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Fuel Subsidies Policy in Brazil: A Simulation of the Macroeconomic Impact

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Abstract

Between 2011 and 2014, the Brazilian government granted generous fuel subsidies via Petrobras. This paper adopts a macroeconomic model to estimate the changes that would take place in the consumption and production of fuels and other goods present in the Brazilian economy if the fuel subsidy were removed. The results suggest that the reduction of fuel subsidies, if offset by a reduction in taxation on consumption, capital, or labor, would reduce fuel consumption and increase the consumption and production of other goods. If the withdrawal of the subsidy were offset by a reduction on fuel tax, the consumption of all goods would increase, thereby proving this measure to be the most beneficial course of action.

Keywords: Fuels; subsidies; production; consumption; prices; macroeconomic model.

1. INTRODUCTION

Fossil fuel prices deserve particular attention because of the influence they have on the well-being of an economy. This is the case because given the consumption of energy and transportation, they indirectly impact economic activity and the public sector's account, which in turn influence the country's debt and its credibility in the eyes of investors. There are direct, as well as indirect, impacts on the environment, which are damaging to the population's health. Direct impacts emerge by way of energy costs and demands, in addition to the incentive to invest in renewable energy directly. Indirectly, there are impacts on economic growth, and a positive relationship between growth and fuel consumption (Pereira and Pereira, 2014). As such, economic policies should ensure that there is a sufficient supply of energy in order to guarantee the smooth functioning of the markets, while avoiding excessive use to prevent harming people's health and the environment (OECD, 2015).

Various countries around the world have energy subsidy policies, which incentivize the consumption of petroleum-based products, natural gas, and electricity. The International Energy Agency estimates (AIE, 2016) indicate that in 2014, 493 billion dollars were granted in subsidies for fossil fuels globally.

The Organization for Economic Co-operation and Development (OECD) defines a subsidy as any method of maintaining prices below market levels for consumers or producers, or which reduce costs for consumers or producers (OECD, 2015, p. 114). Accordingly, subsidies are represented by any difference in price between the amount paid by the end consumer and the international reference price, minus transportation and distribution costs. Subsidies after taxes seek to account for social costs also generated by the negative externalities of energy consumption, like contamination, climate change, and congestion (Barany and Grigonytė, 2015, p. 4).

Taking into account negative externalities, the ideal price of fuel would be above the market equilibrium level, reducing the demand for energy. According to Coady *et al.* (2015), prices for consumers should be composed of the following: the cost (or opportunity cost) for the energy producer; a Pigouvian tax, to reflect the cost of negative externalities; and a consumption tax.

Different countries around the world have policies that function to the contrary, maintaining prices artificially below equilibrium prices, in an effort to stimulate economic growth or benefit the lowest income sector of the population, and hoping that energy would then have less clout in the consumer basket.

Despite this, many studies question the possibility of achieving such goals by way of energy subsidies, arguing that their effects might be contrary to what they intend. Clements *et al.* (2013) assert that these policies may impede growth since they can increase public debt, discourage investment in more efficient and cleaner energy, take the place of other investments that could incentivize growth, encourage smuggling, and decrease competitiveness in the private sector.

The aforementioned study also notes that subsidies are regressive, demonstrating that on average, 20% of the high-income population collect 43% of subsidies, while 20% of the poorest only receive 7%. According to the world average, gasoline is the item that shows the most regressivity, while kerosene shows progressivity.

Ellis (2010) provides the primary economic, environmental, and social impacts of fossil fuel subsidies. Among the economic impacts cited are: the increase in energy consumption, and consequently, the disincentive to use more efficient forms of energy; the possibility of reducing exchange earnings; increased dependence on importation; the incentive to use energy intensively in production, to the detriment of labor; and the possibility of reducing producer's profits, thus creating shortages of the subsidized product. The environmental impacts consist of emissions not only of carbon gas, but of other gases like sulfur dioxide and nitrogen oxide, which can cause harm to human health (such as flu, pneumonia, and asthma), structures, and agriculture. Some social impacts derive from the foregoing, given that such disadvantages are more detrimental to the lower income population.

Accordingly, fuel subsidy policies can cause fiscal, environmental, and health problems, while also reducing innovation within the sector, and damaging economic growth. In addition, they probably benefit the high-income population more than the low-income one.

As such, it can be acknowledged that reforms to end subsidy policies are necessary. These reforms should be well planned, given that an increase in energy prices causes some disadvantages on the short term. First, there would be a direct inflationary impact, since energy is significantly represented in the consumer basket, and an indirect one, given that energy is an input for the majority of goods. There is also the possibility of a decrease in the country's international competitiveness since there would not be simultaneous reforms in other countries, thus causing comparatively high production costs for those that do raise their prices. The lowest class population would suffer more from the impacts of the policy given that, despite regressivity, the removal of subsidies would significantly impact their budgets. Clements *et al.* (2013) argue that an increase of USD 0.25 for a liter of fuel could increase the price level by 5.5% for the poorest families.

In the case of Brazil, between 2011 and 2014 the international price of petroleum was higher than what was seen domestically, and Petrobras continued to sell at a price established by the government, in order to prevent a transfer of the increase onto the domestic market. The state-owned company accordingly provided subsidies for petroleum-based fuels upon importation, and resold them at a lower price on the domestic market, to the clear detriment of the business. This situation was also exacerbated because the company did not stop making investments projected in the 2012-2016 Business Plan.

According to the Brazilian Infrastructure Center's estimates (CBIE, 2014), the price of gasoline in Brazil reached a level 33% lower than in the Gulf of Mexico (the international reference price), while diesel hit a 29% discrepancy.

Fiscal losses for the public sector are not only derived from the sale of fuels at a lower price that than that of cost. Revenues from the Income Tax and the Social Contribution on Net Profits, which have an impact on Petrobras' profits, also decrease. Additionally, the revenue from taxes related to the price of making fuels is lowered. The government ended the Contribution for Economic Strength Intervention [Portuguese CIDE] on fuels during the period from June 2012 to February 2015, further decreasing revenue.

Maintaining fuel prices low by artificial means generates distortions in a variety of the economy's markets. For example, in a direct way, the low price of gasoline causes less demand for alcohol by consumers, which discourages its production. Producers of sugar cane, then, substitute production of alcohol for that of sugar, causing the latter's price to decrease for exportation (ANTT, 2014). Di Bella *et al.* (2015) calculate that, between 2011 and 2013, subsidies cost 1.2% of Brazil's GDP.

Beyond this Introduction, this study is comprised of five other sections. In section 2, a brief overview of the literature on the economic effects of fuel prices is provided. Section 3 describes the economic model and section 4 calibrates it to the data on the Brazilian economy. Section 5 analyzes the results obtained from the removal of the subsidy in Brazil, accompanied by a variety of tax policies; lastly, in section 6 the final conclusions are presented.

2. FOSSIL FUEL SUBSIDIES

The study of fossil fuel subsidies has received substantial attention in recent years in literature on the topic. Institutions such as the OECD, the IMF, the International Energy Agency [Spanish AIE] and the World Bank have determined the value of this policy and evaluated its social and economic impacts. Such works note that the elimination of subsidies reduces the government's budget deficit, causing a more efficient distribution of resources and increasing potential economic growth (Barany and Grigonytė, 2015, p. 1).

Parry and Small (2005) use a closed economy static model to calculate the second-best tax for gasoline in the United Kingdom and United States. The study suggests that the tax should reflect congestion, accidents, and air contamination. The tax should also include a Ramsey tax, which reflects the appropriate equilibrium between the consumption tax and the labor tax, in order to fund government spending. The authors claim that the United Kingdom maintains a high tax rate and as such, in addition to minimizing negative externalities, provides the government with a substantial income without notably affecting economic efficiency, since fuels have a low price elasticity of demand.

Between 2003 and 2005, international fuel prices increased substantially; in Central Africa, Gabon implemented a policy similar to the one Brazil enforced from 2011 to 2014, maintaining fuel prices constant. Leigh (2006) calculates that the subsidy costs in that country ranged from 1.6 to 2% of the GDP in 2005 and 2006, respectively. The author concludes that

10% of the richest population benefitted from a third of the subsidies, while 30% of the poorest received only 10% of the policy's costs.

Lin and Li's article (2012) uses a general equilibrium model to simulate the impacts of removing energy subsidies in China, and compares different strategies that could mitigate the effects of the policy's withdrawal. The results show that the reduction of subsidies would have global effects by way of trade. China would then lose competitiveness in the face of other countries that did not eliminate their subsidies. There would also be effects on energy consumption, which would be transferred to other countries, so as to decrease the Asian country's carbon emissions while increasing emissions in other parts of the world.

Glomm and Jung (2012) study the effect of an energy subsidy reduction with a general dynamic equilibrium model, calibrated for Egypt. The authors conclude that a reduction of 15% in energy subsidies could increase or decrease the country's GDP by 3%. The direction of this effect depends on the policy used by the government to substitute the subsidies. If investment in infrastructure were undertaken, the country's economy would grow. If the policy were substituted for lower taxes, the extra income and excess of energy would be exported at international prices, diminishing the GDP.

Anand *et al.* (2013) evaluate the impact of a reform designed to withdraw energy subsidies in India on the public budget and the population's well-being. This is a country that has elevated spending on subsidies, and increased its GDP by 0.8% between 2009 and 2010 and by 1.9% between 2011 and 2012. The authors argue that the benefit is seven times greater for 10% of the population's richest families than for the poorest 10%. They also calculate that the removal of these subsidies would have a negative impact of 4% on the low-income group's budget and of 5% for the highest income group. The article suggests that the following reforms be adopted: utilization of international petroleum prices as a reference for national prices; gradual removal of subsidies; and the implementation of a transfer income policy, as an offset for individuals from the lowest class.

Coady *et al.* (2017) estimate the worldwide cost of fuel subsidies as the difference between what should be paid at discounted prices, the environmental costs and consumption tax, and what is actually paid in fuel consumption. The quantity calculated is more than USD 4.9 billion for 2013, and is estimated at USD 5.3 billion for 2015, the equivalent of 6.5% of the world's GDP.

Dartanto (2013) argues that subsidy policies reduce the government's budget for sectors that could promote economic growth. The removal of subsidies and investment in infrastructure and education could reduce poverty in the long term, though it could increase in the short term. The author uses a computable general equilibrium model applied to the Indonesian economy to determine the relationship between subsidy policies and fiscal equilibrium, the impact of subsidy withdrawal on poverty, and the effectiveness of a policy to protect low-income families from the effects of subsidy withdrawal in the country. The results demonstrate that a 25% reduction in subsidies could increase poverty by 0.253%. Nonetheless, relocating 50% of the budget designated for the subsidy to transfer income policies could cancel out this increase in poverty.

Another approach is that of Plante (2013), who built a small open economy model and applied it to fuel export and import economies. The goal was to ascertain how subsidies affect macroeconomic variables in the long term, what the role of the subsidy financing method is in those results, and if the distinction between import and export economy is in fact representative. For the import economy model, the author used a lump-sum tax, a labor tax, or a consumption tax for non-fuel goods. In the export economy, the subsidy consists of the sale of fuels at a price lower than the international one. The results show that the subsidy reduces the aggregate economic well-being. This loss of well-being happens because of the distortion of relative prices and not as a result of the way subsidies are financed. The subsidy can also decrease the consumption of non-fuel goods, alter the allocation of work between sectors, and distort relative prices.

In the Brazilian case, Almeida *et al.* (2015) calculate that between 2011 and 2014, losses on gasoline, diesel and liquified petroleum gas importation were BRL 21 billion; the resulting income loss from fuel sales at a price lower than the international one was a total of BRL 98 billion. Between 2010 and 2013, Petrobras' market value decreased by 43%. The authors argue that the subsidy policy adopted by the government hampered investments by other businesses in the national petroleum refinement market, which became unattractive. To improve this situation, policies should be more transparent. For example, a stabilization fund could be created to buffer the elevation of fuel prices, if they are causing economic disequilibrium.

Bistafa (2016) uses a computable dynamic general equilibrium model to study the macroeconomic impacts of petroleum exploration and gasoline price control policies in the ethanol sector, during the period from 2011 to 2014. The author concludes that the gasoline price control policy provoked a 7% reduction in ethanol production, as compared to the scenario without the policy.

Cunha (2015), on the other hand, seeks to analyze the influence of diesel and gasoline prices on inflation in Brazil, calculating the direct effects, which consist of the influence of fuels on the inflation index, and indirect ones, which occur due to increases in input and freight costs.

The author utilized a product matrix input to evaluate the interdependence between productive sectors and as a consequence, identifies how readjustments in fuel prices affect the final price of other goods. Between 2005 and 2013, the 1% increase in the price of diesel caused an increase between 0.03 and 0.04% of the general index of market prices (GIMP). During the same period, a 1% increase in the price of gasoline elevated the General Consumer Price Index (GCPI) by values between 0.04 and 0.06%. The author concludes that the diesel price control policy contributed to inflation control, measured by the GIMP for the years 2007, 2009, 2010, 2011 and 2012. Gasoline price control contributed to GCPI control during the same years, in addition to in 2013.

This article aims to make an innovative contribution to the literature by introducing a model for calculating the changes that occur in consumption and production of fuels and other goods in the Brazilian economy when subsidies for fuel prices are withdrawn, and offset by a decrease in taxation. This work helps us, then, to understand the negative effects of the price control promoted in Brazil between 2011 and 2014, in addition to the potential benefits to the economy of removing subsidies.

3. METHODOLOGY

The model proposed by Plante (2013) was used here, adapted to the Brazilian economy, with the addition of taxation and a fuel production sector, which are not included in the original model. The model examines three sectors of the economy: fuels, tradable goods, and non-tradable goods. The government and families are also included in the model.

The Brazilian economy will be analyzed using data from 2013, evaluating what impact the subsidy withdrawal of 2014 could have on the economy. Accordingly, the new stationary state will be calculated in the absence of the subsidy, keeping in mind that when the government uses the subsidy, it must be financed with a tax increase. Additionally, the difference in relative prices of petroleum-derived goods also affects the stationary state of the economy.

Consumers

The function to be maximized for the actors is represented by:

$$U = \int_0^{\infty} \{ \frac{\left(a_2 C^{T\frac{\sigma_c - 1}{\sigma_c}} + a_1 O^{h\frac{\sigma_c - 1}{\sigma_c}} + C^{n\frac{\sigma_c - 1}{\sigma_c}}\right)^{\left(\frac{\sigma_c}{\sigma_c - 1}\right)\left(1 - \frac{1}{\tau}\right)}}{1 - \frac{1}{\tau}} - k_1 \frac{\left(L^n + L^T + L^0\right)^{1 - \frac{1}{\mu}}}{1 - \frac{1}{\mu}}$$
$$+ k_2 \frac{\left(m^{\frac{\sigma_m - 1}{\sigma_m}} + b_1 F^{\frac{\sigma_m - 1}{\sigma_m}}\right)^{\left(\frac{\sigma_m}{\sigma_m - 1}\right)\left(1 - \frac{1}{\tau}\right)}}{\left(P^{IPC}\right)^{1 - \frac{1}{\tau}} \left(1 - \frac{1}{\tau}\right)} \} e^{-\varphi s} ds \qquad (1)$$

The first part of the function represents the gains associated with the consumption of tradable, non-tradable, and petroleum-derived goods. C^T corresponds to the consumption of tradable goods, O^h to the consumption of petroleum-derived goods per family, C^n to the consumption of non-tradable goods, and *["y" missing in the Spanish]* σ_c*c* represents the elasticity of substitution between goods.

The second part of the function represents the reduction in gains derived from work. L^n is the job supply in the non-tradable goods sector, L^T is the job supply in the tradable goods sector, L^o is the job supply in the fuel sector, μ is wage elasticity in relation to job supply, and k_1 is a constant.

The third part portrays the gains from actors' assets. The parameter m represents local currency, F is foreign currency, b is the actual value of domestically circulated assets, σ_m is the elasticity of substitution between local and foreign currency, k_2 is a constant, and τ corresponds to the elasticity of intertemporal substitution.

The maximization of gains is subject to the restriction of wealth:

$$A = m + b + F \qquad (2)$$

And to flow restriction:

$$\frac{\partial A}{\partial t} = (1 - \tau^1)(W^n L^n + W^T L^T + W^0 L^0) + (1 - \tau^k)(i - \chi)b$$
$$- (1 + \tau^c)(P^T C^T + P^n C^n) - (1 + \tau^{ch}) P^a O^h - \chi m \qquad (3)$$

The consumer earns income $W^n L^n$ from work in the non-tradable goods sector, $W^T L^T$ in the tradable goods sector, or $W^o L^o$ in the petroleum-based goods sector, where W^i represents the actual income for each sector $i = n, T, O$. Assets also generate income at an interest rate i, minus inflation χ. Taxes τ^l and τ^k are collected for work and capital income, respectively. Income is used for the consumption of goods, where there is also tax τ^c, and for fuel consumption, which is taxed at τ^{ch}. Families still pay the government an inflation tax χm. Variable P^T represents the price of tradable goods, and P^n the price of non-tradable goods. Variable P^a is the domestic fuel sale price, which is less than the international price.

Assuming that the equal purchasing power is valid, such that it is possible to establish a relationship between the domestic price of C^n, P^n, and the international price of tradable goods, P^T.

$$p^n = e \cdot P^T \tag{4}$$

Where e is the nominal rate of change, measured in reals per dollar. The depreciation rate of the currency will be:

$$\chi = \frac{\dot{e}}{e} \tag{5}$$

Inflation for tradable goods is determined by:

$$\pi = \chi + \pi^T \tag{6}$$

Since this concerns a small open economy, international prices are not affected, and one can assume that P^T is constant and equal to *1*, such that $\pi = \chi$. The consumer price index equation is determined by:

$$P^{IPC} = \left(P_n^{1-\sigma_c} + \alpha_1^{\sigma_c} P^{S^{1-\sigma_c}} + \alpha_2^{\sigma_c} P^{T^{1-\sigma_c}} \right)^{\frac{1}{1-\sigma_c}} \tag{7}$$

Producers

Companies operate in perfect competition using labor and petroleum-based goods as inputs. There is a representative company for each sector, and the production function is of the Constant Elasticity Substitution type.

$$Q^T = \left[\left(A^T L^T \right)^{\frac{\sigma_T - 1}{\sigma_T}} + c_1 \left(O^T \right)^{\frac{\sigma_T - 1}{\sigma_T}} \right]^{\frac{\sigma_T}{\sigma_T - 1}} \tag{8}$$

$$Q^n = \left[\left(A^n L^n \right)^{\frac{\sigma_n - 1}{\sigma_n}} + d_1 \left(O^n \right)^{\frac{\sigma_n - 1}{\sigma_n}} \right]^{\frac{\sigma_n}{\sigma_n - 1}} \tag{9}$$

Producers maximize their profits:

$$\max_{L^i O^i} Q_i - \frac{W^i}{P^i} L^i - \left(1 + \tau^{ok} \right) \frac{P^S}{p^i} O^i \tag{10}$$

Where $i = T, n$. Parameter A_T represents a scale factor, c_1 and d_1 are distribution parameters, and σ_n is the elasticity of substitution between labor and petroleum-based inputs.

There is also a representative fuel producing company, with the following production function:

$$Q^o = \left(A^o L^o \right)^{\xi} \tag{11}$$

The company maximizes profits:

$$\max_{L^o} Q^o - \frac{W^o}{P^s} L^o \tag{12}$$

Government

Government income is acquired through taxes on consumption and labor, and through seigniorage. The government finances subsidies for the importation of petroleum-based goods, buying at international price P^o and selling domestically at a lower price, P^s. The budgetary restriction is given by:

$$\frac{\partial m}{\partial t} = (P^o - P^S)\gamma(O^h + O^T + O^n) - \tau^l(W^n L^n + W^T L^T + W^o L^o)$$
$$- \tau^k(i - \chi)b - \tau^C(C^T + P^n C^n)$$
$$- \tau^{oh}(P^S O^h + P^S O^T + P^S O^n) - \chi m \quad (13)$$

Current Account

In the external sector account, variation in international currency reserves is reflected by the difference between exported and imported goods, including those derived from petroleum.

$$\frac{\partial F}{\partial t} = P_T Q^T - P_T C^T - \gamma(P^o O^h + P^o O^T + P^o O^n) \quad (14)$$

Where γ represents a parameter used to measure the subset of fuel demand in Brazil that is imported. Resolving the problem of maximizing consumer assets and companies' profits, it obtains the equilibrium equations in a stationary state.

For the maximization of family assets:

$$a_2 \cdot (1 + \tau^{oh}) P^s O^h \cdot O^{h\frac{1-\sigma_o}{\sigma_o}} = a_1 \cdot (1 + \tau^c) P_T \cdot C^T \cdot C^{T\frac{1-\sigma_o}{\sigma_o}} \quad (15)$$

$$(1 + \tau^{oh}) P^s O^h \cdot O^{h\frac{1-\sigma_o}{\sigma_o}} = a_1 (1 + \tau^c) P^n \cdot C^N \cdot C^{N\frac{1-\sigma_o}{\sigma_o}} \quad (16)$$

$$W^T = W^n = W^O \quad (17)$$

$$b_1 F^{\frac{-1}{\sigma_m}} \cdot [(1 - \tau^k) i + \tau^k \chi] = m^{\frac{-1}{\sigma_m}} \cdot (1 - \tau^k)(i - \chi) \quad (18)$$

$$\rho = (1 - \tau^k)(i - \chi) \quad (19)$$

For the maximization of companies' profits:

$$P_T \cdot Q^T (Q^T)^{\frac{1-\sigma_T}{\sigma_T}} (A^T)^{\frac{\sigma_T - 1}{\sigma_T}} (L^T)^{\frac{-1}{\sigma_T}} = W^T \quad (20)$$

$$P_T \cdot Q^T (Q^T)^{\frac{1-\sigma_T}{\sigma_T}} = (1 + \tau^{oh}) \cdot P^s O^T \cdot O^{T\frac{1-\sigma_T}{\sigma_T}} \quad (21)$$

$$P_N \cdot Q^N (Q^N)^{\frac{1-\sigma_N}{\sigma_N}} (A^n)^{\frac{\sigma_N - 1}{\sigma_N}} (L^n)^{\frac{-1}{\sigma_n}} = W^N \quad (22)$$

$$P_N \cdot Q^N (Q^N)^{\frac{1-\sigma_N}{\sigma_N}} = (1 + \tau^{oh}) \cdot P^s O^N \cdot O^{N\frac{1-\sigma_N}{\sigma_N}} \quad (23)$$

$$Q_o = (A_o L_o)^{\xi} \quad (24)$$

$$L_T = \frac{P_T Q^T - (1 + \tau^{oh}) \cdot P^s O^T}{W} \quad (25)$$

$$L_n = \frac{P_n Q^n - (1 + \tau^{oh}) \cdot P^s O^n}{W} \quad (26)$$

For government restrictions:

$$P_n \bar{G} + \bar{T} + (P^o - P^S) \cdot \gamma \cdot (O^h + O^T + O^n)$$
$$= \tau^l (W^n L^n + W^T L^T + W^O L^O) + \tau^k (i - \chi) b +$$
$$\tau^c (P^T C^T + P^n C^n) + \tau^{oh} (P^s O^h + P^s O^T + P^s O^n) + \chi m \quad (27)$$

For market equilibrium:

$$P_N \cdot C^n + P_N \cdot \bar{G} = P_N \cdot Q^n \tag{28}$$

$$P_T \cdot Q^T = P_T \cdot C^T + \gamma \left(P^O O^h + P^O O^T + P^O O^n \right) \tag{29}$$

$$P^s \cdot Q^O = \left(1 - \gamma \right) \cdot P^s \cdot \left(O^h + O^T + O^n \right) \tag{30}$$

Inflation equation:

$$P^{IPC} = \left(P_n^{1-\sigma_c} + \alpha_1^{\sigma_c} P^{S^{1-\sigma_c}} + \alpha_2^{\sigma_c} P^{T^{1-\sigma_c}} \right)^{\frac{1}{1-\sigma_c}} \tag{31}$$

The research strategy consisted of gauging the initial stationary state of the economy with the aid of data on the Brazilian economy and of the equilibrium equation system. Some variables and parameters were removed from the Brazilian economy for 2013, while some others were found to resolve the system of equilibrium equations.

4. DATA AND CALIBRATION

Production and Productivity

The hypothesis recognized industry and agriculture as tradable goods, and services as non-tradable goods. The production values multiplied by the price of tradable $(P_T \cdot Q^T)$ and non-tradable goods $(P_n Q^n)$ correspond to the GDP of industry and agriculture and to the GDP of services, respectively. The fuel consumption per family was subtracted form the value of tradable goods. Government spending $(P_N \cdot \bar{G})$ is the part of the GDP corresponding to the public sector.

The GDP was calculated as the sum of domestic production and tradable, non-tradable, and fuel-based goods. Per the hypothesis, the GDP value was fixed at 1. The labor productivities of tradable and non-tradable goods were obtained from the work of Menezes *et al.* (2014).

Prices and Interest

The subsidized price of fuel was considered to be the price of gasoline in 2013, which was BRL 2.80. In 2013, Petrobras resold gasoline at a price on average 14% lower than the international price (Agencia Nacional de Petróleo-ANP, 2014, p. 153). The price without subsidy was calculated, then, according to the 14% increase in price realized by Petrobras, which was BRL 0.85, according to data obtained from the National Petroleum Agency [Portuguese ANP] (2014). The inflation rate used was given by the Harmonized Index of Consumer Prices for 2013, calculated by the Brazilian Institute of Geography and Statistics [Portuguese IBGE] and the interest rate is the basic rate for the economy (Special System for Settlement and Custody) valid for December of this year, provided by the Central Bank of Brazil.

Capital

Domestically circulated assets were calculated by the budgetary restriction:

$$\begin{aligned} &P_n C_n + P_T C_T + P_S O_h + \left(P_o - P_S \right) \cdot \gamma \cdot O + P_n G = \\ &W \cdot L + \tau_{oh} \cdot P_S \cdot \left(O_n + O_T \right) + b \cdot \left(i - \chi \right) \end{aligned} \tag{32}$$

Consumption, Work Hours, and Wages

The consumption of petroleum-based goods multiplied by its price $(P_s \cdot O)$ was found in the Resource and Usage Table of the IBGE National Accounts. The values O^h, O^T, and O^n are the quantities consumed per family and by companies which produce tradable and non-tradable goods, respectively, divided by P_s.

The total work hours correspond to the proportion of hours worked during the week (44), out of a total of 168 hours per week, resulting in the value 0.2619, such that $L = L^n + L^T + L^O = 0.2619.$

The values of L^n and L^T are calculated with equation (10) and are 0.1967 and 0.00617, respectively. Variable L^O corresponds to the difference between L and $L^n + L^T$, which is 0.0035.

Work performance is the production of tradable and non-tradable goods, excluding fuel consumption by companies. The wage is calculated by dividing work performance by total work, L. All wages are equal, so that families may offer jobs in all three sectors.

Tax Revenue

Tax revenue data was obtained from the "Brazilian Tax Burden 2013" publication by the Department of Federal Revenue of Brazil [Portuguese RFB] (RFB, 2014) and from the Revenue Table by Economic Sector, issued by the same department. The data relevant to the Merchandise and Service Circulation Tax [Portuguese ICMS] were obtained from Brazil's National Financial Policy Council [Portuguese CONFAZ] website and from the contribution to the Federal Savings Bank's Severance Indemnity Fund .

To calculate the ratios, the total revenue was divided by the respective calculation basis. Accordingly, the work ratio was calculated by dividing tax income by employment income according to the RFB (2014), by work output.

$$\tau_t = \frac{IRPF + IRRF + Cont.\,Previd. + FGTS + Sist.S + Sal.Educación}{Rendimiento\ del\ trabajo} \qquad (33)$$

The actual ratio of capital tax is calculated by the sum of current capital income tax revenue divided by the return on capital.

$$\tau_k = \frac{(ITR + ITCD + ITBI + IOF + IRRF - Capital)}{(i - \chi)b} \qquad (34)$$

The consumption tax corresponds to the total of families' consumption taxes, except for the portion of that tax revenue related to fuels. The revenue data was obtained from the RFB (2013) and the data referring to federal revenue for fuels from the same source . The ICMS data on fuels was taken from the ICMS CONFAZ bulletin website .

$$\tau_C = \frac{IPI + ICMS + ISS + II + COFINS + PIS + PASEP}{(C/Y)} \qquad (35)$$

The ratio of actual fuel taxation is calculated from the fuel consumption tax divided by total fuel consumption.

$$\tau_{cb} = \frac{ICMS(combustible) + COFINS(combusible) + PIS(combustible) + CIDE}{((O^h + O^T + O^n)/Y)} \qquad (36)$$

Other Variables

The quantity of national currency consists of the monetary base at the end of 2013 – M0 (paper money issued plus bank reserves). Foreign currency is equal to the total international reserves as of December 2013. The amount of foreign currency has been multiplied by the average annual exchange rate of 2013. All of the foregoing data were found on the Brazilian Institute for Applied Economic Research's database [Portuguese IPEADATA] website.

The percentage of imported fuel was calculated with data from the ANP (2014). Fuel production represents the percentage of spent fuel produced by the country.

The value of elasticity of substitution for consumption is considered to be $\sigma_c = 0.75$, as in Plante's article (2013). For greater credibility, it was considered to be a situation of low substitutability between fuel consumption, tradable, and non-tradable goods, $\sigma_c = 0.25$; an initial stationary state was calibrated for each elasticity.

The values for $P^n C^n$ and $P^T C^T$ were obtained with equations (28) and (29). The values for Q^T and Q^n were calculated with equations (20) through (23), and Q^T and Q^n with equations (20) and (22). $P^n Q^n$ and $P^T Q^T$ were divided by the production values to obtain prices. Consumption values were determined by the division of $P^n C^n$ and $P^T C^T$ by the prices.

Variables a_1 and a_2 were calculated using equations (15) and (16); $b1$ and ρ with (18) and (19); and T, A_o, $Pipc$ with (27), (11), and (31), respectively. Parameter ζ was obtained with the following equation, resulting from equation (12):

$$W^o = P^s \zeta \cdot A^{\alpha\zeta} \cdot L^{\alpha\zeta - 1} \tag{37}$$

The values of each variable are found in Tables 1 and 2:

Table 1. Information on the Brazilian Economy of 2013

Statistic	*Sign*	*Value*	*Source*
Government spending (% GDP)	P^nG	0.2103	IBGE
Tradable sector production (% GDP)	P^TQ^T	0.2525	IBGE
Non-tradable sector production (% GDP)	P^nQ^n	0.6609	IBGE
Tradable sector hours worked	L^T	0.0617	IBGE
Non-tradable sector hours worked	L^n	0.1967	IBGE
Fuel sector hours worked	L^o	0.0035	IBGE
Fuel consumption by family (% GDP)	P^zO^h	0.0339	IBGE and ANP
Tradable sector fuel consumption (% GDP)	P^zO^T	0.0473	IBGE and ANP
Non-tradable sector fuel consumption (% GDP)	P^zO^n	0.0258	IBGE and ANP
Percentage of imported fuel	γ	0.1907	ANP
Subsidized fuel price (BRL)	P^z	2.8	ANP
Non-subsidized fuel price (BRL)	P^o	2.94	ANP
Amount of national currency	m	0.0521	IPEADATA
Amount of foreign currency	F	0.1616	IPEADATA
Inflation (%)	χ	0.0591	IBGE
Interest rate (%)	i	0.1	Central Bank of Brazil [Portuguese BACEN]
Actual work tax percentage (%)	τ_l	0.1574	RFB and IBGE
Actual capital tax percentage (%)	τ_k	0.2253	RFB and IBGE
Actual fuel tax percentage (%)	τ_{ok}	0.1534	RFB and IBGE
Actual consumption tax percentage (%)	τ_c	0.2027	RFB
National and foreign currency elasticity of substitution	σ_m	0.75	Plante (2013)
Tradable sector productivity	A_T	29.9	Menezes *et al.* (2014)
Non-tradable sector productivity	A_n	14.8	Menezes *et al.* (2014)
Domestically traded assets	b	1.8436	RFB and IBGE

Source: Prepared by the authors.

Table 2. Calibration of Initial Stationary State

Parameter	Sign	Values (σ_c)	
		0.25	*0.75*
Non-tradable sector consumption	C_n	2.1648	2.1648
Tradable sector consumption	C_T	4.1026	4.1026
Wage	W	3.2082	3.2082
Weight of foreign currency as a function of utility	b_1	1.5794	1.5794
Non-tradable goods price	P^n	0.2081	0.2081
Tradable goods price	P^T	0.0563	0.0563
Weight of fuels as a function of utility	a_1	1.2638e-08	0.0128
Weight of tradable goods as a function of utility	a_2	3.4900	0.6345
Non-tradable sector elasticity of substitution	σ_n	2.1311	2.1311
Tradable sector elasticity of substitution	σ_T	1.3781	1.3781
Transactions	T	0.0956	0.0956
Fuel production	Q^O	0.0309	0.0309
Fuel sector elasticity of substitution	ζ	0.1295	0.1295
Price level	$Pipc$	0.3854	0.3854
Discount rate	ρ	0.0317	0.0317
Non-tradable goods production	Q^n	3.1755	3.1755
Tradable goods production	Q^T	4.4833	4.4833
Fuel sector productivity	A_o	6.336e-10	6.336e-10

Source: Prepared by the authors

5. RESULTS

Having calculated all of the values, the fuel price value was changed so as to reduce the effect of taxes on the amount spent with the subsidy. What is seen, then, is a neutral change in revenue. There is also a simulation of eliminating the subsidy without changing tax rates.

The subsidy represented 0.45% of the GDP in 2013. This value was calculated from the difference between the subsidized price and the non-subsidized price, multiplied by the amount of fuel consumed. This amount was subtracted from the revenue of each tax to calculate the new contribution.

It was assumed that the price of tradable goods is internationally fixed, such that it was not affected by the changes in subsidies and taxation. Table 3 shows tax contributions when the subsidy policy was in use, and after it was eliminated.

Table 3. Tax Contributions

Tax	With subsidy (%)	Without subsidy (%)
On consumption	20.27	19.49
On fuel consumption	15.34	9.85
On capital income	22.53	15.43
On work income	15.74	15.11

Source: Prepared by the authors.

Tables 4 and 5 demonstrate the changes effected by the selected variables when the fuel price subsidy is withdrawn and the aliquot of each tax is diminished to offset it. To calculate utility variations, the intertemporal elasticity of substitution values and the wage elasticity in relation to job supply from Plante's article (2013) were applied. The values are $\tau = 0.5$ and are $\mu = 1$. Constants are k_1 and are k_2 were taken to be equal to 1.

Table 4. Results for σ_c =0.25

Variable	Without change in taxation (%)	τ_c = 0.1949 (%)	τ_{ch} = 0.0985 (%)	τ_k = 0.1543 (%)	τ_l = 0.1511 (%)
C^T	-0.37	1.73	1.66	2.04	1.70
C^n	-0.11	2.00	1.66	2.31	1.97
U	0.00	-0.01	-0.01	1.30	-0.01
P^n	-1.05	-1.05	0,00	-1.05	-1.05
W	-1.32	-1.32	0,00	-1.32	-1.32
L^o	-41.12	-31.94	12.45	-30.13	-31.75
L^n	0.50	1.95	1.13	2.16	1.93
L^T	0.93	3.04	1.65	3.36	3.02
O^h	-1.58	0.33	1.66	0.80	0.47
O^t	-7.35	-5.41	1.65	-5.12	-5.42
O^n	-11.95	-10.69	1.13	-10.50	-10.70
Q^T	-0.90	1.17	1.65	1.48	1.15
Q^n	-0.07	1.36	1.13	1.57	1.35
Q^o	-6.63	-4.86	1.53	-4.54	-4.83
$Pipc$	-0.43	-0.43	0.23	-0.43	-0.43
χ	0.00	0.00	0.00	5.80	0.00
m	0.00	0.00	0.00	-2.75	0.00

Source: Prepared by the authors.

Cuadro 5. Resultados para σ_c =0.75

Variable	Without change in taxation (%)	τ_c = 0.1949 (%)	τ_{ch} = 0.0985 (%)	τ_k = 0.1543 (%)	τ_l = 0.1511 (%)
C^T	-0.62	1.49	1.66	1.79	1.46
C^n	0.17	2.30	1.66	2.60	2.27
U	0.00	-0.01	-0.01	1.31	-0.01
P^n	-1.05	-1.05	0.00	-1.05	-1.05
W	-1.32	-1.32	0.00	-1.32	-1.32
L^o	-45.41	-37.37	12.45	-35.22	-36.72
L^n	0.70	2.16	1.13	2.36	2.13
L^T	0.62	2.73	1.65	3.05	2.71
O^h	-4.19	-2.63	1.66	-1.86	-2.19
O^t	-7.63	-5.69	1.65	-5.40	-5.71
O^n	-11.78	-10.50	1.13	-10.32	-10.53
Q^T	-1.21	0.87	1.65	1.17	0.84
Q^n	0.12	1.57	1.13	1.77	1.55
Q^o	-7.54	-5.88	1.53	-5.47	-5.75
$Pipc$	-0.44	-0.44	0.23	-0.44	-0.44
χ	0.00	0.00	0.00	5.81	0.00
m	0.00	0.00	0.00	-2.75	0.00

Source: Prepared by the authors.

Removal of Subsidy without Offset by Tax Reduction

When the removal of the subsidy is not offset by a tax reduction, the amount of income at consumers' disposal decreases, causing a consequent decrease in fuel consumption and consumption of tradable and non-tradable goods. When the elasticity of substitution between fuels and other goods is greater, individuals decrease their fuel consumption even more, and increase their consumption of non-tradable goods.

Just as consumption suffers a decrease, the production of all goods is also reduced. Producers of tradable and non-tradable goods also substitute fuel for work, increasing its demand. In the case that non-tradable goods consumption increases, its production will also increase. With an increase in costs for producers, wages decrease.

The price level decreases, so the increase in fuel prices is more than offset by the lowering of non-tradable goods prices. The value of consumer gains is reduced somewhat, because the amount consumed does not increase sufficiently to compensate for the increase in hours worked.

Reduction in Percentage of Consumption Tax

With the increase in fuel prices, there is less consumption during production. When the elasticity of substitution between fuel and other goods is greater, families have more ability to adapt to changes in price and also reduce their fuel consumption, substituting it with the consumption of other goods. When such elasticity is lower, families augment their fuel consumption, given the higher availability of income proportional to the tax reduction. As fuel consumption decreases, the amount of fuel produced nationally also decreases.

The number of hours worked increases, and wages decrease. Work income, consequently, does not see much of a change. With tax reductions, families increase their consumption of other goods. In the case of higher elasticity, consumption increases even more.

The production of non-tradable goods is increased in order to fulfill the higher demand. With an increase in supply, non-tradable goods prices decrease. The price of tradable goods stays constant, given that it is determined internationally. The production of tradable goods also increases, in order to meet the higher demand for such goods.

Producers reduce wages in order to offset the increased fuel costs and increase the demand for labor. With the increase in goods production, producers also replace fuel for work, and hours worked in the tradable and non-tradable goods sectors increase. The fuel sector goes on to produce less. Work in this sector, then, decreases.

The price reduction of non-tradable goods more than compensates for the fuel price increase and the price level reduces. Like in the previous case, the value of family gains is reduced, and the increase in work hours has a greater impact than increased consumption.

Reduction of Fuel Tax Percentage

With the withdrawal of the subsidy and the decrease in fuel taxation, the price of fuel does not change. Its consumption increases, both in production and by families. With more fuel consumption comes greater production, in addition to an increase in the amount of work used as an input in production. The amount of work increases in all sectors, while wages remain constant. With more income available, families consume more tradable and non-tradable goods, in addition to consuming more fuel.

With the higher consumption and utilization of inputs—labor and fuel—, the quantity of these commodities being produced also increases. The price of non-tradable goods remains constant. The price level increases slightly because, without taking into account tax rates, the price of fuel increases. Family gains are reduced somewhat, given the increase in work, which exceeds the consumption increase in the calculation of consumer well-being.

Reduction of Capital Tax Percentage

When capital taxes are reduced, work increases more than when consumption taxes are reduced, generating more income for families. Consumption of all goods increases or decreases, in the case of fuels in the 0.75 elasticity scenario. Production of tradable and non-tradable goods increases further. In this case, gains increase, thanks to the greater increase in consumption, exceeding the increase in work.

Reduction of Employment Income Tax Percentage

With the reduction of labor taxes, the consumer has more income available and increases consumption of tradable and non-tradable goods, and fuels. When the elasticity of substitution between fuels and other goods is 0.75, families begin to consume less fuel and increase their consumption of non-tradable goods.

The production of tradable and non-tradable goods increases in order to supply the higher demand. Companies substitute fuels, which have become more expensive, with labor. The changes are similar to what occurs when consumption taxes are reduced, which also results in greater availability of family income, resulting in lower product prices.

Comparison with Results from the Literature

The results found here are similar to those presented by Pereira and Pereira (2014) in relation to operative costs and energy consumption. As was found in that work, the increase in fuel prices decreases consumption by businesses. On the other hand, the authors conclude that employment decreases, while the results obtained here suggest that it increases.

Plante (2013) concluded that the creation of subsidy policies increases the number of hours worked and actual wages, while in this study, the conclusion is that the removal of subsidies, in the majority of cases, increases the number of hours worked but reduces actual wages. Plante (ibid.) argues that the subsidy policy reduces families' well-being. In this article, well-being remains almost constant, given that despite the increase in consumption with the withdrawal of the subsidy, the number of hours worked increases.

The subsidy values calculated in this analysis were similar to those found by Almeida *et al.* (2015). The amounts calculated by those authors were a BRL 21 billion loss with gasoline importation, and a BRL 98 billion loss with sales at a lower price than the international price, both for the four-year period of the subsidy policy. Accordingly, the annual loss was around BRL 5 billion and BRL 25 billion, respectively, very similar to the 0.11% of the GDP for the importation subsidy and the 0.48% of the GDP for the total sales at a lower price than the international price calculated in this study.

Comparison Between Cases

As was expected, the case which introduces the subsidy removal without any tax reduction is more detrimental to the economy. The consumption and production of goods decreases and work increases in the tradable and non-tradable goods sectors.

Meanwhile, in the case of fuel tax reduction the opposite occurs, with increased consumption and production of all kinds of goods, and thus presenting itself as the best option for the country's economy. When other taxes are altered an intermediate result is obtained, with an increase in production and consumption of some goods and a reduction of others.

6. CONCLUSIONS

This work aimed to evaluate the possible economic impacts caused by the removal of fuel subsidies utilized in the Brazilian economy between 2011 and 2014. For this purpose, Plante's (2013) macroeconomic model was adapted to the Brazilian economy.

The results suggest that the removal of the fuel subsidy, compensated by a reduction in consumption, capital, or labor taxes, decreases fuel consumption and increases consumption and production of other goods.

When the removal of the subsidy is offset by a reduction of fuel taxes, consumption and productivity of all other goods increases, leading to a positive economic situation, though the model doesn't consider the negative externalities caused by the increased consumption of fuel energy.

Until a certain point, this was the strategy used by president Dilma Rousseff's government in 2011, when the CIDE tax on fuel was reduced to zero, as a way to avoid fuel price increases. The salient point is that afterwards, the only option was to reduce federal taxes, and the government explicitly assumed control of prices. This situation was worsened in 2015, when the federal and state governments promoted a tax increase on gasoline, along with the removal of subsidies. What this paper suggests is that a more appropriate path would have been the opposite one: to remove subsidies while decreasing taxes. Despite this, the worsening of the fiscal situation was ultimately more important, and taxes were raised.

The model has limitations in relation to the number of variables that can be analyzed, like the percentage of imported fuel and government spending. Environmental impacts are not analyzed either. For future work, an analysis of the variables not studied here is recommended, given the limitations of the model, such as the impact of removing subsidies for different social classes of Brazilian society. It would also be interesting to adopt a model which allows for an analysis of the economy's transition to a scenario without subsidies. The contribution of subsidies to the increase of negative externalities caused by fuels could also be verified, like increases in transportation and contamination.

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