with

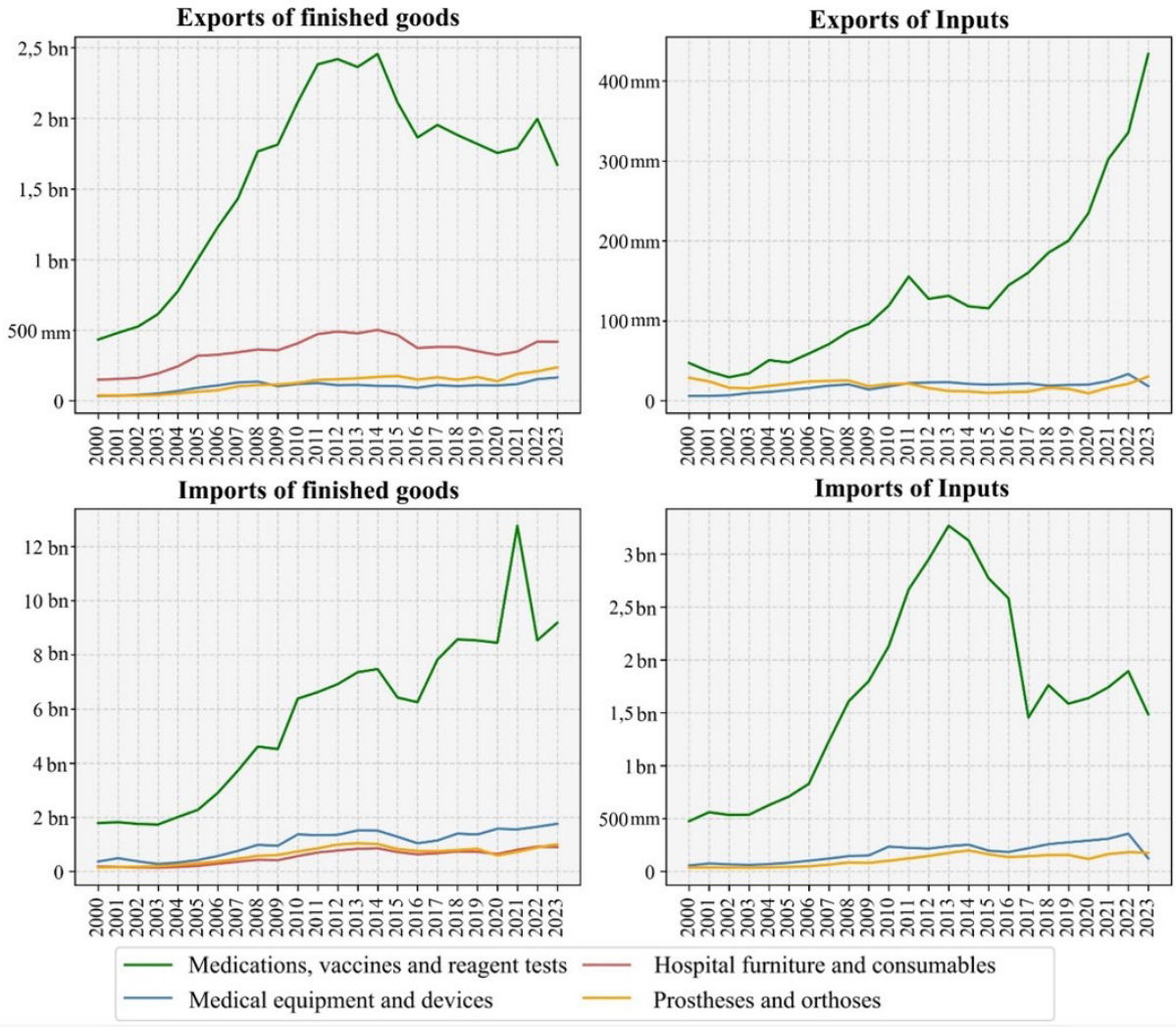


Graph 3 – China: Historical series of exports and imports of productive inputs and finished goods between 2000 and 2023.

Data investigation and organization, and graph elaboration: Clara Penz.
Source: UN Comtrade (2024)e.

countries entering and leaving the lower limits of this group over a short period of time. It may be noted that in the four selected cases it is common to observe deficits in the trade balance, which is frequently indicated as a major problem in the Brazilian case. However, this behavior is general in the major countries with HIC due to the flow dynamics of productive inputs that characterize its spatial productive circuit.

Attention should be drawn to the fact that among all the industrial sector profiles that make up the HIC, and of all the countries represented in that tables, graphs, and maps, just Japan, Mexico, and Hong Kong are most prominent. Japan has a medical equipment and devices sector that surpasses the pharmaceuticals, vaccine, and reagents sector in terms of exporting inputs, while Mexico exports more finished goods and productive inputs from the same sector, and additionally exports more prosthesis inputs than pharmaceuticals, vaccines, and reagents. In the case of Hong Kong, it is surprising that the import and export of industrial inputs for the prosthetics and orthotics sectors are significantly higher than the others (around US$ 3 billion), while pharmaceuticals, vaccines, and reagents are below US$ 1 billion, which is rare in this ranking.



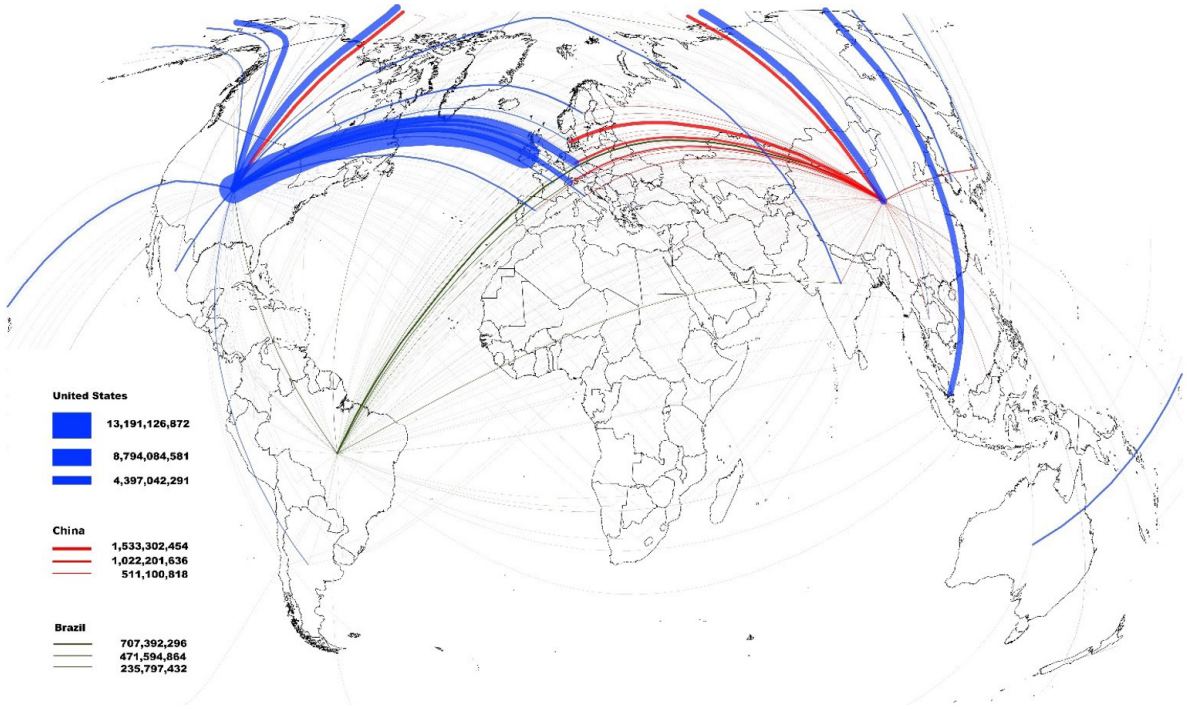
Graph 4 – Brazil: Historical series of exports and imports of productive inputs and finished goods between 2000 and 2023.

Data investigation and organization, and graph elaboration: Clara Penz.
Source: UN Comtrade (2024).

In all graphs produced with the 25 countries, the impact of the pandemic on the considered flows is evident, both in exports and imports, which generally grew. In the post-pandemic period, a significant drop is observed, sometimes in inputs, in other cases in finished goods or both, in many cases reaching levels lower than those prior to the pandemic and generating cyclical crises in the industrial sectors involved.

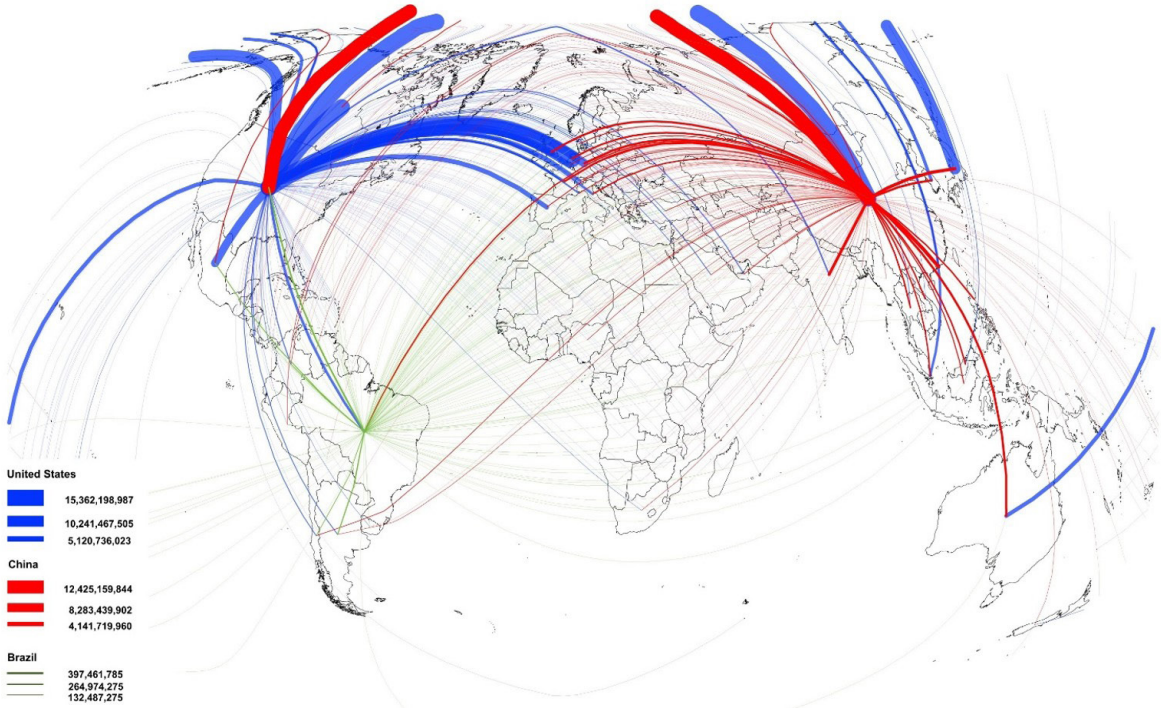
The significant role of cartography should be emphasized in formulating research hypotheses, not merely in representing results. Map 3 presents three selected countries representing Groups 1, 2, and 3 (USA, China, and Brazil) based on the flows of imported productive inputs and indicates the striking characteristic of spatial production circuits and their technical and territorial division of labor, which brings together countries from almost all over the world to supply their production needs. Conversely, the analysis of export flows of finished goods (Map 4) enables us to identify the countries that are primarily consumers of these nations' production.

In addition to the industrial branches that make up the productive spatial circuits of health, it should be remembered that this methodology for organizing and mapping information



Map 3 – Proportion of the health industrial complexes of Groups 1, 2, and 3 according to the import flows of productive inputs from the US, China, and Brazil – 2022.

Data organization: Caroline Fernandes and Clara Penz. Cartography: Antas Jr., with Magrit-CNRS.
Source: Un Comtrade (2024).



Map 4 – Proportion of the health industrial complexes of Groups 1, 2, and 3 according to the export flows of finished goods from the US, China, and Brazil – 2022.

Data organization: Caroline Fernandes and Clara Penz. Cartography: Antas Jr., with Magrit-CNRS.
Source: Un Comtrade (2024).

can be operational for mapping the productive spatial circuits of other industries in global manufacturing, such as the automotive industry. However, it is necessary to consider more elements of the branches being analyzed. In this case, there is an evident need to broaden the knowledge regarding the socio-spatial formations eventually implicated in the survey of the systematized and exhaustively analyzed flows, remembering that here it is only possible to present the analytical methodology and some considerations, since this is a huge task[10].

This initial construction enables us to perceive the most relevant indicators in all countries and is an important step, since it is a procedure that reveals surprises, such as Hong Kong, Mexico, Singapore, and the United Arab Emirates, and reveals the productive capacity of Ireland, which ranked first in the export of industrial inputs in 2022, and that Indonesia and Vietnam have been prominent over recent years. Perhaps some countries included in this mapping do not truly have a HIC, since it is necessary to relate them to the hospital system and the health model of their respective country. Closing the circularity of the political economy of health depends on how the productive system, hospital system, specialized services, and financing interact to serve the population.

For example, does a country such as Switzerland, with less than 10 million inhabitants, a significant industrial complex, and a pharmaceutical production among the top five in the world, actually present this systemic dynamic? Moreover, for Ireland, where the population is half that of Switzerland, is it possible to attribute the enormous consumption of pharmaceutical production inputs to a HIC that composes a well-structured political economy of health? Questions such as these need to be considered in better-specified definitions to arrive at a hierarchy of different groups of countries that possess a HIC.

FINAL CONSIDERATIONS

Quantifying the scale of global HICs is a more intricate task than has been presented herein, hence the reliance on indicators and potential scenarios. By examining HICs through the lens of productive spatial circuits, a clearer understanding is obtained of the underlying logic of the global corporate networks into which they are embedded. Typically, large multinational corporations operating across various sectors form the core of these complexes.

However, it is essential to consider that HICs are national (Antas Jr., 2015), i.e., they are horizontal territorial layers in the form of technical and organizational systems, whether of the companies that constitute a field of specific accumulation, or of the various manners in which the State marks its presence: health systems, hospital systems, universities in training and applied and basic research, state-owned industries producing vaccines and a variety of strategic pharmaceuticals, etc. In addition, there is a whole regulatory apparatus where the State is the main agent, but in which economic agents and, in some way, civil society, also participate.

Therefore, there is an entire political economy of health specific to each socio-spatial formation, and understanding it is fundamental for verifying which countries in the world possess and control a HIC. The Brazilian case illustrates this situation extremely well: observing Map 1 and Table 1, it could hastily be assumed that there is a less important HIC, however, if we include

[10] The information presented here is derived from an investigation of 145 countries. Graphs, such as those presented, were produced for all the assessed countries, as well as spreadsheets containing numerous corresponding statistical data and various maps for the major countries selected thus far.

the productive agents of the different branches, its standing soon becomes apparent. It should be emphasized that, in 2022, Brazil had the largest generic drug industry in Latin America, and the sixth largest in the world (Atradius, 2022). In addition, counting all the companies that participate in the health economy throughout Brazil, it was discovered that 366,235 formed the HEIC in 2017, of which 7,089 were industries (Antas Jr., 2019, p. 55-56). The importance of both the productive apparatus and the other health companies in Brazil is evident.

Given the country's universal healthcare system, a preference for purchasing from domestic companies, often supported by sector-specific financing policies (as in the case of the Brazilian Development Bank - BNDES), funding for applied scientific innovation (through institutions such as CNPq and Fapesp), significant scientific production from major universities, and even subsidies for domestic industries in the sector, a large amount of production is consumed internally. Therefore, evaluating Brazil's HIC using indicators of the exports of finished goods and the imports of industrial inputs can help to determine its approximate size, or at least confirm its existence. This rationale may be applied to other countries with extensive healthcare systems, high domestic consumption, and significant industrial production.

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