A SYSTEMIC AND TEMPORAL ANALYSIS OF THE IMPACT ON REGIONAL DEVELOPMENT OF THE OIL AND GAS SECTOR: THE CASE OF SERGIPE, BRAZIL

Abstract

This study provides a systemic and temporal evaluation of Sergipe's oil and gas sector, emphasizing its economic role and local knowledge integration. We uniquely combine interregional input-output matrices for 2011 and 2018 with Investment Absorption Matrices (MAI) to analyze sectoral linkages and investment impacts. Key indicators include output, income, and investment multipliers, linkage indices, and structural decomposition analysis. Despite a production decline, the sector maintains significant demand-side intersectoral connections, though local input shares and investment impacts remain low. Interregional spillovers have increased, highlighting challenges in strengthening local supply chains. Structural decomposition shows sector output changes driven mainly by final demand shifts, with negative effects from household consumption and exports. Our findings emphasize the need for coordinated public policies to enhance local content and capitalize on offshore oil and gas exploration opportunities in Sergipe. This integrated methodological approach offers new insights for regional economic development strategies.

Keywords: Oil and gas; input-output; structural changes, productive linkages, Sergipe.

1 INTRODUCTION

The energy transition process has intensified since the first Conference of the Parties (COP) in 1995, motivating economies worldwide to adopt policies targeting emission reductions by 2050 (IRENA, 2023). Despite this global trend, oil and its derivatives remain the primary energy source. Petroleum exploration generates substantial revenues for producing regions through taxes and royalties. As an exhaustible resource, Hartwick's (1977) intergenerational equity rule prescribes that all income from net resource extraction should be invested in capital goods. Recent literature broadens this view, emphasizing investments in human, technological, and institutional capital as well (Davis & Tilton, 2005).

In Brazil, significant changes in the regulatory framework have affected oil royalty usage. Since 2013, legislation mandates a portion of royalties be allocated to education and healthcare. Santos et al. (2022), using an interregional input-output model calibrated for 2008, demonstrated that directing these funds to Northeast and Southeast regions could reduce intraregional inequalities.

The O&G sector notably generates spillover effects across business and technological domains. De Negri et al. (2023) highlight Petrobras's R&D strategies as key drivers aligning Brazilian innovation with global scientific frontiers. Local content policies stimulate domestic firm participation in O&G supply chains, as international experiences show (Xavier Jr., 2012). Understanding innovation dynamics within Local Production Systems is crucial, as explored in studies from Italy and Brazil (Morrison & Rabellotti, 2005; Ruffoni et al., 2022), with firm agglomerations fostering interactive learning (Giuliani, 2005).

In Brazil, O&G production is geographically concentrated in ten coastal states, including Sergipe in the Northeast, which accounted for nearly 20% of onshore oil production in the 2000s. Although Sergipe's offshore ultra-deepwater reserves were recently discovered, onshore production has sharply declined since 2014.

Promising prospects exist for Sergipe's O&G sector, driven by Petrobras's 2024–2028 Strategic Plan and the SEAP project, involving investments of over US$5 billion to expand the national gas supply. Expected production exceeds 1 billion barrels of oil equivalent, potentially strengthening local production chains and boosting higher value-added, technologically intense goods and services.

Ribeiro et al. (2024) use a dynamic, interregional computable general equilibrium model to simulate investment shocks in Sergipe, finding that while the O&G sector promotes wealth and employment, it may exacerbate municipal inequalities, highlighting the need for equitable royalty distribution policies. Furthermore, the extractive industries, which include O&G sector, according to Ribeiro et al. (2023a), were one of the most affected during the Covid-19 pandemic.

Historically, the O&G sector has been a key driver of Sergipe's development, increasing wealth, employment, public revenues, and royalties. However, it faces challenges such as income leakage due to its reliance on imported, internationally standardized technologies.

Petrobras's withdrawal in 2019 led to stagnation in Sergipe's O&G production. Ribeiro et al. (2023b) employed the hypothetical extraction method within an interregional input-output framework for 2011, estimating an 8.7% contraction in the state's production due to Petrobras's withdrawal.

Currently, Sergipe faces a dilemma: negligible O&G production versus promising offshore investment prospects. Analyzing the sector's structural dynamics over the 2000s offers valuable insights for policy and planning.

This article conducts a systemic and temporal evaluation of Sergipe's O&G sector using two interregional input-output matrices for 2011 and 2018, capturing peak and decline phases. It uniquely combines input-output analysis with Investment Absorption Matrices, enabling the identification of structural changes and interregional leakages.

Key research questions include: What structural changes occurred between 2011 and 2018? What are the sector's investment and production impacts on state and national economies? What is the scale of interregional spillovers?

This study contributes by mapping Sergipe's O&G production chain, assessing multiplier effects, and applying a novel methodological framework to reveal temporal sectoral dynamics essential for optimizing development policies.

2 THE OIL AND GAS SECTOR: PRODUCTION IN SERGIPE AND INVESTMENT DYNAMICS

The first oil field in the state of Sergipe was discovered in 1963, in the municipality of Carmópolis. Other significant milestones include the discovery of the Gauricema field in 1978 and the construction of the Oil and Natural Gas Processing Unit at the Carmópolis Maritime Terminal in 1982 (Melo, 2012). O&G exploration has since become one of the main drivers of the state's economic development.

Figure 1 shows O&G production in Sergipe between 1997 and 2024. During this period, the peak of oil production in the state occurred in 2008, accounting for 28.3% of the Northeast region's output and 2.6% of national production. When considering only onshore production for that year, Sergipe's share of national output increases to 19.2%. Natural gas production, in turn, peaked in 2010, although it has been significantly less representative at both the regional and national levels. Following these peaks, O&G production in the state has experienced a steady and sharp decline. It is also worth noting that, by the late 1990s, oil production in Sergipe accounted for nearly 4% of Brazil's output.

<Insert Figure 1>

An important aspect to highlight regarding oil and gas production fields—not limited to the case of Sergipe—is the so-called "natural decline" in production. After several years of operation, it is expected that output will reach a peak, followed by a continuous downward trend. Oil companies typically invest in technologies to delay or mitigate these declines; however, they cannot be entirely avoided, as oil and gas are exhaustible and therefore non-renewable natural resources.

In practice, the only way to maintain stable or increasing production levels is by pursuing new production frontiers. With the recent discoveries under the SEAP project, oil and gas production in Sergipe may resume growth by the end of the current decade. As of 2025, the platforms required for this new phase of oil and gas production remain at the contracting/construction stage.

In parallel with the new discoveries and the construction of new assets, the aging infrastructure operating in mature fields—where production is nearing depletion—must be decommissioned. In industry terms, this process is known as decommissioning, which primarily involves dismantling platforms, removing equipment, and plugging wells. Some parts of the infrastructure may be reused or recycled, but a significant portion is ultimately scrapped. Such expenditure, commonly referred to as ABEX (abandonment costs), is allocated to the contracting of various types of equipment and support services required for asset decommissioning.

In Sergipe, Petrobras has already initiated the decommissioning process of onshore production through the sale of its land-based assets to Carmo Energy. In the offshore phase, Petrobras has announced an investment of US$2 billion for the decommissioning of shallow-water production platforms in the state, a process expected to unfold over the next ten years.

Activities in the O&G sector require companies to meet internationally recognized quality standards, due to the technical specifications of the sector and operational safety concerns. Despite these strict requirements, there are opportunities for local firms to participate, largely driven by regulations on local content established by the National Agency of Petroleum (ANP). In oil field bidding rounds, the ANP began to include minimum percentages requiring the nationalization of component production within the supply chain. However, these local companies must be properly qualified to meet the sector's technical standards.

Given this context, the integration of local firms into the O&G sector requires the implementation of support initiatives. The Sergipe Oil and Gas Network (Petrogás), established in 2011 through an agreement between Petrobras and Sebrae, represents one such initiative. Its aim has been to enhance the qualifications of Sergipe-based companies and to foster closer business relationships aligned with the demands of the O&G sector. Although it played a significant role, the network's activities in Sergipe were largely discontinued following Petrobras's exit from the state. However, Petrogás began to be reactivated by Sebrae in 2023, following Petrobras's announcement of new investments in Sergipe.

To begin with, it is important to emphasize that typical investments in the O&G sector are characterized by long maturation periods and multiple sequential phases. Broadly speaking, once a company (or a consortium of companies) secures the rights to a petroleum field through a bidding process, it initiates what are known as exploratory investments. These are capital-intensive activities involving the deployment of drilling rigs, which are used to search for oil and gas and to assess the reserve potential of the targeted field.

After conducting an exploratory analysis of the field and estimating the existing oil and gas reserves, the construction of the assets required for the expected oil and gas production begins—specifically, the oil platform, technically known as the Floating Production, Storage, and Offloading (FPSO) unit, which typically takes between 3 and 5 years to complete.

Furthermore, as explained in the previous section, after decades of production and natural decline, a field's useful life approaches its end (or even the expiration of the concession period, approximately 30 years). At this stage, there are also investment expenses related to the asset's decommissioning (ABEX).

When estimating the macroeconomic, sectoral, and regional impacts of the oil and gas sector, therefore at least three main dimensions must be considered. The first concerns investment expenditures required to enable production, which translate into demand for capital goods and services. The second relates to the actual production of oil and gas, which requires intermediate goods and services to facilitate extraction, whether onshore or offshore. Finally, the third dimension involves the equipment and contracted services for the decommissioning of assets at the end of their useful life. However, due to data limitations, this study focuses only on the first two impacts: prior investments and oil and gas production.

3 METHOD AND DATABASE

To identify and assess the contribution of the oil and gas sector to Sergipe's economy, the following procedures are followed using input-output tables: (i) identification of the segments involved in the production chain, from equipment manufacturers and other capital goods producers during the investment phase, through suppliers of inputs and raw materials in the production phase, to final consumers; (ii) measurement of production, investment, and income multipliers; (iii) assessment of the degree of productive linkage; (iv) identification of the sectors with the greatest influence on the rest of the production chain based on their intersectoral relationships (field of influence); and (v) Structural Decomposition Analysis.

The input-output model developed by Leontief (1936) represents the economic system using matrices, enabling the identification of various interrelationships among sectors within a specific economy. An input-output model with *n* sectors can be formally specified as follows:

$$\mathbf{x}_{\mathrm{i}} = \sum_j^n \mathbf{Z}_{\mathrm{ij}} + (\mathbf{c}_i + \mathbf{i}_{\mathrm{i}} + \mathbf{g}_i + \mathbf{e}_i); \quad \forall_{i,j} = 1,\ldots,n. \quad (1)$$

Where: $\mathbf{x_i}$ = is the gross output of sector *i*; $\sum_j^n \boldsymbol{Z}_{ij}$ = represents the intermediate input sales from sector *i* to sector *j*; e $(\mathbf{c}_i + \mathbf{i}_{\mathrm{i}} + \mathbf{g}_i + \mathbf{e}_i)$ = is the final demand, with **c** = household consumption, **i** = investment, **g** = government expenditures, and **e** = exports of sector *i*. The model adopts Leontief production functions, which assume constant returns to scale and are based on the hypotheses of perfectly elastic supply and constant technical coefficients over time (Miller & Blair, 2022). In other words, input-output models use comparative static analysis, providing a "snapshot" of the production structure at a given point in time.

Interregional input-output models are more appropriate than models specified for a single region. This is because in regional models the linkages between different spatial units are not considered, effectively isolating the region under analysis from the rest of the country, state, or larger region to which it belongs. According to Miller and Blair (2022), the basic matrix structure of an interregional input-output model for two regions can be expressed as follows: consider a model with two regions, three productive sectors in region L, and two productive sectors in region M.

$$\mathbf{Z} = \begin{bmatrix} \mathbf{Z}^{LL} & \vdots & \mathbf{Z}^{LM} \\ \cdots & \cdots & \cdots \\ \mathbf{Z}^{ML} & \vdots & \mathbf{Z}^{MM} \end{bmatrix} \quad (2)$$

Where: $\mathbf{Z}^{LM}$ represents interregional trade flows (e.g., exports from region L) and; $\mathbf{Z}^{LL}$ represents intraregional trade flows (e.g., trade within region L). The solution of the model is given by equation 3, that is:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} \quad (3)$$

Where $\mathbf{B} = (\mathbf{I} - \mathbf{A})^{-1} = \mathbf{B}(b_{ij})$ is the Leontief inverse matrix, with **I** as the identity matrix and **A** as the technological matrix, specified as $\mathbf{A}[a_{ij}] = \frac{z_{ij}}{x_j}$. Where, z_{ij} is the trade flow between *i* and *j*. The main advantage of using this model is the ability to measure the magnitude of effects in each sector and region, with interregional interdependencies defined by both the supplying region's sectors and the demanding region's sectors. In other words, the interregional model explicitly captures leakage effects between regions.

3.1 Input-Output Indicators

The simple output and income multipliers for sector *j* can be defined, respectively, as $\mathbf{m(o)_j} = \sum_{i=1}^{n} b_{ij}$ e $\mathbf{m(h)_j} = \sum_{i=1}^{n} a_{n+1}, ib_{ij}$, where b_{ij} are elements of the Leontief inverse matrix, and a_{n+1} is the income coefficient, defined as the ratio between the gross value added (GVA) and the output of sector *j*. The multiplier indicates that for each R$1 change in the final demand of sector *j*, direct and indirect effects occur throughout the production chain and the entire economy must produce $\mathbf{m(o)_j}$, which can be decomposed into intraregional effects (within the region itself) and interregional effects (in other regions).

To measure the degree of productive linkage in Agriculture, the Rasmussen (1958) and Hirschman (1958) linkage indices are used, which assess backward and forward linkages in the production chain.

These indices are expressed as the ratio between the sector's average impact and the overall average impact on the economy, that is:

$$U_{oj} = \frac{\frac{1}{n}\mathbf{B}_{oj}}{\frac{1}{n^2}\sum_{i=1}^{n}\mathbf{B}_{oj}} \quad (4) \qquad U_{io} = \frac{\frac{1}{n}\mathbf{B}_{io}}{\frac{1}{n^2}\sum_{j=1}^{m}\mathbf{B}_{io}} \quad (5)$$

Where U_{oj} is the backward linkage (BL), index, and U_{io} s the forward linkage (FL) index, n is the number of sectors. A sector is considered key when both indices exceed one, indicating intermediate purchases and sales above the economy's average.

In order to identify the main links that may generate the greatest impacts on Brazilian regions, the field of influence method developed by Sonis and Hewings (1991) is used. This method allows the visualization of the sectors that most influence the rest of the production chain through their intersectoral relationships. To measure the impact of variations in each element of the Technological Matrix (**A**), a small variation must be introduced[i] ε , in each element a_{ij}individually; that is, $\Delta\mathbf{A}$ it is matrix $\mathbf{E} = |\varepsilon_{ij}|$, such that:

$$\varepsilon_{ij} = \begin{cases} \varepsilon \ se \ i = i_1 \ e \ j = j_1 \\ 0 \ se \ i \neq i_1 \ e \ j \neq j_1 \end{cases} \quad (6)$$

A variation of magnitude $\Delta\mathbf{A}$ in the coefficients of matrix A results in a new technological matrix, that is: $\mathbf{A}^* = \mathbf{A} + \Delta\mathbf{A}$. Thus, the Leontief inverse matrix can be reformulated as: $\mathbf{B}^* = (\mathbf{I} - \mathbf{A} - \Delta\mathbf{A})^{-1}$. The field of influence of each coefficient is approximately equal to:

$$\mathbf{F}(\varepsilon_{ij}) = \frac{\mathbf{B}^* - \mathbf{B}}{\varepsilon_{ij}} \quad (7)$$

The total influence of each technical coefficient or link in the IP is given by equation (13). The greater the value of S_{ij}, the larger the field of influence of coefficient a_{ij} on the production chain.

$$\mathbf{S}_{ij} = \sum_{k=1}^{n}\sum_{l=1}^{n}\left[f_{kl}(\varepsilon_{ij})\right]^2 \quad (8)$$

We also estimate the investment multiplier for the oil and gas sector. The so-called investment vector must be defined, reflecting the sectoral composition of investment in the oil and gas industry. This allows us to estimate the direct and indirect effects of each monetary unit invested to enable oil and gas production in Sergipe. Based on the interregional input-output model, it is possible to estimate how much of these investment impacts are intraregional (confined to Sergipe's economy) and how much are interregional, that is, those that spill over into the rest of the country.

3.2 Structural changes and technological patterns

To assess potential structural changes in Sergipe's oil and gas sector between 2011 and 2018, Structural Decomposition Analysis (SDA) is employed. SDA is a comparative static technique that allows the disaggregation of the effects of changes on macroeconomic variables. The basic premise of this analysis is that variations in output result from changes in sectoral technology and shifts in the components of final demand (Oosterhaven, 2024).

Based on the basic input-output model described earlier, the production vector is calculated for the year 2011 (denoted by subscript 0) and 2018 (subscript 1), as shown in the following equations.

$$\mathbf{x}_{i,i}^{1} = \mathbf{B}_{i,i}^{1}\mathbf{y}_{i,i}^{1} \tag{9}$$

$$\mathbf{x}_{i,i}^{0} = \mathbf{B}_{i,i}^{0}\mathbf{y}_{i,i}^{0} \tag{10}$$

Output $\mathbf{x}_{i,i}$ in each year is given by the pre-multiplication of the final demand vector, $\mathbf{y}_{i,i}$, by the Leontief inverse matrix, $\mathbf{B}_{i,i}$. The change in output is represented by:

$$\Delta\mathbf{x} = \mathbf{x}_{i,i}^{1} - \mathbf{x}_{i,i}^{0} = \mathbf{B}_{i,i}^{1}\mathbf{y}_{i,i}^{1} - \mathbf{B}_{i,i}^{0}\mathbf{y}_{i,i}^{0} \tag{11}$$

The objective is to decompose the change in sectoral output into technological changes—represented by the variation in the Leontief inverse matrices between the two periods analyzed ($\Delta\mathbf{B}_{i,i} = \mathbf{B}_{i,i}^{1} - \mathbf{B}_{i,i}^{0}$), and changes in the components of final demand ($\Delta\mathbf{y}_{i,i} = \mathbf{y}_{i,i}^{1} - \mathbf{y}_{i,i}^{0}$). Despite the range of computational methods developed in the literature for structural decomposition analysis, as presented in Miller and Blair (2022), Dietzenbacher and Los (1998) argue that the most appropriate form of decomposition is given by:

$$\Delta\mathbf{x} = \frac{1}{2}\Delta\mathbf{B}\left(\mathbf{y}_{i,i}^{0} + \mathbf{y}_{i,i}^{1}\right) + \frac{1}{2}\Delta\mathbf{y}\left(\mathbf{B}_{i,i}^{0} + \mathbf{B}_{i,i}^{1}\right) \tag{12}$$

Where $\Delta\mathbf{B}\left(\mathbf{y}_{i,i}^{0} + \mathbf{y}_{i,i}^{1}\right)$ corresponds to changes resulting from technological variations between 2011 and 2018, that is, changes in the Leontief inverse matrices, and $\Delta\mathbf{y}\left(\mathbf{B}_{i,i}^{0} + \mathbf{B}_{i,i}^{1}\right)$ c corresponds to changes resulting from variations in final demand.

To aggregate the final effects of the change in output Δx, it is necessary to decompose it into two or more components, such that:

$$i'\Delta\mathbf{x} = i'\left[\frac{1}{2}\Delta\mathbf{B}\left(\mathbf{y}_{i,i}^{0} + \mathbf{y}_{i,i}^{1}\right)\right] + i'\left[\frac{1}{2}\Delta\mathbf{y}\left(\mathbf{B}_{i,i}^{0} + \mathbf{B}_{i,i}^{1}\right)\right] \tag{13}$$

It is also possible to disaggregate the final demand vector into its components (household consumption, government consumption, consumption by non-profit institutions serving households, gross fixed capital formation, and changes in inventories) to assess their individual contributions to changes in output resulting from variations in final demand. This enables the decomposition of the structural changes in Sergipe's oil and gas sector between 2011 and 2018.

3.3 Data Sources

To identify and assess the contribution of the oil and gas sector to Sergipe's economy, two input-output matrices (IOM) for the years 2011 and 2018 are employed. These matrices were constructed in accordance with the latest revision of the 2010 System of National Accounts (United Nations, 2009) and are thus mutually compatible. The 2011 IOM was estimated by Haddad et al. (2017) and was originally calibrated for Brazil's 27 states. The 2018 IOM was developed by the Infrastructure Secretariat of the State of Bahia and initially constructed for 53 Brazilian regions (Seinfra, 2022). For the purposes of this study, both matrices were aggregated into two regions: Sergipe and the rest of Brazil. Moreover, the matrices share the same sectoral structure, encompassing 68 economic sectors. It is important to note that the Brazilian Institute of Geography and Statistics (IBGE) does not produce IOM for individual states. The matrices used in this study result from efforts of state-level research institutions to construct IOM at the regional level. It is also worth emphasizing that the time lag of the input-output matrices employed does not lead to significant distortions in the results, as structural changes in the economy tend to occur only over the long term.

Another data source used in this study is the Investment Absorption Matrix (MAI). This represents an academic effort to fill a gap in the official data provided by IBGE (Miguez & Freitas, 2021), estimating the sectoral composition of investments (gross fixed capital formation) for each of the economic activities covered by the Brazilian IOM. In the official IBGE input-output data, there is only a single consolidated investment vector for the entire Brazilian economy.

The study resulted in the construction of annual MAIs for the period 2000–2020, with investment values measured in nominal terms. Therefore, the sectoral compositions of investment in the oil and gas sector, as recorded in the 2018 and 2011 MAIs (the latter recalculated at 2018 prices using sectoral deflators for gross fixed capital formation), are used to calculate the direct and indirect effects derived from the investment multipliers.

It is worth emphasizing that the MAI is available only at the national level and not at the state level. However, since the sectoral composition of investment typical of oil and gas extraction projects tends to be reasonably homogeneous in terms of the types of capital goods required, the use of the national MAI to estimate the investment impacts of the oil and gas sector specifically in Sergipe does not significantly compromise the accuracy of the results.

Once the sectoral composition of investment in Sergipe's O&G sector is defined, the Gross Fixed Capital Formation vectors present in the inter-regional IOM are used to identify the portion allocated to capital goods producers operating within Sergipe and the portion that spills over to capital goods producers located in other states of the country.

4 RESULTS AND DISCUSSION

4.1 Analysis of Direct Effects

In 2011, 78% of the sales from Sergipe's O&G sector were destined for intermediate consumption, while 22% corresponded to final demand. By 2018, this had shifted to 86% and 14%, respectively. Intuitively, this would suggest that despite the decline in production observed earlier, the sector became more interconnected. However, productive linkages, as measured by the Hirschman-Rasmussen linkage indices, do not consider the size of the activity but only the number of intersectoral connections. More specifically, Figure 2 illustrates the composition of final demand for products from Sergipe's O&G sector.

<Insert Figure 2>

Some important changes in the composition of final demand can be observed, notably the significant increase in the share of investment and the sharp decline in the share of exports. Figure 3 presents the cost structure of Sergipe's O&G sector in 2011 and 2018. In other words, this structure represents the composition of the gross output from the demand perspective.

<Insert Figure 3>

In 2011, the largest portion of the cost structure of Sergipe's O&G sector corresponded to the remuneration of production factors, that is, gross value added (GVA) (61%), followed by purchases of domestic intermediate inputs (30%), imports of intermediate inputs (5%), and tax payments (3%). By 2018, intermediate consumption accounted for the largest share of the sector's cost structure (50%), followed by GVA (42%). Additionally, proportionally, tax payments (7%) surpassed the share of imported inputs (2%). Santos and Ribeiro (2018) highlight that the oil and gas sector in Sergipe employs workers on high wages and, at the same time, most have a university degree. Furthermore, these authors point out that although the sector's intermediate trade relationships in Sergipe are concentrated in a few sectors—as will be shown later—it has a strong capacity for value addition.

In intersectoral terms, Figure 4 presents the supply chain of inputs for the O&G sector originating within the state of Sergipe. In 2011, 53.7% of the domestic inputs were sourced from within the state, whereas in 2018 this share decreased to 46.5%, making the sector more dependent on inputs originating from the rest of Brazil. This indicates that efforts to increase local content remain a challenge for expanding local firms in the sector. The main input suppliers are the following sectors: (i) Construction; (ii) Business services; (iii) Non-real estate rentals and intellectual property asset; (iv) Trade; (v) O&G sector itself; and (vi) Transportation. Except for the O&G sector and the Non-real estate rentals sector [...], the other sectors proportionally saw a reduction in their input supply in 2018.

<Insert Figure 4>

Figure 5 shows the main input suppliers to the O&G sector of Sergipe from the rest of Brazil. As mentioned earlier, the sector has become more dependent on the rest of the country, with the share of domestic inputs sourced from outside the state rising from 46.3% to 53.3% between 2011 and 2018. Most of the main local suppliers lost market share, including Construction, Trade, and Transportation. On the other hand, Non-real estate rentals and intellectual property asset saw a slight increase in their share, while the O&G sector experienced more significant growth.

<Insert Figure 5>

It is important to analyze the characteristics of the investments made by the O&G sector in Sergipe, estimated according to the methodology previously explained. Overall, approximately 85% of the sector's investment is concentrated in demand for just three activities: i) O&G; ii) Machinery and mechanical equipment; and iii) Other transportation equipment. Figure 6 presents the complete sectoral composition of the O&G sector investment in Sergipe, estimated for the years 2011 and 2018.

<Insert Figure 6>

Besides the high concentration of investment in a few capital goods, notable changes occurred in the share of the construction sector within total investment, which was significantly higher in 2011 compared to 2018. This shift is directly linked to the weakening of local content policies, leading to an increased demand for construction services from non-Brazilian providers at the expense of domestic suppliers. Additionally, the growing share of services in total investment stands out, reflecting a sectoral trend. This dynamic is associated with the acceleration of digitalization processes and the integration of new technologies in the analysis and execution of investment projects.

After decomposing investment by sector, the analysis focuses on the estimated shares that stimulated growth in Sergipe's economy versus those that "leaked" and benefited investment goods producers in other states. Contrary to what was observed in intermediate purchases—where Sergipe's O&G sector increased its reliance on suppliers from the rest of Brazil—in the case of investments, there was an increase, albeit small, in the share of demand met by local producers.

In 2011, 35.5% of the investment goods demand from Sergipe's O&G sector, supplied by companies operating in Brazil, was met by producers in Sergipe; this share increased to 37.3% in 2018. These figures indicate some success in local enterprise development policies aimed at serving Sergipe's O&G sector, particularly regarding support services for executing investments, as illustrated in Figure 7. However, this success is not observed when analyzing demand behavior for capital goods from the industrial sector, such as machinery, equipment, and vessels. The impacts generated by demand for these types of capital goods on Sergipe's economy remain very limited, with dependency on the rest of the country still high and increasing over the period analyzed, as also shown in Figures 7 and 8.

<Insert Figure 7>

<Insert Figure 8>

In summary, our exploration results indicate that the O&G sector in Sergipe underwent significant changes between 2011 and 2018, both in demand structure and in the composition of inputs and investments. There was a reduction in the share of local inputs in the cost structure and an increased dependence on suppliers from other regions of the country, particularly regarding industrial goods. Despite this, there was a slight improvement in the regional integration of the sector's investments, with a higher participation of local services. These findings reflect the challenges faced in expanding local content and strengthening internal production linkages, which is critical given the expected resumption of investments with the SEAP project. The following analysis delves deeper into the direct and indirect effects generated by the sector, using the Leontief inverse matrix and the MAI, thus broadening the understanding of the intersectoral and interregional impacts associated with oil activity in Sergipe.

4.2 Analysis of Direct and Indirect Effects

A more comprehensive analysis of the effects generated by the O&G sector can be conducted through the calculation of linkage effects and multipliers. Additionally, the examination of the field of influence and structural decomposition makes it possible to understand the dynamics of intersectoral linkages and the role of final demand components in the sector's output variation.

Table 1 presents the simple output and income multipliers of the O&G sector in Sergipe, along with their respective leakages to the rest of Brazil. These multipliers are decomposed into intraregional (within the state), interregional (spillover effects), and total effects, which represent the sum of both components.

<Insert Table 1>

For every R$ 1.00 increase in final demand for the O&G sector in Sergipe in 2011, the Brazilian economy needed to produce R$ 1.53, R$ 1.20 within Sergipe itself and R$ 0.32 in the rest of Brazil, resulting in a spillover rate of 21%. The output multiplier was below the average for Sergipe's economy (R$ 1.75). Although this multiplier increased in 2018, the spillover effect grew proportionally more, rising to 30%. This is consistent with earlier findings indicating that the sector has become increasingly dependent on suppliers from outside the state.

Regarding the income multiplier, for every R$ 1.00 increase in final demand for Sergipe's O&G sector in 2011, an additional R$ 0.86 in income was generated across the Brazilian economy, R$ 0.73 within Sergipe and R$ 0.14 in the rest of the country, corresponding to a spillover rate of 21%. By 2018, the intraregional multiplier declined to R$ 0.59, while spillover rose to 28%. This probably reflects the observed decline in production and the consequent reduction in income generation within the state. Additionally, royalty payments also decreased, as these are directly linked to production levels.

Table 2 presents the Hirschman-Rasmussen linkage indices for Sergipe's O&G sector. In both years, the sector can be classified, following Miller and Blair (2022), as dependent on intermediate demand, since the backward linkage index (BL) is below the state economy average (BL < 1), while the forward linkage index (FL) is above the average (FL > 1). It is worth noting that during the period under analysis, production linkages increased modestly for both indicators, an outcome that was, to some extent, anticipated earlier in this section.

<Insert Table 2>

To assess whether the O&G sector in Sergipe experienced an increase or decrease in the intensity of its intersectoral linkages during the period under analysis, Figure 9 presents the field of influence results for 2011 and 2018. To facilitate interpretation, the results for each production link are highlighted using a color scale, identifying influence fields above the average, that is, the most relevant linkages for each region's economy (Sergipe and the rest of Brazil). Like input-output tables, the rows in Figure 9 represent input-supplying sectors, while the columns denote input-purchasing sectors. The O&G sector in Sergipe is outlined in red.

<Insert Figure 9>

On the sales side, it is observed that the intensity of linkages increased between 2011 and 2018, particularly with sector 3 – Other Industries (above average by more than 2 standard deviations) and sector 4 – SIUP from the rest of Brazil. On the purchases side, an above-average relationship emerged with sector 3 – Other Industries from the rest of Brazil. Overall, the trade relationships of Sergipe's oil and gas sector did not show above-average linkages within Sergipe's production structure in either year analyzed, but only with sectors from the rest of Brazil, which corroborates the initial analyses in this section.

To decompose the change in production of Sergipe's oil and gas sector between 2011 and 2018, Figure 10 presents the results of the structural decomposition analysis. As noted in the methodology section, the variation in production was broken down into changes resulting from technological variation (intersectoral linkages) and changes in final demand.

Except for the Construction sector, changes in production were predominantly driven by variations in final demand, including in the O&G sector. This finding aligns with empirical literature on structural decomposition in Brazil, such as the works of Guilhoto et al. (2001), Sousa Filho et al. (2020), and Ribeiro et al. (2023c), which identify final demand as the main factor explaining sectoral production changes in Brazil. Moreover, technological changes showed negative results across all Sergipe sectors.

<Insert Figure 10>

Figure 11 shows the share of each final demand component in the total change in production for each sector. The most relevant final demand component, although negative in explaining the production variation of the O&G sector in Sergipe, is household consumption, followed by exports.

<Insert Figure 11>

Finally, it is important to present the results of the investment multipliers for the O&G sector in Sergipe, which indicate the extent to which this expenditure can stimulate growth in other activities both within the state and in the rest of Brazil (see Table 3). For every R$ 1 invested by the O&G sector in Sergipe, direct and indirect impacts amounted to R$ 1.75 in 2011 and R$ 1.88 in 2018.

Unlike the output multipliers, where most effects (direct and indirect) occur within the state, approximately 75% of the investment impacts took place outside Sergipe in both years analyzed.

<Insert Table 3>

The effects generated on the local economy remained largely confined to the service activities within the O&G sector's production chain, but they exhibit a lower degree of productive linkage compared to the industrial sectors.

5 CONCLUSIONS AND POLICY IMPLICATION

The systemic and temporal evaluation of Sergipe's O&G sector, based on interregional input–output and investment absorption matrices for 2011 and 2018, reveals key structural dynamics in the state economy. Despite a sharp decline in output after 2014, the O&G sector maintained relevant productive linkages, with modest increases in backward and forward indices, signaling resilience in its intersectoral integration.

Production and income multipliers indicate moderate direct and indirect effects, though slightly below state averages. There is growing interregional leakage, reflecting the sector's increasing reliance on inputs from other Brazilian states. Investment multipliers reveal low intraregional impacts which are largely due to the sector's dependence on capital goods from external industrial hubs, despite a small increase in the participation of local support services.

The structural decomposition analysis highlights that changes in sectoral output were primarily driven by final demand, with negative contributions from household consumption and exports. These findings reinforce the importance of stimulating domestic demand and export capacity, especially through policies that foster technological upgrading and regional supply chain development.

Although informative, the study has limitations: the analysis relies on only two time points (2011 and 2018), which constrains dynamic tracking; input-output data come from different sources, potentially introducing heterogeneity; and sectoral/regional aggregation limits granularity.

From a policy perspective, the findings emphasize the urgency of promoting local content through targeted incentives, technical education aligned with the sector's needs, and enhanced collaboration between firms, research institutions, and government agencies. Programs such as Rede Petrogás could be instrumental in fostering innovation and productive densification.

Considering the Sergipe Deep Waters (SEAP) project, expected to begin operations in 2028 and attract over US$5 billion in investments, the strengthening of local production chains becomes even more critical. SEAP offers a unique opportunity to reverse past trends of external dependence and to build a more integrated, innovation-driven O&G ecosystem in the state.

Finally, future research should explore the economic potential of planned decommissioning activities, which represent billions in expenditures and offer new opportunities for local industrial participation. The methodological approach presented here can be extended to monitor ongoing developments as Sergipe advances in the offshore oil frontier, ensuring these investments contribute meaningfully to regional development.

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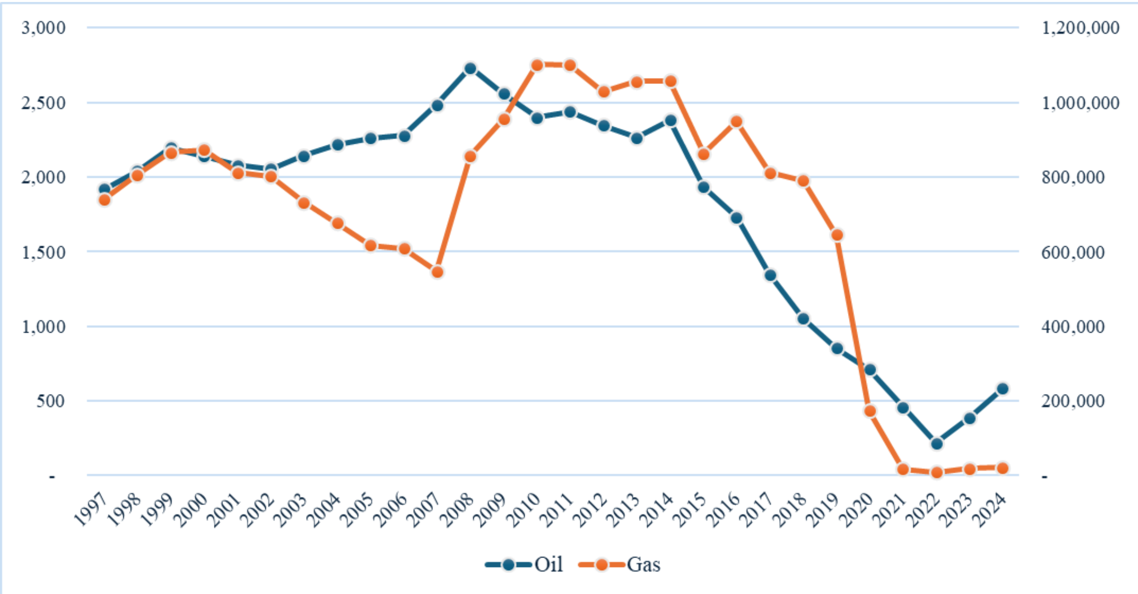
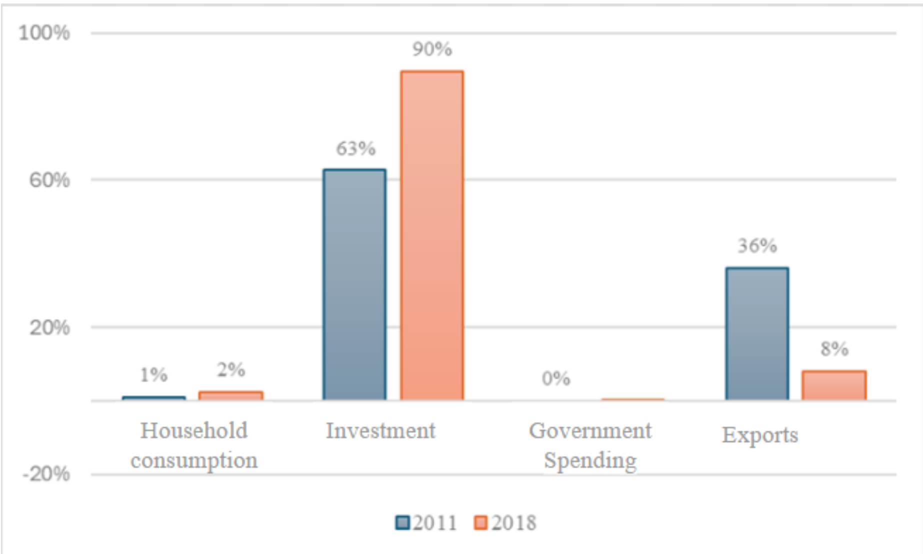
Figures and Tables

Figure 1: Oil and Gas Production in Sergipe: 1997–2024 (in 1,000 m³)



Source: Authors' own based on ANP data.

Figure 2: Composition of final demand for the O&G sector in Sergipe



Source: Author's own based on IOM.

Figure 3: Cost structure of the O&G sector in Sergipe

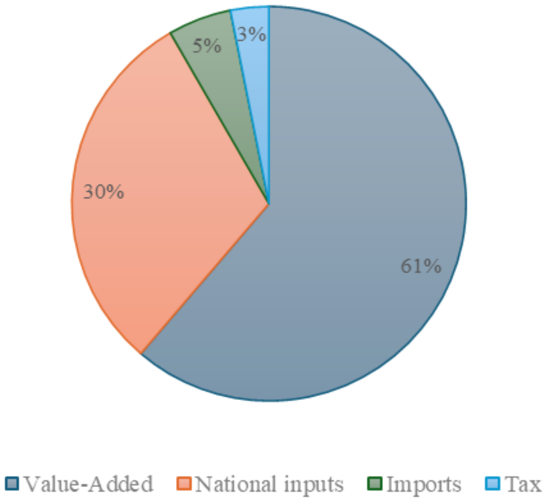


Figure 3A: 2011

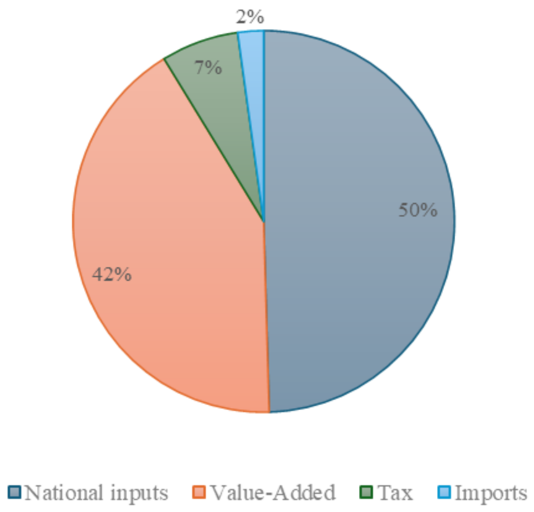
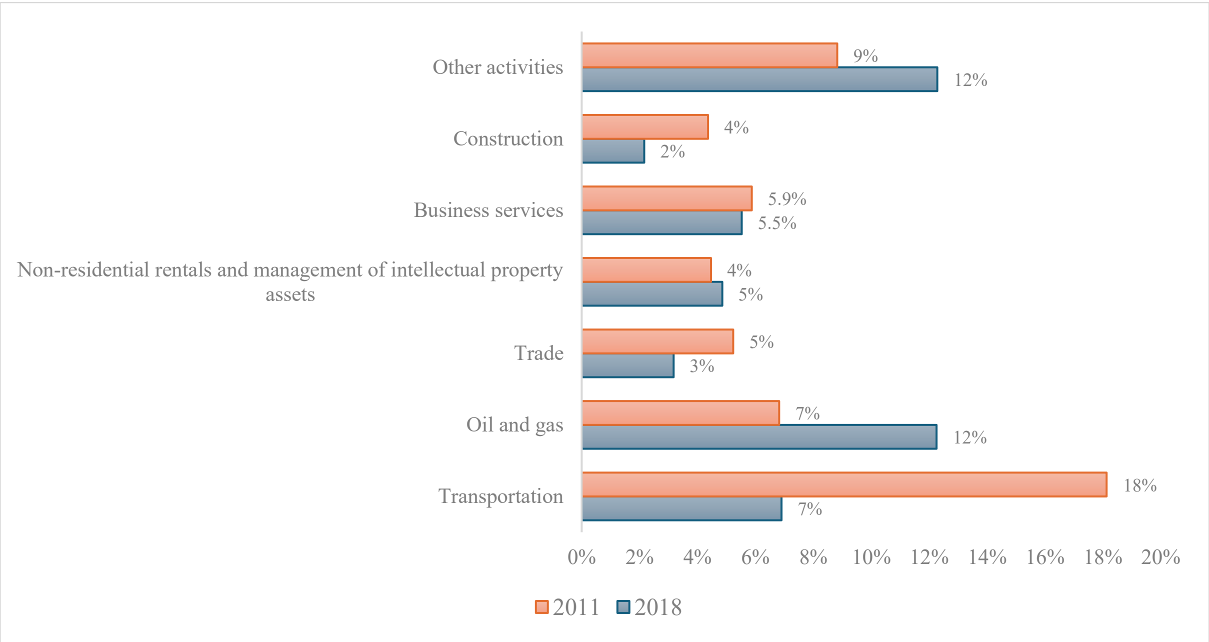


Figure 3B: 2018

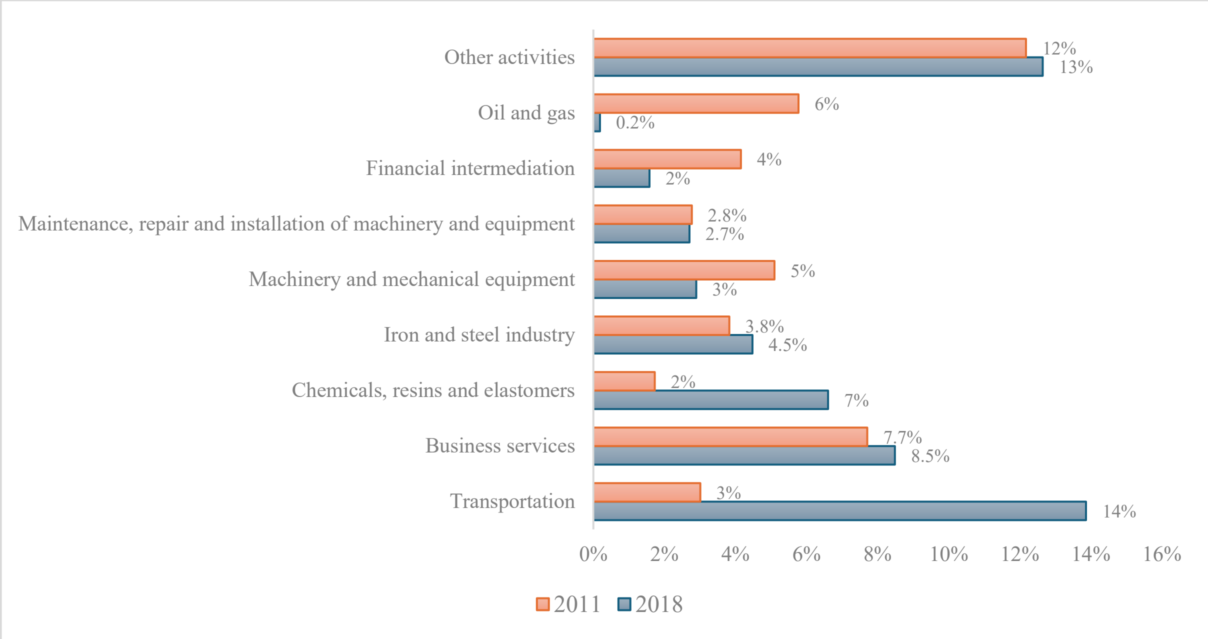
Source: Author’s own based on IOM.

Figure 4: Origin of intermediate purchases by the O&G sector of Sergipe within the state



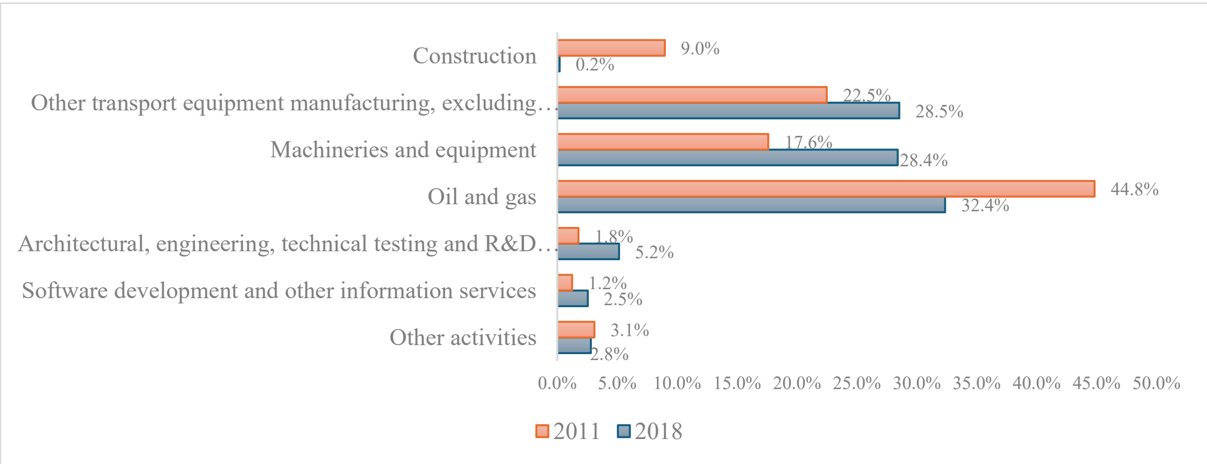
Source: Author’s own based on IOM.

Figure 5: Origin of intermediate purchases by the O&G Sector of Sergipe from the rest of Brazil



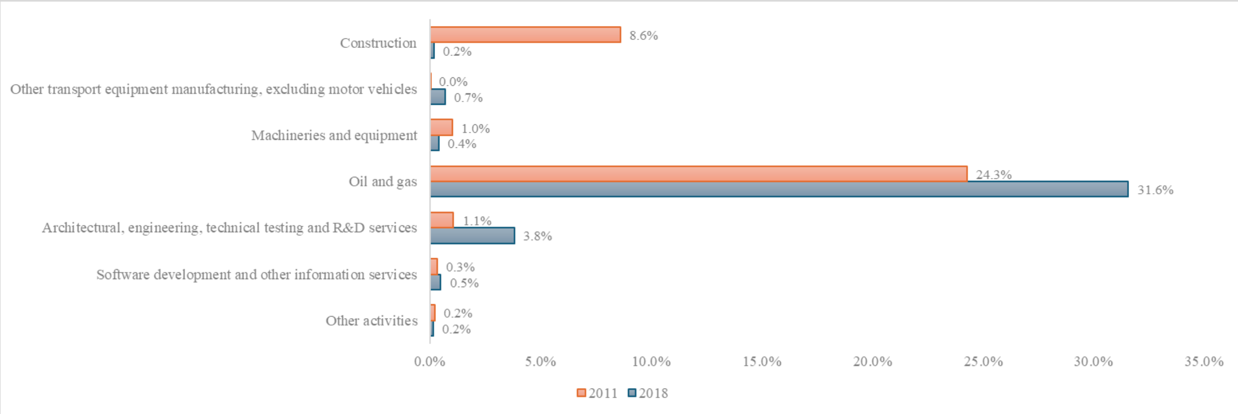
Source: Author's own based on IOM.

Figure 6: Composition of investment in the O&G sector of Sergipe (national supply)



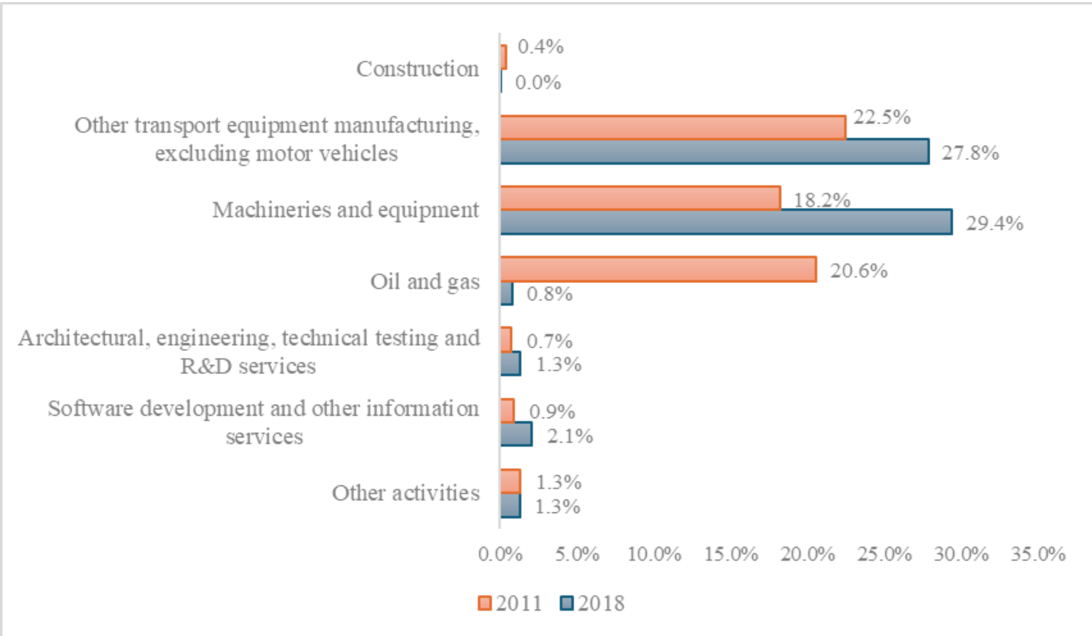
Source: Author's own based on MAI and IOM.

Figure 7: Origin of investment required by the O&G sector in Sergipe from within the state



Source: Author’s own based on MAI and IOM.

Figure 8: Origin of investment required by the O&G sector of Sergipe from the rest of Brazil



Source: Author’s own based on MAI and IOM.

Figure 9: Field of Influence of Sergipe's production structure: 2011 and 2018

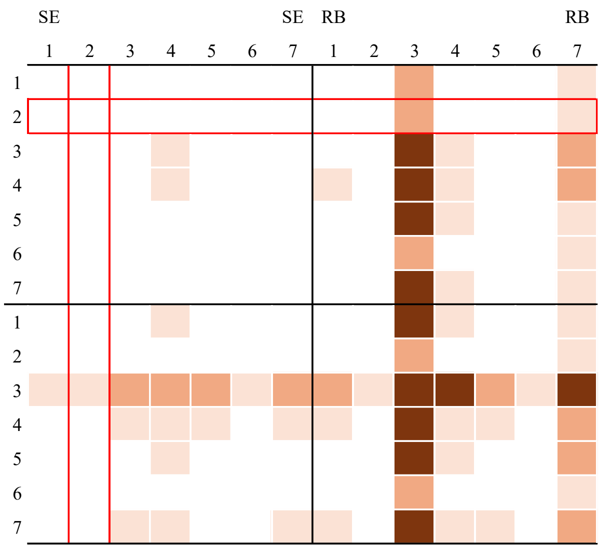


Figure 9A: Field of influence 2011

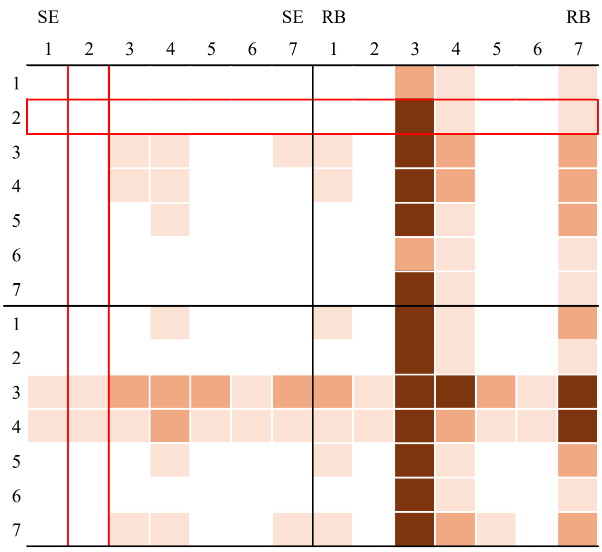
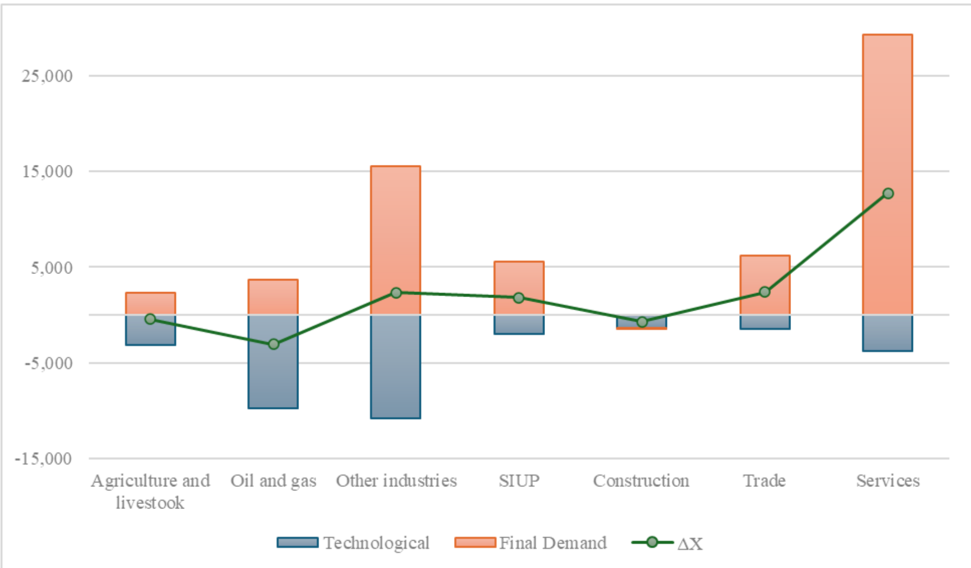


Figure 9B: Field of influence 2018

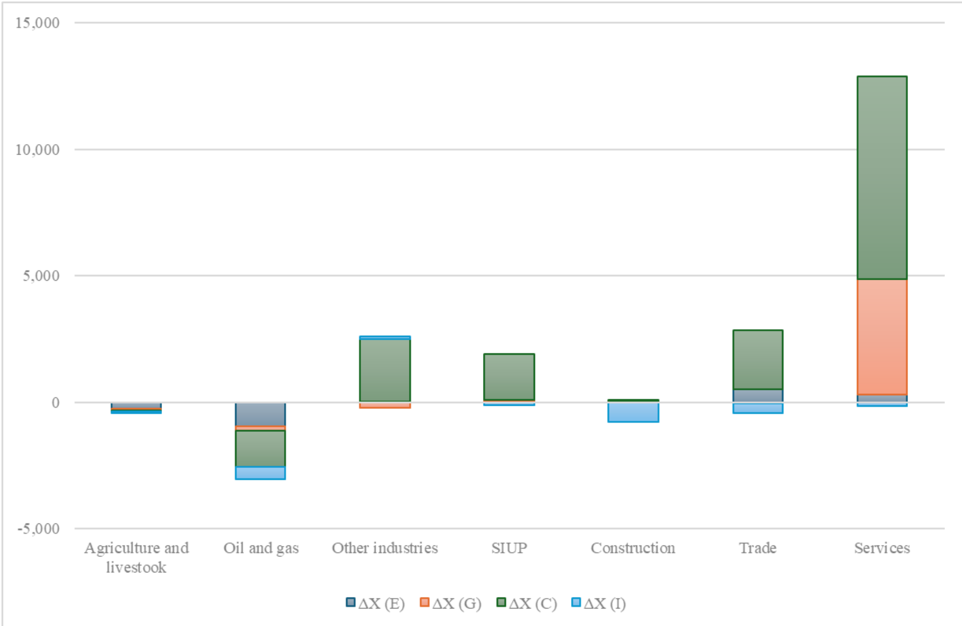
Source: Author's own based on IOM.

Figure 10: Sergipe – Structural Decomposition, 2011 - 2018 (in million BRL, at 2018 prices)



Source: Author's own based on IOM.

Figure 11: Sergipe — Influence of final demand components on output variation, 2011 - 2018 (in million BRL, 2018 prices)



Source: Author’s own based on IOM.

Table 1: Simple output and income multipliers of the O&G sector in Sergipe

	Variables	2011	2018
Output	Intra	1.20	1.31
	Inter	0.32	0.57
	Total	1.53	1.89
	Economic average	**1.75**	**1.74**
Income	Intra	0.73	0.59
	Inter	0.14	0.23
	Total	0.86	0.82
	Economic average	**0.83**	**0.81**

Source: Author's own based on IOM.

Table 2: Linkage Indices of Sergipe's O&G sector

Years	BL	FL
2011	0.95	1.05
2018	0.96	1.18

Source: Author's own based on IOM.

Table 3: Simple investment multipliers for the O&G sector in Sergipe

Effects	**2011**	**2018**
Intra	0.43	0.49
Inter	1.31	1.39
Total	1.75	1.88
Economy average	**1.79**	**1.89**

Source: Author's own based on MAI and IOM.

[i] $e = 0.001$.