
HEALTH ECONOMIC-INDUSTRIAL COMPLEX (CEIS): BRAZILIAN EXTERNAL DEPENDENCE IN LIGHT OF THE GTAP MODEL

Complexo econômico-industrial da saúde (CEIS): a dependência externa brasileira à luz do modelo GTAP

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Abstract: If one has in mind the Covid-19 context and the Brazilian external dependence on health-service provision inputs, the aim of the present article is to contribute to debates on Health Economic-Industrial Complex (Complexo Econômico Industrial da Saúde - CEIS). We started the analysis by assessing the effects of internal health-service demand increase, which was simulated by the increased demand of the federal government based on the Global Trade Analysis Project (GTAP) model, version 10 (2014). Effects were observed on the Brazilian production, imports, exports and trade balance, as well as on its main partner countries, given the origin of their imports for the health sector. The governmental demand increase has intensified production for the health-services sector and the demand for imports, mainly in the industrial and pharmaceutical sectors. The trade balance deficit shows the weakness of CEIS-associated sectors. On the other hand, Brazilian trading partners, and the rest of the world, have benefited from their increased exports and from surpluses in these sectors' trade balances.

Keywords: Covid-19, CEIS, Governmental demand; GTAP.

Resumo: Considerando o contexto da Covid-19 e a dependência externa do Brasil em insumos para prestação de serviços de saúde, o objetivo deste artigo é contribuir com os debates sobre o Complexo Econômico-Industrial da Saúde (CEIS). A análise avaliou os efeitos do aumento da demanda interna por serviços de saúde, que foi simulado com base no aumento da demanda do Governo Federal usando o modelo GTAP (Global Trade Analysis Project), versão 10 (2014). Foram observados impactos na produção brasileira, nas importações, exportações e na balança comercial, além de efeitos nos principais países parceiros, considerando de onde vêm as importações para o setor de saúde. O aumento da demanda governamental intensificou a produção voltada para o setor de serviços de saúde e a demanda por importações, principalmente nos setores industrial e farmacêutico. O déficit na balança comercial mostrou a fragilidade dos setores ligados ao CEIS. Por outro lado, os parceiros comerciais do Brasil - e o resto do mundo - se beneficiaram com o aumento das exportações e com os superávits nas balanças comerciais desses setores.

Palavras-chave: Covid-19, CEIS, Demanda governamental, GTAP.

JEL Code: I15; C68; F14.

1 INTRODUCTION

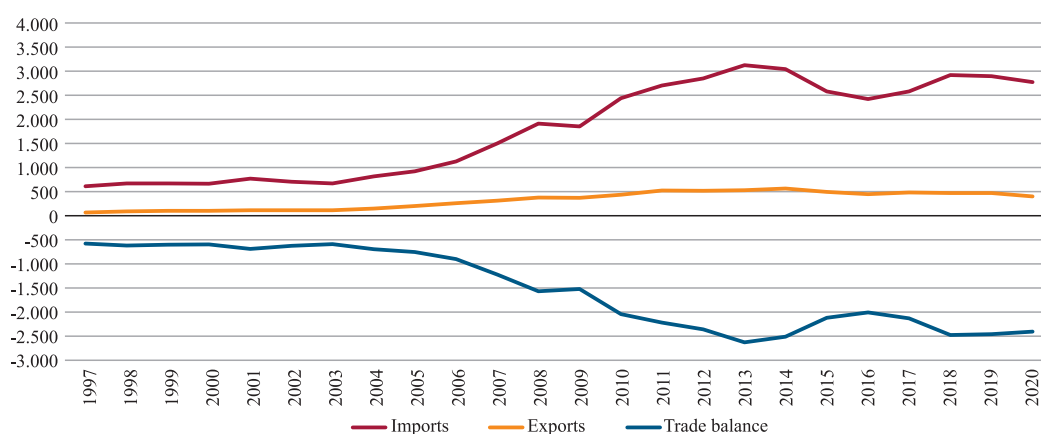
The concept of health in Brazil has evolved from a restricted view of disease control to a broader understanding of its role in social and economic development. This perspective diverges from the traditional definition of health as mere absence of disease, emphasizing instead its strategic contribution to innovation, competitiveness, and national development (Gadelha, 2009). With the 1988 Federal Constitution and the creation of the Unified Health System (SUS), health became a State duty, requiring strategies that integrate economic and social dimensions. Within this framework, the Health Economic-Industrial Complex (CEIS) was established as a systemic approach linking healthcare provision with industrial and technological development.

CEIS encompasses pharmaceutical and biotechnological industries, medical and hospital equipment, and the wide network of health services provided by both the public and private sectors. Its articulation generates employment, innovation, investment, and income, representing close to 9% of Brazil's GDP, 10% of skilled jobs, and more than one-quarter of national R&D investment. By combining production and services, CEIS strengthens the connection between industrial policy and social policy, positioning health as a driver of competitiveness and development.

Despite this strategic relevance, Brazil has faced difficulties in consolidating CEIS as an autonomous and competitive structure. The country remains highly dependent on imported medicines, medical devices, and critical technologies, which limits its capacity to respond to crises and increases vulnerability to external shocks. The Covid-19 pandemic exposed this fragility, when shortages of ventilators, protective equipment, and pharmaceutical products revealed the lack of productive security. Estimates indicate that around 95% of medicines and 80% of complex devices in the domestic market are imported.

This dependence is directly reflected in the trade balance of health-related goods. Figure 1 shows the persistent deficit recorded between 1996 and 2020, with a sharp deterioration after the 2008 global crisis and an increasing share of imports from China. Such imbalance not only affects the national economy but also raises the cost of maintaining SUS, undermining its ability to guarantee universal access to healthcare. During the pandemic, federal expenditures on health supplies expanded significantly, financing purchases of ventilators, medicines, and the expansion of ICU capacity, but largely through imported inputs.

Figure 1 – CEIS Trade Balance Evolution in Brazil (1996 to 2020) – values in millions of dollars



Source: Elaborated by the authors based on Comex Stat.

In this context, analyzing the interaction between health demand, industrial capacity, and external dependence becomes essential for the design of development strategies. The present study simulates an increase in government demand for health services using the Global Trade Analysis Project (GTAP) model, version 10 (2014). The analysis evaluates impacts on Brazilian production, imports, exports, and trade balance, as well as on its main partner countries. Beyond its empirical contribution, the study highlights the vulnerabilities of CEIS and offers insights for strengthening domestic production, reducing dependence on external suppliers, and promoting a more resilient and sustainable health system.

2 LITERATURE REVIEW

2.1 CEIS and the Impact of COVID-19

The CEIS in Brazil, as explored by Gadelha et al. (2013), constitutes an interdependent system of production and innovation, essential for the country's economic and social development. This study highlights the CEIS as a crucial vector in the articulation between the generation of knowledge, the significant sectoral economic base and the active role of the State in promoting innovation and regulation. However, the analysis by Gadelha et al. (2013) reveals challenges in maintaining Brazil's global competitiveness, especially in the pharmaceutical sector, in the face of trade liberalization and global technological transformations. The work highlights the need to strengthen strategies that align national productive capacity with innovation initiatives to overcome regressive specialization and ensure sustainable development in health.

The global health crisis caused by Covid-19 has further highlighted the interdependence between economic development and health, reiterating the central importance of the CEIS, as discussed by Gadelha and Braga (2021). Faced with the challenges posed by the global health crisis, they advocate a revitalization of the CEIS development strategies, placing health and well-being at the heart of policies to overcome development challenges. This proposal for a renewed and progressive approach aims to absorb the changes in the current scenario and intertwine economic dynamism with social and environmental demands, positioning the pandemic as a decisive moment to reassess and strengthen the Brazilian CEIS.

2.2 Innovation and Production Strategies

Oliveira and Silva (2019) carry out a detailed analysis of industrial policies in the context of the CEIS, focusing on the model of Productive Development Partnerships (PDPs), assessing their implementation in the pharmaceutical sector over the last two decades in Brazil. The authors point out that although the PDPs have proved essential for building the productive and technological capacity of the national industry, they are not enough on their own to fully structure the National Health Innovation System. However, the study highlights the importance of these partnerships as significant initiatives for advancing socio-economic development that tackles the social and material aspects of underdevelopment in Brazil.

Complementing this analysis, Silva and Rezende (2017) explore Productive Development Partnerships as a mechanism of the Brazilian state not only for the development of the CEIS, but also as an affirmation of the right to health. They discuss how the cooperation between public and private laboratories within the scope of PDPs aims to enhance the development, transfer and absorption of technology, as well as strengthen the country's productive and technological capacities in strategic areas for SUS. The study identifies the social actors involved in these partnerships and maps their interactions, highlighting the need for efficient management and the importance of collaboration among the various entities to optimize the results of these initiatives.

Nicolella and Guilhoto (2004), using an input-output matrix for the year 1999, analyzed the contribution of the health sector, both public and private, demonstrating its capacity to generate employment and increase production. Andrade et al. (2011) constructed an input-output matrix with sectoral breakdowns for the health-related subsectors, enabling a structural assessment of the production linkages in the health chain in Brazil. Based on the calculation of multipliers, the authors observed that the sub-sectors associated with the production of pharmaceutical products and medical devices showed greater internal and external linkage effects, given their high share of imports.

Motta et al. (2017) investigated how changes in household consumption patterns in relation to health goods and services impact the macroeconomy and the welfare of the population. Their analysis indicated that an increase in demand for health services could result in a multifaceted effect on the economy, affecting various sectors in different ways. They noted that to maintain household welfare in the face of an increase in health expenditure, a corresponding increase in income would be necessary, especially in the health services and pharmaceutical sectors.

2.3 Technological Dependency Challenges

The Brazilian industry has been facing, for several decades, a situation of very low competitiveness, whose causes include systemic cost factors such as interest rate levels, scarce sources of long-term financing, a complex and burdensome tax system, insufficient and poor infrastructure; and modest productivity gains due to a low investment environment. All of this is punctuated by long episodes of currency overvaluation. The consequences are most adverse. The share of the manufacturing industry has regressed in the productive structure since the 1980s. Worse, it was in the sectors of higher technological intensity that this setback proved to be more serious. In international trade of industrial goods, it shrank even further, going from 0.8% of total manufacturing exports in 2006 to 0.6% in 2017 (Santos et al., 2017).

Mota et al. (2012) and Mota (2013) investigate the articulation of the Brazilian pharmaceutical industry with the international market. Mota et al. (2012) question whether the trade liberalization initiated in the 1990s led to a pattern of regressive specialization in the sector. Through the analysis of foreign trade data, the authors identified an aggravation of the country's external dependence, both in terms of pharmaceutical inputs and final products. This phenomenon suggests a displacement of local production and technological efforts in favor of greater integration with the international market, highlighting a regressive specialization that compromises the autonomy and innovation capacity of the Brazilian pharmaceutical sector. Mota (2013) reinforces indications of regressive specialization in Brazil, highlighting the knowledge and technology deficit behind the trade deficit of the pharmaceutical industry.

Given the increase in demand for health services and its impact on the economy, the Covid-19 pandemic has imposed significant challenges on the Brazilian health system. Noronha et al. (2020) carried out an analysis of the Brazilian health system's capacity to respond to the additional demand caused by the pandemic. Using simulations that considered different infection rates and time periods, the authors identified that many health micro-regions could operate above their capacity, resulting in a potential degradation of care for patients with severe symptoms. This study highlighted the importance of measures to slow the virus's spread, the need to expand bed infrastructure and the restructuring of health services from a regional perspective to manage the new demand.

Complementing this perspective, Réquia et al. (2020) applied a multi-criteria spatial methodology to assess the risk of the health system of several Brazilian municipalities exceeding its capacity due to the increase in Covid-19 cases. The analysis revealed a projected average deficit of hospital beds, signaling challenges for the North and Northeast regions of the country. Even with the implementation of measures to reduce social contacts and increase investments in the health system, the study indicated that significant challenges in hospital bed capacity would persist in several municipalities.

Szylovec et al. (2021) address Brazil's actions in the face of the global health crisis caused by Covid-19, focusing on the measures implemented in the initial period of the pandemic, between January and March 2020. Using a variety of sources, including official data, epidemiological bulletins and journalistic coverage, the study details the country's interdisciplinary and intersectoral response. Despite the adoption of various non-pharmaceutical measures aimed at controlling and mitigating the spread of the virus, the study highlights the inadequacy of these strategies in addressing pre-existing regional and social inequalities.

Brazil's response to the Covid-19 pandemic and its subsequent effects on the CEIS highlight the intricate relationship between technological development and external dependency. Gadelha and Braga (2016) had already predicted the need for an integrated approach to economic, social and environmental development, where we can highlight this as a moment of validation of the hypothesis of the endogenous interdependence of the CEIS. The global health crisis has reinforced the urgency of overcoming traditional dichotomies and rethinking development strategies that consider health and well-being as pillars of economic and social progress. The pandemic has underlined the importance of a robust health infrastructure, as well as a scientific, technological and industrial capacity focused on health needs as a fundamental element in guaranteeing life.

In a context of fiscal austerity, Aragão and Funcia (2019) discuss how the Covid-19 crisis highlighted Brazil's vulnerability due to its external technological dependence, especially regarding access to essential health products. The non-pharmaceutical measures, crucial for pandemic control, encountered obstacles in the lack of critical supplies, such as ventilators and intubation drugs, due to this dependence. The scarcity of these essential items revealed the population's increased exposure to risks, highlighting the need for policies that strengthen national productive capacity and reduce external dependence during critical situations.

3 METHODOLOGY AND DATABASE

3.1 GTAP Model

The GTAP framework is based on both microeconomic fundamentals and data from countries' input-output and external sector matrices (exports, imports, tariffs). GTAP modeling was documented by Hertel et al. (1997) and McDougall (2003).

GTAP uses regional agents to represent each region/country, which accounts for collecting income generated by production processes (VOA) and by taxes collected from private agents, by governmental investments and manufacturers – TAXES, exports XTAX and imports MTAX.

The collected income is distributed among three final-demand components, namely: private agents (PRIVEXP), government (GOVEXP) and global savings (SAVE). This distribution is ruled by the per capita utility function, based on the Cobb-Douglas functional form, so that each of them has a constant share in the regional income.

In mathematical terms, regional agent's utility maximization is expressed by equation:

$$\max U = U_P^{B_P} U_G^{B_G} U_S^{B_S} \quad (1)$$

$$s. a Y = P U$$

Wherein, U is the regional agent utility, which is formed by private agent (P), government (G) and global savings (S) utilities, based on the Cobb-Douglas function, with parameter B . B . participation; Y is regional agent's *per capita* income and P is the price vector. P, G and S restrictions are:

$$Y_P = P_P U_P \quad (2)$$

$$Y_G = P_G U_G \quad (3)$$

$$Y_S = P_S U_S \quad (4)$$

Therefore, the share of each one of the three final-demand components is given by equation:

$$\frac{Y_i}{Y} = \frac{\Phi_i^{-1} B_i}{\sum_j \Phi_j^{-1} B_j} \quad (5)$$

Wherein, subscript i can represent P, G or S; B_i is the Cobb-Douglas function parameter; Φ_i is the elasticity of expenditure with utility function U_i for sub-functions of private agent (U_P), government (U_G) and global savings (U_S). utilities. Thus, the demand system (5) can be rewritten for P, G and S through equations:

$$\frac{Y_P}{Y} = \left(\frac{\Phi_P}{\Phi} \right)^{-1} B_P \quad (6)$$

$$\frac{Y_G}{Y} = \Phi B_G \quad (7)$$

$$\frac{Y_S}{Y} = \Phi B_S \quad (8)$$

Or in as percentage change in the GTAP modeling:

$$y_P - y = -(\Phi_P - \Phi) + b_p \quad (9)$$

$$y_G - y = \Phi + b_G \quad (10)$$

$$y_S - y = \Phi + b_S \quad (11)$$

Nomenclature equations (9)-(11) in GTAP embody the following forms:

$$y_P(r) - y(r) = -[uepriv(r) - uelas(r)] + dppriv(r) \quad (12)$$

$$y_G(r) - y(r) = uelas(r) + dpgov(r) \quad (13)$$

$$y_S(r) - y(r) = uelas(r) + dpsave(r) \quad (14)$$

Parameter $uelas(r)$ represents income elasticity, which is defined as mean private agent income, governmental income and global savings elasticity weight. However, since governmental income elasticity and global savings are fixed, changes in $uelas(r)$ only depend on changes in cost per private agent utility elasticity ($uepriv(r)$):

$$uelas(r) = XSHRPRIV(r) * uepriv(r) - dpav(r) \quad (15)$$

Wherein, $dpav(r)$ is the parameter for changes in the mean distribution of shares belonging to the three final-demand components:

$$dpav(r) = XSHRPRIV(r) * dppriv(r) + XSHRGOV(r) * dpgov(r) + XSHRSVE(r) * dpsave(r) \quad (16)$$

Wherein, $XSHRPRIV(r)$, $XSHRGOV(r)$ and $XSHRSVE(r)$, respectively, are the private agent, governmental and global savings shares in regional income; $dppriv(r)$, $dpgov(r)$ and $dpsave(r)$ represent the consumption distribution parameter recorded for these three final-demand components, in the same order, which corresponds to parameter recorded for the regional agent's Cobb-Douglas function presented on equation (1).

Producers' behavior aims at maximizing their own profits within a perfectly competitive market structure, where prices reflect associated-industries' marginal cost and constant returns to scale. The production process demands production factors, such as land, capital, skilled and unskilled labor, "wages" (VOA) are paid for. Output is domestically sold to private agents (VDPA) and to the government (VDGA), in addition to buying and selling relationships set among producers (VDFA). Producers also interact with external sectors by buying imported goods (VIFA) and by selling exported ones (VXMD).

3.2 Database and Empirical Strategy

The GTAP model (version 10, 2014), which comprises 65 productive sectors and 141 countries/regions, was herein used. Table 1 shows GTAP's sectoral and regional aggregation. These 65 sectors were grouped into twelve categories, namely: i) agriculture, ii) livestock, iii) extraction, iv) processed food, v) textiles, vi) light manufacturing, vii) pharmaceuticals, viii) heavy manufacturing, ix) utilities and construction, x) transportation and communication, xi) health and social services¹, and xii) other services. The 141 countries/regions were grouped into Brazil's twelve main health-related imports sector partners: United States, Germany, China, Switzerland, Italy, France, Japan, United Kingdom, Ireland, Belgium, India and Mexico. Altogether, these countries accounted for 80% of Brazil's total imports to the 65 sectors, in 2014, as well as to 128 other countries/regions that were added to calculation as "rest of the world".

¹ The human health and social care sectors include the provision of health care-related services provided by medical and other health professionals in hospitals and other facilities, residential health care activities, and social care activities indirectly related to health.

The empirical strategy started from observing the federal government's increased expenditures during the Covid-19 pandemic. According to the Transparency Portal, the amount of money transferred from the federal government to the Ministry of Health to face the emergency arising from the new coronavirus totaled 39,299,135,197.90 billion reais, in 2020, and this number corresponds to 1.19%² increase in investments in this sector (Brasil, 2020b). Accordingly, we simulated 1.19% increase (shock) in governmental demand based on the *dpgov* parameter found in the GTAP model (equations 13 and 16).

Government demand (expenditures) expansion was distributed among sectors, based on their internal (domestic production) and external (trading partners) share in total consumption (equation 13), since the government's utility is modeled by a Cobb-Douglas function. According to equation 16, the increased governmental demand also increased the government's share in the total final demand proportional to the shock.

Two GTAP model limitations to assess the present elements need to be highlighted. The first one refers to final regional agent demand modeling, in per capita terms. It means that the governmental demand is not the equivalent representation to countries' total demand, whose values are underestimated. However, this limitation is not an obstacle, since the present article is not focused on the exact nominal assessment of effects caused by the increased demand by the federal government, but rather on assessing the direction taken by these effects considering governmental purchases' share in and outside the economy. The second limitation concerns the impossibility of applying an increased governmental demand shock to a specific sector. However, it should be noticed that expenditures with the health sector corresponded to 41.31% of the total governmental consumption, and it totaled internal and external consumption to the GTAP 10 database.

According to GTAP 10 data, the Brazilian government's expenditures mainly head towards the domestic market, which accounts for 99.95% of the total expenses – only 0.045% of it regards imported goods. Table 2 shows the Brazilian government consumption composition of the domestic and imported sectors, based on the sector classification introduced in Table 1.

Table 1 – Sectoral composition of Brazilian governmental expenditures between domestic and imported sectors - amounts expressed in millions of dollars (US\$) and rates (%)

Sectoral composition	National		Imported	
	US\$ %		US\$ %	
Agriculture	9.39	0.00	0.00	0.00
Livestock	41.18	0.01	0.01	0.00
Extraction	0.16	0.00	0.00	0.00
Processed Foods	1.99	0.00	0.36	0.17
Textiles	4.32	0.00	6.60	3.08
Light Manufacturing	18.90	0.00	1.78	0.83
Pharmaceuticals	0.90	0.00	3.68	1.72
Heavy Manufacturing	25.70	0.01	22.98	10.73
Utilities and construction	6613.95	1.39	0.00	0.00
Transportation and communication	349.91	0.07	0.47	0.22
Health and social care services	196539.91	41.34	2.96	1.38
Other Services	271955.63	57.18	175.24	81.86
Total	475561.92	100.00	214.07	100.00

Source: elaborated from GTAP 10 data.

The government's domestic expenses focus on the service sector, mainly on "other services" (57.18%), which include financial services, public administration and national defense, education, among others, as well as on health services and social assistance (41.34%), besides the utilities and construction sector (1.39%) – other sectors account for 0.08% of the total of expenses. Government imports are distributed among "other services" (81.86%), heavy manufacturing (10.73%), textiles (3.08%), pharmaceuticals

² This value was reached by proportionality considering that the total amount spent by the federal government during the pandemic totaled 524.02 billion, and this number corresponds to 15.85% of public expenditures.

(1.72%), health care services (1.38%) and other sectors (1.23%). It is noteworthy that imports for the textile and pharmaceutical products sectors are higher than those focusing these sectors' domestic consumption. The value recorded for imports in the heavy manufacturing sectors (22.98 million dollars) is close to the total spent on domestic purchases for these sectors (25.70 million dollars).

Table 2 – Regional and Sector Classification

Regional Classification	Sector Classification
Brazil Main Brazilian partners regarding the origin of their health imports: United States, Germany, China, Switzerland, Italy, France, Japan, United Kingdom, Ireland, Belgium, India, and Mexico. Rest of World: Australia, New Zealand, Canada, Austria, Cyprus, Czech Republic, Denmark, Estonia, Finland, Greece, Hungary, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Norway, Bulgaria, Croatia, Romania, Israel, Hong Kong, Korea, Mongolia, Taiwan, Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, Vietnam, Bangladesh, Nepal, Pakistan, Sri Lanka, Argentina, Bolivia, Chile, Colombia, Ecuador, Paraguay, Uruguay, Venezuela, Costa Rica, Guatemala, Honduras, Nicaragua, Panama, El Salvador, Dominican Republic, Jamaica, Trinidad and Tobago, Albania, Belarus, Russian Federation, Ukraine, Kazakhstan, Tajikistan, Armenia, Azerbaijan, Georgia, Bahrain, Iran, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, Turkey, United Arab Emirates, Egypt, Morocco, Tunisia, Benin, Burkina Faso, Cameroon, Ivory Coast, Ghana, Guinea, Nigeria, Senegal, Togo, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Rwanda, Uganda, Zambia, Zimbabwe, Botswana, South Africa, Puerto Rico (PRI), Caribbean, Rest of North America, Rest of South America, Rest of Central America, Remainder of EFTA, Remainder of Asia, Remainder of East Asia, Remainder of Southeast Asia, Remainder of South Asia, Remainder of West Asia, Remainder of North Africa, Remainder of West Africa, Remainder of East Africa, Remainder of South Central Africa, Remainder of Eastern Europe, Remainder of Europe, Remainder of former Soviet Republics, Remainder of Oceania, Remainder of the European Union, Remainder of the World.	<u>Agriculture</u>: Raw rice (pdr), wheat and rye (wht), other grains (gro), vegetables and fruits (v_f), oilseeds (osd), sugar cane and beets (c_b), vegetable fibers (pf), other crops (ocr), processed rice (pcr). <u>Livestock</u>: animal husbandry (ctl), other animal products (oap), raw milk (rmk), other animal products (wol), meat: cattle, sheep, goat horse (cmt), other meat products (omt). <u>Extraction</u>: forestry, logging (frs), fishing, hunting, kinetic restocking (fsh), coal (coa), petroleum (oil), gas (gas), other extractions (oxt). <u>Processed foods</u>: vegetable oils (vol), dairy products (mil), sugar (sgr), other foods (ofd), beverages and tobacco (b_t). <u>Textiles</u>: textiles (tex), clothing (wap). <u>Light manufacturing</u>: leather products (lea), lumber and wood products (lum), paper and stationery products (ppp), metal products (fmp), motor vehicles (mvh), other transport equipment (otn), other manufacturing (omf). <u>Pharmaceuticals</u>: manufacturing of pharmaceutical products (bhp). <u>Heavy manufacturing</u>: refined petroleum and coke (p_c), chemicals (chm), rubber and plastics products manufacturing (rpp), non-metallic minerals (nmm), iron and steel (i_s), non-ferrous metals (nfm), electronic equipment (ele), electrical equipment (eeq), other machinery and equipment (ome). <u>Utilities and construction</u>: electricity (ely), gas distribution (gdt), water (collection, treatment, and distribution) (wtr), construction (cns). <u>Transport and communication</u>: trade (tdr), accommodation, food, and services (afs), other transport (otp), shipping (wtp), air transport (atp), warehousing and support activities (whs), communication (can). <u>Health and social care services</u>: human health and social care (hht). <u>Other services</u>: financial services (ofi), insurance (ins), real estate activities (rsa), other business services (obs), recreation and other services (ros), public administration and defense (osg), education (edu), human health (hht), housing (dwe).

Source: Elaborated by the authors based on GTAP 10 database.

4 RESULTS AND DISCUSSION

Results encompass variations in the Brazilian economy's production (Table 3), imports (Table 4), exports (Table 5) and in the trade balance (Table 6), as well as in its main partner countries (and the rest of world), when it comes to the origin of its health-related sectors' imports.

Based on Table 3, 1.19% increase in the Brazilian federal government's demand led to increased production, mainly in sectors the government has large participation in, such as the case of positive variations in health and social assistance services' production (0.59%), in other services (0.10%) and in pharmaceutical products (0.07%), which particularly resulted from health services' production increase. The other sectors presented lower participation in national production chains.

The increased demand recorded for the national government and the production reallocation necessary to meet this demand, mainly when it comes to health services' provision, have affected the imports and exports, as shown in Tables 4 and 5, respectively. The highest variation in imports was recorded for the pharmaceuticals (0.37%), utilities and construction (0.15%), textiles (0.11%) and light manufacturing (0.10%) sectors. In addition, during the Covid-19 pandemic, Brazil's foreign dependence on health-related sectors from masks to pharmaceutical and high-technology products was notable (Morosini, 2020). It is emphasized that the pharmaceutical subsector has a high connection with the health sector both internally and externally to the economy (Andrade *et al.*, 2011; Gava *et al.*, 2016).

Besides leading to national economy reorientation, the increased governmental demand affected the economies of other countries. It was observed that production (Table 3) and exports (Table 5) for the agrifood and industrial sectors regarding their health imports' origin increased both in Brazil's main trading partners) and in the rest of the world. However, there was drop in both production and exports in the textile sectors, in Ireland and India, as well as in Irish light and heavy manufacturing sectors.

Table 3 – Production variation (percentage values) – 2014

qo	Brazil	United States	Germany	China	Switzerland	Italy	France	Japan	United Kingdom	Ireland	Belgium	India	Mexico	Rest of the World
Agriculture	-0.14	0.01	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00
Livestock	-0.19	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00
Extraction	-0.08	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
Processed Foods	-0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Textiles	-0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	-0.00	0.00	0.00
Light Manufacturing	-0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	-0.00	0.00	0.00
Pharmaceuticals	0.07	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.00
Heavy Manufacturing	-0.20	0.00	-0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	0.00	0.00	0.00
Utilities and construction	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
Transportation and communication	-0.16	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
Health and social care services	0.59	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.00	-0.00	-0.00
Other Services	0.10	-0.00	-0.00	-0.00	0.00	-0.00	-0.00	-0.00	0.00	0.00	-0.00	0.00	-0.00	-0.00

Source: based on GTAP results.

Table 4 – Variation of imports (percentage values) – 2014

qiw	Brazil	United States	Germany	China	Switzerland	Italy	France	Japan	United Kingdom	Ireland	Belgium	India	Mexico	Rest of the World
Agriculture	-0.04	-0.00	-0.00	-0.02	-0.00	-0.00	-0.00	-0.01	-0.00	0.00	0.00	0.00	-0.00	-0.00
Livestock	0.03	-0.01	0.00	-0.01	-0.00	-0.00	-0.00	-0.02	-0.00	0.00	0.00	0.00	0.00	-0.02
Extraction	-0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	0.00	-0.00	0.00
Processed Foods	0.00	-0.00	-0.00	-0.01	-0.00	0.00	-0.00	-0.00	-0.00	0.01	0.00	-0.01	-0.00	-0.00
Textiles	0.11	-0.00	-0.00	0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.00	-0.00	-0.00
Light Manufacturing	0.10	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
Pharmaceuticals	0.37	-0.00	0.00	-0.00	-0.00	0.00	0.00	-0.00	-0.00	0.00	0.00	0.00	-0.00	-0.00
Heavy Manufacturing	0.04	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
Utilities and construction	0.15	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.00	-0.00	-0.00
Transportation and communication	-0.04	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.00	-0.00	-0.00

qiw	Brazil	United States	Germany	China	Switzerland	Italy	France	Japan	United Kingdom	Ireland	Belgium	India	Mexico	Rest of the World
Health and social care services	-0.04	-0.00	0.00	-0.00	0.00	-0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00	-0.00	-0.00
Other Services	0.08	-0.01	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00

Source: based on GTAP results.

Table 5 – Exports variation (percentage values) – 2014

qxw	Brazil	United States	Germany	China	Switzerland	Italy	France	Japan	United Kingdom	Ireland	Belgium	India	Mexico	Rest of the World
Agriculture	-0.16	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Livestock	-0.40	0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.02	0.02	0.02	0.03	0.01	0.02
Extraction	0.11	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.00	-0.01	-0.00	-0.01	-0.00	-0.00
Processed Foods	-0.31	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01
Textiles	-0.67	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	-0.00	0.00	0.00
Light Manufacturing	-0.52	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	-0.00	0.00	0.00	0.00	0.00
Pharmaceuticals	-0.55	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.02	0.01
Heavy Manufacturing	-0.44	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	0.00	0.00	0.00
Utilities and construction	-0.42	0.00	-0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	-0.00	0.00	0.00
Transportation and communication	-0.34	0.00	-0.00	-0.00	0.00	0.00	0.00	0.00	0.00	-0.00	-0.00	-0.00	0.00	-0.00
Health and social care services	-0.45	0.00	-0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	-0.00	-0.00	0.00	0.00
Other Services	-0.41	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00

Source: based on GTAP results.

Table 6 – Variation of the trade balance (values in millions of dollars) – 2014

DTBALi	Brazil	United States	Germany	China	Switzerland	Italy	France	Japan	United Kingdom	Ireland	Belgium	India	Mexico	Rest of the World
Agriculture	-42.89	8.22	0.61	9.92	0.12	0.94	2.02	0.75	0.41	0.00	0.04	1.53	0.84	19.15
Livestock	-60.97	8.48	3.71	3.63	0.25	1.40	2.57	2.07	1.44	0.83	1.03	1.59	0.30	36.00
Extraction	99.27	-2.11	5.02	8.17	-0.20	3.02	1.76	10.79	0.60	0.17	0.46	6.17	-3.24	127.96
Processed Foods	-60.74	8.34	3.97	2.82	0.59	1.83	4.86	1.57	2.94	0.05	0.12	0.95	0.74	35.05
Textiles	-16.38	7.52	1.42	-2.58	0.20	0.59	0.94	1.53	1.77	0.08	0.31	-1.71	0.19	6.74
Light Manufacturing	-194.49	58.45	8.69	20.82	1.92	4.51	9.52	10.50	10.77	0.13	1.84	-0.21	2.64	70.07
Pharmaceuticals	-38.09	11.00	2.72	2.02	0.41	1.36	2.31	1.00	2.55	-0.32	1.27	0.42	0.72	12.39
Heavy Manufacturing	-268.40	78.50	0.82	25.13	1.49	1.87	7.82	12.87	9.65	-1.86	1.87	5.62	9.79	124.48
Utilities and construction	-5.94	0.46	0.17	0.31	0.13	0.29	0.25	0.44	0.32	0.04	0.08	-0.07	0.01	3.52
Transportation and communication	-21.85	6.33	0.14	2.22	-0.27	0.49	0.41	0.26	1.80	-0.41	-1.10	-2.42	0.14	-9.93
Health and social care services	-1.25	0.18	0.08	0.16	0.01	-0.00	0.07	0.08	0.20	-0.00	0.00	-0.04	0.03	0.47
Other Services	-103.86	25.55	5.88	5.56	1.73	2.58	4.52	3.38	9.85	1.53	1.70	-0.61	0.46	41.73
Total	-715.59	210.92	33.23	78.18	6.38	18.88	37.05	45.24	42.30	0.24	7.62	11.22	12.62	211.71

Source: based on GTAP results.

As for Brazilian exports, they fell in all sectors except the extractive sector (0.11%), which serves as an input for production in other countries, as can be seen from the negative variations in production (Table 3) and in exports (Table 5) and the increase in imports (Table 2) from other countries in this segment.

The balance of trade (Table 6) is derived from the difference between the variation in the value of exports and imports of the countries and is presented in millions of dollars. Brazil is the only country to have a trade balance deficit (-715.59) arising mainly from the (-268.40) and light (-194.49) manufacturing sectors. Only the Brazilian extractive sector shows a surplus (99.27), a result linked to the increase in world imports in this sector, except Ireland and Mexico (Table 4).

The negative balance of trade is in line with works that emphasize Brazilian vulnerability and external dependence, consequently, the CEIS (Furtado, 1961, 1964; Gadelha, 2003, 2004, 2006; Gadelha et al., 2021).

The trade balance of the other countries is positive, with greater gains for the United States (210.92) and China (78.18). Among the negative sectoral balances in the main exporting countries in the health sectors to Brazil, we highlight: i) Ireland's deficit in the balance of trade in the pharmaceutical products sector, opposite to that observed in the other Brazilian trade partners and the rest of the world, and ii) China's trade deficit in the textiles which is justified by the intensification of Chinese production industrial sectors with higher added value giving way to other Asian countries the production in sectors with lower added value, such as textiles (Gaulier et al., 2007).

The results, especially for the pharmaceutical sectors, appear to be robust when analyzing GTAP 10 for the year 2011, applying the same shock in the GTAP model, equivalent to a 1.19% increase in public spending, as shown in Appendix A. However, the higher trade deficit in 2014 (-715.59) compared to 2011 (-286.67) indicates an increase in external dependence related to the health sectors. This greater external dependence in 2014 compared to 2011 is consistent with the national trade data presented in Figure 1 and is also corroborated by the increase in Brazilian imports of other health-related sectors such as textiles and heavy manufactures in 2014, which was not the case in 2011.

5 CONCLUDING REMARKS

The aim of the present study was to contribute to debates on health care in Brazil, based on the analysis applied to the impacts of increased Brazilian federal government's demand, according to the GTAP model, during the Covid-19.

The increased governmental demand implied increase in the domestic health services sector's production and in its associated sectors, such as pharmaceuticals. Overall, there was increase in foreign health-related sectors' (pharmaceuticals, manufactures) imports and decrease in most sectors' exports, and it had negative effect on the trade balance and, consequently, increased the country's external vulnerability. These results draw attention to the CEIS' external dependence and vulnerability, which does not meet the government's domestic demand. On the other hand, the origin of health imports coming from the main trading partners benefited from their increased exports and positive trade balances.

Brazil's vulnerability and external dependence reflect its production pattern and international position in the external market, which is featured as primary-product exporter and dependent on foreign manufacturing - from textile products, such as masks (N95), higher technological content products like medical devices and medicines. Thus, despite its continuous health service supply by SUS, the country lacks productive security for this system's operation.

The challenge of structuring CEIS is posed by the capabilities of the private sector, universities, research and development institutions, and by public development banks, according to which, the national State must systemically take emergency and structuring actions that echo on SUS response ability, in the short, mid and long terms, on a broader reindustrialization perspective, to reduce, or revert, the country's dependence on imported equipment and inputs, to ensure greater balance in sector's trade balance and better conditions for public health policies' development. Furthermore, CEIS' organization is an opportunity to boost the development of productive forces and, consequently, the Brazilian economy growth, given the role it plays as job positions and income generator.

The limitation of this work lies in the lack of a parameter in the GTAP model that allows for an increase in government demand in specific sectors; however, since health-related sectors make up a large part of government demand, the results are still reliable.

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APPENDIX A

Table A.1 – Production Variation (Percentage Values) – 2011

qo	Brazil	United States	Germany	China	Switzerland	Italy	France	Japan	United Kingdom	Ireland	Belgium	India	Mexico	Rest of the World
Agriculture	-0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Livestock	-0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
Extraction	-0.06	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
Processed Foods	-0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Textiles	-0.20	0.00	0.00	-0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	0.00
Light Manufacturing	-0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pharmaceuticals	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heavy Manufacturing	-0.17	0.00	-0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	0.00	0.00	0.00
Utilities and construction	-0.03	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
Transportation and communication	-0.16	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
Health and social care services	0.58	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
Other Services	0.09	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.00	-0.00	0.00	-0.00	-0.00

Table A.2 – Variation of imports (percentage values) – 2011

qiw	Brazil	United States	Germany	China	Switzerland	Italy	France	Japan	United Kingdom	Ireland	Belgium	India	Mexico	Rest of the World
Agriculture	-0.09	-0.00	0.00	-0.01	-0.00	-0.00	0.00	-0.00	-0.00	0.00	0.00	0.00	0.00	-0.00
Livestock	-0.08	-0.00	-0.00	-0.00	-0.00	0.00	-0.00	-0.01	-0.00	0.00	0.00	0.00	-0.00	-0.01
Extraction	-0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	0.00	-0.00	0.00
Processed Foods	-0.08	-0.00	-0.00	-0.00	-0.00	0.00	-0.00	-0.00	-0.00	0.00	0.00	-0.00	-0.00	-0.00
Textiles	-0.01	-0.00	-0.00	0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.00	0.00	-0.00
Light Manufacturing	0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00
Pharmaceuticals	0.27	-0.00	0.00	-0.00	0.00	0.00	0.00	-0.00	-0.00	0.00	0.00	0.00	-0.00	-0.00
Heavy Manufacturing	-0.02	-0.00	-0.00	0.00	0.00	-0.00	0.00	-0.00	-0.00	-0.00	0.00	-0.00	-0.00	-0.00
Utilities and construction	0.07	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.00	0.00	-0.00	-0.00
Transportation and communication	-0.12	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.00	-0.00	-0.00
Health and social care services	-0.13	-0.00	0.00	-0.00	0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.00	0.00	-0.00	-0.00
Other Services	0.01	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00

Table A.3 – Exports variation (percentage values) – 2011

qxw	Brazil	United States	Germany	China	Switzerland	Italy	France	Japan	United Kingdom	Ireland	Belgium	India	Mexico	Rest of the World
Agriculture	-0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Livestock	-0.19	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01
Extraction	0.07	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.00	-0.00	-0.00	-0.01	-0.00	-0.00
Processed Foods	-0.17	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Textiles	-0.39	0.00	0.00	-0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	0.00
Light Manufacturing	-0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pharmaceuticals	-0.31	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Heavy Manufacturing	-0.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	0.00	0.00	0.00
Utilities and construction	-0.25	0.00	-0.00	-0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	0.00
Transportation and communication	-0.20	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.00	-0.00
Health and social care services	-0.28	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.00	-0.00
Other Services	-0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	0.00	0.00

Table A.4 – Variation of the trade balance (values in millions of dollars) – 2011

DTBALi	Brazil	United States	Germany	China	Switzerland	Italy	France	Japan	United Kingdom	Ireland	Belgium	India	Mexico	Rest of the World
Agriculture	-7.13	1.56	0.01	1.94	0.04	0.24	0.47	0.5	0.21	0	0.03	0.19	0.25	2.66
Livestock	-25.32	3.22	1.71	1.31	0.1	0.59	1.24	1.38	0.57	0.3	0.45	0.38	0.21	14.39
Extraction	65.64	2.06	3.31	5.55	-0.05	2.52	1.34	6.89	-0.01	0.11	0.52	3.04	-1.88	-88
Processed Foods	-34.6	4.21	2.38	1.26	0.31	1.03	2.54	1.15	1.49	0.11	0.44	0.51	0.45	20.98
Textiles	-4.5	3.9	0.78	-5.95	0.12	0.26	0.5	0.88	0.9	0.05	0.19	-0.9	0.1	4.38
Light Manufacturing	-106.48	27.45	5.68	6.33	1.1	3.15	5.49	5.87	5.45	0.23	1.3	1.04	0.96	46.39
Pharmaceuticals	-22.71	6.29	1.75	1.03	0.32	0.96	1.28	0.46	1.44	-0.19	0.96	0.24	0.46	7.57
Heavy Manufacturing	-121.12	33.17	-2.64	2.75	0.59	1.17	4.19	3.88	5.13	-1.18	0.87	3.03	3.7	74.75
Utilities and construction	-3.3	0.23	0.08	0.04	0.08	0.14	0.07	0.15	0.14	0.02	0.05	-0.02	0	2.32
Transportation and communication	16.39	0.14	-1.84	-1.29	-0.73	-0.7	-2.1	-0.76	-0.57	-0.78	-1.48	-2.05	0.04	-21.9
Health and social care services	0.69	-0.53	0	-0.06	0	-0.03	-0.06	0.04	0.08	-0.01	-0.02	-0.03	0.02	-0.09
Other Services	-44.23	9.74	2.17	1.97	0.56	1.04	1.99	1.64	3.61	0.41	0.67	-0.91	0.29	21.07
Total	-286.67	91.44	13.39	14.88	2.44	10.37	16.95	22.08	18.44	-0.93	3.98	4.52	4.60	84.52