Economic impacts of the new reality of the Brazilian pre-salt exploration. Is there a threat to ethanol?

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Abstract - From the mid-2000s onwards, the Brazilian ethanol production returned to thrive. In the meantime, in 2007 the discovery of large reserves of oil in the pre-salt layer in the Brazilian coastline was announced. Thus, the promising outlook for the Brazilian ethanol industry began to give way to the development of pre-salt oil with an ambitious investment program. Beyond that, between 2011 and 2014 the Government adopted a new domestic pricing policy for gasoline and diesel, aiming to reduce inflationary pressures, but gradually reducing ethanol competitiveness, besides imposing a high commitment of Petrobras' financial situation, hampering investment in the pre-salt itself. Considering such challenges and the importance of the oil and ethanol sectors to the Brazilian economy, this study aims to evaluate the long run economic impacts of the pre-salt oil production, with special attention to the consequences to the ethanol sector. An evaluation of the 2011-2014 gasoline price control policy impacts on the ethanol sector is realized. An adapted recursive dynamic general equilibrium model is employed in which the pre-salt oil sector is added as a backstop technology. The results suggest that premature stimulus of pre-salt production to achieve the Government's expected oil production brings more costs than benefits to the Brazilian economy. It was found that without Government interference, the pre-salt oil production would be competitive only after 2025-2035. With respect to the impact on the ethanol industry, it was found that the pre-salt development does not impair the Brazilian ethanol production. Nonetheless, the gasoline price control policy had a negative impact on the ethanol sector.

Keywords: Pre-salt. Oil. Ethanol. Biofuel. economic impacts. Gasoline price control. Computable general equilibrium.

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1. INTRODUCTION

Since 2003 the Brazilian biofuel industry, particularly ethanol, received a new thrust to production, with the market launch of flex-fuel cars, after more than a decade of strong decline in the share of ethanol as a fuel (Chagas, 2012). The growing international appeal for sustainable energy sources in order to mitigate CO_2 emissions highlighted the Brazilian experience. With the huge reduction in production costs, productivity gains and increase in international oil prices over the 2000s, this biofuel has become highly competitive in relation to gasoline (Milk & Cortez, 2008). Chart 1 show that since 2004 there is a growing increase in ethanol sales in the Brazilian market, reaching its peak in 2009, when it exceeded, in large-scale, gasoline sales, which remained virtually unchanged during this period. The share of flex-fuel vehicles in the national light vehicles fleet, in turn, showed steady growth and approached record 55% in 2014 (Sindipeças, 2015).

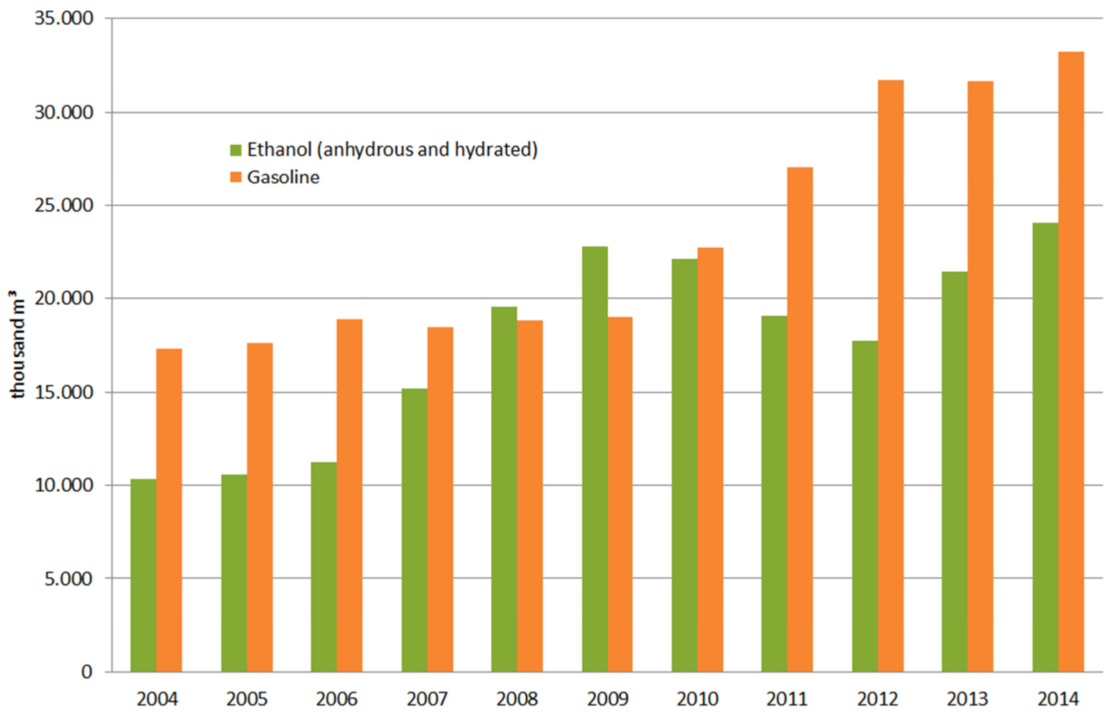

Chart 1 – Ethanol and gasoline sales in Brazil 2004-2014.
Source: ANP. Self-elaboration

In the meantime, in 2006 the first discovery of oil in the pre-salt occurs. A consortium led by Petrobras when drilling more than five thousand meters from the sea surface, overcoming a layer of salt, finds oil. Initial analysis indicated reserves between 5 and 8 billion barrels of oil, encouraging drilling of other wells. In late 2007, the government officially announced the new geological reality: the pre-salt region in the Brazilian coastline, with the presence of oil and gas in deep layers, with a length of 800 km, from the state of Espírito Santo to Santa Catarina.

The importance and grandeur of the discovery generated great impact in various sectors of Brazilian society. Then President Luiz Inácio Lula da Silva said that Brazil had won a "winning ticket" (Ribeiro, 2008) and that the pre-salt would be the "passport to the future" to mention the giant reserves (Goy, 2008). On May 1, 2009, labor day, during allusive ceremony to the extraction of the first barrel of oil from pre-salt layer, then President declared "oil self-sufficiency" and the conquest of the "second independence of Brazil" (Biblioteca da Presidência da República, 2009).

The size of the discovery is translated into its potential. Prior to discovery of pre-salt in 2006, proven Brazilian reserves stood at around 12.2 billion barrels (National Petroleum Agency - ANP, 2007). The ANP says that Brazil's reserves may double by 2022, from 15.6 billion barrels in 2013 to around 31 billion barrels (Gaier, 2014). The State Treasury of Rio de Janeiro estimate reserves of 50 to 70 billion barrels (Sefaz-RJ, 2010). According to Polito (2014), the state-owned Pre-Salt Oil S.A. declare potential reserves of 28 to 35 billion barrels. Thus, the pre-salt oil discoveries configured among the most important of the decade. Paduan (2012) states that in the last five years, of every three barrels of oil discovered in the world, one was discovered in Brazil.

Thus, ethanol’s clean and renewable energy, the fuel of the future, of which Brazil would be a major world supplier, begins to give way to an ambitious investment program for the development of pre-salt. The ANP estimated that investments in the pre-salt could exceed US$ 400 billion in materials, platforms, vessels, drilling rigs, systems, equipment and services by 2020 (Portal Brazil, 2012). Petrobras 2012 Business Plan foresaw investments of US$ 236.5 billion in the period of 2012 to 2016. The British group BG, forecasted investments of US$ 30 billion and Repsol YPF, the figure of US$ 14 billion, with Brazil offering the biggest global opportunities for the offshore oil industry (Ernst & Young, 2011). The pre-salt discovery ushered a new paradigm of economic development opportunities in Brazil, since a greater supply of the fossil fuel would multiply the growth potential of the Brazilian economy, attracting investment and innovation that would bring social development, energy security and even rebalance the geopolitical configuration of the continent.

In September 2008 the first oil originating in the pre-salt is produced. In September 2010, Petrobras holds the largest capitalization in the global stock market that amounted to R$ 120 billion (Petrobras, 2010), as one of the sources of funding for the realization of its strategic plan of the pre-salt exploration. In late 2010 the National Congress concludes the change in legislation in the oil sector, establishing the sharing regime and granting Petrobras as compulsory operator, with minimum 30% stake in the projects. Invigorates the developmentalist and interventionist local content policy, in order to increase the participation of national industry in the supply chain of oil industry through local content rules. In October 2013, it is held the first auction of pre-salt under the sharing regime and a consortium formed by Petrobras, Shell, Total, CNPC and CNOOC scooped, by R$ 15 billion (minimum price), the Libra oil field, with estimated recoverable volume from 8 to 12 billion barrels of oil (Petrobras, 2013). Concurrently with these events, Petrobras starts off the billionaire Abreu e Lima refinery in Pernambuco state, with successive delays. At the end of 2014 Brazil was configured in the 15th position in the world ranking of proven oil reserves and 13th place in terms of production, totaling 2.3 million barrels/day, equivalent to 2.6% of the world total (ANP, 2015). Between 2000 and 2014, the sector's share of GDP in Brazil increased from 3% to 13% (Petrobras, 2014).

From 2011, the ethanol industry suffers another blow when the government adopts a new pricing policy for gasoline and diesel, in order to keep them artificially below the international price to reduce inflationary pressures. Note that in Chart 2 that from 2011 until the end of 2014 the international reference price of gasoline has always been above the price charged domestically.

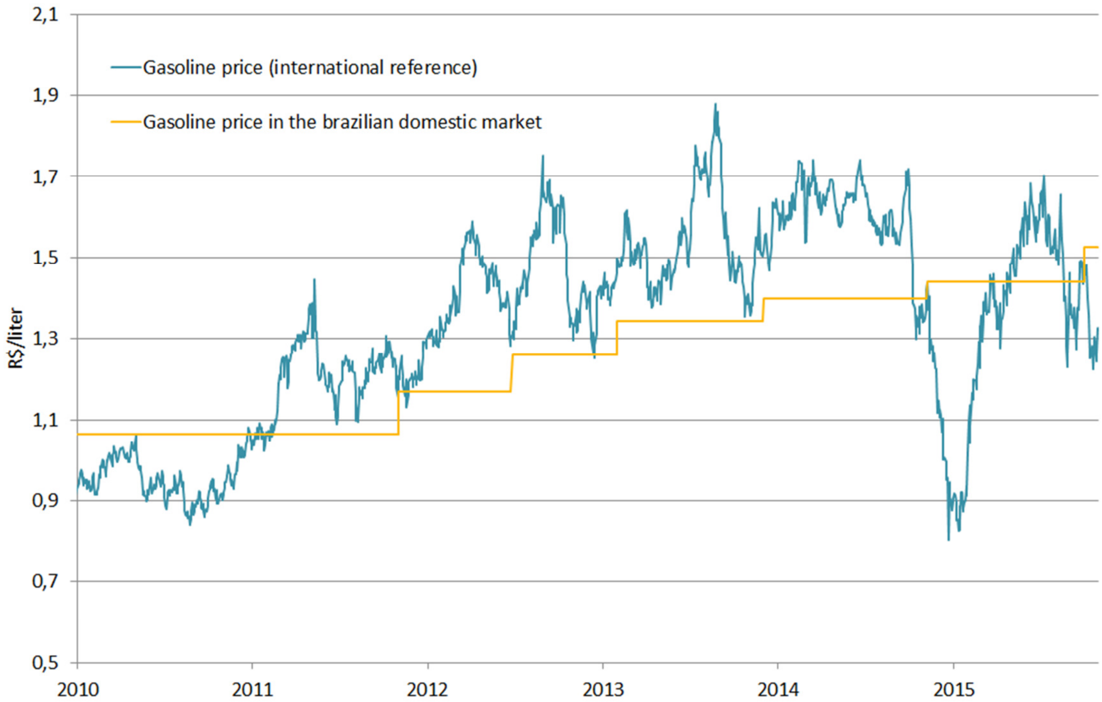

Chart 2 – Gap between domestic and international gasoline prices.
Source: Bloomberg, ANP. Self-elaboration

An important side effect of fuel price control policy was the gradual loss of ethanol competitiveness compared to gasoline and increasing financial fragility of this sector. It is noted in Chart 1 that from 2010 domestic ethanol sales decline, while gasoline sales soar. The Brazilian production of ethanol began to suffer one of the most serious crises in decades, with high indebtedness of producers, as well as adverse weather conditions. From 2011 to 2014, 26 plants closed their activities only in São Paulo, the largest Brazilian production hub (Neto, 2014). Since 2008, between 60 and 70 plants closed, another 70 are operating under bankruptcy protection scheme of a universe of 380 plants. It is estimated that since the beginning of the crisis, the sugar and alcohol sector eliminated 100,000 direct jobs and 250,000 indirect, of a total of 1.5 million and 2.5 million respectively (O Estado de São Paulo, 2014).

Almeida, Oliveira, & Losekann (2015) estimate that in the 2011-2014 period Petrobras losses with price control policy reached R$ 119 billion. Still, the authors conclude that the company's debt increase between 2011 and 2013 was equivalent to the amount of accumulated losses by 2014. This, concurrent with the period of high investments due to the pre-salt exploration, resulted in increase of its debt and deterioration of the financial situation. Thus, discretionary government intervention in the oil products pricing policy had serious consequences for the ethanol industry, and for the oil industry.

In conjunction with the local content rules regime, which affected productive efficiency, Petrobras was also affected by fuel prices containment policy, bad investments, political interference, mismanagement, corporatism, and notorious corruption scandals. All these aspects have brought immense financial difficulties to Petrobras, leading to a rating downgrade to speculative category. According to Forbes (2015) classification of the world's largest companies by market capitalization in 2012, Petrobras held the 10th position and succumbed to become the 416th in 2014. Its market value shrunk from US$ 270 billion to just US$ 25 billion. At the end of 2014, the company achieved the rank of largest holder of corporate debt in the world, with over US$ 130 billion (Fortune, 2015). Compounding this scenario, international oil prices fell sharply. The barrel of oil West Texas Intermediate (WTI) that was quoted at US$ 105 in mid-2014, at the end of August 2015 reached a new record low below US$ 30. This led the world's largest oil companies to cut costs, reduce investment and generated mergers for synergy gains.

Due to this new reality, Petrobras had to suit its ambitious investment plan. In mid-2015 it announced the first reduction, with investments intention of US$ 130.3 billion between 2015-2019, a significant reduction compared to the previous plan, which provided for investments of US$ 220.6 billion in the 2014-2018 period, with emphasis on the pre-salt. At the end of 2015 announced a second reduction of US$ 130.3 billion to US$ 119.3 billion. Thus, oil production target in Brazil for 2020, the year in which it is estimated that the pre-salt represents more than 50% of national production was reduced from 4.2 million barrels of oil equivalent per day (bpd) to 2.8 million bpd, as can be seen in Chart 3. These targets consider an average oil price (Brent) of US$ 60/barrel in 2015 and US$ 70/barrel in the 2016-2019 period.

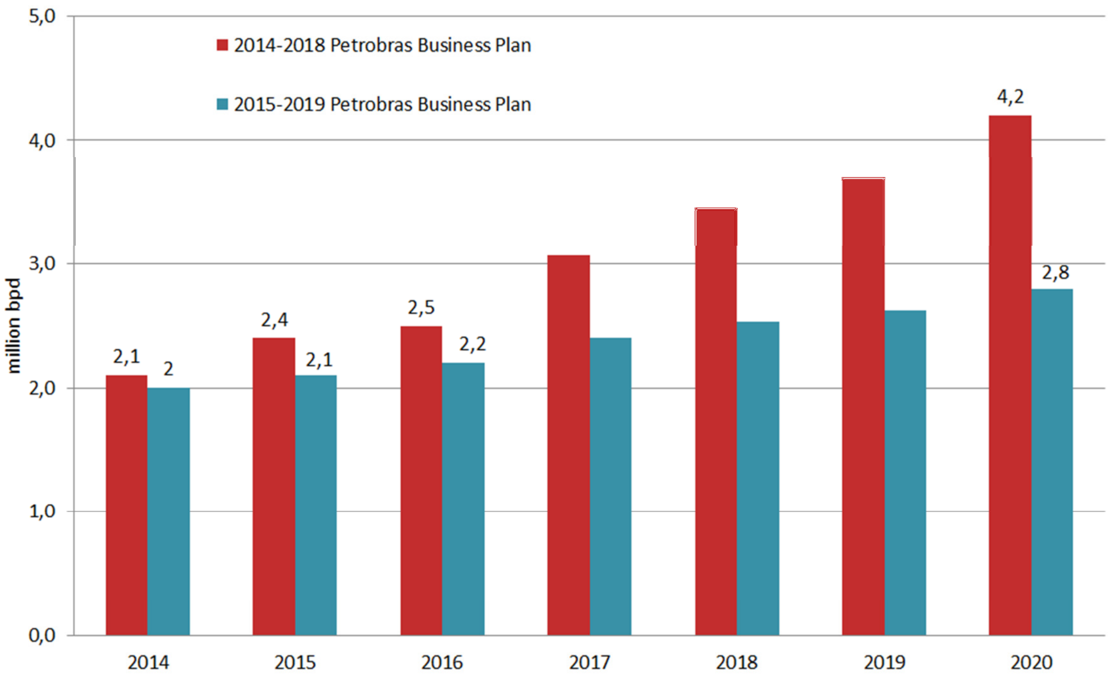

Chart 3 - Brazilian oil production estimates.
Source: Petrobras Business Plans. Self-elaboration

In the light of the challenges the oil sector is going through, what are the possible impacts of the pre-salt development on the Brazilian economy? In particular, how the increase of pre-salt oil production in the coming years should affect the ethanol industry? Changes in Petrobras' business plan bring gains or losses for the economy as a whole? The investment in the development of pre-salt is the most desirable from the standpoint of the allocation of scarce resources? What is the impact of gasoline price control policy, which ran from 2011 to 2014, on the ethanol industry?

The purpose of this paper is to study the macroeconomic and sectoral impacts associated with the new reality of oil production in Brazil from the pre-salt exploration, considering its consequences on the production of ethanol. A computable general equilibrium dynamic model is adopted, which is capable of projecting an increase in pre-salt oil production in the Brazilian economy and observe its long-term effects.

Besides this introduction, this paper is composed of brief literature review, followed by the methodology, results section, and finally, the conclusion. This paper contributes to the literature as it projects the possible impacts of the pre-salt exploitation according to the current business plan and assesses how this should affect the ethanol industry. In addition, an economic impact of gasoline prices containment policy that was in force from 2011 to 2014 on the ethanol industry is estimated.

2. LITERATURE REVIEW

Jacoby, O'Sullivan & Paltsev (2011) work analyzes the exploration of shale gas reserves in the US economy and the impact on emissions. They use a computable general equilibrium model EPPA, similar to the one used in this paper. The authors conclude that shale gas supply is a blessing to the American economy and is help to its climate policy.

Canelas (2007) describes the growing importance of the Brazilian oil industry, prior to the pre-salt discovery announcement. Its relative share in GDP increased from 3.8% in 1990 to 8.1% in 2004. A more recent study by the National Industry Confederation (2012) sought to complement the Canelas (2007) work and measure the Brazilian oil sector, gas and biofuels, contribution incorporating more updated information. In 2010, the share of oil and gas industry in the Brazilian GDP reached the record level of 12%, generating 400 thousand jobs.

The works of Haddad & Giuberti (2011), Magalhães & Domingues (2012) and Moraes (2013) were the first to analyze the potential impacts of the pre-salt exploration in the Brazilian economy, with particular attention to evidence of symptoms of Dutch disease, using computable general equilibrium models. In a regional analysis of the state of Espírito Santo, Haddad & Giuberti (2011) impose to the model an exogenous technology shock, which increases the productivity proportional to the increase in expected production to simulate the pre-salt input. The results show a more than 7%. increase in GDP of Espírito Santo. The non-tradable sector benefits from increased oil production, while the tradable sector is the most affected, with evidence of deindustrialization and appreciation of real exchange rate consistent with Dutch disease.

Magalhães & Domingues (2012) study focuses not on regional impacts, but on the Brazilian economy as a whole, especially on manufacturing industry and exports. The shocks were applied by increasing the supply of natural resources in the industry to achieve the expected growth of the pre-salt production. The results suggest that the pre-salt exploration increases the world production of oil by 1.37% to 2020, compared to the baseline scenario and reduces the international oil price by 9.8%. The effects found on GDP and exports are positive and significant, 4.8% and 19.7% respectively by 2020, relative to the baseline scenario. As Haddad & Giuberti (2011) also find symptoms of Dutch disease.

The shocks simulated by Magalhães & Domingues (2012), on total oil resources stock and by Haddad & Giuberti (2011), through increased productivity, are limited ways of introducing pre-salt in the models, since the pre-salt oil differs from the conventional extraction as it has higher costs and additional technologies to exploit it. To work around this simplification, Moraes (2013) uses the computable dynamic general equilibrium model EPPA and introduces a non-conventional oil sector with an alternative technology, a more consistent way to represent the pre-salt in relation to those adopted in previous work. By simulating a scenario with the introduction of subsidies to pre-salt production, ensuring the realization of the projected production by Petrobras, Moraes (2013) found results of an inefficient allocation of resources, especially capital, resulting in reduction of GDP comparted to base scenario, with symptoms of Dutch disease.

Petrobras is the company that most invests in Brazil and during the 2010-2014 period engendered in a rapid expansion of investment, accounting for 8.8% of total investments in the country (1.8% of GDP) (Ministério da Fazenda, 2015). Recent domestic and international challenges imposed on Petrobras, resulting in a sharp reduction of investment in the sector, generated total negative impact estimated of 2% of GDP in 2014 (Ministério da Fazenda, 2015). Colomer & Rodrigues (2015) estimate that Petrobras forsaken R$ 62 billion in revenue by 2019.

Thus, when analyzing the impact of the new reality of the pre-salt exploration in the Brazilian economy, this paper contributes using economic quantitative modeling introducing the pre-salt sector considering its technological and cost differences compared to conventional oil extraction, as Moraes (2013), as well as the recent change in the expected trajectory of investments and the new price reality of the commodity.

The economic viability of the pre-salt exploration is surrounded by uncertainties. Its extraction costs are considered strategic information confidential to the company and its operation partners. Petrobras says that does not identify risk of infeasibility in the exploration of Libra block due to oil price drop, although the company has set the price of oil above US$ 45 per barrel as the pre-salt feasibility, including return on capital (Nunes & Pita, 2015).

At least in its initial phase, extraction costs in the pre-salt are larger than in conventional reserves. In 2008, the average cost of oil extraction by Petrobras was estimated at US$ 30 per barrel and it was assumed that the cost of extraction in the pre-salt was 50% higher (House of Representatives, 2009). Recently, the president of the state-owned Pre-salt Oil S.A. stated that the minimum price needed to make Libra project in the pre-salt economically viable is expected to surpass US$ 55 (Ramalho, 2015).

OPEC notes that the giant pre-salt reserves, considering the Libra field, with estimated 8 to 12 billion barrels, have a break-even with the price of oil above US$ 55 per barrel, well above the US$ 45 per barrel previously disclosed by Petrobras (Opec, 2015). Also believes that some of its most important wells may be operating at a loss, imposing serious financial consequences to Petrobras, currently the world's most indebted oil company. Pacca, Moreira & Parente (2014) estimate a cost of US$ 49 per barrel for the pre-salt and US$ 41.4 per barrel for the Brazilian conventional oil and confirms that US$ 42 per barrel corresponds to the cost of finding oil in South and Central America between 2004 and 2006.

In short, pre-salt costs have a high degree of uncertainty and lack of transparent and accurate information, making it difficult to analyze its economic viability. With this, it is needed to simulate different hypotheses on extraction cost of the pre-salt oil.

Biofuels are important alternatives to fossil fuels and have considerable potential for mitigating greenhouse gas emissions. In Brazil ethanol was presented as an economic alternative and environmentally sustainable to gasoline (Serigati, 2014) and gained new momentum with the introduction of flex-fuel engines from 2003.

The historical development of the Brazilian ethanol industry since 1970 is described by Hira & Oliveira (2009) and Serigati (2014). The outlook for the Brazilian ethanol industry is addressed by Jonker et al. (2015) and the results suggest that the costs of sugarcane cultivation can be reduced by up to 37% from 2010 to 2030, boosting its competitiveness. Promising prospects for the Brazilian ethanol industry are also evidenced by Ajanovic & Haas (2014), when analyzing the biofuel market by 2030 for Brazil, United States and European Union, which together accounted for three-quarters of the global biofuel supply. Currently, only the production of Brazilian ethanol has a favorable cost-benefit whose cost of production is on average two times lower than in the European Union. In the US, the competitiveness of ethanol is due to favorable agricultural policies.

The impact of increased ethanol demand versus gasoline in the Brazilian economy was approached by Costa, Guilhoto & Moraes (2011). Using an inter-regional input-output matrix, it indicates potential to generate jobs and income in a gasoline replacement scenario for ethanol. The authors defend the differentiated tax policy for the ethanol sector since there are significant socioeconomic benefits and highlight the importance of ethanol consolidation in the Brazilian energy matrix, as it generates positive social externalities for the entire population.

The first concerns the pre-salt impacts on the ethanol industry emerged shortly after its discovery announcement. For Pires & Schechtman (2008), vehicle fuel policies in Brazil have always been characterized by cyclothymic movements in response to short term situations without a long-term vision. They consider the discovery of pre-salt serendipitous, but it could lead to a setback in the national energy matrix. Same view is shared by Serigati (2014), where not long ago, ethanol was the main item of Brazilian energy policy and with the discovery of pre-salt oil, the biofuel was no longer a priority, which together with other factors such as high leverage, crop failures, rising cost of raw materials, postponement of renewal cycles of sugarcane plantations, attractive sugar prices in the international market and the domestic fuel price control policy, eroded the competitiveness of the ethanol industry.

Pacca, Moreira & Parente (2014) seek to assess bioenergy potential vis a vis the potential of the pre-salt reserves to meet Brazilian demand for energy by 2070. They perform cost-benefit analysis in many conventional oil production scenarios, pre-salt and ethanol. They conclude that there is no doubt that biofuels are relevant alternative to fossil fuels and that ethanol is viable in the presence of specific policies. The rate of return on investment (ROI) in ethanol is greater than the pre-salt ROI in most scenarios analyzed. Thus, the supply of ethanol can partially guarantee the supply of liquid fuels in the long run.

In addition, this paper also helps to quantify the impact of gasoline price control policy, guided by artificial control of inflation during the period 2011-2014, had on the ethanol industry. The negative impact of gasoline price control policy on Petrobras, was estimated by Almeida, Oliveria & Losekann (2015) of R$ 119 billion, leading to financial deterioration of the company and its investment capacity. The FAO (2014) discusses the influence of control policy of oil prices in the ethanol price in Brazil and estimated a loss of R$ 0.15 per liter of ethanol sold in the country. In the absence of gasoline price control policy, among other factors, a liter of ethanol would be sold on average 60% higher, which represented in a severe loss of competitiveness and profitability of the ethanol industry.

It is noted, therefore, a lack of quantitative studies in the literature on the possible impacts of the exploitation of pre-salt and gasoline price control policy on the ethanol industry and the Brazilian economy as a whole. Such studies are important to guide policy decisions and private investments towards the most promising energy source and cost-effective.

3. METHODOLOGY

The computable general equilibrium models (CGE) seek to represent a complex real economy and are important in helping to identify general equilibrium effects caused by exogenous changes that would not be easily identified a priori by its complexity or unexpected and non-obvious relationships (Piermartini & The, 2005). The use of these models allows to infer directions and relative magnitudes of exogenous shocks, and to compare alternative scenarios. The analysis of the model results allows us to identify relationships between sectors and economic agents that could not possibly be identified in theoretical or analytical models.

The general equilibrium models mimic the circular flow of goods, services and income of the economy, as can be seen in Figure 1, where consumers offer capital and labor (primary factors of production) to the productive sectors, and these in turn, offer goods and services to consumers. It is also considered the existence of a reverse flow of payments corresponding to the flow of goods and services, through which consumers receive an income of productive sectors by capital and labor provided and with the funds received, effecting payment for goods and services consumed (expenses).

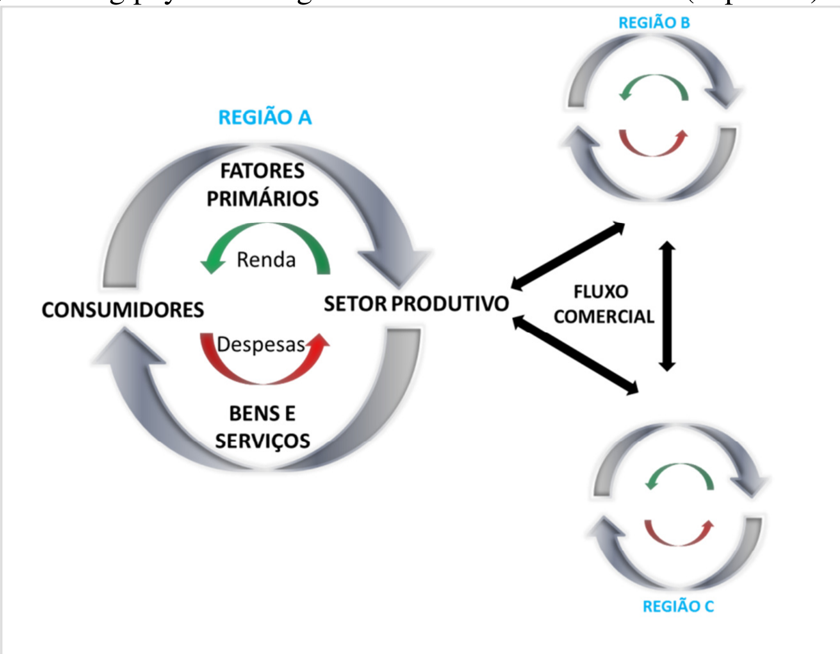

Figure 1 – Circular flow of goods and services.
Source: Adapted from Paltsev, et al. (2005). Self-elaboration

The equilibrium in the circular flow of goods and services in the economy is represented by conservation product and value. The conservation of the product occurs even when the economy is not in equilibrium. The conservation of value reflect the accounting principle of budgetary balance in that for each activity in the economy, the value of the companies must be balanced by the revenue value (Wing, 2004).

The formulation of the general equilibrium model is expressed in mathematical terms as a system of simultaneous equations representing the market equilibrium conditions. Modeling CGE uses economic theory of general equilibrium as an operational tool for empirical orientation analysis on issues related to market economies, resource allocation, trade, technological changes, and shock effects, among others (Sadoulet & De Janvry, 1995).

The EPPA model is a CGE dynamic recursive model, multi-regional and multi-sector with a long-term simulation horizon. This model was developed for the study of climate and energy policies and its characterization is described by Paltsev, et al. (2005) and Gurgel (2011), and considers the interactions between the various economic sectors, consumers, government and bilateral trade of goods and services between countries, accounting for the global economy through 16 countries and regions. In this paper, these features are essential, since the impact of the increase in oil reserves directly or indirectly affect all other economic sectors, through the energy market and sectors of the oil supply chain, highly dependent on international trade.

The data that feeds the model are mainly formed by input-output matrices representing the structures of the economies of the regions, from the Global Trade Analysis Project (GTAP) (Hertel, 1997) and (Dimaranan & McDougall, 2002). This is a consistent database on regional macroeconomic consumption, production and bilateral trade flows. Data on energy production and use in physical units are derived both from the GTAP 7 database as the International Energy Agency (IEA, 1997, 2004, 2005). The modeling of the ethanol industry was built as described in Melillo & et al (2009) and Gurgel, Reilly & Paltsev (2007).

The model was built as a mixed complementarity problem, non-linear, using the syntax algorithm Modeling Programming System for General Equilibrium (MPSGE) developed by Rutherford (1999). The MPSGE consists of a set of algebraic equations that characterize the zero economic profit conditions for production, balance between supply and demand in the markets for goods and factors of production and balance between income and consumer spending. The economic equilibrium problem therefore involves three inequalities that need to be met: zero profit, market equilibrium and equilibrium of income. These conditions are associated with no negative sets of variables: price, quantities and income levels.

The zero profit condition requires that any sector obtains zero profit, for example, input values must be greater than or equal to the value of production, when production is not null. This condition means that there is economic activity, with economic sectors under constant returns to scale and economic profit is zero, or no economic activity, since the profit would be negative. The equilibrium condition in the markets requires that any good with positive price must maintain the equilibrium between supply and demand, and any oversupplied good will have its price equal to zero. The income equilibrium condition requires that for each agent (including the government), the amount of income must be equal to the value of factor endowments and tax revenues.

In this article we used the EPPA model - version 5, calibrated for the base year of 2004. The simulations are made in corresponding intervals of every 5 years, from 2005 to 2100. The GTAP data for the world economy were organized in countries and regions, sectors and production factors presented in Table 1.

Table 1 – Aggregation of regions, sectors and factors used in EPPA model

Regions	Sectors		Factors
United States (USA)	**Non-Energy**	**Energy**[4]	Capital
Canada (CAN)	Agriculture - Crops (CROP)	Coal (COAL)	Labor
Mexico (MEX)	Agriculture - Livestock (LIVE)	Conventional Crude Oil (OIL)	Crude Oil
Japan (JPN)	Agriculture – Forestry (FORS)	Refined Oil (ROIL)	Shale Oil
European Union (EUR)	Food (FOOD)	Natural Gas (GAS)	Coal
Australia and New Zealand (ANZ)	Services (SERV)	Elec.: Fossil	Natural Gas
Russia (RUS)	Chemicals, Rubber, Plastics and	Elec.: Hydro	Hydro

[4] NGCC: Natural Gas Combined Cycle; CCS: Carbon Capture and Sequestration and IGCC: Integrated Gas Combined Cycle with Carbon Capture and Sequestration

	Paper (CRPP)		
Eastern Europe (ROE)	Iron and Steel Industry (IRON)	Elec.: Nuclear	Nuclear
China (CHN)	Energy Intensive (EINT)	Elec.: Wind	Wind & Solar
India (IND)	Other Industry (OTHR)	Elec.: Solar	Land – Crops
Brazil (BRA)	Transportation (TRAN)	Elec.: Biomass	Land – Livestock
East Asian (ASI)		Elec.: NGCC	Land - Forestry
Middle East (MÊS)		Elec. :NGCC– CCS	Natural Forests
Africa (AFR)		Elec.: IGCC – CCS	Natural Pastures
Latin America (LAM)		Synthetic Gas	
Rest of Asia (REA)		Biofuels - 2nd gen.	
		Shale Oil	
		Biofuels – 1st gen.	

Source: Gurgel (2011). Self-elaboration

Production functions for each sector of the economy describe the combinations of primary factors and intermediate inputs to produce goods and services. In each region there is a representative consumer who aims to maximize the welfare through the consumption of goods and services. The representation of the ability of individuals to replace different inputs and assets, both in production and consumption, it is essential in EPPA and is given by the elasticities of substitution in production and utility functions. In production, this reflects the technology used, i.e., the possibility of replacing various production factors and intermediate inputs in the production process. For the representative consumer, substitution between goods and services illustrates consumer preferences. The government is modeled as a passive entity that collects taxes and distributes the full amount of resources to families.

The behavior of the representative firm aims to maximize profit subject to technological restrictions, choosing in each region and in each sector, a product level, a number of primary factors and intermediate inputs from other sectors. The representative consumer has allocations of production factors that can be sold or leased to firms and chooses in each period and region, the levels of consumption and savings that maximize their welfare, subject to budget constraint for their level of income.

In EPPA, the production technology is represented by nested constant elasticities substitution functions (Constant Elasticity of Substitution - CES), with various levels of disaggregation, allowing greater possibility of substitution of inputs and making more flexible the choice of substitution elasticities.

In EPPA modeling there is a nested common structure between the sectors of services, transport, energy-intensive and other industries. Intermediate inputs are considered perfect complement (Leontief), together with a basket of capital-labor-energy (KLE), which in turn consists of an aggregation of added value and energy. Imports of a particular good originating from different regions are first combined as Armington goods under σ_{MM} elasticity, that is, objects in the same industry from different regions are considered imperfect substitutes, and later aggregate imports are combined with domestic production of the same good, in the σ_{DM} elasticity, in order to create a basket of goods offered within the region.

The refined oil sector (roil) considers crude oil as a complementary intermediate input for the generation of refined petroleum products, and not as part of the energy demand, as shown in Figure 2.

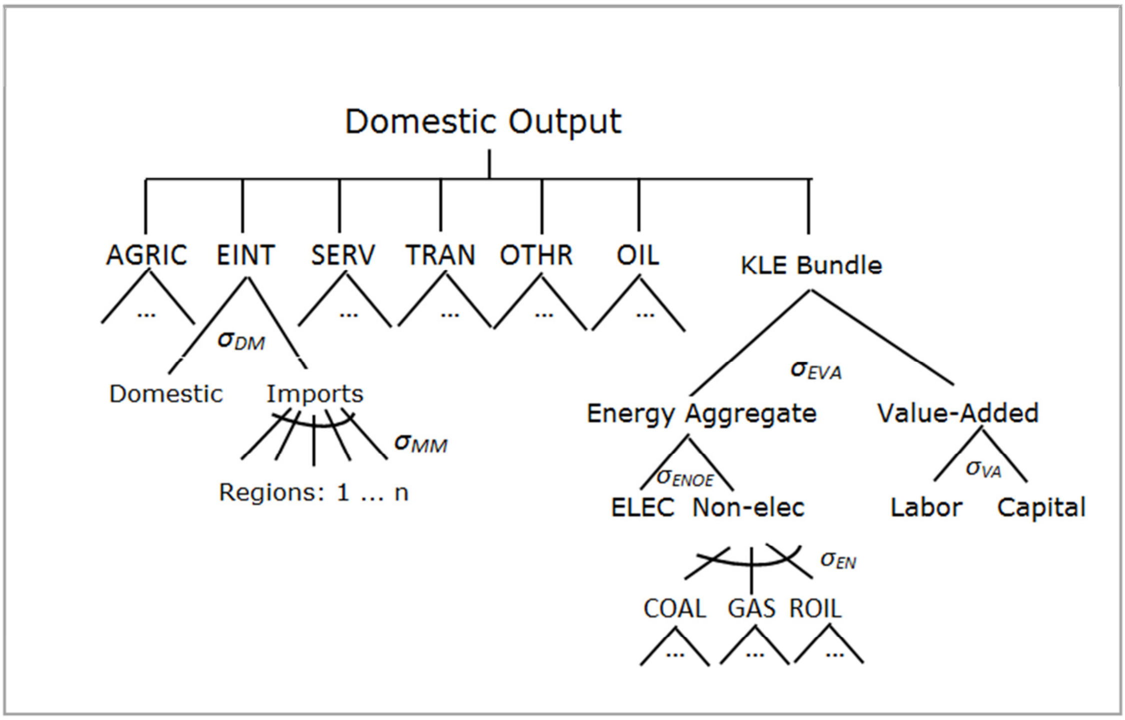

Figure 2 – Nested structure of refined oil sector.
Source: Paltsev, et al. (2005). Self-elaboration

In the characterization of international trade in EPPA, crude oil is treated as a homogeneous product, whereupon all countries and regions are faced with a single price in the world market. Coal, gas and refined oil are considered Armington goods due to product differentiation and quality. All goods produced are traded on global markets.

By using an Armington formulation, the EPPA has an explicit representation of bilateral trade flows so that the regions are at the same time exporters and importers of a particular good. Bilateral flows involve export taxes, import tariffs and international transport margins explicitly represented in the model.

Consumption is represented in the model by a nested CES structure to describe representative consumer preferences. The elasticity between non-energy inputs for consumption varies over time and according to the region, being a function of growth of per capita income. The share of consumption in each period is also updated in terms of per capita income growth between periods. The consumption-investment decision is endogenous in the model, since the savings goes directly in the utility function, generating a demand for savings.

Welfare is measured in terms of Hicksian equivalent variation, which measures the change in consumer income necessary for this to achieve, after a change in relative prices, the initial utility level in each model period.

In dynamic-recursive models, such as EPPA, economic optimization decisions are made each period considering only the price and quantities values in force at that time. The equilibrium results generated in a period are then used as reference values for the optimization process of the next period. Accordingly, in each period, the model has a static solution process, in that the agents do not care about values or future trends expected for the other variables.

The factors that influence the model evolution in time are related to capital accumulation, increased labor force, changes in factors and inputs productivity, changes in consumption patterns through the evolution of income and depletion of natural resources. These aspects, together with the implemented shocks in the model in various scenarios determine the model dynamics.

In this paper, the 5th version of the model was adapted to include the production of pre-salt as an alternative backstop technology, as performed by Moraes (2013), making endogenous the costs and benefits of the exploitation of pre-salt reserves, as well as its ability to compete with other energy technologies. This adaptation of the model was based, mutatis mutandis for the Brazilian case, on the work of Choumert et al. (2006), which modified the original EPPA model improving the oil and refining sectors. One of the changes was the introduction of new oil extraction technologies from unconventional reserves (oil sands in Canada and extra-heavy oil in Venezuela). For endogenously modeling the pre-salt, it was added the specific production industry which produces crude oil from the extracted fossil fuel from pre-salt reserve, as can be seen in Figure 3, making the product a perfect substitute for crude oil extracted from conventional reserves and therefore can be exported or consumed by the Brazilian refining sector.

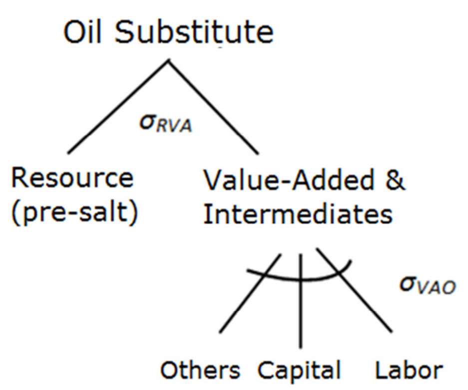

Figure 3 – Pre-salt production sector.
Source: Adaptation of oil sand production sector Choumert, Paltsev & Reilly (2006)

The biofuels technology, which represents the ethanol industry in the model has the same structure of shale oil, however, the specific resource is land. In addition, shale resources are exhaustible, while the land resource is considered renewable and productivity increases exogenously with time.

Due to the lack of data and detailed estimates of the costs of extraction and production of pre-salt layer, already mentioned in the literature review, substitution elasticities used for this sector are the same considered in oil sands production sector ($\sigma_{RVA} = 0{,}5 \; e \; \sigma_{VAO} = 0{,}2$) of the work of Choumert, Paltsev, & Reilly (2006). In order to reduce uncertainties about these elasticities, Moraes (2013) conducted an elasticity sensitivity analysis and found no significant changes in its results. As for the composition of inputs and production factors in extraction technology, Choumert, Paltsev & Reilly (2006) set the percentages of capital and labor in the oil sands production costs based on assumptions about the composition of capital expenditures (CAPEX) and operating expenses (OPEX) of this resource. Due to the unavailability of such information on the pre-salt, it was used the same percentages of capital and labor costs on the pre-salt production[5]. The model also considers the technically recoverable reserves estimated in the pre-salt[6].

Initial amount of fossil resource reserves available was calibrated and a technological learning curve was introduced, represented by a gradual reduction in the mark-up[7], an improvement over the simulations carried out by Moraes (2013). As already described in the literature review, the pre-salt costs have a high degree of uncertainty and lack of transparent and accurate information, therefore various scenarios were simulated by changing the cost mark-up level of this new technology in relation to the extraction technology of conventional oil. The simulated scenarios were compared with the BAU (Business As Usual), which represents the trajectory of the economy projected by the EPPA model without considering the production of pre-salt, but set to reproduce the national oil production up to 2010[8] and the difference between the simulated scenarios and BAU is the effect of the pre-salt considering the assumptions made in each model.

To reproduce the scenario according to Petrobras' 2015-2019 Business Plan (Petrobras, 2015) it was necessary to introduce a subsidy for the production of pre-salt, since the pre-salt extraction technology is more resource intensive and therefore more expensive than the traditional extraction reserves. The introduction of subsidies is the closest way to represent the funding effort by Petrobras for investments in the pre-salt, resources that would be available for use in other sectors of the economy, if there were no pre-salt. That is, to allow the model to generate some production of pre-salt resource in a period prior to that would take place endogenously if only the competitiveness of the pre-salt and its opportunity costs to conventional resource were considered, it was introduced in one of the scenarios a subsidy curve[9] in order to reproduce the oil production targets, already recently revised down by Petrobras, based on the latest 2015-2019 Business Plan.

In order to analyze the impact of the pre-salt exploitation on the ethanol sector, a comparison between the expected ethanol production in each scenario, in relation to the ethanol production in the scenario without the pre-salt exploration (Business as Usual) . Finally, to analyze the gasoline prices control policy scenario that was in force between 2011 and 2014, it was introduced a subsidy to gasoline consumption in Brazil, corresponding to a 15% reduction in the price of this fuel during the period from 2011 to 2015 equivalent to the average gap of domestic price versus the international price in this period. The introduction of a subsidy rather than a direct control over the price of gasoline domestically was considered more appropriate, since the control of an endogenous variable, as the price of gasoline in the domestic market in the model does not capture the implicit subsidy associated to this price control policy. In short, the simulated scenarios in this paper are:

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[5] The work of Moraes (2013) conducted a sensitivity analysis of this parameter and found no significant changes in the main results.

[6] It was considered a technically recoverable oil reserve of 70 billion barrels (Lacerda, 2009) converted to eJ, power unit used by the EPPA.

[7] The model considers a 5% reduction in the mark-up for each interaction from 2015, i.e. a learning curve that reduces costs by approximately 1% per year.

[8] It was necessary to calibrate the base model as the Brazilian oil production in 2010 has been held under the knowledge of the pre-salt and therefore would be higher than projected in a scenario where there would be no existence of this resource.

[9] In the *mkp 50% scenario with subsidy* is considered a subsidy to production/investment in the pre-salt oil sector of 41% from 2015, 47% from 2020, dropping to 40% from 2030 and being reduced gradually each period down to zero.

- ***BAU*: scenario without the presence of the pre-salt sector in the model;**
- ***mkp 75%*: scenario with the presence of the pre-salt, with 75% mark-up cost compared to conventional oil and a learning curve that reduces this cost by about 1% per year;**
- ***mkp 50%*: scenario with the presence of the pre-salt, with 50% mark-up cost compared to conventional oil and a learning curve that reduces this cost by about 1% per year;**
- ***mkp 25%*: scenario with the presence of the pre-salt, with 25% mark-up cost compared to conventional oil and a learning curve that reduces this cost by about 1% per year;**
- ***mkp 10%*: scenario with the presence of the pre-salt, with 10% mark-up cost compared to conventional oil and a learning curve that reduces this cost by about 1% per year;**
- ***mkp 50% with subsidy*: scenario with the presence of the pre-salt, with a 50% mark-up cost compared to conventional oil, a learning curve that reduces this cost by about 1% per year and a subsidy curve to investments to make the pre -salt competitive in this decade in order to reproduce the production projected in the 2015-2019 Petrobras' Business plan;**
- ***price control*: scenario with the domestic gasoline price control policy, with introduction of a subsidy to simulate a 15% reduction in the average domestic price in relation to changes in the international price (adjusted for exchange rate variation) for the 2011-2015 period.**

4. RESULTS

Domestic oil production in the five simulated scenarios is shown in Figure 4. Oil production in the BAU scenario is quite close to the actual production observed in recent years. In the absence of pre-salt oil exploitation, the model projects that the total oil production in Brazil will reach the equivalent peak of 2.8 million barrels of oil equivalent per day in 2045 and start declining process due to the gradual exhaustion of reserves. By adding the pre-salt reserves in the model, the domestic oil production can reach up to 5.5 million barrels of oil equivalent per day, depending on the mark-up level considered. This is equivalent to approximately half the production of Saudi Arabia in 2014, historically one of the largest oil producers.

Figure 4 also shows the oil production projection stipulated in the latest 2015-2019 Petrobras Business Plan up to 2020 (Petrobras, 2015), which provides for an increase in oil production from the current 2.1 million of barrels of oil equivalent per day in 2015 to 2.8 million in 2020. The *mkp 10%* and *mkp 50% with subsidy* scenarios are the closest in reproducing Petrobras projected production. The *mkp 10%* scenario is quite optimistic about the operating costs of the pre-salt oil, below the estimates disclosed in the various sources analyzed and even then its trajectory by 2020 is slightly lower than that of Petrobras production target. The *mkp 50% with subsidy* scenario undertakes a subsidy curve to capital investment in the pre-salt, calibrated to achieve the production levels expected by Petrobras. The 2015 oil production in all scenarios is similar to current production in the pre-salt and conventional fields. Based on cost estimates available, it is believed that the mark-up calibrations in scenarios *mkp 50%*

and *mkp 75%* are those that best represent the true costs of the pre-salt extraction. Important evidence is that, considering such more realistic scenarios, the oil production in pre-salt becomes competitive only from 2025 at *mkp 50%* scenario and from 2035 in *75% mkp* scenario, if market forces are to operate freely in oil production and investments in the sector. These results suggest that efforts and capital committed to extract these reserves with the maximum speed cannot be considered the best strategy in terms of timing and opportunity costs involved, given the global price conditions, production and reserves.

The trajectories indicate that, to generate an oil production compatible with Petrobras' production targets in the coming years, will be required the introduction of subsidies, transferring productive resources for the pre-salt sector. This forced relocation, generated by the subsidy introduction compared to the previous allocation, generated by the free operation of market forces, impacts the aggregate output of the economy, among other consequences.

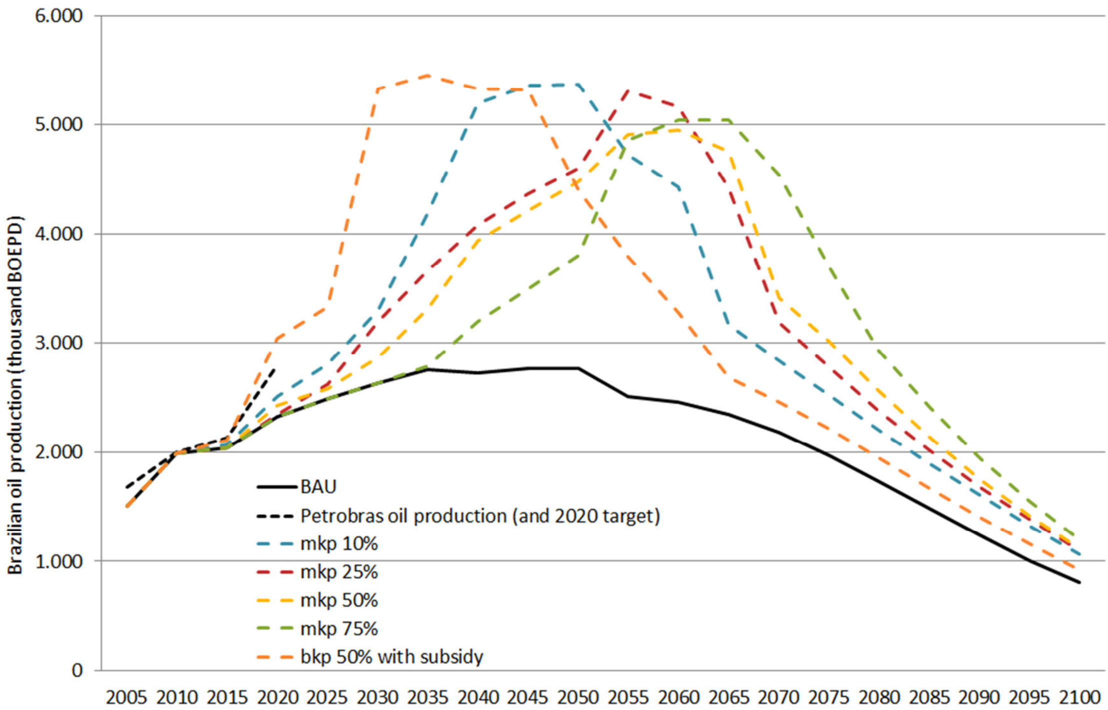

Figure 4 – Domestic oil production in simulated scenarios.
Source: Self-elaboration

Figure 5 shows the GDP growth trajectory between the different simulated scenarios compared to the BAU reference scenario. It is important to note that negative impacts do not necessarily mean decline of GDP, but growth will be lower than in the BAU reference scenario. Note that the impact of the pre-salt on GDP, except in the *mkp 75%* scenario, is predominantly negative over the whole analysed period and worsens according the mark-up is reduced. The most negative impact on GDP is given in the scenario with the introduction of subsidies, reaching a maximum negative effect of approximately 4% of GDP compared to that would be observed in the BAU reference scenario in 2055. The negative effects on GDP observed in *mkp 50% with subsidy* scenario are due predominantly to allocation distortion of investments and primary factors generated by the incentives (subsidies) introduced to the pre-salt sector. The negative effects on GDP observed in *mkp 10%*, *mkp 25%* and *mkp 50%* scenarios can be credited mainly to Dutch disease symptoms, as evidence found by Haddad & Giuberti (2011), Magalhães & Domingues (2012) and Moraes (2013).

In the *mkp 75%* scenario, the exploration of pre-salt begins after 2035 and has positive effects on GDP throughout most of the analyzed period and the impact begins to take effect at the time the production in pre-salt becomes competitive as a result of increased availability of non-renewable energy resources, probably in a period in which oil becomes more scarce in the world and the pre-salt exploration becomes more profitable. It is important to note the temporal aspect of the impact of the scenarios on GDP. In all scenarios without subsidy GDP increases during the first years of the pre-salt production, relative to BAU, since the exploitation of this feature becomes competitive, however, impacts gradually decline thereafter, to the extent that the oil industry grows, occupying more space in the economy draining more capital and labor from other sectors, which gradually lose competitiveness, which is also enhanced by the exchange rate appreciation effect resulting from export of large part of the reserves, thus making the competitiveness reduction of the other sectors gradual and not immediate. As the pre-salt production gains scale, it increases competition for resources (labor and capital) in the economy and the effects of exchange rate appreciation, draining factors from other sectors and reducing their competitiveness, with a negative net effect on GDP. After the peak of oil exploration, when the pre-salt production curve enters the period of decline, due to the gradual depletion of reserves, productive resources before used in this activity becomes more available to the rest of the economy, being gradually relocated to other sectors, gradually recovering their competitiveness and returning to activity level close to that seen in the BAU scenario.

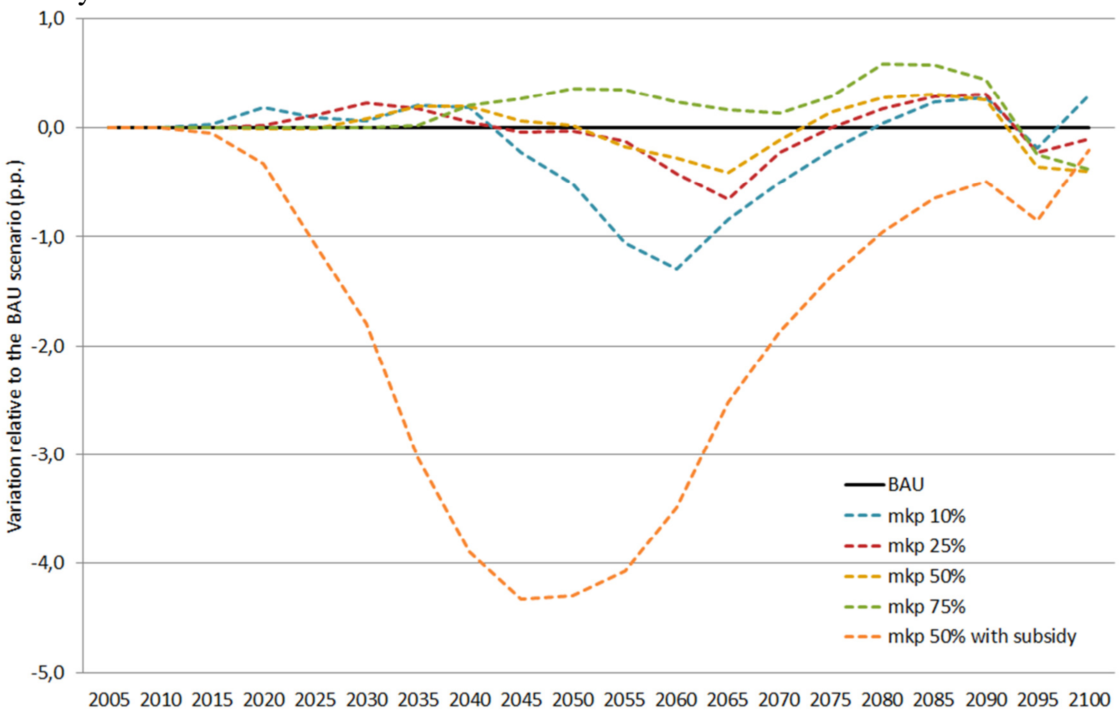

Figure 5 - Impacts on GDP of simulated scenarios compared to the BAU scenario.
Source: Self-elaboration

It is also noteworthy the pre-salt development impact on international oil price. One can hypothesize that with the export of large volumes of oil, resulting from the pre-salt extraction, could put a downward pressure on international price of this commodity. However, according to Figure 6, the model results indicate a maximum reduction of 2% in the international oil price during the peak production period of each scenario, which suggests that the pre-salt has no significant impact on the international oil price in relation to the reference scenario, unlike evidence found in Magalhães & Domingues (2012) in which the pre-salt exploration can reduce the international oil price up to 10%. The difference is because Magalhães & Domingues (2012) work apply a positive productivity shock in the extraction of conventional oil resources in the model, simulating an increase in the amount of this natural resource, while this paper considers the explicit costs of the pre-salt extraction, which is higher than the extraction of conventional oil, so there is not an abrupt increase in supply at once. Low influence of the pre-salt in the international oil price means it partially replaces the provision of some other less competitive global source of oil.

The model projections for the international oil prices (in real terms) indicate trend consistent with the reference scenario price trends designed by the US Energy Information Administration (EIA) to the projection horizon (2040) (EIA, 2014).

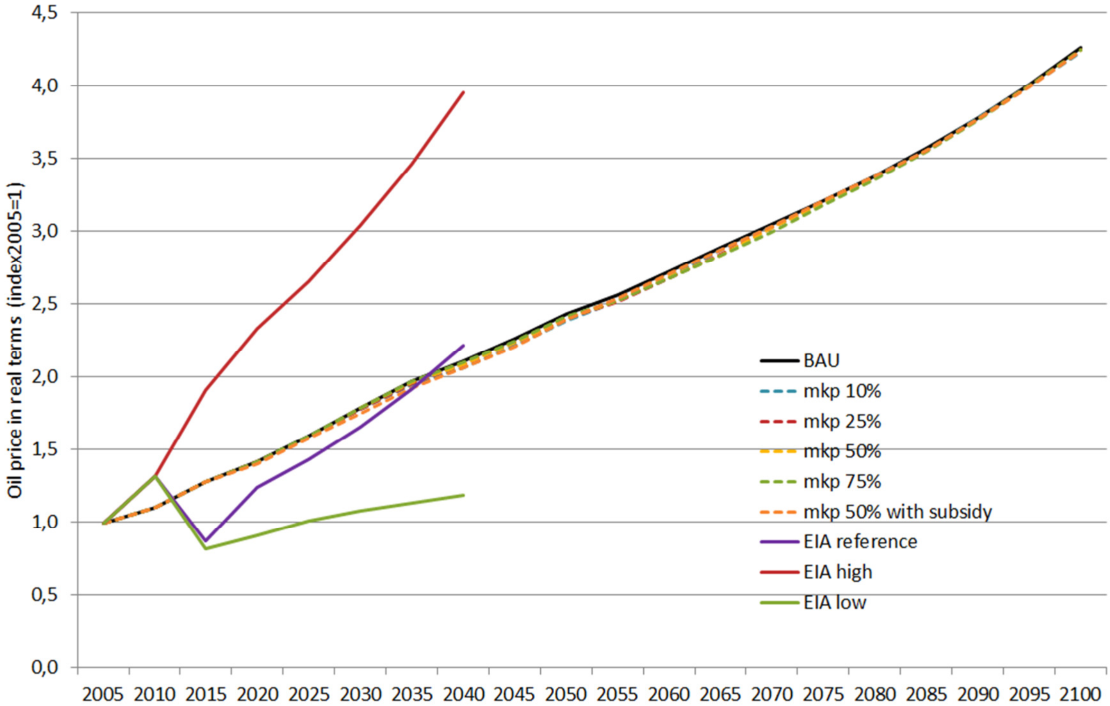

Figure 6 – Oil prices (in real terms) projected in simulated scenarios and by EIA.
Source: EIA (2014) and self-elaboration

In short, despite data limitations and dependence on assumptions made, the scenarios modeling the pre-salt as a backstop technology allows to understand how the representation of the economic costs of the pre-salt development are essential to understand the impact of this investment on the Brazilian economy. As the development of pre-salt is more costly that the production of conventional oil, even considering a learning curve/technological advance, the results indicate an inefficient allocation of scarce resources, if the pre-salt is stimulated prematurely.

Figure 7 shows how the pre-salt development affects the ethanol industry relative to BAU. In all scenarios simulated in the model, except the *mkp 75%* scenario point to the same dynamic, differing only in magnitude. At first, the pre-salt exploration results in a decrease of the ethanol production, with the *mkp 50% with subsidy* scenario the one that most negatively affects the sector, with maximum impact relative to BAU of approximately -6.0 pp in 2040. This impact is related to two factors: first, the predominance of direct competition effect of the oil with ethanol in flex-fuel vehicles, since the renewable fuel is relatively more expensive on the increased supply of oil ("substitution" effect); and the second, lower economic activity resulting from the macroeconomic effect of the pre-salt exploration, resulting in lower demand for fuels in general ("income" effect).

From 2060, the pre-salt exploration begins to positively affect the ethanol sector relative to the BAU scenario. This is both due to the increase of the relative price of oil products compared to the ethanol, in that oil production curve declines and oil products thereof become relatively scarcer, increasing biofuel consumption.

It is important to note that in the BAU scenario, as oil production is considerably lower in the absence of pre-salt, biofuels end up gaining more space in the tanks of light vehicles well before 2050, with little increase in consumption after 2050. In the scenarios where the pre-salt oil is produced, the share of biofuels is more modest until 2050/2060, but crescent, gaining more space from then on, due to the decline in oil production of pre-salt and higher growth of domestic oil refining industry, which leads to a rapid increase in consumption of biofuel and consequently larger volumes consumed relative to BAU.

The *mkp 75%* scenario does not impact the ethanol industry by 2040, when pre-salt production starts, but from its development, the ethanol industry, unlike the other scenarios, has an initially positive impact that is maintained throughout the analysis horizon, reaching a maximum impact of 9.26 percentage points above the BAU in ethanol production in 2080. This pronounced increase in ethanol production compared to BAU scenario is due to the greater expansion of the refining sector in relation to the BAU in the second half of the time horizon model, considering the complementary anhydrous ethanol since ethanol substitution capacity for the gas in the flex fleet is already greatly reduced in these years.

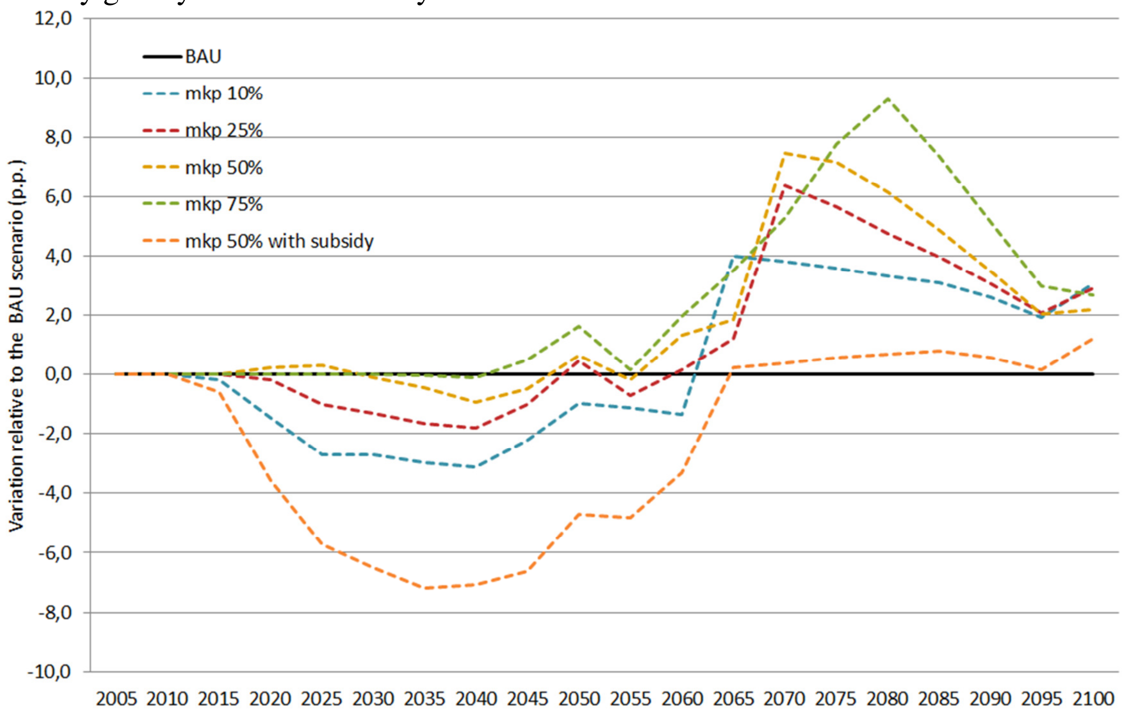

Figure 7 – Impacts on the ethanol industry compared to the BAU scenario.
Source: Self-elaboration

Note also, that unlike the initial intuition that the pre-salt could replace or impair the ethanol technology, the pre-salt development marginally affects the ethanol industry, initially in a negative way to the middle of the century and later positively but also modest. Figure 8 highlights the share of expenditure on ethanol in fuel consumption composition for light vehicles (gasoline type C and ethanol) in Brazil. From 2050, ethanol already represents more than 90% of the composition of spending on fuel in all simulated scenarios. Importantly, in the model construction, it is assumed that the flex-fuel vehicles continue to increase its share in the light vehicle fleet over time to become 99% of the fleet after 2050. These results indicate that the two sources of energy, pre-salt and ethanol, have space in the Brazilian energy matrix and can thrive simultaneously. But if specific policies that benefit or greatly impair a particular source over another are adopted, this may not be true, as can be seen in the price control scenario in Figure 8 and which will be discussed in more detail below. Importantly, the fact that a significant portion of the oil extracted from the pre-salt is exported, it does not compete directly with ethanol domestically, limiting the effect of exploitation of pre-salt on the ethanol industry.

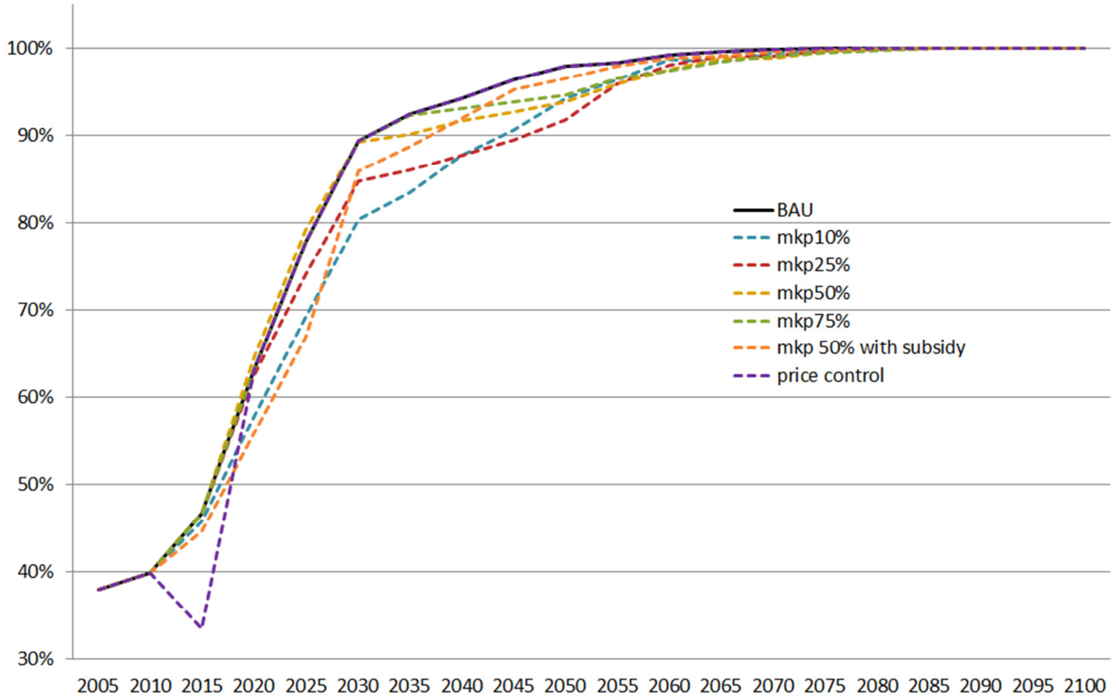

Figure 8 – Share of expenditure (2004 US$) with ethanol in fuel for light vehicles (gasoline type C and hydrous ethanol) in Brazil.
Source: Self-elaboration

Nevertheless, the announcement of the pre-salt discovery in late 2007, a time when the ethanol industry was gaining traction, increasing investment, production growth, international recognition, as well as advertising and highlighted by the Brazilian government, changed suddenly the focus of national energy policy. The campaign for biofuel, green fuel, clean, with low carbon emission made with national technology and that has comparative advantages, in tune with the global movement to encourage renewable energy sources, lost steam, giving way for investments in the significant pre-salt reserves. In other words, the results suggest that the negative impact of the pre-salt on the production of ethanol has more reasons associated to changes in political priorities on energy policy than on economic fundamentals.

Although the simulated scenarios above show that the long-term impacts of the pre-salt exploration does not impair the ethanol industry, and do not cause pronounced negative impacts in its production, the simulated *price control* scenario, in which a gasoline price policy was in force between 2011 and 2014 is an example of the harmful effects when a mistaken policy is put into practice.

Figure 9 shows the impact on the domestic ethanol production relative to the BAU when gasoline consumption is subsidized, resulting in a decrease in the domestic price by 15% compared to the international price, as was simulated in *price control* scenario. If the incentive (subsidy) to gasoline consumption on one hand jeopardized the financial health of Petrobras, also compromising the pre-salt exploration, as described by Almeida, Oliveira, & Losekann (2015), on the other hand the scenario simulation shows that there were harmful effects on the ethanol industry, unbalancing its competitiveness compared to gasoline. Figure 8 is already shows signs of this effect since the share of ethanol in fuel expenditure for light vehicles is reduced. The estimated effect of such policy shock on the ethanol production is a 7% reduction over the analyzed period, relative to BAU. Note that the 7% decrease in ethanol production resulting from price control policy is greater than falling ethanol output from all other simulated scenarios, including the scenario with the introduction of subsidies to pre-salt development, indicating that the effect of an artificial fuel price control can be more harmful to the ethanol industry than the pre-salt development. The results trend is in line with the decreased ethanol production observed up to 2015, but of lesser magnitude than the 15% reduction observed in ethanol production in this period, according to the Sugar Cane Industry Association (UNICA). Such impact weakened the ethanol producing companies, leading together with other factors, to bankruptcies and layoffs. In short, the gasoline price control policy along with other administered prices, in an effort to contain inflationary pressures, proved to be mistaken with negative sectoral impacts. Nevertheless, according to the model, in the absence of new price controls in the future, the negative effect of this policy is eliminated by 2020, leading to production of ethanol at the same level that would be observed in the BAU scenario.

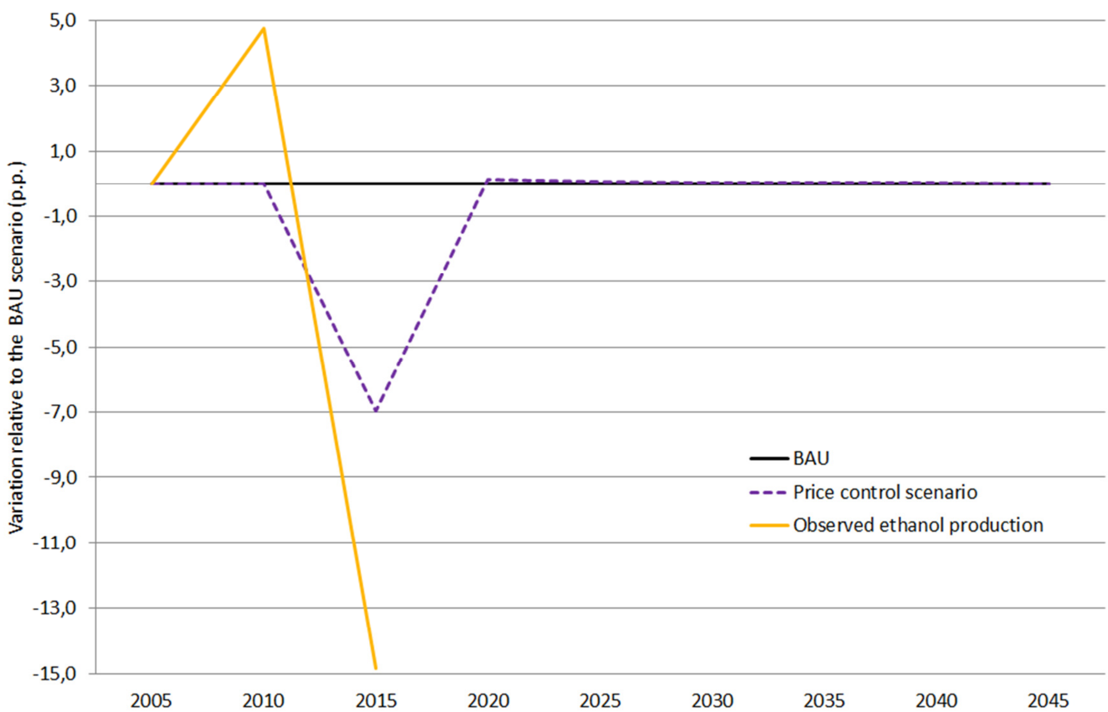

Figure 9 – Impacts of *price control* scenario on ethanol production compared to BAU and ethanol production observed in Brazil.

Source: UNICA. Self-elaboration

5. CONCLUSIONS

This paper aimed to investigate the macroeconomic impacts associated with the development of pre-salt development, considering the review of the oil production targets contained in Petrobras 2015-2019 Business Plan, with attention to its consequences and impacts on the sector ethanol. In addition, we sought to evaluate, also on the ethanol industry, the potential impacts of domestic gasoline price control policy that was in force between 2011 and 2014. The computable dynamic general equilibrium model EPPA was used to estimate such impacts. The introduction of the pre-salt in the model was made through the incorporation of a new sector in the Brazilian economy, acting endogenously, with its own characteristics, such as its higher operating costs compared to conventional oil. Due to lack of information about the pre-salt extraction costs, various cost mark-up scenarios of this technology compared to conventional oil production were simulated. It is noteworthy that one of the limitations of computable general equilibrium models is that the results are highly dependent on assumptions and model calibration. Therefore, we sought to mitigate this limitation by estimating alternative mark-up scenarios, similar to a sensitivity analysis.

The results obtained from the simulated scenarios show that the pre-salt development is anticipated as the mark-up compared to conventional oil is reduced, but the main macroeconomic impacts are mostly similar between different scenarios, except for the intertemporal shift and marginally changed magnitudes.

The results allow to further conclude that the early pre-salt reserves development brings more costs than benefits to the Brazilian economy in the long run, even considering a gradual improvement from current levels of technology and knowledge for the pre-salt development. The incentives required to achieve the current Petrobras production targets, although reduced compared to previous targets, harm the economy by forcibly targeting of resources to a less productive sector, artificially attracting primary factors and production inputs from other sectors of the economy, distorting the efficient allocation of resources. This would result in a GDP up to 4 percentage points lower that would occur in a scenario excluding the pre-salt discoveries. If the pre-salt development occurs without such subsidies, under realistic assumptions, it becomes competitive only between 2025 and 2035, well after government desire, and peak production should take place between 2055 and 2065, reaching up 5.5 million barrels of oil equivalent per day, which represents about half of the production of Saudi Arabia in 2014, historically one of the largest oil producers. These results are similar to those found by Moraes (2013). Moreover, Brazilian pre-salt oil production has no power to influence international oil prices, since only reduces the production somewhere else in the world, keeping the global oil supply at levels similar to a scenario without the pre-salt development.

Without subsidies, the economic impacts can range from -0.5% to + 0.5% of GDP relative to the scenario without considering pre-salt reserves. We also conclude that premature pre-salt development reduces domestic ethanol production by about 6% by 2035. If the pre-salt development is to occur without the introduction of specific incentives, the ethanol industry is slightly harmed in the first decades of exploitation and benefits from a gradual exhaustion of reserves that occurs on the horizon after 2050, relative to the scenario excluding the pre-salt development. Thus, we concluded that the production of oil from pre-salt reserves does not impair the Brazilian ethanol production and the two energy sources can coexist if left to market forces to determine their viability. However, the announcement of the pre-salt reserves in late 2007, at a time when the ethanol industry was gaining traction and international prominence, made the national energy policy focus suddenly shift towards the early pre-salt development. The clean and renewable fuel campaign, with lower carbon emissions compared to fossil fuels, made with national technology, with comparative advantages to be exported worldwide and in tune with the global movement to encourage renewable energy sources, lost steam, giving way for investments in the significant pre-salt reserves.

Nevertheless, the domestic gasoline price control policy, for purposes of inflationary pressures mitigation was proved mistaken for both sectors. On the one hand, it acted harmfully on ethanol, resulting in consumption and production decrease at a delicate time for the sector. On the other hand, it hindered the development of the pre-salt, once it committed Petrobras financial health, at the time the largest Brazilian company. Note also that a price control policy can be more harmful to ethanol than the development of the pre-salt reserves.

From this paper, it is clear that there is room in the literature to improve the information on costs and technological details in studies about pre-salt oil production. Still, alternative methods, such as general equilibrium dynamic intertemporal optimization modeling would also be desirable to investigate the issue. Finally, the effects of early pre-salt development and possible incentives for ethanol production on the Brazilian energy matrix evolution of are important issues to be investigated in future studies.

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