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Article

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Suggested Citation: Magalhães, Aline Souza; Domingues, Edson Paulo (2014) : Blessing or curse: Impacts of the Brazilian Pre-Salt oil exploration, EconomiA, ISSN 1517-7580, Elsevier, Amsterdam, Vol. 15, Iss. 3, pp. 343-362, <https://doi.org/10.1016/j.econ.2014.11.002>

This Version is available at:

<https://hdl.handle.net/10419/179581>

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Blessing or curse: Impacts of the Brazilian Pre-Salt oil exploration[☆]

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Available online 26 November 2014

Abstract

The discoveries of oil and gas in the so-called “Pre-Salt layer” have triggered a lot of discussions about their economic effect. In this paper we discuss in detail a less discussed dimension: the impact of Pre-Salt layer in the structure of the Brazilian economy, especially the composition of the industry and exports. Similar consequences in the country of “Dutch disease” and “deindustrialization” due to revenues from oil exports are evaluated. The methodology used is a dynamic global general equilibrium model, with specific features for the treatment of the issues raised.

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JEL classification: Q32; Q34; L6; C68

Keywords: Pre-Salt; Dutch disease; Industry; Computable general equilibrium model

Resumo

As descobertas de reservas de petróleo e gás na chamada “camada de Pré-sal” tem desencadeado uma série de discussões acerca do seu efeito econômico. Neste trabalho abordamos detalhadamente uma dimensão menos discutida: os impactos do Pré-Sal na estrutura da economia brasileira, especialmente da composição da indústria e da pauta de exportações. Consequências no país similares às da “doença holandesa” e “desindustrialização”, em decorrência das receitas com as exportações de Petróleo, são avaliadas. A metodologia utilizada é um modelo de equilíbrio geral computável global, com características específicas para o tratamento das questões levantadas.

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Palavras-chave: Pré-sal; Doença Holandesa; Indústria; modelo de equilíbrio geral computável

[☆] The authors thank Terrie L. Walmsley, Alla Gollub and other instructors of the 2012 Short Course in Dynamic Global Trade Analysis (Copenhagen, Denmark) by introducing the GDYN model and assistance in the simulations. The work also benefited from the suggestions of the anonymous referee. The analysis and conclusions are the sole responsibility of the authors. This article has benefited from the resources of “Edital Universal” 2011 – CNPq, PPM program (Fapemig) and is part of the research of NEMEA (Center for Economic Studies in Applied and Environmental Modeling, www.facebook.com/nemeaeconomia).

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Peer review under responsibility of National Association of Postgraduate Centers in Economics, ANPEC.

1. The Pre-Salt oil reserves and economic impacts in Brazil

The energy issue is a topic of great importance in the Brazilian economy, which has attracted academic, government and media discussions.

The high profile given to megareserves discoveries of oil in the country makes room for a new paradigm of economic development because it involves aspects related to both the potential for economic growth, social development and energy security and environmental sustainability strategies and even geopolitical and national security.¹

The country, which until 2006 was not self-sufficient in oil, Brazil sees the possibility of becoming a major world player in the production of this energy commodity. The discoveries of oil and natural gas in 2007 in the so called “Pre-Salt layer” (extending from the coast of Espírito Santo to Santa Catarina) bring new challenges for the country, once given the huge potential reserves, Brazil would become a net exporter of oil and oil products. To get an idea of its potential, based on conservative estimates, the Pre-Salt should double the oil reserves of the country to 31 billion barrels, only considering the portion already discovered (EXAME, 2012). It is believed that there are another 87 billion barrels undiscovered, which would put the country at the level of reserves in Iraq,² for example. Moreover, for every three barrels of oil discovered in the world in the last five years, one was discovered in Brazil, which still accounts for 63% of global oil discoveries in deep waters. Projections indicate that, with the development of newly discovered reserves, Brazil is the country with the highest production growth from countries outside OPEC in 2030 (EXAME, 2012; ANP, 2012).

According to the National Petroleum Agency (ANP), investment demand for the Pre-Salt is expected to exceed 400 billion dollars in materials, systems, equipment and services by 2020 (ANP, 2012). Among the investments already announced are the Petrobras – which announced in its Business Plan (PETROBRAS, 2012), \$ 142 billion of investments for the five-year period from 2012 to 2016 – the British BG Group, with investments of \$ 30 billion and Repsol YPF to US \$ 14 billion (Ernst and Young Tergo, 2011).

Nevertheless, Brazil is faced with numerous challenges with the Pre-Salt. One is to reconcile the blessings afforded by exploration, such as increased production and export possibilities and the large increase in public revenues, with the threat of fiscal and macroeconomic imbalances, the literature has termed “the resource curse”. The idea of the resource curse date of the pioneering work of ECLAC (Prebisch, 1949; Singer, 1950; Furtado, 1957) that predicts, in general terms, that the abundance of natural resources can have an adverse effect on the country’s development. The abundance of natural resources would impact on the productivity of the economy, deteriorating terms of trade and specialization in primary commodities in developing countries. Furtado (1957), for example, studies the case of Venezuela and implications of its dependence on oil. In recent decades, the literature has been addressing this problem (Auty and Gelb, 2001; Sachs and Warner, 1995; Auty, 1990; Gelb, 1988; Stevens, 1986; Corden and Neary, 1982),³ in spite of the empirical evidence that many countries abundant in natural resources tend to grow more slowly than similar countries that do not have the same allocation of resources. The main channel blamed for this effect is linked to the loss of domestic competitiveness caused by the appreciation of the local currency, due to the low cost of exported products that bring significant revenues in foreign currency into the local economy industries.

This discussion goes back to the phenomenon occurred in Holland in the 1960s, when the discovery of large natural gas deposits had diverse effects on resource allocation in the economy. If, on the one hand, exports provided an increase in income, on the other, the currency appreciation, due to the entry of foreign exchange from sales of gas, reduced the competitiveness of exports of manufactured products, redirecting specialization for primary products intensive in natural resources. Thus, the discovery caused a shrinking of the manufacturing sector as a result of the shift factors for the extraction of natural resources. This phenomenon is known in the literature as “Dutch disease” (Xavier, 2011; Nakahodo and Jank, 2006; Corden, 1984; Corden and Neary, 1982).⁴ Ultimately this phenomenon would trigger a

¹ Another question that too has been raised is the discussion involving the collection and distribution of royalties between regions.

² The oil reserves of Iraq stood at 115 billion barrels in 2011 (BP statistics, 2012).

³ An extensive literature review on the subject can be found in Stevens (2003).

⁴ The literature suggests that some countries have managed to avoid the supposed “curse, receiving the “blessing of the abundance of natural resources. Are the cases of Chile (Hojman, 2002), Indonesia (Booth, 1995), Malaysia (Rasiah and Shari, 2001) and Norway (Wright and Czelusta, 2007). Among the measures adopted by these countries are exchange rate policies to avoid excessive appreciation of the exchange rate, policies targeting the revenues to investment in productive activities through stabilization funds or earmarked revenue streams and encouraging private sector participation in investments (Stevens, 2003).

process of “deindustrialization” and may be defined as the reduction of the share of the value of production and employment of the industrial sector in the country’s total (Rowthorn and Ramaswamy, 1999; Tregenna, 2009).⁵

In Brazil, there is no consensus in the literature about the existence of the “Dutch disease” and a consequent process of “deindustrialization” in the country due to the appreciation of the 2000s. Part of the literature, in principle deals with the process of industrialization as arising from trade liberalization, low industrial investment and macroeconomic policies adopted in the 1980s and 1990s (Marquetti, 2002; Feijó et al., 2005). New factors, however, have intensified this debate since 2004, due to the combination of overvaluation of the Brazilian currency in real terms, coupled with the significant increase in the relative prices of the main commodities exported by the country, which has put in vogue the possibility of the occurrence of effects related to Dutch disease.

On one side, Oreiro and Feijó (2010), Bresser-Pereira and Marconi (2008), Bresser-Pereira (2008), Loures et al. (2006) and Palma (2005) share the view that there is evidence that the Brazilian economy has shown symptoms of the Dutch disease, and in a broader sense, a process of deindustrialization. For Palma (2005), the “new Dutch disease” that would have affected Brazil was caused by economic policies that have resulted in relative loss of industry in GDP and a return to a pattern of specialization based on extractive commodities. Bresser-Pereira and Marconi (2008) also support the argument that industrialization would be an implication of Dutch disease, whereas between 1992 and 2007, there has been an increase in the share of commodities and a reduction in the share of industrial products, which have including having a negative contribution to the trade balance. To Oreiro and Feijó (2010, p. 231) “there are no negligible signs of change in the pattern of specialization of the productive structure of the Brazilian economy towards activities intensive in natural resources and low-tech.”

Arguments challenging the thesis or deindustrialization Dutch disease can be found in Nakahodo and Jank (2006), Barros and Pereira (2008), Nassif (2008) and Souza (2012). As Nassif (2008, p. 89), one can not say that the country has contracted the Dutch or gone through a process of deindustrialization disease because “there was not a change in the widespread reallocation of productive factors and the pattern of specialization from sectors with intensive technologies of scale to industries based on natural resources and labor.” In the latest study, covering the period from 1999 to 2008, Souza (2012) also finds no evidence that Brazil has presented the symptoms of Dutch disease.

Indeed, the hypothesis of “Dutch disease” has been a major concern arising from the expansion of commodity exports in Brazil, and indeed, the discovery of Pre-Salt layer is a new element to be considered in the relationship between exchange rate appreciation, commodity exports and industrialization, especially when considering the prospects for the export of much of the oil production from Pre-Salt.

Besides all this discussion, another important question has been raised as to the Pre-Salt. Some claim that the greatest legacy would not be the oil itself or the accumulation of reserves and trade surpluses, but rather the development of a high-tech industry. This industry, centered in Petrobras, sustain the demands of a production chain of high complexity, such as oil drilling in deep water at distances that can reach 300 km of the coast. Given the prospects of strong investments in exploration, development and maintenance of production, the Pre-Salt tends to engender positive impacts along the supply chain, particularly the capital goods industry, with the potential for income generation, employment and knowledge (Ernst and Young Tergo, 2011; Xavier, 2011).

Aiming to encourage the domestic production chain and to encourage technological development and work qualification, the Brazilian government established as a requirement in the bidding for the exploration of fields, patterns of Local Content (LC), in which companies must meet certain percentage commitment to purchase domestic goods and services. Since the first round of grant of exploration fields (completed in 1999), ANP applies the concept of CL. However, from the 5th round, completed in 2003, the concession contracts now require minimum percentages to offer CL, established in bids, ranging between 37% and 77%, according to the activity and the location of field exploration and development of production (Bone, 2011; Xavier, 2011).

However, many controversies surround this policy of local content because of potential bottlenecks in the supply that still would be unable to meet the demand of Petrobras and also the other operators in the industry chain. According to a study by the Institute of Economics of UFRJ, the local industry would only have capacity to meet the need of oil in five of the 24 categories of equipment critical to the exploration and production (EXAME, 2012). Moreover, according to the ANP (2012), for 80% of the equipment that will be demanded there are few suppliers in the country.

⁵ As explained, although related, concepts of “curse of natural resources,” “Dutch disease” and “deindustrialization” in the literature are not identical.

Foreign companies are the only suppliers in about 75% of the items. Domestic suppliers prevail or hold exclusivity in only 4–7% of the items, such as automation systems, pumps and heat exchangers.

Considering all these discussions, a point little explored in the literature that will be discussed in this article is the impact that production in Pre-Salt megareserves would have on the Brazilian industry and whether this impact would strengthen an effect like “curse of abundance of natural resources.” The hypothesis is that even with projected investments for the development of the oil production chain, with potential positive effects on the supply chain and inputs, the discovery of Pre-Salt in an industrialized economy like Brazil can engender a perverse effect on other sectors of the industry, to the extent that these sectors may be affected by the concentration of factors, appreciation, higher costs, reduced exports and consequent reduction of its share in the economy, as in the case of Dutch disease.

The aim of this paper is to contribute to this debate by analyzing the economic impacts of planned investments for exploration and development of production of Pre-Salt. Moreover, given that in the future it is expected that much of the oil production is exported matters to assess what the impact on the Brazilian industry of a list of exports and production factors that concentrates energy commodities.

To study and simulate the impact of the Pre-Salt, it is necessary to take a global simulation model that captures the participation of countries in the oil trade, their supply chains and the insertion of Brazil in this market.⁶ For this we use a global dynamic computable general equilibrium model, GDyn, a dynamic version of the GTAP model (Hertel, 1997), widely used and documented in the literature. As far as we know, this is the first application of the GDyn model for Brazil.

Besides this introduction, this paper is divided into 4 more parts. The Section 2 presents the model and the database used in this work. Sections 3 and 4 discuss the simulations and the results obtained, and finally the last section weaves his final remarks.

2. Methodology

2.1. Global computable general equilibrium model

Global computable general equilibrium (CGE) models deal with an articulated set of countries or regions in which the flow of international trade, capital flows and productive factors are considered. The Global Trade Analysis Project (GTAP), headquartered at Purdue University (USA), is a research project initiated in 1980 to develop a database and a model of global computable general equilibrium, which can be used to various configurations of specific aggregations from its database. Several works for the Brazilian economy have used the theoretical framework and the GTAP database (Oliveira and Ferreira Filho, 2008; Gurgel, 2006; Figueiredo et al., 2001 among others). The GTAP is the subject of ongoing research and collaboration of several researchers and universities, both in its database as its specification, being able to analyze various issues, such as trade policy today (dealing directly with trade tariffs, trade barriers, subsidies, policies domestic support, and quotas), environmental policies (carbon markets and the Kyoto Protocol) and agricultural policies.

The most recent GTAP database consists of 57 sectors, and 129 regions (most of the countries) for the year 2007.

The traditional GTAP model, operated in comparative static exercises, adopts assumptions of perfect competition and constant returns to scale.⁷

Some aspects of this model include the treatment of private household preferences with non-homothetic formulation, the explicit treatment of international trade and transport margins.

⁶ A brief analysis of the impact of the Pre-Salt in the Brazilian productive structure is presented in Haddad (2012) through simulations with the EFES model (Haddad and Domingues, 2001). An analysis of the impacts of the Pre-Salt in the state of Espírito Santo is shown in Haddad and Giuberti (2010), through simulations with the BMES model.

⁷ Given the wide aggregation of sectors used in the model, there is no concrete evidence which would show increasing returns to scale and if there would be market power globally. In practice, what we see in the international market of commodities (such as oil) is some volatility in prices, and even in this case there is doubt whether any country or group of countries controls its price. The assumption of perfect competition and constant returns, for this configuration of a global economy of sectors and countries is quite reasonable, so that is adopted in the vast majority of global CGE models used in academic articles. Furthermore, it is known from theoretical and practical difficulty of using these assumptions in general equilibrium models, being more suited to partial equilibrium studies, which focus on the behavior of firms in a specific market.

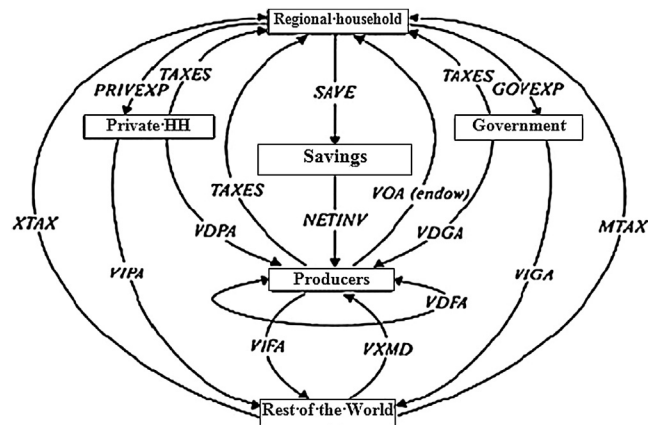


Fig. 1. Inter-relationships in the economy, GDyn model.

Source: Hertel (1997).

The model also allows a wide range of operational choices including structural unemployment and trade balance rigidity (which facilitate comparison of the results with studies based on econometric regression models, which in most cases use partial equilibrium hypothesis).

In this article we use the recursive dynamic version of GTAP which incorporates international mobility of capital, capital accumulation and adaptive expectations theory of investments.

This version of GTAP is known in the literature as GDyn (GTAP-Dynamic), and is being made available to researchers since the end of 2011. This work is the first to use this model in a study for the Brazilian economy.

In setting recursive dynamics, GDyn can be used to determine how changes in policy, allocation, people and technology can affect the trajectory of the economy over time, with their cumulative effects explicitly determined.

That is, unlike an exercise in comparative statics, in which only the end result of adjustment to the new equilibrium of the economy is calculated, in this version the adjustment paths of the variables can be observed, and can be made explicit a dated trajectory of shocks in the economy.

In addition to the results produced by traditional GTAP, as variations resulting in bilateral trade, sectoral and regional production, its dynamic version allows to estimate the changes in the external and internal wealth and growth rates in capital and investment. Thus, the model allows to design dynamic gains of policies, rather than just comparative static gains. The GDyn is extensively documented in [Ianchovichina and Walmsley \(2011\)](#).⁸ The main equations of the theoretical structure of the model can be found in [Appendix 1](#). In this paper we will present the most important features of the model for simulations of the Pre-Salt.

The GDyn is particularly suited to this study, since we are dealing with a relevant market in terms of bilateral trade, oil. A significant increase in Brazilian oil production resulting from the Pre-Salt may have impacts on the international market of this product, both in terms of prices as market share, as Brazil becomes a major international provider of this product. A global model as GDyn can explicitly address these aspects, an advantage over national CGE models, in which the foreign market is taken as exogenous, thus not responding to shocks on the domestic economy. Furthermore, the structure of recursive dynamic model allows that the shocks resulting from the expansion of exploration and production of oil are taken annually in reference to the official schedule of investment and production of Pre-Salt, making it more realistic the simulations and results of impact on the economy.

An overview of the model can be represented by [Fig. 1](#), which describes the relationships of the economic system. At the top of the figure is the regional agent that through an aggregate utility function, allocate his expenses between the private agent (or household) (PRIVEXP), the global saving (SAVE) and the government consumption (GOVEXP). Revenues from regional agent come from taxes (TAXES), tariffs on imports and exports (respectively MTAX and XTAX) and remuneration of primary factors (capital and labor) of producers (the value of the sale prices of agents,

⁸ Some applications of the dynamic GTAP were performed as in the study of the financial crisis in East Asia, on the growth of China, and China's accession to the WTO. About GTAP see <https://www.gtap.agecon.purdue.edu>. The dynamic model is described in <https://www.gtap.agecon.purdue.edu/models/Dynamic/model.asp>.

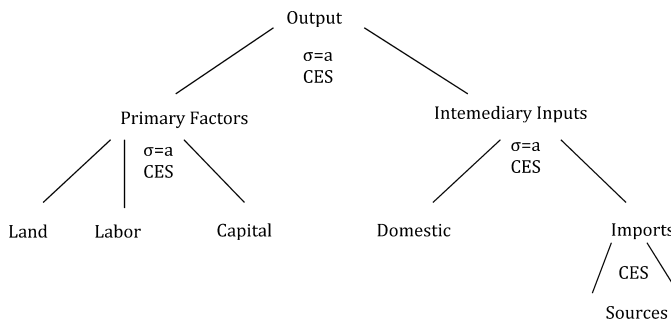


Fig. 2. Simplified hierarchical structure of the technology of production of the sectors.

represented by VOA). The income of domestic agents (private and government agent) is spent on consumption of domestic goods (VDPA and VDGA) and imported (VIPA and BEAM) in import tariffs (MTAX), the consumer tax (TAXES), and savings (SAVE). Turning to producers, they sell their production to domestic and external agents. Thus, its revenue comprised the total value of private sector at market price (VDPA), the total value of government at market price (VDGA), intermediate consumption among producers (VDFA), and exports to external agents (VXMD). On the other hand, producers realize their expenses in buying commodities from the private agent (VDPA) in taxes paid (TAXES), and imports (VIFA). It is noteworthy that the model assumes zero profit for producers, so that all revenues generated are spent (Hertel, 1997).

The hierarchical structure of production technology shown in Fig. 2 describes briefly the behavior of the firms. Each sector in each region of the model produces a single product. Productive sectors are subject to a technology of constant returns to scale, which combines intermediate inputs (domestic and imported) and a composite of primary factors, with separability between these two components. The sectors are profit maximizers agents and thus choose the optimal composition of inputs and primary factors separately, i.e., the elasticity of substitution between any primary factor and intermediate input is zero. This technology is further simplified by using Constant Elasticity of Substitution functions (CES) on the aggregation of primary factors and the combination of intermediate inputs for the production of products. These assumptions reduce the number of required parameters for calibration on the production function; only two parameters are needed by industry.

In the version of the model used in this work there are five primary factors: skilled labor, unskilled labor, capital, land and natural resources. Labor, land and natural resources are fixed factors regionally and cannot move between countries. The labor supply factor is exogenously determined in this work based in a scenario of growth of the working age population. Land and natural resources are fixed supply of productive factors, the availability of which is usually determined by historical growth rates.

In the simulations, an important point is the use of natural resources by the oil extraction industry. The exploration of Pre-Salt means an enlargement of natural resources in the sector, which may well expand their production with the addition of primary factors (capital and labor since the land input is not used in the industry) and intermediate inputs. This induced demand brings both positive and negative aspects, because it tends to raise the price of inputs and factors.

2.1.1. Investment, international mobility and capital accumulation

The main distinguishing characteristics of GDyn are its specification of the investment income flows associated with financial assets. The model distinguishes between physical and financial assets, and in the latter between domestic and foreign. The model allows to determine the accumulation of capital and assets of each national economy, and the assets and liabilities of firms and households in each region. The theory of investment in each region is characterized by adaptive expectations, in which the deviations between actual and expected rates of return are corrected over time by displacing of the investment and international mobility of the capital.

More specifically, the investment theory of the model follows assumptions of adaptive expectations with lagged adjustment. Investors act progressively over time in order to eliminate discrepancies between actual and expected rates of return. Moreover, the very expected rate of return may be wrong, and these errors are corrected over time. In estimates of future rates of return investors assume a normal rate of growth of capital stock, which can also be adjusted

over time. These lagged adjustment mechanisms generate behavior toward a stable equilibrium rates of return and growth of capital stock in countries where the intertemporal dynamics of the model acts over a few periods.

Adjustment mechanisms described above require a broad set of parameters that govern the international mobility of capital and the lagged adjustment mechanisms and rates of return on investment. Golub and McDougall (2012) present the data and the econometric procedure used in calibrating these parameters.

It is worth noting that the specification of investment adopted in the model seeks to adapt the behavior of investment and international capital mobility to the stylized facts and empirical evidence. For instance, the model adopts, as “stable equilibrium”, expected rates of return, investment and capital stock growth in China consistently higher than the rest of the world. This is an important stylized fact of the world economy in recent decades, which may be an element of the reference scenario in the analysis with the model.

The international capital mobility is a new feature of GDyn, implying the need for treatment of international income flows. A phenomenon or policy that attracts capital to a country, such as the Pre-Salt, can have a strong impact on the Gross Domestic Product, but if this investment is financed abroad its impact on the Gross National Product and National Income will be much weaker. The distinction in the model between ownership and location of assets allows the income generated by the assets in a region be decoupled from agents (firms or households) located in the region. In the case of the Pre-Salt, we expect an investment over 10 years, financed at least partly abroad and therefore a future stream of payments of foreign income that will produce impacts on balance of payments, the exchange rate and relative prices in the economy, with impact also on the trade balance.

Thus, the GDyn uses a simplified and unified treatment of capital mobility and investment in the context of a global CGE model. This specification endogenously captures the overall effects of accumulation of capital and wealth in the country, and also the effects of income arising from foreign ownership of assets.

2.1.2. Exports and imports

The model determines global markets for products, so that your balance is determined by supply and demand conditions of all countries. The demand for imports of a country is determined by its demand for imported inputs and goods consumed by final demand.

2.1.3. Final demand: private consumption, saving and government

Final demand in each region is represented by an aggregate called “Regional Household”, which is a Cobb–Douglas combination of private household consumption, saving and government spending. Private consumption optimizer is represented by an agent governed by a function of spending CDE (constant difference of elasticity). Government consumption follows a Cobb–Douglas function, which implies a constant share of public spending on goods and services. The savings is a residual element of the country’s income and determines the net investment in the economy.

2.2. Database

Specific aggregation of the database of the version 8 of GDyn was built for application in this study. The 57 regions were grouped in 7: Brazil, Petroleum Exporting Countries,⁹ European Union, United States, India, China and Rest of World. The purpose of this aggregation is to have specific results for the Brazilian economy and the impact on major oil producers. 117 products were aggregated into 23, listed in Table 1, favoring the products directly linked to the production of oil and gas. The aggregation chosen, therefore, highlights the Oil, Gas and Manufacturing Industry, which are the focus of analysis.

Some indicators of the database of the model allow an exploratory analysis of the role of the oil sector in the economies of these countries and importance in the world market. These indicators are also important in explaining the results obtained in the simulations.

Table 2 shows the share of manufacturing sector in the regions, which serves as an indicator of the productive structure of each. The Petroleum Exporting Countries have about 10% of its production structure concentrated in the extraction of oil and gas industry; this participation does not exceed 1% in the European Union, United States, India or China. In Brazil, the share of this sector is 1.6%. It is worth noting that the rest of the manufacturing industry, excluding

⁹ This group is composed of Canada, Mexico, Venezuela, Norway, Russia, Kazakhstan, Iran, Iraq, Kuwait, Qatar, Saudi Arabia, UAE and Nigeria.

Table 1
Aggregation of sectors, regions and primary factors.

Sectors	Regions	Primary factors
Farming, fishing and forestry	Brazil	Land
Oil extraction	Oil exporters	Unqualified labor
Extraction of natural gas	European Union	Qualified labor
Mineral extraction	USA	Capital
Food	India	Natural resources
Beverage and tobacco products	China	
Textiles and clothing items	Rest of the world	
Leather products and footwear		
Wood products		
Pulp and paper		
Oil refining		
Chemicals, rubber and plastic		
Nonmetallic mineral products		
Ferrous metals		
Metal products		
Motor vehicles and parts		
Transportation equipment		
Electronic equipment		
Machinery and equipment		
electricity		
Metal products		
Gas and tap Water		
Construction		
Servicing		

Table 2
Sector Participation in regional production (2007).

Sectors	Brazil	Oil exporters	European Union	USA	India	China	Rest of world
Farming, fishing and forestry	5.2%	4.0%	1.7%	1.6%	11.6%	7.2%	4.3%
Oil extraction	1.6%	9.7%	0.2%	0.5%	0.7%	0.9%	1.6%
Extraction of natural gas	0.1%	1.6%	0.1%	0.1%	0.1%	0.0%	0.5%
Mineral extraction	1.4%	0.8%	0.3%	0.2%	0.7%	1.3%	1.0%
Food	6.1%	3.9%	3.5%	2.6%	5.5%	3.9%	4.3%
Beverage and tobacco products	0.9%	0.6%	1.1%	0.6%	0.6%	0.9%	1.1%
Textiles and clothing items	1.7%	0.6%	1.4%	1.0%	3.0%	4.6%	1.8%
Leather products and footwear	0.6%	0.2%	0.4%	0.1%	0.3%	1.1%	0.3%
Wood products	0.6%	0.6%	0.8%	1.1%	0.3%	1.5%	0.6%
Pulp and paper	1.8%	1.1%	2.1%	1.8%	0.7%	1.5%	1.6%
Oil refining	2.4%	4.4%	2.2%	2.1%	4.7%	2.9%	3.3%
Chemicals, rubber and plastic	5.8%	3.0%	4.6%	3.7%	4.8%	7.1%	4.5%
Nonmetallic mineral products	0.9%	1.2%	1.2%	0.5%	1.5%	3.1%	1.0%
Ferrous metals	1.7%	1.6%	1.1%	0.7%	2.6%	4.9%	1.8%
Metal products	2.0%	2.3%	2.9%	2.0%	3.0%	4.6%	2.6%
Motor vehicles and parts	3.0%	2.4%	3.4%	2.3%	1.4%	2.8%	2.9%
Transportation equipment	0.6%	0.5%	1.0%	1.1%	0.8%	0.9%	0.6%
Electronic equipment	2.2%	1.0%	1.4%	2.1%	1.0%	4.7%	3.8%
Machinery and equipment	3.0%	3.0%	6.8%	4.5%	6.7%	10.8%	5.2%
Electricity	1.9%	2.6%	1.6%	1.5%	3.4%	2.6%	2.1%
Gas and tap water	0.8%	1.0%	0.3%	0.9%	0.4%	0.2%	0.5%
Construction	5.2%	10.0%	8.4%	6.3%	10.8%	8.8%	7.3%
Servicing	50.5%	43.8%	53.5%	62.6%	35.6%	23.5%	47.3%
Total	100%	100%	100%	100%	100%	100%	100%

Source: GTAP database version 8.

Table 5
International Trade - Oil (US \$ million, 2007).

Region	Exports	Imports	Balance	Self sufficiency
Brazil	6975	9036	−2061	95%
Oil exporters	741,142	14,614	726,528	313%
European Union	21,748	296,162	−274,414	18%
USA	360	251,241	−250,881	36%
India	1	66,483	−66,483	19%
China	1283	88,795	−87,512	51%
Rest of the world	294,183	377,876	−83,693	83%

Source: GTAP database version 8.

cost of the oil imply that most of the inputs used is domestic, and only a small portion refers to imported inputs. On average, over 90% of production costs of oil extraction are from local suppliers, both in Brazil and in other countries. In the case of Brazil, the data show that 22% of services used in the oil industry are imported, and 78% domestic; in the case of the inputs of chemicals 41% is imported; for the other inputs of the oil industry imports are negligible (data not shown in Table 5).

The international oil market is concentrated in the exports of the group of exporting countries, with 70% of total exports and trade surplus. United States and European Union are the largest importers of oil, with about half of the world's purchases. The rate of self-sufficiency, which shows the share of local production in the consumption of oil, indicates that Brazil is very close to self-sufficiency (95%), well above the indicator of India (19%) and China (51%).

3. Simulations

In this section we report the procedures used in the simulations for the later discussion of the main results of the exploration of megareserves oil from Pre-Salt. Fig. 3 illustrates the dynamics of the simulations and how the model is fed with information from the 2007 base year model.

The mechanisms allow dynamic recursive temporal explicitly using EGC model in which endogenous variables fit over the period of analysis after the initial shock in both the baseline (or reference scenario) as the specific shock simulation that this work is defined as the Pre-Salt shock.

The baseline scenario should reflect as much as possible, the projected changes in the global economy over the study period (2007–2020). Therefore, it represents what would be the trajectory of the economy without the shock

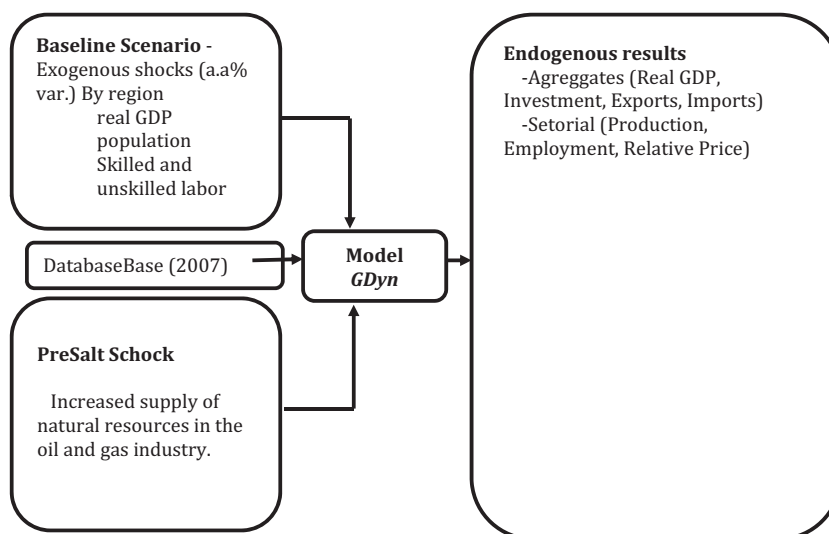


Fig. 3. Design simulations with the GDyn model.

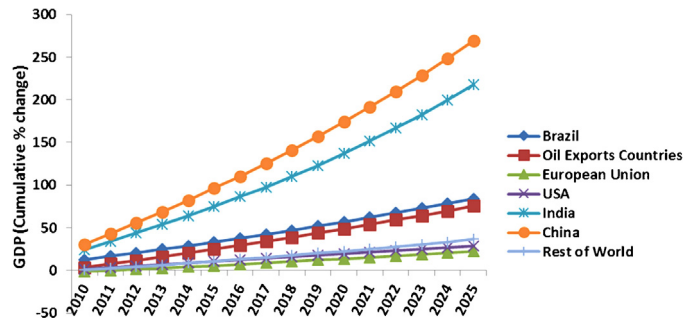


Fig. 4. Growth in real GDP in the baseline scenario. 2010–2020 (cumulative % change).

Source: Authors' calculations from the results of the model GDyn.

exploration of Pre-Salt layer, for example. The preparation of a base or counterfactual scenario is an important component in the simulation when using a dynamic model, and your choice may affect the results of the scenario into account (Adams and Parmenter, 2000). Such a construction allows viewing two trajectories for each variable of interest: a trajectory that shows how the variable would change over time not considering the issue under study; and the trajectory that determines how the variable behave with the “shock” of the Pre-Salt, as is the case of this work.

The difference between these trajectories (base scenario and the scenario with the shock of the Pre-Salt) represents the additional effect of increased exploration and production of oil due to the Pre-Salt. Typically, these differences are accumulated over the period of analysis to illustrate the impact on certain variable, as shown in the example of Fig. 3.

3.1. Baseline scenario

The baseline scenario adopts projections of key macroeconomic variables of the country, such as real GDP, population and skilled and unskilled labor force. In this paper, we use the projections provided by the CEPII (Centre d'études prospectives et d'informations internationales) for 122 countries in the period 2007–2020.¹⁰

An initial simulation is performed so that all macroeconomic variables such as GDP, are projected for each year according to the growth rates obtained from the CEPII. In this simulation, the variable of technological change or productivity responds endogenously to ensure that real GDP follows the projection. The values of this variable, in turn, provide an estimate of how technology should be modified over time. The base scenario is then simulated again, but using the values found for the technology variable (become exogenous), making real GDP be determined endogenously. The goal of these simulations is to ensure that GDP responds as designed and also to establish a baseline for later comparison with the scenario being studied.

As an illustration, Fig. 4 shows the growth rates of real GDP between 2010 and 2020 for the regions of the model. China and India have more intense growth rates than other countries, as expected. The Brazil grows at a cumulative rate of about 57% between 2007 and 2020, which equates to an average annual rate of 3.4%.

Fig. 5, in turn, shows the growth of the production of the most dynamic sectors in the scenario for Brazil. Among the most dynamic sectors of the scenario are civil construction, nonmetallic mineral products, chemicals, rubber and plastics, mineral extraction, and motor vehicle and parts and electronic equipment.

3.2. Pre-Salt shocks

The structure of shocks of the Pre-Salt represents an increase of the supply of natural resources in the extraction of oil and natural gas industry of the model. This shock is defined based on projections of domestic physical production of oil and natural for the period 2010–2020 gas, provided by the “Ten Year Energy Expansion Plan 2020” (EPE, 2011).

¹⁰ To do so, the projections were adjusted to achieve annual growth rates and then aggregated for the regions used in the simulations. The projections for each year were calibrated from the share of each region in the amount of GDP and world population. The data are available in the CEPII page <http://www.cepii.fr/anglaisgraph/bdd/baseline.htm> (accessed 24.06.12).

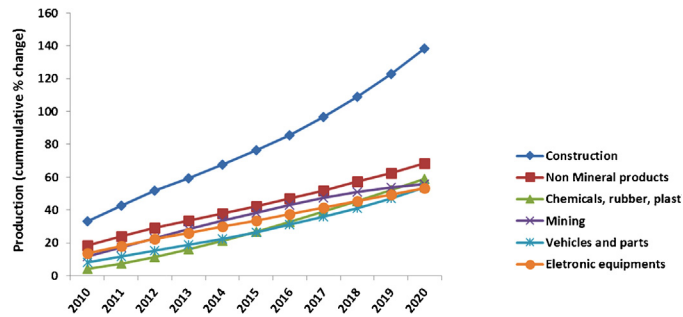


Fig. 5. Production growth of the most dynamic sectors in the baseline scenario. Brazil – 2010–2020 (cumulative %var.).
Source: Authors' calculations.

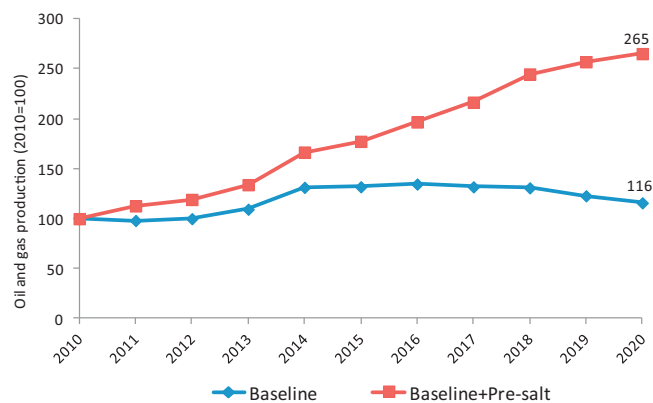


Fig. 6. Changes in the level of oil and natural gas in Brazil (2010 = 100).
Source: Authors' calculations based on Plano Decenal de Energia 2020 (EPE, 2011).

This period corresponds to projections about the difference in the physical production of oil and natural gas with and without the Pre-Salt, as shown in Fig. 6.

From these forecasts of annual production growth, the shocks were calculated as the necessary for growth rate in the supply of natural resources in both sectors for the additional growth of the Pre-Salt production be reached. Thus, to have an additional increase of 128% in oil production in 2020,¹¹ due to the exploration of Pre-Salt layer would require a uniform shock of about 8% in the supply of natural resources of the industry from 2010 to 2020. This same calculation was performed for the natural gas sector, in which the projection of 159% additional production equals a rise in the natural resources sector of 9.5% yearly. This configuration permits that the structure of shocks of the main macroeconomic and sectoral variables of the model (such as investment and capital) be determined endogenously.

It should be noted that in a dynamic global general equilibrium model, as used in this work, in addition to the importance of the implemented shocks to the supply of natural resources in the oil and gas sectors, several factors account for the magnitude and the direction the projected results. In this context, we can mention the role of capital mobility between regions and their accumulation, the distinction between the location of financial assets and their ownership (firms and households), cost differentials, return rates and international prices, plus all the productive structure of the economies of each country. Such elements of analysis are not taken into account by partial equilibrium models or even national general equilibrium models which make clear the advantages of using a global CGE model to study the Pre-Salt.

Based on the theoretical framework and the structure of the database model, the increased supply of natural resources in a specific sector has repercussions on the whole economy. An overview of the causality mechanisms of the

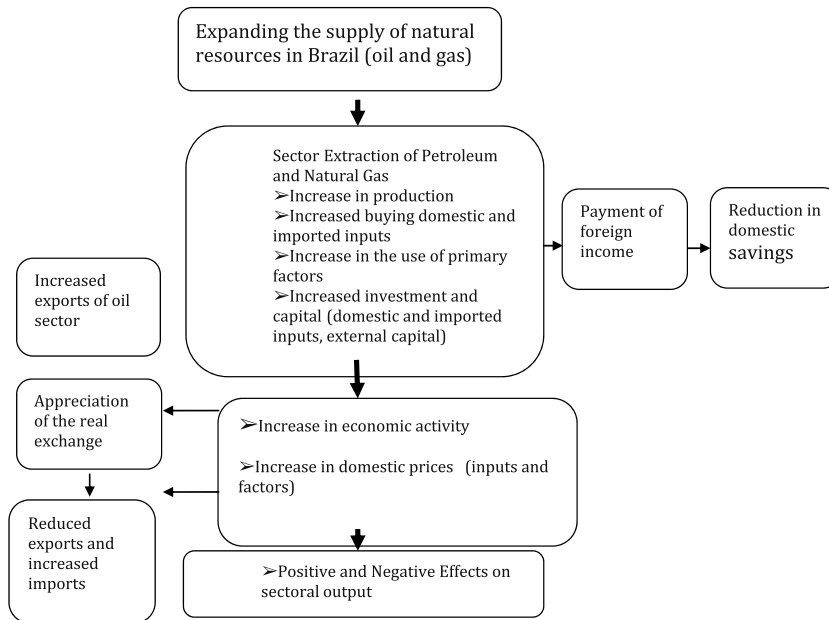


Fig. 7. Major causal mechanisms for interpreting the effects of the expansion of the Pre-Salt exploration in Brazil.

simulations, useful for interpreting the results obtained, can be seen in Fig. 7, which describes the main implications of the expansion of the supply of natural resources in sector i of region j .

4. Discussion of results

In this section, we present the impact of the development of Pre-Salt oil reserves on the Brazilian industry. In order to better understand the impact of sector effects, first, we discuss the global and national impacts on key macroeconomic variables.

4.1. Global and national results

The exploration of Pre-Salt from Brazil involves the increase in Brazilian oil production and the consequent expansion of its exports. This increased Brazilian production will be reflected in the rise of global production and falling international prices relative to the baseline scenario. Fig. 8 illustrates the relative increase of 1.37% in world production, and prices down 9.8%. Remember that the specification of imperfect substitution in international trade implies that the increase in Brazilian exports partially displaces exports of other countries.

One of the main results of the Pre-Salt discoveries is the elevation of investment and capital flows to the Brazilian economy. The results in Fig. 9 indicate an increase in investment in Brazil of 6.3% accumulated in 2020, and declines in the European Union, in the Petroleum Exporting Countries and in the United States (remember that these variations are not absolute, but relative to a baseline scenario).

The positive effect on the Brazilian economy can also be seen in the impact on GDP (Fig. 10). The mechanisms of accumulation of income and external payments of the model also permit to evaluate the expansion of the flow of wealth sent abroad, as shown by the Foreign Income (right side of Fig. 10). Thus, the expansion of production and export of oil by Brazil has positive impacts on GDP, Investment and Capital Stock, but also extends the amount of foreign income, which may contribute for increasing balance of payments deficits in the future.

With this table, Fig. 11 summarizes the main macroeconomic aggregates effects of Pre-Salt in Brazil. It is noteworthy that the results should be read as the cumulative deviation from baseline over the period of analysis (2010–2020),

¹¹ Projection calculated based on data from the Ten-Year Energy Plan 2020 (EPE, 2011).

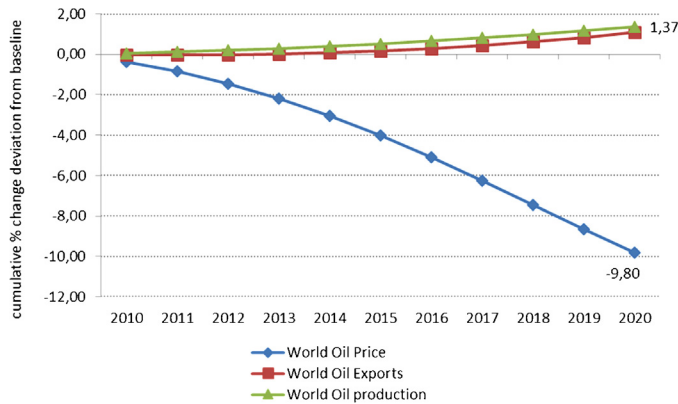


Fig. 8. Results of the simulations: impact on production, exports and the world price of oil resulting from the Pre-Salt (accumulated% change relative to the baseline scenario).
 Source: Authors' calculations from the results of GDyn model.

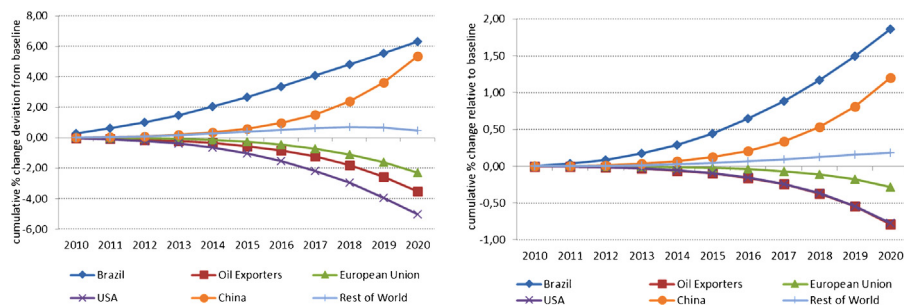


Fig. 9. Simulation results: impact on investment and capital stock in the regions as a result of the Pre-Salt in Brazil (accumulated% change relative to the baseline scenario).
 Source: Authors' calculations from the results of GDyn model.

i.e., represent the additional effect of the Pre-Salt on the economy compared to the baseline scenario. One of the advantages of a dynamic model is the visualization of the growth trajectory of each variable over the period. GDP, Investment, exports and imports have growth potential relative to the baseline scenario. The results suggest, therefore, an additional cumulative impact of 4.8% on real GDP in 2020 due to the Pre-Salt. This result is explained by the dynamics of growth of GDP components, in particular, the cumulative increase in investment and exports (6.19% and 19.73% in 2020, respectively), which are favored by expanding the supply of natural resources the extraction of oil and natural gas sectors. The growth of aggregate exports is mainly sustained by the expansion of extractive industries. Exports and imports grow over the period almost the same rate relative to the baseline scenario, due to the demand for inputs and rising domestic prices.

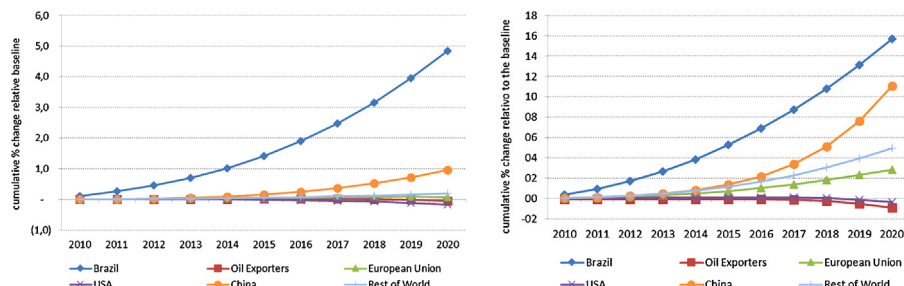


Fig. 10. Results of the simulations: impact on GDP and Foreign Income arising from the Pre-Salt in Brazil (%var accumulated relative to the base scenario).
 Source: Authors' calculations from the results of GDyn model.

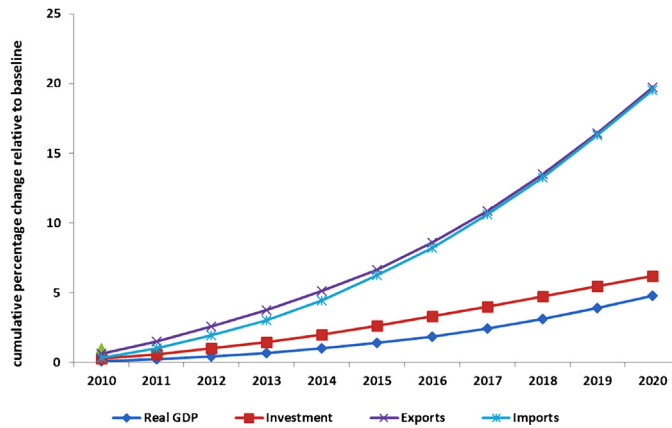


Fig. 11. Macroeconomic impacts arising from the Pre-Salt in Brazil: cumulative percentage change relative to baseline (%var).
 Source: Authors' calculations from the results of the model GDyn.

4.2. Sectoral results

The sectoral results projected by the expansion of the Pre-Salt exploration, in turn, relate to the aggregate national results, although they are determined by a set of structural data and theoretical specification of the model.

Fig. 12 reports the projected impacts on output from the extraction of oil and natural gas sectors over the period and also the change of participation in national and global production. We decided to show them separately, as they are the sectors that receive the shocks of the simulation and also are the most directly affected by the exploration of Pre-Salt.

The sectors of oil extraction and natural gas, as previously mentioned, have an additional cumulative growth of 130% and 160% of production in 2020, considering the exploration of Pre-Salt reserves in relation to the reference scenario, compatible with official projections of the Ten Year Energy Plan 2020. This large effect on production has important implications for the participation of sectors in national and also global production. The results suggest, for example, that the share of oil extraction in the domestic production that is only 1.6% in 2007 (base year of the model) goes to 7.78% in 2020, i.e., the sector increases its relative size almost 5 times. In terms of global production forecasts indicate that Brazil doubles its share of world oil production, reaching 4.5% in 2020. The same reasoning applies to the natural gas extraction industry, which increases its share of production, although the industry is still very small in relation to national and global production.

So far, the results, such as GDP growth or investment performance of the oil and natural gas sectors, can be considered as positive effects (“blessings”) enabled by the discovery of a large reserve of natural resources in the country, as is Pre-Salt. However, when analyzing the rest of the industry the effects are quite heterogeneous.

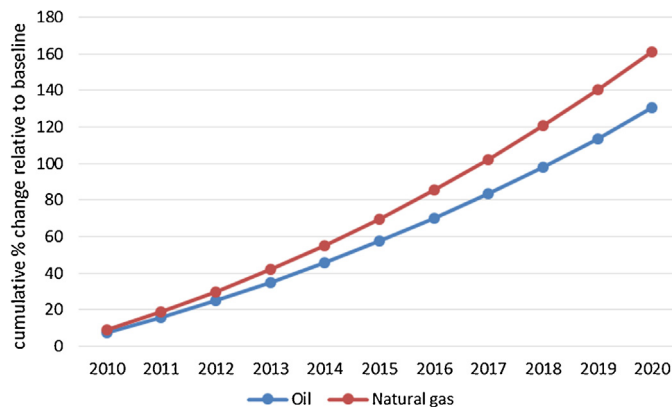


Fig. 12. Sectoral impacts arising from the Pre-Salt: cumulative percentage change relative to baseline (%var).
 Source: Authors' calculations from the results of the model GDyn.

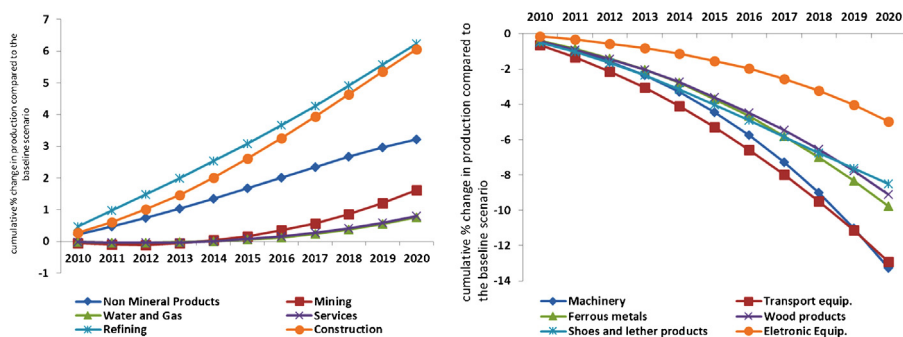


Fig. 13. Sectoral impacts arising from the Pre-Salt: cumulative percentage change in production compared to the baseline scenario. *Source:* Authors' calculations from the results of the model GDyn.

In order to discuss this point, Fig. 13 depicts the projection of the relevant sectoral impacts on production (accumulated deviations relative to the base resulting from the Pre-Salt scenario). As the industries have positive growth in the base scenario, negative impacts shown in the figure are reductions in the production relative to the base scenario and therefore should not be read as absolute declines of production.

That said, the left graph illustrates the impacts on sectors adversely affected by the Pre-Salt. Are among them, machinery and equipment, with cumulative reduction of 13.2% of production compared to the baseline scenario in 2020, followed by transport equipment, down 12.9% and ferrous metals (−9.75%). These results can be explained by a number of factors. In general, industries are positively affected by investment of the Pre-Salt (activity), but this is not enough to reverse the negative effects caused by the movement of production factors (domestic competitive effect), rise of input prices, exports reduction and import growth (external competitive effect). Machinery and equipment are the most affected sectors since, besides presenting significant reductions in the use of capital (−12.8% and −12.3% accumulated in relation to the baseline in 2020) and work (−13.9% and −13.0%, respectively), the price differential between domestic and imported accentuates the fall in exports for these sectors, as discussed in Fig. 11.

Moreover, one must note the external competitive effects caused by increased imports, which explain the negative results on the production of Leather and Footwear Artifacts and Wood Products industries. These sectors show significant increase in imports, around 45% and 34% compared to the baseline scenario in 2020, respectively.

On the other hand, in the right graph of Fig. 13, we have the positively affected sectors, including services. In Section 2.2 we show a high share of services sector as input for the extraction of oil, which explains this result, besides the fact of the little competition with imports in this segment. Among the biggest beneficiaries is the Petroleum Refining industry (6.24% cumulative increase over the baseline), an expected result given that the sector makes up oil production chain, using inputs from the oil extraction industry. Coupled with the growth of investment and shifting capital and labor to the industry, reducing costs (domestic oil prices fall 12% in the year to 2020) also explain the positive result in refining. The same reasoning applies to gas and water pipes, since the sector is directly affected by increased production of natural gas, although the results are in smaller proportions. The mineral extraction sector, with high participation in Brazilian exports (about 12%), despite suffering negative effects of the shift of factors of production, is benefited by export expansion.

An interesting impact refers to the construction sector (6.06%), which is favored by the impacts of the expansion of aggregate investment in the economy, especially in the Pre-Salt. The high share of sales of the construction sector to the investment corroborates this result, together with the fact that the performance of this sector also has repercussions on economic activity in the rest of the supply chain of the civil construction. Hence, the high impact on inputs to construction, for example non-metallic mineral products (which includes cement).

Although in the aggregate, exports show positive growth, mainly due to the expansion of exports of oil extraction industry in most industries this is not verified. The fall in production in many industries is mainly explained by the significant reduction of their exports (relative to baseline), as shown in Fig. 14, which presents the share of the most relevant industrial sectors in the total export of Brazil. Machinery and equipment, for example, faced a cumulative decline of almost 30% in exports, justifying, in large part, the loss of private sector participation in the production of

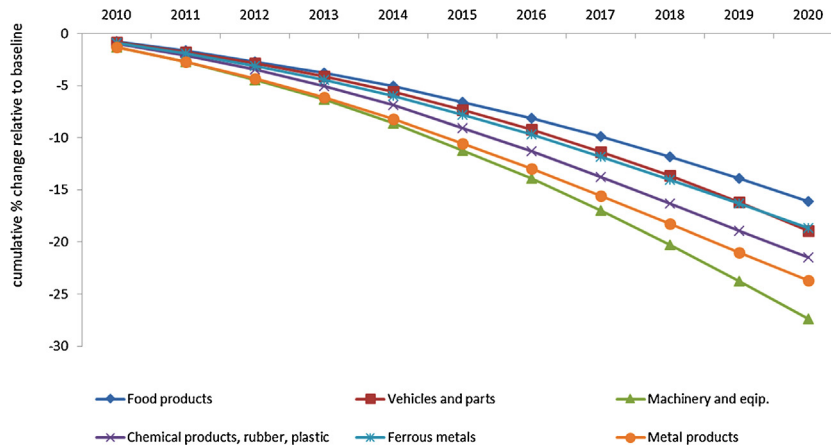


Fig. 14. Sectoral impacts arising from the Pre-Salt: cumulative percentage change in exports relative to baseline (%var).

Source: Authors' calculations from the results of the model GDyn.

the country. The fall is also important in metal products, chemicals, rubber and plastics, automotive vehicles and parts, ferrous metals, and food.

The combination of these results with the change in participation observed in the extraction of oil and natural gas sectors points to a possible change in the productive structure of the economy, favoring the sectors related to mining activity at the expense of industrial sectors such as capital goods.

This trend suggested by the impacts of the Pre-Salt simulations can be seen in Table 6, which reports the share of sectors in total production in Brazil before and after the Pre-Salt. Note that most industrial sectors show relative share

Table 6
Share of sectors in total production in Brazil before and after the Pre-Salt 2007 and 2020 – (%).

Sectors	Initial share (2007)	Final share (2020)	Change
Farming, fishing and forestry	5.16	5.82	↑ 0.67
Oil extraction	1.60	7.78	↑ 6.19
Extraction of natural gas	0.07	0.26	↑ 0.20
Mineral extraction	1.40	2.22	↑ 0.83
Food	6.06	4.91	↓ -1.14
Beverage and tobacco products	0.90	0.72	↓ -0.18
Textiles and clothing items	1.66	1.20	↓ -0.46
Leather products and footwear	0.60	0.41	↓ -0.20
Wood products	0.58	0.46	↓ -0.12
Pulp and paper	1.75	1.37	↓ -0.38
Oil refining	2.35	4.93	↑ 2.58
Chemicals, rubber and plastic	5.85	5.60	↓ -0.25
Nonmetallic mineral products	0.94	1.08	↑ 0.14
Ferrous metals	1.74	1.53	↓ -0.21
Metal products	2.05	1.74	↓ -0.31
Motor vehicles and parts	3.01	2.42	↓ -0.59
Transportation equipment	0.59	0.34	↓ -0.25
Electronic equipment	2.21	1.76	↓ -0.45
Machinery and equipment	3.01	1.99	↓ -1.01
Electricity	1.94	1.78	↓ -0.17
Gas and tap water	0.78	0.69	↓ -0.09
Construction	5.22	7.00	↑ 1.78
Services	50.55	43.99	↓ -6.56

Source: Authors' calculations from the results of the model GDyn.

decline in the economy in 2020, highlighting the sector of machinery and equipment, foods, motor vehicles and parts, and textiles and clothing items. The total reduction in the share of manufacturing industry, that goes from 33.3% in 2007 to 30.4% in 2020 (down nearly 3 percentage points), is a significant result when compared with the loss of industry participation by 2 percentage points recorded between 1997 and 2009 (Bonnelli and Pessoa, 2010). In contrast, when we analyze all the primary sectors (Agriculture and Extractive Industry), the share rises from 8.2% to 16% in 2020.

The results presented refer to the elements pointed by the hypothesis of “Dutch disease”. Impacts of Pre-Salt and its exploitation have a great effect on the exports of this commodity, that due to the entry of foreign exchange that comes from exports and intensification of inflows of capital ends up having an effect of currency appreciation (which in the model is captured by the difference between domestic and international prices), thus reducing the competitiveness of exports of manufactured products. Consequently, this causes a redirection of production and exports for commodities intensive in natural resources, decreasing the participation of various industrial sectors.

Adding to this picture the fact that Brazil has already started the process of exploration of Pre-Salt as a country that borrows abroad to finance investment. This obviously imposes constraints on the balance of payments, which will have long term impact on the economy. As shown in Section 4.1, the rise in rents sent abroad is significant.

5. Final remarks

The objective of this work was to study the impact of the Pre-Salt oil exploration in the Brazilian economy, with a focus on issues relating to the impact on the productive structure and in the export sectors. The literature on the impact of large discoveries of natural resources shows the possibility of a negative effect on the economy’s productive structure, when the revenues from exports derived of the exploitation of that resource leads to the concentration of productive factors in this sector, and the effect of export revenues makes the appreciated exchange rates, negatively affecting exports and positively imports.

In this paper we use a global dynamic CGE model, from the GTAP project, which incorporates international mobility of capital, capital accumulation and adaptive expectations theory of investments. This work is the first to use this model in a study for the Brazilian economy. The model is particularly suited to this study, since we are dealing with a relevant market in terms of bilateral trade, oil. A significant increase in Brazilian oil production resulting from the Pre-Salt has an impact on the international market of this product, both in terms of prices as market share, with Brazil becoming an international provider of this product, doubling its share of world production and its participation in the Brazilian economy. The effects on GDP and investment in Brazil are positive and significant.

However, the sectoral impact of the Pre-Salt is very heterogeneous. There are a number of sectors benefited, but also a set of sectors that lose share in the Brazilian economy and exports, like a “Dutch disease” effect. The explanation for this result is due to the effect of concentration of productive factors in the extraction of oil, rising prices of inputs (such as labor and capital) and revenue from exports that affect the balance of payments. As a result, the Brazilian economy becomes more dependent on oil production sector, and revenues from these exports come to dominate the foreign trade of the country.

Some assumptions limit the results. The main one is the rigidity in labor supply in the Brazilian economy. The availability of labor is defined in the baseline scenario, and therefore does not change with the aggregate investment and the production of Pre-Salt. This condition drives the effect of rising production costs and loss of participation of other sectors. If the investments of the Pre-Salt are accompanied by expanding the labor supply, the above negative effects can be reduced.

In our simulations, we ignore how the Pre-Salt investments can change technology in the oil sectors and in other sectors, which could foster growth and exports. Another issue relates to the government revenue from the oil, which will go to investments in education (by law). This can diminish the impact on exchange rate and increase labor productivity in the long run.

Appendix 1. Main elements of the theoretical structure of the dynamic model Gdyn

In this appendix, we present the main elements of the theoretical structure of the model Gdyn from the equations of the dynamic module of the model. The equations shown in Table A1 comprise the theory of capital accumulation

Table A1

Representation of equations and notations in the stylized model.

where:

$$1. \hat{K} = I \cdot dt$$

$$2. \hat{R}_E = -\phi[\hat{K} - \Omega dt] - \mu \log\left(\frac{R_E}{R_A}\right) dt$$

$$3. \Gamma_E = \Lambda \left(\frac{\hat{R}_T}{\hat{R}_E}\right)$$

$$4. \Gamma_E = \phi \frac{I}{K} (\hat{I} - \hat{K}) + \phi d\Omega$$

$$5. \omega = \prod \left[\hat{K} \frac{\hat{R}_A}{\phi} \right] - \Omega dt$$

K is the stock of capital; I is the investment; R_E is the expected rate of return; R_E is the effective rate of return; R_T is the target rate of return; Ω is the normal growth rate of capital – that is the rate of growth consistent with an environment of nonexistence of changes in rates of return; dt is the change in years, $\log(R_E/R_A)$ is the measurement error in expectations; ϕ is the elasticity of the rate of return with respect to the capital stock; μ is the rate at which errors in agents' expectations are eliminated; Γ_E is the expected growth rate of the expected rate of return; Λ is the rate at which the differences between the expected and actual rates of return are eliminated; ω is the change in the normal growth rate of capital; caret represents the proportional change.

Note: All variables are defined by region except R_T .

and investment with adaptive expectations and that jointly determine the regional investment supply. There is perfect capital mobility in the long run with the regional rates of return adjusting gradually toward a common target rate.

References

- Adams, P., Parmenter, B., 2000. *Economic Forecasting*. Allen and Unwin Academic, Sydney.
- ANP – Agência Nacional do Petróleo, 2012. Pré-sal demanda US\$ 400 bilhões até 2020 (09/05/2012), Available at: <http://www.anp.gov.br/?pg=60260&m=pr%E9-sal&t1=&t2=pr%E9-sal&t3=&t4=&ar=0&ps=1&cachebust=1344963737539>. Acesso em 14/08/12
- Auty, R.M., 1990. *Resource-based Industrialisation: Sowing the Oil in Eight Exporting Countries*. Clarendon Press, Oxford.
- Auty, R.M., Gelb, A.H., 2001. Political economy of resource-abundant states. In: Auty, R.M. (Ed.), *Resource Abundance and Economic Development*. Oxford University Press, New York.
- Barros, O., Pereira, R.R., 2008. Desmistificando a tese de desindustrialização: reestruturação da indústria brasileira em uma época de transformações globais. In: Barros, O., Giambiagi, F. (Eds.), *Brasil Globalizado: o Brasil em um mundo surpreendente*. Editora Elsevier, pp. 299–330.
- Bone, R.B., 2011. Mudanças nas regras do conteúdo local nas licitações do setor petrolífero e os reflexos na contratação de fornecedores domésticos da Petróbras. In: De Negri, J.A., et al. (Org.), *Poder de compra da Petrobras: impactos econômicos nos seus fornecedores*. Ipea, Brasília.
- Bonnelli, R., Pessoa, S.A., 2010. *Desindustrialização no Brasil: Um Resumo da Evidência*. FGV: Texto para Discussão n. 7.
- BP – British Petroleum Statistical Review of World Energy June 2012, 2012. Available at: <http://www.bp.com>
- Bresser-Pereira, L.C., 2008. The Dutch disease and its neutralization: a Ricardian approach. *Rev. Econ. Polít.* 28 (1).
- Bresser-Pereira, L.C., Marconi, N., 2008. Existe doença holandesa no Brasil? Anais do IV Fórum de Economia de São Paulo. Fundação Getúlio Vargas, São Paulo.
- Booth, A., 1995. The state and the economy in Indonesia in the nineteenth and twentieth centuries. In: Harriss, John, Janet Hunter, Colin, M., Lewis (Eds.), *The new institutional economics and third world development*. Psychology Press.
- Corden, W.M., 1984. Booming sector and Dutch disease economics: survey and consolidation. *Oxf. Econ. Pap.* 36 (3), 359–380.
- Corden, W.M., Neary, J.P., 1982. Booming sector and de-industrialization in a small open economy. *Econ. J.* 92 (368), 825–848.
- EPE – Empresa de Pesquisa Energética, 2011. Plano Decenal de Expansão de Energia 2020. MME/EPE, Brasília.
- Ernst, Young Tergo, 2011. *Brasil sustentável: perspectivas dos mercados de petróleo, etanol e gás*. Ernst & Young/FGV, Rio de Janeiro.
- EXAME – Revista Exame, 2012. Pré-Sal e a nova economia brasileira. Edição 1019, ano 46, n. 12.
- Feijó, C.A., Carvalho, P.G., Almeida, J.S.G., 2005, November. Ocorreu uma desindustrialização no Brasil? IEDI, São Paulo.
- Figueiredo, A.M.R., Ferreira, A.V., Teixeira, E.C., 2001. Impactos da integração econômica nas commodities da economia brasileira e da União Européia. *Rev. Bras. Econ.* 55 (1), 77–106.
- Furtado, C., 1957 [2008]. O desenvolvimento recente da Venezuela. In: Celso Furtado Ensaios sobre a Venezuela. Contraponto e Centro Celso Furtado, Rio de Janeiro, pp. 35–118.
- Gelb, A.H. and associates, 1988. *Oil Windfalls: Blessing or Curse?* Oxford University Press, Oxford.
- Golub, A., McDougall, R.A., 2012. An overview of the dynamic GTAP data base: the data base construction and aggregation programs. In: Ianchovichina, E., Walmsley, T. (Eds.), *Dynamic Modeling and Applications in Global Economic Analysis*. Cambridge University Press.
- Gurgel, A.C., 2006. Impactos da liberalização comercial de produtos do agronegócio na Rodada de Doha. *Rev. Bras. Econ.* 60 (2 (June)).
- Haddad, E.A., 2012. *Cenário 2030: O Pré-Sal e a estrutura da economia brasileira* (nota técnica). São Paulo, TD Nereus 07-2012.
- Haddad, E.A., Domingues, E.P., 2001. EFES - Um modelo aplicado de equilíbrio geral para a economia brasileira: projeções setoriais para 1999–2004. *Est. Econ.* 31 (1), 89–125.

- Haddad, E.A., Giuberti, A.C., 2010. Economic impacts of pre-salt on a regional economy: the case of Espírito Santo Brazil. *European Congress of the Regional Science Association International– Sustainable Regional Growth and Development in the Creative Knowledge Economy*, vol. 50.
- Hertel, T.W., 1997. *Global Trade Analysis: Modeling and Applications*. Cambridge University Press, New York.
- Hojman, D.E., 2002. The political economy of Chile's fast growth: an Olsonian interpretation. *Public Choice* 111.
- Ianchovichina, E., Walmsley, T., 2011. *Dynamic Modeling and Applications in Global Economic Analysis*. Cambridge University Press (forthcoming).
- Loures, R.R., Oreiro, J.L., Passos, C.A.K., 2006. Desindustrialização: a crônica da servidão consentida. *Econ. Tecnol.*, ano 2 4.
- Marquetti, A., 2002. *Progresso Técnico. Distribuição e Crescimento na Economia Brasileira: 1955–1998*. *Est. Econ.* 32 (1).
- Nakahodo, S.N., Jank, M.S., 2006. A falácia da doença holandesa. Documento de Pesquisa. Instituto de Estudos do Comércio e Negociações Internacionais. Mimeo, São Paulo.
- Nassif, A., 2008. Há Evidências de Desindustrialização no Brasil? *Rev. Econ. Polít.* 28 (1).
- Oliveira, S.J.M., Ferreira Filho, J.B.S., 2008. A expansão da União Européia em 2004 e seus impactos no agronegócio brasileiro. *Rev. Econ. Sociol. Rural* 46 (4 (December)).
- Oreiro, J.L., Feijó, C., 2010. Desindustrialização: conceituação, causas, efeitos e o caso brasileiro. *Rev. Econ. Polít.* 30 (2).
- Palma, G., 2005. Quatro fontes de desindustrialização e um novo conceito de doença holandesa. In: *Conferência de Industrialização, Desindustrialização e Desenvolvimento*, Federação das Indústrias do Estado de São Paulo, Ago.
- PETROBRAS – Petróleo Brasileiro S.A., 2012. *Plano de Negócios 2012–2012*. Rio de Janeiro.
- Prebisch, R., 1949. El desarrollo económico de la América Latina y algunos de sus principales problemas. In: *Estudio económico de América Latina*. CEPAL, Santiago do Chile.
- Rasiah, R., Shari, I., 2001. Market, government and Malaysia's new economic policy. *Camb. J. Econ.* 25 (1).
- Rowthorn, R., Ramaswamy, R., 1999. Growth, trade and deindustrialization. *IMF Staff Pap.* 46 (1).
- Sachs, J., Warner, A.M., 1995. Natural Resource Abundance and Economic Growth. NBER Working Paper no. 5398.
- Singer, H.W., 1950. The distribution of gains between investing and borrowing countries. *Am. Econ. Rev.* 40 (2), 473–485.
- Souza, C.R.S., 2012. O Brasil pegou a doença holandesa? Tese de Doutorado. Universidade de São Paulo, São Paulo, Available at: http://www.teses.usp.br/teses/disponiveis/12/12138/tde-18122009-092539/publico/Cristiano_Ricardo_Siqueira_Souza.pdf [accessed April 2012].
- Stevens, P., 2003. *Resource Impact: A Curse or a Blessing*. Draft Working Paper. Centre for Energy, Petroleum and Mineral Law and Policy, University of Dundee, pp. 35.
- Stevens, P., 1986. The impact of oil on the role of the state in economic development: a case study of the Arab world. *Arab Affairs* 1 (1).
- Tregenna, F., 2009. Characterizing deindustrialization: an analysis of changes in manufacturing employment and output internationally. *Camb. J. Econ.* 33.
- Wright, G., Czelusta, J., 2007. Resource-based growth: past and present. In: *Lederman, D., Maloney, W.F. (Eds.), Natural Resources. Neither Curse nor Destiny*, World Bank. Stanford University Press.
- Xavier, C., 2011. Políticas de conteúdo local para o setor petrolífero brasileiro: aumentando o impacto econômico dos recursos minerais. In: *De Negri, J.A., et al. (Eds.), Poder de compra da Petrobras: impactos econômicos nos seus fornecedores*. Ipea, Brasília.