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Sectoral capabilities and productive structure: An input-output analysis of the key sectors of the Brazilian economy

Características setoriais e estrutura produtiva: Uma análise insumo-produto dos setores-chave da economia brasileira

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RESUMO: A complexa relação entre estrutura de produção e crescimento econômico tem sido significativamente discutida entre economistas brasileiros. Esse debate tornou-se especialmente relevante depois dos anos 2000, quando o Brasil passou por um período de crescimento originado pelo aumento das exportações de *commodities*, período este que contrastou com a estagnação observada nas duas décadas anteriores. Para analisar a capacidade das exportações de *commodities* em promover crescimento sustentado no longo prazo, este trabalho avalia a performance setorial e seus efeitos em setores relacionados nas cadeias à jusante e à montante através de matrizes insumo-produto. Essa análise gera duas conclusões principais. Primeiro, a expansão da produção agrícola e de *commodities* minerais exibem pouca capacidade de promover crescimento, pois esses setores apresentam baixos índices de ligação. Segundo, a análise da estrutura produtiva brasileira demonstra que setores relacionados à manufatura podem estimular outros setores, tais como serviços sofisticados, devido aos seus elevados encadeamentos com outros setores. Este estudo demonstra ainda que uma estratégia de desenvolvimento deve se beneficiar das vantagens comparativas a fim de promover uma mudança estrutural orientada pra expansão da manufatura.

PALAVRAS-CHAVE: manufatura; mudança estrutural; estratégias de desenvolvimento; modelos insumo-produto; encadeamentos produtivos.

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ABSTRACT: The complex relationship between production structure and economic growth has been the subject of considerable debate among Brazilian economists. This debate became especially relevant after the 2000s, when Brazil experienced a period of growth from the rise of commodity exports, which contrasted with the stagnation observed in the previous two decades. To analyse the capacity of commodity exports to generate long-term economic growth, this paper assesses this sector's performance and its effects on related sectors in the upstream supply chain through input-output tables. These analyses lead to two main conclusions. First, expansion of agricultural and mineral commodities production exhibited little capacity to boost the economy because they have the lowest linkage indices. Second, the analysis of the Brazilian production structure demonstrated that sectors related to manufacturing can stimulate other sectors, such as sophisticated services, because of their high linkage effects on other sectors. This study also demonstrates that a development strategy should take benefit of comparative advantages in order to reach a structural change oriented toward expanding manufacturing.
KEYWORDS: manufacturing; structural change; development strategies; input-output models; backward and forward linkages.
JEL Classification: C67; L16; O11.

INTRODUCTION

After at least two decades of slow economic growth, the Brazilian economy gained momentum in the early 2000s. The growth cycle that followed, especially after 2003, was characterised by income redistribution, a steady decrease in unemployment and increases in investments. This scenario, which is strongly related to the performance of the world economy, led to intense economic growth in the following years. Given the importance of this economic growth to policy making, researchers put forth a vast range of interpretations that sought to determine the factors and instruments that triggered this process[1]. Over the last decade, changes in the intensity of trade flows have begun to be observed more clearly. Strong economic performance and intense international trade were accompanied by an increase in commodity prices. This new economic reality resulted in an increase in Brazilian exports that rose from 10.2% of the gross domestic product (GDP) in 2000 (at current prices), peaking to 16.5% in 2004 and dropping to 10.7% in 2010 due to the global financial crisis. Despite this decrease in exports, Brazilian commodities played a key role in the economy's dynamism that was highly associated with Asian demand, most notably from China (Prates, 2006; Rocha, 2011)[2].

Once the international market began to demand Brazil's main export products, economic growth, led by exports of primary products (especially commodities), assumed a prominent position in interpretations of the growth experienced during

[1] The growth rate has decreased since 2011 in Brazil (IBGE).

[2] Regarding the recent rise in commodity prices, see Prates (2007).

that period. Some economists suggested that expansion based on the production and export of commoditised sectors do not have a negative effect on the economy. In addition to being capable of generating income in export sectors, primary sectors have indirect effects on other productive chains. Primary sectors also have the capacity to generate income beyond consumption that could resupply the domestic production and related services (Schultz, 1964; Lipton, 1968; Chayanov, 1966; Davis, 1995; Mikesell, 1997). This line of thought has regularly refuted the necessity of industrial and foreign trade policies. These economists note that state intervention of industrial sectors would promote an "artificial" industrialisation incompatible with international patterns based on a competitive free market.

In contrast, several studies have attempted to demonstrate the limitations of promoting a country's productive and international trade structure based on a free-market strategy. Both classic Kaldorian interpretations (Kaldor, 1966, 1981; Cornwall, 1977; Thirlwall and Hussein, 1982; McCombie and Thirlwall, 1994a, 1994b; Verdoorn, 1949; Thirlwall, 1979; Dasgupta and Singh, 2006; Dixon and Thirlwall, 1975; Moreno-Brid, 2003) and those based on the structuralist approach of Latin American thinking (Prebisch 1986, Singer, 1950; Furtado, 1961; and Tavares, 1998) have emphasised the limitations of promoting economic development based on a productive trade structure of low value-added products. This school of thought is commonly referred to as "developmental theory". Lately, another group of structuralist theorists observed the negative effects of currency appreciation in the manufacturing sector caused by exports of commodities, a process known as the "Dutch disease". These theorists argue that the existence of comparative advantages in natural resources would significantly increase the exports of low value-added products, such as commodities, in turn resulting in a major inflow of foreign currency into the domestic economy and the appreciation of the domestic currency in real terms. Traditional service sectors are less affected by these events because manufacturing and more sophisticated services are tradable and their corresponding demand is partially supplied by imported goods (causing a demand leakage). If commodity prices rise, the implications would be more serious for the domestic industry than for non-tradable sectors. The exchange rate would continue to appreciate, and the competitiveness of higher value-added products would be reduced, possibly triggering a process of "deindustrialisation" of the economy[3]. This argument is rooted in the New Developmentalism theory, which argues that the tendency of exchange rate overvaluation has to be neutralized in order to assure a sustained economic growth period and thus to ensure the catch up process (Bresser-Pereira, Oreiro e Marconi, 2015).

The main argument of those who criticise economic growth based on primary product exports is that manufacturing is the main engine of economic development. Rosenstein-Rodan (1943), Prebisch (1949), Lewis (1954), Rostow (1956), Furtado

[3] See Palma (2005) and Bresser-Pereira (2008). The exchange rate appreciation can also occur because of capital inflows due to interest rate differentials.

(1961) and Kaldor (1966) were some of the first intellectuals to emphasise the importance of manufacturing for economic development[4]. According to these scholars, development is essentially a process of structural change. Sustained economic growth is associated with the diversification of domestic production, i.e., the generation of new activities to expand the possibilities of production, linkages and higher value-added goods by providing incentives for manufacturing. Similarly, Chenery *et al.* (1986) argue that economic development is triggered by structural transformations induced by an increasing demand for product diversity and technological progress. These transformations would also lead to a more productive use of inputs and increased productivity. The industrialisation process feeds itself and diversifies the production structure. These changes in demand resulting from growth entail a dynamic element that transforms the production structure. These changes create a shift in the composition of production and supply that requires new investments, which produce technological improvements that further stimulate demand.

Hirschman (1958) has studied the impacts of stimulating certain sectors in detail and argues that a development strategy should focus on ensuring investment in sectors that can generate backward and forward linkages. Examples include stimulating the production of inputs used in production and generating economies of scale inside a sector or the production of intermediate goods that can be used as inputs in other sectors. These strategies also lead to productivity gains and cost savings in sectors in the later stages of the production chain.

Thus, this paper evaluates the dynamic effects of a development strategy based on commodity production, which can be stimulated by the growth of their exports, such as the strategy adopted by Brazil in recent years, as well as highlighting which sectors of the Brazilian industry have the greatest potential to boost economic growth, based on the linkage effects, in order to discuss the strength of such strategy and its alternative, based on the expansion of manufacturing production. This evaluation compares possible production linkages that can be created by stimulating the sectors in which Brazil enjoys comparative advantages in production with linkages that could be generated by providing incentives to manufacturing.

It is relevant to highlight that both strategies, based on the expansion of primary or manufacturing production, increase the demand for services. In the primary export-led strategy, the increase in demand for services is explained by income gains because of increased export revenue and the appreciation of the exchange rate, as noted by Corden and Neary (1982) and Bresser-Pereira (2008). The increased demand can target traditional services, such as personal services, or modern services, such as logistics or consulting (Rowthorn and Coutts, 2004; Palma, 2005; Dasgupta and Singh, 2006). In the manufacturing-led strategy, the increase in demand for services results from income increases and servitisation, which is defined as the expansion of more sophisticated and high-value-added service activities re-

[4] Fagerberg and Verspagen (1999), Rodrik (2007), Szirmai (2012), and also support this argument.

lated to manufacturing, such as marketing, design and software (Lodefalk, 2010; Nordås and Kim, 2013). Therefore, we will also analyse the linkages of the service sectors.

Although a vast range of studies have emphasized that economic growth is a sector-specific issue, as it was quoted above, the main contribution of this paper is related to a sectoral input-output analysis (which includes their linkages and multipliers) that not only disaggregates the productive structure in three sectors, i.e., primary sector, manufacturing and services, and their sub-sectors. For this purpose, this paper will adopt a methodology based on input-output tables. The remainder of this paper is organised as follows. Second section provides a brief analysis of the main features of the post-1990s Brazilian development strategy. Then, in third section, the input-output methodology adopted in this analysis is presented. In fourth section, output multipliers, Hirschman-Rasmussen Backward Linkages (BL) and Forward Linkages (FL) indices and Pure Normalised Backward Linkages (PNBL) and Forward Linkages (PNFL) indices comprising all productive sectors are calculated for the Brazilian economy in order to identify which sectors can stimulate the production in other sectors more intensively. Finally, concluding remarks, in which former or possible development strategies will be analysed according to the previous discussion, are provided in fifth section.

THE RISE AND FALL OF INDUSTRIALISATION IN BRAZIL

The crisis of the 1980s disrupted the economic growth-promoting mechanisms adopted by Brazil in previous decades. This crisis occurred because of a marked contraction in international credit markets and a repatriation of capital flows to central economies. The state apparatus was weakened by the deterioration of the global macroeconomic environment, high government indebtedness in the 1970s, and the debt nationalisation process, which forced the government to bear the burden of private decisions. The government also experienced a fiscal and financial crisis because these difficulties undermined its ability to promote investment and development to the same degree as in previous decades.

Under these circumstances, the Brazilian development model began to be strongly criticised. Heavy criticism developed regarding both the conduct of Brazil's economic policy in the previous decade and the limits of the model applied to the Brazilian economy since the 1930s. According to Bacha and Bonelli (2005), economic stagnation in the 1980s was a consequence of not only macroeconomic imbalances but also of a greater structural crisis. This crisis arose from the exhaustion of a development model built on a closed economy marked by strong state intervention and based on the import substitution industrialisation (ISI) model. It was argued that a radical shift in Brazil's economic policy was required and that the foundations of the development model based on ISI should be replaced.

ISI provided to be an incentive to a Chenery-style industrial development model (strengthening the industry of intermediate inputs with major linkages in the

production structure). However, free-market economists argued that ISI was based on protectionist policies that would give rise to distortions in relative prices and in the allocation of resources in the economy, thus causing inefficiency (Bonelli, 2005).

This strategy began to show signs of exhaustion in the 1980s as the import coefficient decreased drastically. The average import coefficient (calculated at constant prices) was 25.3% in the 1920s, decreasing to 11.7% in the 1950s, 5.6% in the 1960s and 4% in the 1980s[5]. The structural change of the Brazilian economy reached a level of productive diversification that made domestic demand less dependent on global production, thus bringing the ISI implementation cycle to an end.

Meanwhile, in the mid-1960s, the development strategy applied to the Brazilian economy led to a marked increase in the exports of manufactured goods. This increase was supported by an industrial policy based on high foreign trade tariffs and high subsidies to neutralise the Dutch disease (Bresser-Pereira, 2008)[6] and a quite stable real exchange rate between 1967 and 1979[7]. Manufactured goods comprised only 6.2% of exports in 1964 (initial available data) and reached an average of 54.1% in the 1980s. This number only began to decrease in the second half of the 2010s, after production started to meet the external demand for commodities (averaging 37.8% from 2010 to 2011)[8].

The combination of this previous import substitution process and a subsequent increase in the exports of manufactured goods (always supported by industrial policies that favoured both a managed exchange rate and a public spending scheme promoting the development of strategic sectors) contributed significantly to Brazil's industrialisation process. The share of manufacturing in value-added products rose from 15.1% in 1947 (initial available data) to 21.2% in the 1970s[9], during the import substitution phase, and remained relatively high at the time that the relative share of exports of manufactured goods were increasing. The share of manufacturing in value-added products started to decrease in the 1980s because of the aforementioned crisis and continued to drop in the following decades when the government ceased the neutralisation of the Dutch disease and most industrial policies. The exchange rate was kept chronically appreciated, and commercial and financial openness, especially the latter, were implemented. Consequently, the share decreased continuously to 16.8% in the 2000s and 15.8% in the 2010s.

Since the 1970s, economic development in the Brazilian economy had been

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[5] Source: IPEADATA.

[6] According to Bresser-Pereira (2009, p. 144), to neutralise the Dutch disease, "the government did not levy a tax on the exports of commodities because it felt it lacked the political capital to do so, but the tax was adopted in practice through a 'confisco cambial' implied in import tariffs and subsidies to manufactured goods exports". This was an "industrial policy" that involved a macroeconomic policy: the determination of the effective exchange rate after tariffs and subsidies.

[7] When it is calculated by the relation between the national currency and the dollar.

[8] Source: Department of Planning and Development of Foreign Trade – DEPLA (Brazil).

[9] Source: IPEADATA. The shares were calculated based on the series at constant prices.

geared toward foreign trade, particularly the export of manufactured goods associated with the end of the import substitution process. Thus, it did not appear that production conditions were deteriorating or that the production structure was inefficient because, among other factors, a substantial percentage of manufacturing production was facing international competition. However, the country's fiscal situation and external accounts deteriorated, partially due to the financing of these strategies; this scenery weakened the ability of the state to continue this process and contributed to the revival of arguments in favour of free market ideology, in line with the Washington Consensus.

A lower participation of the state in the economy and the promotion of competitiveness as the main engine of productivity growth were the basis of the new development model established in the 1990s. These principles were based on the Washington Consensus (Williamson, 1989)[10] to install a market economy that would promote greater productivity through specialisation in production and by targeting investments to sectors in which Brazil enjoyed comparative advantages. Policies designed to promote the manufacturing sector lost strength during this period and were virtually abandoned as a result of the then-prevailing maxim that "the best industrial policy is no industrial policy" (Stallings and Peres, 2000). Therefore, as a result of market forces, the 1990s were marked by major economic changes that resulted in a regressive structural change of the Brazilian economy. According to Franco (1998), this model would spearhead a process of industrial restructuring that would increase the competitiveness of the Brazilian economy; it would eliminate less efficient companies and sectors and promote new technologies so that the country would be able to compete in the international arena.

In Brazil, this strategy took form through reductions in quantitative controls and import tariffs as well as through the absence of public policies focused on promoting growth in strategic sectors for the country's development. The trade liberalisation process focused on increasing imports without providing incentives for exports. This model virtually eliminated non-tariff barriers to trade[11], and custom tariffs were reduced considerably based on the country's structure of comparative advantages[12]. This environment, combined with currency appreciation, resulted in a second large wave of reductions in the share of manufacturing in value-added goods in the second half of the 1990s[13].

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[10] The ten prepositions were the following: (1) fiscal discipline, (2) reduction of public spending, (3) tax reform, (4) interest rates determined by the market, (5) exchange rates determined by the market, (6) liberalisation of imports, (7) liberalisation of foreign direct investment flows, (8) privatisation of state enterprises, (9) economic and labor deregulation, and (10) respect for intellectual property.

[11] According to Carneiro (2002), nontariff barriers to trade, which many analysts saw as the main protectionist instrument, were completely removed after Annex C (a list of 1,300 products whose imports were forbidden because similar domestic products were available).

[12] Nominal import tariffs were reduced by 55.3% between 1990 and 1994, with the maximum tariff not exceeding 40%.

[13] The first phase of the Brazilian deindustrialisation process was in the 1980s, and it might be associated

The trade liberalisation process focused specially on imports because better conditions were not created to improve exports, such as changes in financing and logistics, and previous policies to stimulate exports were abandoned. Moreover, the domestic currency appreciated in real terms — a long-term appreciation caused by the fact that the industrial policy that neutralised the Dutch disease ceased with trade liberalisation (Bresser-Pereira, 2009). These factors constrained access to foreign demand and investments. Thus, investments increased to a lesser extent than expected in both the public and private sectors during this period, decreasing from an average rate of 19.4% between 1990 and 1994 to 17.1% between 1995 and 1999[14]. This decrease was reflected in an average annual growth rate of 2.9% in the 1990s, significantly contrasting with the average annual growth rate of 8.7% in the 1970s[15].

To face the challenges of the new economic environment, companies began to take strict adjustment measures during the 1990s to rationalise their production by replacing imported inputs with local inputs[16]. Import penetration coefficients increased significantly between 1990 and 1998. Thus, as argued by Belluzzo and Almeida (2002), there was a "shrinking" of supply chains, which were also affected by "predatory" imports. Industrial companies began to look for ways to improve their competitiveness by cutting costs, replacing local products with imported inputs and reducing inter-sectoral linkages not completely established (Rocha, 2011). According to the Brazilian Institute for Geography and Statistics (IBGE)[17], the penetration coefficient for intermediate goods rose from 2.7% in 1990 to 10.5% in 1998. The substitution process was even more pronounced for manufactured intermediate goods: whereas the penetration coefficient was 6.1% in 1990, it increased to 21.9% by 1998. Thus, as local inputs were largely replaced by imports, the process of developing domestic production required an increasing amount of foreign currency, which made it increasingly difficult to keep that growth strategy[18]. As argued by Laplane and Sarti (2006, p. 276), from a trade balance perspective, this process "turned the surplus in the trade in manufactured goods registered in the first half of the decade into a deficit from 1995 on, clearly indicating that it

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with significant macroeconomic imbalances — fiscal crisis, high foreign debt and inflation—observed during that period.

[14] There was a 7.4% annual reduction in investment in the productive state sector between 1981 and 1989; the investment rates in the private sector remained unchanged in real terms (data extracted from Carneiro, 2002).

[15] Data presented here were calculated by IBGE.

[16] See Rocha (2011), Marconi and Rocha (2012) for more information on the imported input coefficients.

[17] Extracted from Carneiro (2002).

[18] As discussed in Rocha (2011, p. 55), "substituting local inputs with imported ones was seen as the easiest way to meet demand and revealed the contradiction between striving for efficiency gains at the microeconomic level and the sustainability of the process at the macroeconomic level, i.e. the contrast between competitive pressure and the weakening of industrial chains."

would be difficult to keep the economy on a growth path. The trade balance was more significantly negative precisely in 1997, when industrial production was growing at the highest rates, reinforcing the interpretation that the increasing imported contents of local products were generating an even more pronounced deficit". Exports of manufactured products recovered for several years in the 2000s, possibly because of the depreciation of the national currency and the growth of world demand. However, this movement was interrupted by changes in the global commodity market when the 2008-2009 financial crisis took place.

As a result of an extremely weakened productive structure ensuing from over a decade of strongly market-oriented policies, the exchange rate appreciation and the global economic growth, production and exports of primary products became the engine of Brazil's growth. A new cycle of economic expansion began in 2002 with the so-called boom of commodity prices. In mid-2004, global demand began to rise more intensely because of the growth of the Asian economies, particularly that of China. This shift (along with a monetary policy that caused a significant increase in the differential between domestic and external interest rates) resulted in a strong appreciation of the domestic currency. Additionally, this shift caused a consequent increase in imports of manufactured goods, which rose by 155% at constant prices between 2002 and 2008[19].

This scenario contributed to the third phase of reductions in the share of manufacturing in the Brazilian GDP after 2002. At this time, no relevant policies were effectively adopted to mitigate the overvaluation of the domestic currency, and, consequently, it has undermined the competitiveness of Brazilian manufactured products abroad. At the same time, the increasing demand for natural resources, resulting from a faster growth of Asian economies, boosted Brazilian exports of primary products to Asia, which also caused commodity prices to increase. The trend of rising commodity prices was only reversed in 2009 because of the 2008-2009 financial crisis. As a result of this new dynamic, many questions emerged regarding the composition of the domestic productive structure, specifically concerning the sectors that boosted the economy. The share of the services sector in value-added products increased by 1.1 percentage points (p.p.) between 1995 and 2009[20]. The shares of mineral and agricultural commodities also increased in that period by 0.9 p.p., whereas the share of the manufacturing decreased by 2.0 p.p. The share of the manufacturing sector decreased to 16.6%. Growth in the commodities sector stimulated services activities, including both traditional and modern services. Shares of sales and transports increased by 0.8 and 0.4 p.p., respectively. Real estate and financial intermediation share decreased by 0.5 and 1.8 p.p., re-

[19] Calculated by the authors based on information from FUNCEX (Foreign Trade Study Center Foundation).

[20] We considered the period for which data for National Accounts were available under the same methodology and disaggregation.

spectively. Business services (which includes traditional and modern services) increased by 1.3 p.p. Community, social and personal services decreased by 0.7 p.p.

This analysis intends to show that the Brazilian economy adopted a development strategy based on the manufacturing sector in the past. In more recent years, Brazil has turned to a primary export-led strategy. In the next sections, we will evaluate the capacity of both strategies to increase economic growth using indicators that measure the impact of the production of one sector over other sectors.

THEORETICAL FOUNDATIONS OF THE INPUT-OUTPUT MODEL

This study used input-output analyses to examine the capacity of sectoral diversification to promote economic growth. This methodology is useful because these models can incorporate inter-relationships between various industries and they allow us to compare manufacturing and other sectors' linkages in the Brazilian economy. Using this methodology, it is possible to empirically investigate the economic role of a productive sector without restricting the analysis to its "direct effects" on the economy regarding generating production, employment, value-added products, tax revenue, and exports. With this method, it is possible to also investigate the "indirect effects", i.e., the effects that a sector can exert on other sectors through channels established by input-output transactions between different economic sectors.

Input-output matrices from 2000 to 2009 were used to calculate these indices. Because of the non-linear periodicity of the information contained in this publication, Brazilian matrices were estimated for each year of the study period according to the methodology presented by Guilhoto and Sesso Filho (2005) based on preliminary data of Brazil's National Accounts. This methodology consists of a procedure for combining information from the Table of Resources (V) and the Table of Use of goods and services at consumer prices (U) published by the IBGE for the Brazilian economy. These tables include 55 sectors and they were aggregated into 18 sectors in this paper[21]. The perception and understanding of the results is made easier, and the aggregated sectors hold similar characteristics. The aggregation was defined based on, first, the grouping of sectors that produce manufactured, commodities and non-tradable goods and services, then on technology intensity of sectors, following the classification of OECD (2011)[22], similarity on the productive process and proximity in the productive chain. The correspondence between the sectors of the initial matrix (55 sectors) and the resulting matrix (18 sectors) is shown in Appendix 1.

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[21] Similar option was adopted by Dietzenbacher (1992).

[22] Technology intensity of sectors is an important criteria for discussing economic development strategies.

Methodology

The methodology adopted in this study is based on the input-output model, which was originally developed by Leontief (1951). The economy's total production (X) is the result of the sum of the production intended for intermediate consumption by different sectors (Z) and the final demand. The economy's total production (X) also represents the extent to which sector j used goods produced by sector i in its total production and indicates the percentage of inputs sold to industry j by sector i in relation to the total production of sector j[23].

$$a_{ij} = \frac{Z_{ij}}{X_j} \qquad (1)$$

where Z_{ij} is the inter-sectoral sales of sector i to sector j and $X\ Z_j$ is the total production of sector j. Thus, we obtain

$$X = AX + Y \qquad (2)$$

By solving this equation, the total output required to meet the final demand can be expressed as

$$X = (I - A)^{-1} Y \qquad (3)$$

where $(I - A) = L$ is the inverse of Leontief's matrix.

Using Leontief's model, various analyses can assess the impact of demand variation on production, employment and value-added goods, among other variables. Based on the ratio between the value of the variable K employed and the production of the corresponding sector, the direct coefficient (k) is calculated for each variable (e.g., employment, value-added goods, wages) as follows:

$$k_j = \frac{K_j}{X_j} \qquad (4)$$

Once k is calculated, along with Leontief's inverse matrix (L), it is possible to calculate the amount of K directly and indirectly generated for each monetary unit produced for the final demand for each sector. This value is referred to as the generator, which relates production for final demand to a given variable of the economy. Thus, the generator of a variable K for each sector can be calculated by summing each column of matrix GK as follows:

$$GK = \sum_{i=1}^{n} \hat{k}_i \cdot L_{ij} \qquad (5)$$

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[23] For more details, see Miller and Blair (2009), Guilhoto (2009), Borghi (2013).

Dividing the generator, GK, by the respective direct coefficient, it is possible to obtain the multiplier of variable K that associates the direct effect of a variable regarding its total (direct and indirect) effect on the economy as follows:

$$MK_j = GK_j / k_i \qquad (6)$$

In this manner, multipliers for employment and production can be obtained[24]. In addition, the input-output methodology allows other indicators of economic importance to be calculated. The seminal works of Hirschman (1958) and Rasmussen (1956) allow one defines the interrelationships between the sectors and the power of each sector in the economy to establish linkages. The Hirschman-Rasmussen BL indices determine the demand of a sector for other sectors, and the FL indices determine the degree to which this sector is demanded by other sectors. To calculate the Hirschman-Rasmussen BL index, l_{ij} is defined as the elements of matrix L, L^* is the average of all elements of L and L_{*j} is the sum of a column of L. The BL is expressed as follows:

$$BL_j = (L_{*j}/n)/L^* \qquad (7)$$

The Hirschman-Rasmussen FL index is calculated from the matrix of coefficients in row (F) obtained from the intermediate consumption matrix (Z) and is expressed as

$$F = \hat{x}^{-1} \cdot \mathrm{Z} \qquad (8)$$

As in Leontief's inverse matrix, the matrix of Ghost is deduced with g_{ij} as follows:

$$G = (I - F)^{-1} \qquad (9)$$

Considering G^* as the average of all elements of G and G_{i*} as the sum of the elements in each row, the Hirschman-Rasmussen FL index is obtained as follows:

$$FL_i = (G_{i*}/n)/G^* \qquad (10)$$

[24] This paper used type I multipliers, which only consider multiplicative effects restricted to demand for intermediate inputs, without making household demand endogenous to the model. If household demand were endogenised in the system, the induced effect would be considered, and type II multipliers would be used (Guilhoto, 2009).

Sectors can be classified into the following four groups depending on their index values: (i) independent from (or not highly related to) other sectors if both linkage indices are less than 1; (ii) dependent on (or strongly related to) other sectors if both linkage indices are greater than 1, denoting sectors that play a key role in the economy; (iii) dependent on intersectoral supply (or stimulates production in other sectors) if only the BL index is greater than 1; and (iv) dependent on intersectoral demand (or dependent on the production of other sectors) if only the FL index is greater than 1. However, as observed by Cella (1984) and Clements (1990), these indices do not consider the production levels of each analysed sector.

To correct and refine the solutions presented by Cella (1984) and Clements (1990), Guilhoto et al. (1994) introduced the first version of what would be considered a pure linkage index, which later became known as the GHS methodology. Guilhoto, Sonis and Hewings (1996) present decompositions of Leontief's inverse matrix that integrate the main techniques used in input-output structures to decompose and distinguish the impact of an economic sector on its various components. The consolidated GHS methodology is based on a block matrix of technical coefficients (A):

$$A = \begin{bmatrix} A_{jj} & A_{jr} \\ A_{rj} & A_{rr} \end{bmatrix} \qquad (11)$$

where A is composed of square and rectangular matrices. A_{jj} and represent square matrices of the direct technical coefficients of sector j and the remainder of the economy (entire economy minus sector j), respectively. A_{jr} and A_{rj} represent rectangular matrices of direct inputs purchased by sector j from the remainder of the economy and direct inputs purchased by the remainder of the economy from sector j, respectively.

Based on matrix A in (11), a triple multiplicative decomposition of Leontief's inverse matrix can be expressed as follows:

$$L = (I - A)^{-1} = \begin{bmatrix} L_{jj} & L_{jr} \\ L_{rj} & L_{rr} \end{bmatrix} = \begin{bmatrix} \Delta_{jj} & 0 \\ 0 & \Delta_{rr} \end{bmatrix} \begin{bmatrix} \Delta_j & 0 \\ 0 & \Delta_r \end{bmatrix} \begin{bmatrix} I & A_{jr}\Delta_r \\ A_{rj}\Delta_j & I \end{bmatrix} \qquad (12)$$

where

$$\Delta_j = (I - A_{jj})^{-1} \qquad (13)$$

$$\Delta_j = (I - A_{rr})^{-1} \qquad (14)$$

$$\Delta_{jj} = (I - \Delta_j A_{jr} \Delta_r A_{rj})^{-1} \qquad (15)$$

$$\Delta_{jj} = (I - \Delta_j A_{jr} \Delta_r A_{rj})^{-1} \qquad (16)$$

From Leontief's model in (3) and Equation (12), we obtain the following:

$$\begin{pmatrix} X_j \\ X_r \end{pmatrix} = \begin{pmatrix} \Delta_{jj} & 0 \\ 0 & \Delta_{rr} \end{pmatrix} \begin{pmatrix} \Delta_j Y_j + \Delta_j A_{jr} \Delta_r Y_r \\ \Delta_r A_{rj} \Delta_j Y_j + \Delta_r Y_r \end{pmatrix} a_{ij} = \frac{z_{ij}}{x_j} \qquad (17)$$

Through this process, pure BL (PBL) and pure FL (PFL) indices can be deduced in their new definition as follows:

$$PBL = \Delta_r A_{rj} \Delta_j Y_j \qquad (18)$$

$$PFL = \Delta_j A_{jr} \Delta_r Y_r \qquad (19)$$

In Equation (18), the index indicates the impact of the value of the total output of sector *j* on the remainder of the economy, minus demand for inputs that sector *j* produces for itself and the returns of the remainder of the economy for sector *j* and vice versa. The PFL in Equation (19) indicates the impact of the value of the total production of the remainder of the economy on sector *j*. The PBL and PFL are summed to calculate the pure total linkage (PTL) index for each sector of the economy, expressed in current values:

$$PTL = PBL + PFL \qquad (20)$$

However, because these indices do not consider the size of the sectors, which is an important aspect for identifying key sectors of the economy, a "normalisation" procedure should be applied to these indices based on the approach of normalised pure linkage indices. For this purpose, the pure indices of each sector are divided by the average of pure indices for the economy as a whole. Thus, the normalised PBL (PBLN) index, the normalised PFL (PFLN) index and the normalised PTL (PTLN) index can be represented as follows:

$$PBLN_i = PBL_i \Big/ \left(\sum_{i=1}^{n} PBL_i / n \right) \qquad (21)$$

$$PFLN_i = PFL_i \Big/ \left(\sum_{i=1}^{n} PFL_i / n \right) \qquad (22)$$

$$PTLN_i = PTL_i \Big/ \left(\sum_{i=1}^{n} PTL_i / n \right) \qquad (23)$$

RESULTS

In this section, the results obtained using the proposed methodology based on the input-output analysis are presented in the following order: output multipliers, Hirschman-Rasmussen indices, PBLN indices, and PFLN indices.

The output multiplier indicates how much is produced for each monetary unit spent on final consumption. These multipliers incorporate direct and indirect effects to measure the impacts of a demand shock on the economy. Type I multipliers are used in this analysis. As seen from Table 1, the greatest multipliers of the Brazilian economy (greater than 2.0 for at least half of years) were identified in six sectors: food/beverages, transportation equipment, petroleum, chemical products, electric material and communications and apparel/leather/footwear, with food/beverages and transportation equipment being the two most prominent sectors. Transportation equipment includes the auto industry. The apparel/leather/footwear sector also has a high multiplier effect and is labour intensive, making it important for the development of productive chains that employ a large amount of people. The three lowest multipliers in the tradable sectors are miscellaneous, mineral commodities and agricultural commodities. The mineral commodities sector is associated with a strong bias toward Brazil's comparative advantages. Finally, the analysis of the non-tradable sector shows that services have little capacity to stimulate the economy, exhibiting the lowest ranks. Although construction and utilities appear with the highest multipliers among services, they are even lower than commodities' output multipliers.

Table 1: Output Multipliers: 2000-2009

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Avg	Rank
Agricultural commodities	1.75	1.68	1.69	1.74	1.78	1.81	1.81	1.81	1.81	1.80	1.77	10
Petroleum	2.19	2.22	2.25	2.11	2.13	2.22	2.22	2.15	2.20	2.11	2.18	3
Mineral commodities	1.05	1.95	1.95	2.02	1.90	1.99	1.99	2.03	1.93	1.94	1.97	8
Food and beverages	2.33	2.26	2.29	2.36	2.36	2.41	2.36	2.38	2.42	2.39	2.35	1
Textiles and footwear	1.99	1.98	2.03	2.09	2.06	2.04	2.00	1.98	1.96	1.91	2.01	5
Miscellaneous	1.84	1.82	1.81	1.87	1.85	1.85	1.84	1.83	1.80	1.78	1.83	9
Chemical products	2.07	1.98	2.00	2.13	2.09	2.11	2.08	2.07	2.07	2.00	2.06	4
Metal products (incl. Machinery)	1.95	1.89	1.94	2.00	1.98	2.02	2.00	2.01	1.98	1.94	1.97	7
Electric mat. and communic	1.97	1.93	1.94	2.01	2.01	2.05	2.02	2.02	1.99	1.97	1.99	6
Transportation equipment	2.11	2.10	2.15	2.30	2.28	2.37	2.32	2.30	2.25	2.26	2.24	2
Utilities	1.68	1.81	1.75	1.73	1.65	1.66	1.65	1.63	1.73	1.69	1.70	12
Construction	1.78	1.75	1.76	1.79	1.72	1.75	1.75	1.73	1.74	1.76	1.75	11

Sales	1.42	1.40	1.41	1.43	1.42	1.43	1.43	1.42	1.42	1.42	1.42	18
Traditional services	1.47	1.47	1.48	1.52	1.50	1.53	1.52	1.52	1.53	1.53	1.51	17
Modern services	1.67	1.62	1.58	1.58	1.62	1.55	1.56	1.54	1.58	1.57	1.59	13
Business services	1.60	1.60	1.60	1.59	1.57	1.55	1.55	1.56	1.55	1.56	1.57	14
Health and education	1.48	1.49	1.51	1.53	1.55	1.54	1.54	1.52	1.49	1.49	1.51	16
Public admin	1.53	1.50	1.55	1.50	1.53	1.54	1.51	1.53	1.51	1.50	1.52	15

The results of the analysis of multipliers can be complemented by Hirschman-Rasmussen FL and BL indices (Graph 1). The BL index indicates the extent to which the output of a particular sector stimulates the production of its inputs. The FL index allows one to analyse the importance of a given sector as an input supplier. These indices allow one to investigate the behaviour of the economy's internal structure and identify key sectors that depend on inter-industrial supply and inter-industrial demand or are relatively independent from the other sectors[25]. Located in the upper-right quadrant, the key sectors of the Brazilian economy in the 2000s were petroleum and chemical products. These sectors exhibited a high potential to boost other sectors of the economy in addition to being major input suppliers. The petroleum sector had the greatest capacity to supply inputs to the remaining sectors. Although it is classified as a commodity, petroleum is also characterised by a high production rate for each monetary unit spent on final consumption. The petroleum sector is a supplier of inputs for manufacturing, mainly for the chemical, synthetic materials and the apparel sectors[26]. Their linkages indices are much larger than those estimated to other mineral commodities sectors.

There are no tradable sectors of the Brazilian economy in the group that are relatively independent from the other sectors (lower-left quadrant), indicating that there is a significant degree of dependence between several manufacturing sectors of the economy. This result may have been caused by the development process of Brazilian manufacturing during the ISI period, when input production and inter-industrial demand were strongly stimulated.

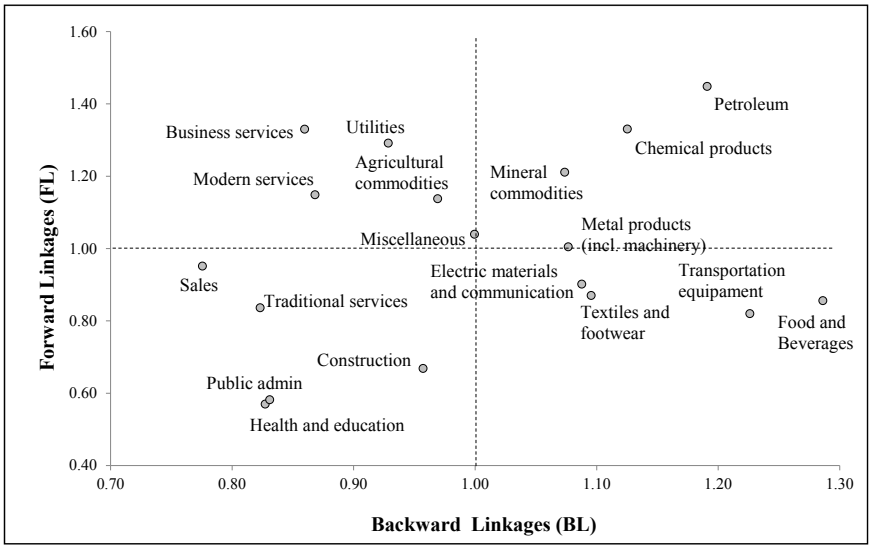
Located in the lower-right quadrant, the food/beverages and transportation equipment sectors stimulate production of intermediate good in other sectors and, consequently, they are strongly dependent on inter-industrial supply. The data demonstrate the importance of these sectors and their ability to increase production in other sectors. In the upper-left quadrant, agricultural commodities, modern ser-

[25] Although we estimate these indices from 2000 to 2009, we also present the average to rank the sectors as this work is not focused on the tendency over time, but on the comparison between sectors. Moreover, estimating it for all years and taking the average reduces the bias caused by relative price changes and conjectural variations on technical coefficients, usually caused by changes in imported coefficients.

[26] The highest increase in linkage indices in this sector was registered from 2004-2006, during which Brazil became self-sufficient in oil production.

vices, business services and utilities are the sectors with the largest inter-industrial demand dependence. These sectors present the lowest capacity to increase production in other sectors of the economy; they actually depend on the production of other sectors. This result is expected for the services sector. Moreover, traditional services are in the lower-left quadrant, which indicates the sector's lack of dynamism. Therefore, the growth rates of the economy would likely be lower if increases in income stimulate the production of those less dynamic services.

Graph 1: Hirschman-Rasmussen BL and FL indices – Average 2000-2009



Source: Elaborated by the authors based on the estimated Brazilian input-output tables.

However, the Hirschman-Rasmussen index does not consider the size of sectors in the economy, which helps to identify key sectors. Thus, Table 2 includes these indices normalised by the sector size. The backward linkages (first four columns) assess the pure impact of a sector on its chain, and the forward linkages (last four columns) measure the sector's capacity to supply inputs to the domestic industry. Food/beverages, traditional services, public administration, health/education, construction and transportation equipment occupy the first six positions of the backward linkages (considering their averages). The food/beverages sector has the largest index because of the importance of its demand from other industrial complexes and its size compared with the other sectors. In addition, the transportation equipment sector's output has a rising pure impact and has demanded inputs from the other sectors of the economy over time. Moreover, traditional services and construction appear as sectors with a high demand from other sectors in the economy because of their relative size in the economic structure. Services represent nearly two thirds of the Brazilian economy, and these two groups are the most relevant.

As expected, products with a lower degree of processing that are employed in the production of other goods exhibited relatively high forward linkages. The transportation equipment and electrical materials/communications equipment sectors, whose degree of processing is higher and whose chain is closer to final goods, ranked 14th and 15th, respectively. Agricultural commodities, some services and chemical products present high forward linkages because they are important suppliers for the economy as a whole. Moreover, although mineral commodities have a low degree of processing, they are ranked only 8th. This position is due to the low significance of this sector as a domestic supplier because of the high volume of raw mineral exports.

The difference between normalised and non-normalised pure linkage indices (presented in Graph 1) is especially significant for large sectors. In these sectors, the size is more relevant to explain the results than the capacity to increase, by each unit produced, the demand and supply of other sectors.

Table 2

	Normalised pure backward linkage				Normalised pure forward linkage			
	2000-04	2005-09	Average	Ranking	2000-04	2005-09	Average	Ranking
Agricultural commodities	0,80	0,82	0,81	8	2,09	1,88	1,98	2
Petroleum	0,34	0,40	0,37	16	1,27	1,45	1,36	7
Mineral commodities	0,44	0,52	0,48	14	1,26	1,36	1,31	8
Food and beverages	2,54	2,48	2,51	1	0,65	0,65	0,65	10
Textiles and footwear	0,58	0,48	0,53	13	0,19	0,15	0,17	16
Miscellaneous	0,41	0,36	0,39	15	0,44	0,35	0,39	12
Chemical products	0,54	0,55	0,54	12	1,79	1,69	1,74	4
Metal products (incl. Machinery)	0,64	0,76	0,70	9	0,58	0,59	0,59	11
Electric mat. and communic.	0,64	0,68	0,66	10	0,33	0,32	0,32	14
Transportation equipment	1,17	1,38	1,28	6	0,21	0,29	0,25	15
Utilities	0,23	0,23	0,23	17	1,08	1,04	1,06	9
Construction	1,64	1,47	1,55	5	0,33	0,33	0,33	13
Sales	0,87	0,96	0,91	7	1,62	1,73	1,68	5
Traditional services	2,44	2,38	2,41	2	1,90	1,91	1,90	3
Modern services	0,70	0,58	0,64	11	2,41	2,48	2,44	1
Business services	0,18	0,19	0,18	18	1,64	1,62	1,63	6
Health and education	1,81	1,76	1,79	4	0,07	0,06	0,06	18
Public admin	2,04	2,02	2,03	3	0,12	0,11	0,11	17

Source: Elaborated by the authors based on the estimated Brazilian input-output tables.

CONCLUDING REMARKS

Although the Brazilian development model adopted since the *Plano Real* in 1994 was able to guarantee price stabilisation, it failed to promote economic growth during the 1990s. Only in the early 2000s did the national economy resume its growth path with improvements in external demand for Brazilian products. Given this joint process, most interpretations of the recent expansion of the Brazilian economy identified commodity production and its exports as the main drivers of this growth pattern.

To assess this phenomenon, this study analysed the abilities of various sectors to boost the Brazilian economy. Input-output matrices were used to quantify the potential of commodities, manufacturing and services to leverage demand from other sectors and to identify key input-supplying sectors. Agricultural and mineral commodities and non-tradable sectors exhibited little capacity to boost the economy. In addition to their low multipliers, BL indices for these sectors are low because their supply chains are not large. In contrast, the FL indices of the most modern and dynamic service sectors are high, and these sectors can stimulate general output when associated with manufacturing production, especially production that is more sophisticated and that demands high value-added services.

The results observed for Brazil in the period under consideration corroborates our theoretical argument: a growth strategy based on comparative advantages associated with the production of primary goods does not have the same ability to stimulate economic growth as a strategy based on the expansion of manufacturing, because the linkages of the latter are higher. Additionally, a strategy based on the expansion of service sectors, particularly the traditional ones — which can occur when the country faces a Dutch disease process — also does not generate relevant linkages, unless we consider the sector size in the analysis.

Although it also falls under the commodity category, the petroleum sector has notably different characteristics than the other sectors. In addition to the relative importance of petroleum as a demand sector and thus as a booster of other supply chains, this sector is the leading supplier of inputs for the economy. The petroleum sector is a provider of inputs used for manufacturing, the main industrialised products produced by the chemical products sector and the synthetic materials produced by the apparel sector. The petroleum sector is also an indirect supplier for the transportation equipment and electrical materials/communications equipment sectors and several other industries. Thus, the contrasting behaviour of the petroleum sector compared to the other sectors clearly demonstrates the importance of adding value to commodities rather than simply exporting raw or semi-manufactured goods.

The analysis of multipliers and linkage indices also emphasised the importance of transportation equipment and food\beverages as sectors that are highly dependent on inter-industrial supply. These sectors have a high potential to turn final demand into production both within themselves and in their upstream supply chain. These results emphasise the importance of focusing development strategy on con-

solidating a production structure in which supply chains are organised so that final demand can boost the remainder of the economy.

Therefore, the analysis of the Brazilian production structure clearly shows that sectors related to manufacturing products can boost the economy to a greater extent than other sectors due to their linkage effects on other sectors of the economy. Efforts to promote a dynamic production structure must be associated with a development strategy that considers the advantages of a production structure oriented toward expanding manufacturing. Interpretations of the recent growth of Brazil's economy that are based on the expansion of "commoditised" and non-tradable sectors or on the country's comparative advantages limit the understanding of the complex factors that boost an economy. Therefore, a development strategy that guarantees high growth rates over the long term should recognise the importance of a productive structure oriented toward manufacturing, even if this sector is boosted by primary commodities, such as the petroleum industry.

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Appendix 1

	Brazilian National Account System (SCN) – 55 Sectors
Agricultural commodities	0101, 0102, 0302, 0306, 0307, 0310
Petroleum	0201, 0303
Mineral commodities	0202, 0203, 0319, 0320, 0321, 0322
Food and beverages	0301
Textiles and footwear	0303, 0304, 0305
Miscellaneous	0308, 0334
Chemical products	0311, 0312, 0313,0314, 0315, 0316, 0317, 0318
Metal products (incl. Machinery)	0323, 0324
Electric mat. and communic.	0325, 0326, 0327, 0328, 0329
Transportation equipment	0330, 0331, 0332, 0333
Utilities	0401
Construction	0501
Sales	0601
Traditional services	0701, 1001, 1101, 1102
Modern services	0801, 0901
Business services	1103
Health and education	1104, 1105, 1106, 1201, 1202
Public admin	1203