Norwegian University
of Life Sciences

Master's Thesis 2022 30 ECTS
School of Economics and Business

The Impacts of the Biodiesel Policy and Regulation on the Demand for Soybean Oil in Brazil

Rodrigo dos Santos Lara
Master of Science in Economics with Specialization in Agribusiness and Food Economics

Acknowledgments

Once I heard that gratitude is the only treasure of the humble ones. It made sense to me. Gratitude is acknowledging that nothing can be achieved without the help of others.

First and foremost, I am grateful for the opportunity to have an education. I come from a family that very few have had such an opportunity. My grandmother, for example, cannot read or write. Education should never be taken for granted. Education is power. Education changes lives. Education enables social mobility. Education unites.

I am grateful for my family, my parents Olga and Antonio and my siblings Dayane and Gabriel, who believed in me even when my dreams seemed too big.

I am grateful for my partner Magnus who has helped me throughout this master's degree. He was the one who supported me while I was locked in the room for hours, days, months writing this thesis.

I am grateful for my supervisor Roberto Garcia. I am so impressed by how fast he can provide thorough feedback. I felt challenged by his high expectations. I learned so much from him during this process of writing this thesis that would not fit here. Muchas gracias!

I am grateful for Aida Ardebili who kindly provided valuable insights and suggestions on the data modelling part of this thesis. She has always been there for me since the very beginning of this degree when I was still in Brazil. Thank you!

I am grateful for everyone who directly or indirectly helped me get where I am and to finish a master's degree in Norway.

The Impacts of the Biodiesel Policy and Regulation on the Demand for Soybean Oil in Brazil

Abstract

Brazil started producing ethanol in 1975 as a response to the oil shocks from the 1970s. The Brazilian Ethanol program implemented the production and use of the new fuel by offering tax breaks and low-interest loans to sugarcane producers and to the automobile industry to produce cars that ran on ethanol. The ethanol program used regulation establishing a minimum amount of ethanol to be blended with gasoline. The program successfully implemented and encouraged the use of ethanol, reduced the use of gasoline, and boosted the sugarcane sector in Brazil.

Following suit, the National Program for the Production and Use of Biodiesel was launched in 2004. The biodiesel program's main objectives were to create a domestic market for soybeans, to reduce diesel imports, and to have a green fuel as a substitute to diesel. The program also made use of regulation starting at 2 per cent of biodiesel to be blended with diesel which would, according to the plan, reach 15 per cent in 2023. In September 2021, the biodiesel content in diesel was reduced from 13 to 10 per cent to avoid an increase in diesel prices due to high soybean oil prices. Soybean oil is the main raw material for biodiesel in Brazil accounting for almost 70 per cent of the total. In 2020, due to the increase in the domestic demand, Brazil imported its second highest volume of soybean oil since 1961.

This study aims at investigating whether the governmental decision to reduce in three per cent the biodiesel content in diesel makes sense considering the impact of the biodiesel policy and regulation on the demand for soybean oil. To do so, monthly data between January 2008 and December 2021 are used to analyze demand using Ordinary Least Squares (OLS) regression. First, we estimate the impact of the biodiesel production volumes on the demand for soybean oil – representing the impact of the biodiesel policy. Then, we estimate how much the impact of the biodiesel policy changes when the content of biodiesel in diesel is higher than 10% – representing the impact of the biodiesel regulation. The results show that the biodiesel policy has a positive impact on the demand for soybean oil which increases by 0.23% given a 1% increase in the production of biodiesel. When the regulation is in place, the impact of the biodiesel policy goes from 0.23 to 0.49%. The governmental decision from September 2021 to reduce the biodiesel content in diesel in three per cent makes sense considering the impact of the biodiesel policy and regulation on the demand for soybean oil. The regulation has a clear impact on the dynamics of the market. Reducing the content of biodiesel in diesel comes to soften the pressure on the domestic supply of soybean oil and to avoid an increase in the prices of diesel driven by high soybean oil prices.

Keywords: Biofuels; Biodiesel; Soybeans; Soybean Oil; Demand; Regulation.

Table of Contents

1 – Introduction 1
2 – Background 5
2.1 – Petroleum crises and the instability in Brazil 5
2.2 – Sugarcane and Ethanol as a response to crisis and instability 7
2.3 – Oilseeds and biodiesel 8
2.4 – Soybeans and Soybean Oil in Brazil 13
2.5 – Diesel and Biodiesel 16
3 – Theory 18
3.1 – Consumer Theory 18
3.2 – Government Intervention in the Market 19
3.3 – Commodity Market 21
3.4 – Related Literature 22
4 – Data and Methodology 25
4.1 – Data 25
4.2 – OLS regression with time series data 26
4.3 – The Model 28
5 – Results 30
5.1 – Model Specification 30
5.2 – Model Estimation and Results 34
6 – Conclusion 38
6.2 – Limitations and Recommendations for Future Research 39
Bibliography 40

List of Tables

Table 1: Petroleum import and demand 6
Table 2: Diesel share of total fuel demand 9
Table 3: Expected biodiesel content in diesel until 2023 12
Table 4: Brazilian Soybean Market 14
Table 5: Brazilian Soybean Oil Market 15
Table 6: Brazilian Diesel Market 16
Table 7: Biodiesel Production Volumes 17
Table 8: Descriptive Statistics 30
Table 9: Dickey-Fuller Test for Stationarity 30
Table 10: Dickey-Fuller Test with a Trend for Stationarity 31
Table 11: VIF Test for Multicollinearity 34
Table 12: Regression Results 35

List of Figures

Figure 1:Kernel Density test for Normality 35

The Impacts of the Biodiesel Policy and Regulation on the Demand for Soybean Oil in Brazil

1 – Introduction

Since the oil shocks of the 1970s, the world has been trying to find substitutes for petroleum-based fuels. Even though the reasons for this differ from country to country and throughout time, the major reasons were to reduce the dependency on imported oil and to curb green-house gases emissions (Leite & Leal, 2007). In 1973, OPEC halted the supply of petroleum to Israel allied countries for a period of six months during the Yom Kippur War – this is known as the Arab oil embargo. As a result, the oil prices skyrocketed – the US dollar price of a barrel increased from $3 to $12 dollars between 1973 and 1974 (Nunes, 2016). Then, in 1979, Iran was unable to keep up its share of petroleum supply to the world in the aftermath of the Iranian Revolution, reducing the world oil supply by 8 per cent. Consequently, the barrel price went from $12.76 in 1978 to $35.70 in 1980 (Melo, 2008). The second motivation for the search for alternative fuels was the concern with the air quality in big cities and the negative effects of vehicle gases emissions. However, this issue only became known after 1980 when scientists started warning governments about global warming and became more relevant after 1997 when the Kyoto Protocol was signed (Leite & Leal, 2007).

Biofuel production had started 22 years before in Brazil. In 1975, the Brazilian Ethanol program was introduced as a response to the increase in the oil price. Brazil was heavily dependent on oil imports. It produced 160,000 barrels per day which was only 20 per cent of the domestic demand (Pugliese et at., 2017). The program would support the production and use of ethanol, a domestic substitute to gasoline. Ethanol is produced from sugarcane and its expansion in production boosted the sugarcane sector by creating a new domestic market for the grass. Between 1975/1976 and 1989/1990 in Brazil the total crushed volume of sugarcane increased from 68 to 222 million tons and the total ethanol produced went from 555,000 to 11 million cubic meters. Only in 1989 did Brazil start exporting ethanol with a volume of 39,000 cubic meters which became 407,000 cubic meters in 1999 (MAPA, 2007). The program used regulation in the form of mandates establishing a minimum amount of ethanol to be blended with gasoline. Currently, most small and medium-sized vehicles run both on gasoline and ethanol in Brazil.

In 2004, Brazil launched the National Program for the Production and Use of Biodiesel, or the biodiesel program, which would support the production and use of biodiesel. It can be argued that the biodiesel program was an improved version of the ethanol program because it included social and regional development objectives. The expectations were to accrue similar, or even better, benefits than those from the ethanol program. The biodiesel program's mains objectives were to create a domestic market for soybeans, to reduce diesel imports and to have a green fuel as a substitute to diesel (Pedroti, 2011). The program also made use of regulation by setting a minimum content of biodiesel to be added in diesel starting at 2 per cent in 2008 and reaching 15 per cent in 2023 (CNPE, 2018). The biodiesel content is added to diesel by fuel distributors before the fuel is sold to gas stations. A regulation of 13 per cent means that if 100 liters of diesel are sold, 87 liters are petroleum diesel and 13 liters are biodiesel.

Biofuel policies have had impacts on the different commodity markets both in Brazil and abroad. There has been some news about a potential competition between food and biofuel industries for the same commodities which could lead to an increase in food prices. An example of such a trend is in the US where the incentives for cleaner fuels and the increased capacity of biofuel production and increased the demand for vegetable oils there. Food companies are competing with energy companies for the same commodity which caused soybean oil prices to more than double between 2019 and 2021 in the United States (Terazono & Jacobs, 2021).

In Brazil, soybean oil was the main raw material used in the production of biodiesel accounting for about 70 per cent of the total between 2017 and 2020 (ANP, 2022a). To produce one liter of biodiesel, 1.3 liters of soybean oil are required (Elgharbawy et al., 2021). Soybean oil imports have been increasing to meet the domestic demand. In 2020, Brazil imported its second highest volume of soybean oil since 1961 (FAOstat, 2022) and soybean oil consumption increased by 314 per cent in comparison with 2019 (ABIOVE, 2022). To avoid an increase in diesel prices led by high soybean oil prices, the Brazilian government decided to reduce from 13 to 10 per cent the minimum content of biodiesel in diesel for November and December 2021(Senado Federal, 2021). This change came as a surprise to soybean farmers and the biodiesel producers in Brazil. It was supposed to be a temporary change valid only for the last two months of 2021, but it ended up being extended to all 2022 (ANP, 2021).

Brazil is a continental country whose movement of goods is done mostly by trucks. In 2018, the transportation sector consumed about 33 per cent of the total amount of energy used there. Diesel and gasoline are the most consumed fuels representing 45 and 27 per cent of the total, respectively (Cachola et al., 2022). Understanding the impacts of the biodiesel policy and regulation on the demand for soybean oil and fuel markets is of paramount importance for policy makers, soybean farmers, the soybean oil producers, and consumers in Brazil. If the price of diesel can increase due to high soybean oil prices driven by the demand for the production of biodiesel, the prices for all goods and services that require movement can also increase.

This thesis aims at investigating whether the governmental decision to reduce in three per cent the biodiesel content in diesel makes sense considering the impact of the biodiesel policy and regulation on the demand for soybean oil. To do so, we first estimate the impact of the biodiesel policy on the demand for soybean oil. Then, we estimate the impact of the biodiesel policy on the demand for soybean oil when the regulation sets the biodiesel content in diesel higher than 10 per cent. Thus, the research questions are: What is the percentage impact of the biodiesel policy on the demand for soybean oil? How much does the impact of the biodiesel policy change when the regulation is in place?

To answer those questions, Ordinary Least Squares (OLS) regression is performed using monthly data from January 2008 to December 2021. Even though the biodiesel policy began in March 2005, it was preferred to use data starting in 2008 because it was the first year that adding biodiesel in diesel became mandatory and the volume of biodiesel produced overcame 1 million metric cubes. The domestic demand for soybean oil is used as the dependent variable. The explanatory variables used are the production of biodiesel representing the biodiesel policy, real prices of soybean oil, real prices of diesel, soybean oil beginning stocks, monthly GDP representing income in Brazil, and a dummy variable for regulation which takes the value of 1 when biodiesel content in diesel is above 10 per cent. To meet the assumptions of OLS regression and to obtain relevant results for the variables of interest, different model specifications are tried and relevant tests are performed, such as, stationarity, multicollinearity, serial correlation, heteroskedasticity and normality.

The thesis is organized in six chapters. Chapter 1 is the introduction and where the motivation, objectives and research questions are presented. Chapter 2 provides background both on the ethanol and the biodiesel programs and the soybean market in Brazil. In chapter 3, the consumer theory and the theories about government intervention and commodity market are presented as well as the related literature. In chapter 4, OLS regression for time series data is introduced, the assumptions are stated, and a step-by-step specification is presented together with the data sources and variables to be used in the analysis. The results of the analysis are reported in chapter 5 and the research questions are answered. Chapter 6 highlights the main findings and provides the limitations of the study and recommendations for future work.

2 – Background

2.1 – Petroleum crises and the instability in Brazil

During the 1950s, petroleum became the primary source of energy to supply the industrial sector in Brazil. In 1953, *Petrobras,* the state-owned multinational in the petroleum industry, was founded to develop the production of petroleum to meet domestic demand in Brazil (Azevedo & Neto, 2020). *Petrobras*' history and economic development in Brazil are intertwined. The company worked as a state monopoly until 1997 giving the government total control over the oil industry (Bregman, 2017).

In 1960, the Organization of Petroleum Exporting Countries (OPEC) was created with the mission to unify petroleum policies concerning supply and prices among its members, the five founding countries were Iran, Iraq, Kuwait, Saudi Arabia, and Venezuela. OPEC had altogether 67 per cent of world oil reserves, 38 per cent of global oil production, and therefore, considerable power over the world oil market (Ebghaei, 2007).

During the 1970s, OPEC started using its market power to regulate the supply of petroleum in the world. First, in 1973, the organization halted the oil supply to countries which were Israel's allies, especially the US. This is known as the Arab Embargo during the Yom Kippur war. The US dollar price of a barrel increased from $3 to $12 between 1973 and 1974 (Nunes, 2016). Second, in 1979, OPEC increased successively the price of petroleum when Iran was unable to keep up its supply of petroleum because of the Iranian Revolution (Pfluck, 2016). During the second crisis, the barrel price rose from $12.76 in 1978 to $35.70 in 1980 (Melo, 2008).

According to Veloso et al. (2008), between 1968 and 1973 Brazil was living a period called "the Economic Miracle" which was characterized by a robust GDP growth followed by a declining inflation rate and a surplus in the balance of payments. The authors compared the average GDP growth rates between 1964-1967 and 1968-1973: GDP increased from 4.2 to 11.1 per cent; the inflation declined from 45.5 to 19.1 per cent; and the balance of payment went from a deficit of $ 13.3 million to a surplus of $ 1.1 billion.

However, Pfluck (2016) argues that such economic performance came with a cost. By the end of the 1960s Brazil was relying more and more on international loans to enhance its import, investment, and domestic consumption capacities. During 1967-1973, world trade was expanding through higher liquidity – more US dollars were being issued. Therefore, the international financial market offered credit with better repayment conditions. Among the underdeveloped countries, Brazil had the highest external debt, which made matters worse especially after the second crisis with the increase in interest rates, and the highest dependency on imported petroleum.

As illustrated in table 1, both in 1973 and 1979, Brazil imported more than 90 per cent of its petroleum needs and the demand increased 43.3 per cent during those 6 years. Between 1980 and 1985, Brazil imported 30.5 per cent more than in 1970-1975, however, it is possible to see a downward trend starting in 1980 until 1989 when Brazil imported less than 50 per cent of its demand for petroleum.

Table 1: Petroleum import and demand

Year	**Imports**	**Demand**	**% Imports**
	thousand cubic meters		
1970	20,848	29,833	69.9%
1971	23,732	31,458	75.4%
1972	30,032	37,750	79.6%
1973	40,890	45,079	90.7%
1974	40,261	47,373	85.0%
1975	41,683	51,156	81.5%
1976	47,828	54,412	87.9%
1977	47,330	55,700	85.0%
1978	52,275	62,099	84.2%
1979	58,197	64,624	90.1%
1980	50,564	63,162	80.1%
1981	49,026	60,879	80.5%
1982	46,291	60,228	76.9%
1983	42,321	58,714	72.1%
1984	37,791	62,571	60.4%
1985	31,629	62,952	50.2%
1986	34,872	66,991	52.1%
1987	35,882	68,582	52.3%
1988	37,165	69,108	53.8%
1989	34,336	69,179	49.6%

Source: IPEAdata, 2022

According to Fishlow (1986), Brazil needed affordable petroleum because fuel was critical to the country for several reasons: the movement of goods in the country was done mostly by truck; the automobile industry was in full development and played an essential role in the national industry; and, most importantly, there was no available substitute in the short term. Therefore, fuel became a serious threat to economic growth which could lead to fewer imports of equipment and other inputs due to the higher costs in purchasing petroleum.

Brazil had to find a way to reduce its dependency on petroleum and the importance that the commodity had on its economy, and that is when the Brazilian Ethanol program came into existence.

2.2 – Sugarcane and Ethanol as a response to crisis and instability

In 1975, the Brazilian Ethanol program was introduced as a response to the increase in the oil price after the crisis in 1973. The term alcohol refers to ethyl alcohol or ethanol which is produced from the sugarcane in Brazil. There are two types depending on the amount of water, hydrous- and anhydrous ethanol with, respectively, 4-5 per cent and less than 1 per cent water content (Carvalho et al., 2013). However, the main difference is in their use. Hydrous ethanol is an automotive gasoline substitute used since 1979 whereas anhydrous ethanol has been used as a gasoline additive since 1938 in Brazil (Copesucar, 2020).

The history of ethanol dates back to the 1930s, 40 years before the ethanol program. In 1933, the Sugar and Alcohol Institute was founded, and in 1938, it became mandatory to add anhydrous ethanol to the domestic gasoline (Leite & Cortez, 2008). In fact, the addition of anhydrous ethanol to the gasoline started as optional in 1931 with a volume of 5 per cent only for imported gasoline and two years later it became mandatory. Only in 1938 was the policy also extended to domestically produced gasoline. However, the sugarcane sector needed governmental support to produce the new fuel and that is what the ethanol program implemented. The subsidies included subsidized credit for the installation of new distilleries, reduction in the tax of manufactured goods and the automobile tax for vehicles running on ethanol, and a set price limit for hydrous ethanol equivalent to 65 per cent of gasoline’s price, among others (Rodrigues & Ross, 2020).

According to Michellon et al. (2008), the ethanol program had four phases. The first phase from 1975 to 1979 was marked by the production of anhydrous ethanol to be blended with gasoline. The second phase from 1979 to 1986 was marked by the production of hydrous ethanol to meet growing demand from vehicles running exclusively on ethanol. The third phase lasted from 1986 to 2003 which is known as the stagnation phase. The program struggled due to lower petroleum prices and a rise in the price of sugar, but mainly from insufficient governmental support and financing as a result of fiscal and inflationary problems. The fourth phase was from 2003 to 2008, known as the redefinition phase. There was a new increase in the petroleum prices and an increase in environmental awareness which brought the program back to life. Furthermore, vehicles that used both ethanol and gasoline, i.e., flex fuel, were produced and became very popular boosting domestic demand for ethanol.

The addition of anhydrous ethanol to gasoline was one of the main reasons for the success of the ethanol program. The content of ethanol in gasoline has changed throughout the years in a way to better match supply and demand for both anhydrous and hydrous ethanol. The percentage ranged from 5 to 25 per cent between 1931 and 2006 (Rico, 2007). Currently, it is between 17 and 28.5 per cent (Planalto, 1993).

The sugarcane sector benefitted enormously from the ethanol program in Brazil. Between 1975/1976 and 1989/1990, the total crushed volume of sugarcane increased from 68 to 222 million tons and the total ethanol produced went from 555,000 to 11 million cubic meters. Only in 1989 did Brazil start exporting ethanol with a volume of 39,000 cubic meters which became 407,000 cubic meters in 1999 (MAPA, 2007). Nevertheless, the ethanol program succeeded in achieving its main objective which was to reduce dependency on imported petroleum. As illustrated in table 1, the share of imported petroleum reduced from 80.5 per cent in 1981 to 49.6 per cent in 1989.

2.3 – Oilseeds and biodiesel

The biodiesel program had a smooth beginning due to the experience with the ethanol program which helped overcoming barriers and optimizing the process to produce a new biofuel in Brazil. Biodiesel is a biodegradable fuel derived from renewable sources such as vegetable oils and animal fats. It can replace petroleum diesel, partially or totally, in engines from trucks, pick-ups, tractors, and machines that produce energy (MME, 2022). In Brazil, biodiesel replaced diesel partially according to the content set by the regulation. Studies show that biodiesel reduces CO_2 emissions by 80 per cent in comparison with petroleum diesel, and it is therefore a better choice for the environment (Pires et al., 2010).

After the Kyoto Protocol was signed in 1997, the debate about environmental issues, especially climate change and the use of fossil fuels, became of paramount importance. This was the main motivation behind the implementation of the biodiesel program in Brazil. Diesel was still the fuel with the highest share in the Brazilian fuel matrix as summarized in table 2. Between 2000 and 2004, the demand for diesel increased 11 per cent whereas the total fuel demand decreased by 1.5 per cent. The share of diesel in total fuel demand increased from 39.1 to 44.3 per cent, more than 5 per cent.

Table 2: Diesel share of total fuel demand

Year	Diesel	Total Fuel	% Diesel
	million cubic meters		
2000	35.15	89.82	39.14
2001	37.02	89.62	41.31
2002	37.67	88.50	42.56
2003	36.85	83.73	44.01
2004	39.23	88.42	44.36

Source: ANP, 2022b

In November 2004, the Brazilian National Program for the Production and Use of Biodiesel, the biodiesel program, was launched to enable the production and use of biodiesel. It was an interministerial program from the Federal Government to implement sustainably, technically, and economically the production and use of biodiesel with a focus on productive inclusion and sustainable rural development through job and income generation. The program's guidelines were to implement a sustainable program which would: promote productive inclusion of family farming; guarantee minimum prices, quality, and supply; and produce biodiesel from different raw materials strengthening regional potentialities (MAPA, 2019).

Because the production of biodiesel can use different types of oilseeds as raw materials, this was considered a competitive advantage for Brazil since all regions of the country can produce at least one type. They include palm, cotton, peanut, castor beans, jatropha, soybeans, sunflower, and canola. However, soybeans, palm, castor beans and sunflower have better performance in terms of costs and yield (Oliveira, et al., 2017). Animal fats, such as beef tallow and pork fat, can also be used as raw materials to produce biodiesel and they are largely abundant in Brazil as well (MME, 2022).

According to Silva (2013), the program aimed at setting up a supply chain for the production of biodiesel, reducing the greenhouse gases emissions, enhancing the quality and competitivity of the biodiesel produced in Brazil, and promoting the use of different oilseeds in the production of biodiesel. The use of different types of oilseeds enabled the social aspect of the program, which was the inclusion of family farming to produce, for example, castor beans in poor regions of the country bringing regional development. The social aspect of the program, obtained through the Social Fuel Seal, was unique in the world, and it involved partnerships and cooperation among different actors – the government, small farmers and farmer associations, and private companies.

Pedroti (2011) outlines the main objectives of the program:

- Creating a second market for soybean: the production of biodiesel would help create an additional market for soybean oil through a boost in the domestic demand. Therefore, soybeans could be used to produce meal, oil, and biodiesel domestically as well as for exports *in natura*.
- Reduction in diesel imports: reducing imports of diesel was not only an economic issue, but also a way to ensure energy security. There was also the possibility of Brazil becoming an exporter of biodiesel, similarly to what happened to ethanol.
- Inclusion of a green fuel in the Brazilian energy matrix: biodiesel comes as a substitute for diesel, and it reduces the emission of CO2. The government's aim was to reduce the greenhouse emissions to the atmosphere and improve the environment image of Brazil around the world.
- Family farming and regional development: biodiesel comes as a way to generate income in the countryside through support for the small farmers. Not only would soybeans farmers be benefited, but the program would also encourage the production of other oilseeds such castor beans in the Northeast of Brazil, one of the least developed regions in the country.
- Inserting Brazil into the world: the aim was to show Brazil as world leader in alternative sources of energy to replace fossil fuels. This could be as exporter of biodiesel, but also as an exporter of technology for the production of biodiesel especially to countries in South America and Africa. This was an example of emerging economies leading the world towards a more sustainable future.

There are four essential characteristics in the biodiesel policy that enabled the fuel introduction in the market and kept the market running, and they are: the social fuel seal; the tax regime; the funding program from the National Bank for Economic and Social Development (*BNDES*); and the biodiesel public auctions (Prates et al., 2007).

The Social Fuel Seal was created in 2007 and given to biodiesel companies that supported family farming. To qualify for the seal, companies had to purchase at least 15 per cent of their biodiesel's raw materials from small family farmers if they were located in the North and Midwest regions, or, 30 per cent from agricultural farmers if they were located in the South, Southeast and Northeast regions. Another requirement was when contracts were negotiated in terms of prices, deadlines, price adjustments and delivery requirements, there was supposed to be at least one accredited representative from the farmers. The companies were also responsible for providing training and technical support for the farmers. Nevertheless, the benefits for the companies were worthwhile because they had reductions in three different taxes and better financing conditions together with *BNDES* and other state-owned banks and bodies. They could also use the seal in advertising campaigns to promote their social commitment and improve their public image (Sallet & Alvim, 2011).

The tax regime involved reductions in three different federal taxes. The reductions depended on the type of oilseed, the participation of family farming, and the region where the companies were located. There were no taxes whatsoever for biodiesel produced from family farming using castor bean or palm in the North and Northeast regions. For biodiesel produced from other raw materials from family farmers, the federal taxes totaled 7 cents of Brazilian reais per liter. For biodiesel produced from castor bean or palm in the North or Northeast regions, but not family farmers, the federal taxes totaled 15 cents of Brazilian reais per liter. In comparison, diesel had 22 cents of Brazilian reais in federal taxes. There were also efforts from the federal government for state governments to also reduce their taxes to support and stimulate the production of biodiesel. Some states even created special tax regimes for biodiesel, such as, Rio Grande do Sul and Goiás (Prates et al., 2007).

The funding program from *BNDES* covered all stages of the production of biodiesel – from raw materials to the final product. The bank has a vital role in the Brazilian economy because it provides long-term loans with better repayment conditions for projects in different economic areas, such as, infrastructure, agribusiness, innovation, exports, regional development, small-and-medium enterprises, environment, and others. The bank worked to stimulate the demand for biodiesel by, for instance, encouraging the use of the fuel in all its official cars and offering benefits for manufacturers of farming implements and electric generators so that they could extend the guarantees for equipment using at least 20 per cent biodiesel. The bank was also responsible for inviting other state-owned banks to implement specific funding programs for the production of biodiesel, especially banks that had long experience in providing funding for agriculture including family farming (Prates et al., 2007).

Biodiesel auctions started in 2005 where the refineries had to buy biodiesel to blend with diesel. At first, the auctions aimed at building a market for biodiesel by stimulating its production in volumes big enough to meet the volumes of biodiesel to be blended with diesel. However, the auctions continued as a way to guarantee that all diesel sold in the country had the biodiesel content determined by the regulation. During the auctions, the government set a price ceiling for a given volume of biodiesel. The winners of the auctions are the biodiesel producers that bid the lowest price below the price ceiling. The biodiesel is, then, sold to *Petrobrás* which sells it to the fuel distributors. The distributors blend the biodiesel with diesel according to the content established by the regulation, and then, sell the final product to gas stations ready for consumption. In that way, the government can assure the blending law enforcement, standardization and quality of both biodiesel and diesel even in the outermost regions of the country. Moreover, the auctions foster competition among biodiesel producers to bid their cheapest selling price for the fuel which enables the government to keep prices low for final consumers (Sallet, 2011).

The blending of biodiesel with diesel started as optional in 2005 at 2 per cent content, called B2 diesel. It became mandatory in 2008. A regulation of 13 per cent means that if 100 liters of diesel are sold, 87 liters are petroleum diesel and 13 liters are biodiesel. The percentages changed over time, but it was supposed to reach 15 per cent in 2023 as illustrated in table 3.

Table 3: Expected biodiesel content in diesel until 2023

Year	**Biodiesel Content**
March 2005	2
July 2008	3
July 2009	4
January 2010	5
August 2014	6
November 2014	7
March 2017	8
March 2018	10
March 2019	11
March 2020	12
March 2021	13
March 2022	14
March 2023	15

Source: ME, 2020

However, in September of 2021, the government decided to reduce from 13 to 10 per cent the minimum amount of biodiesel to be blended with diesel. This decision came as a response to higher soybean oil prices, which is the main raw material to produce biodiesel. Soybean oil accounts for 71 per cent of the total, so the reduction was an attempt to avoid an increase in diesel prices driven by higher soybean oil prices used to produce biodiesel (Senado Federal, 2021). This was supposed to be a temporary change valid only for the last two months of 2021, but it ended up being extended for all 2022 (ANP, 2021).

Such governmental decision came as a surprise to farmers who have benefited much from the heated domestic demand for soybean oil. Also, some argued that the reduction could increase the risk of bankruptcy for biodiesel industries. However, the government was unable to predict such dominance of soybean oil as raw material for biodiesel which has changed its market dynamics in Brazil.

2.4 – Soybeans and Soybean Oil in Brazil

Soybeans were commercially introduced in Brazil in the 1960s in Rio Grande do Sul and during the last 50 years the oilseed has spread to all regions of the country. However, the Midwest region has always stood out in its production. More recently, the North and the Northeast regions have become important production regions, mainly in the states known as *MATOPIBA*, i.e., Maranhão, Tocantins, Piauí and Bahia (Contini et al., 2018,).

Gazzoni & Dall'agnol (2018) highlight the factors that contributed for the soybean crop to succeed in Brazil. These include: i) fiscal incentives to wheat producers from 1950 to 1970 which in turn would also benefit soybeans since they used the same land, labor and machines during the summer; ii) high soybean prices on the world market in the mid-1970s; iii) substitution of animal to vegetable fat since they are considered healthier; iv) easiness to have full harvest mechanization; v) the creation of a dynamic and efficient cooperative system which supported soybean production, processing and trading; vi) the creation of a private-public sector research network; and vii) the creation of a private network for the production of inputs for soybeans as well as machines and equipment developed especially for Brazilian production conditions.

Table 4 shows the soybean market in Brazil from 2000 to 2021 in terms of production, exports, imports, and consumption. According to table 4, comparing the figures in 2000 and 2021, Brazil steadily increased its soybean production by 323 per cent, exports by 647 per cent, imports by 6 per cent, and consumption by 125 per cent. The increase in consumption can be explained by a higher level of soybean processing to supply soybean oil for the production of biodiesel. Those two decades were important for the soybean market to develop domestically and increase its share in the world trade. Brazil became the largest exporter of soybeans in 2013 when it exported 3 million tons more than the United States; and became the largest producer in 2019 when Brazil produced about 8 million tons more than the US, ending the US dominance since 1961 (FAOstat, 2022).

Table 4: Brazilian Soybean Market

Year	Production	Exports	Imports	Consumption
		million metric tons		
2000	32.82	11.52	0.81	21.18
2001	37.91	15.68	0.85	23.10
2002	42.11	15.97	1.05	25.76
2003	51.92	19.89	1.19	27.45
2004	49.55	19.25	0.35	28.71
2005	51.18	22.44	0.37	29.86
2006	52.46	24.96	0.05	28.33
2007	57.86	23.73	0.10	31.48
2008	59.83	24.50	0.10	32.33
2009	57.35	28.56	0.10	30.43
2010	68.76	29.07	0.12	35.51
2011	74.82	32.99	0.04	37.27
2012	65.85	32.47	0.27	36.43
2013	81.72	42.80	0.28	36.24
2014	86.76	45.69	0.58	37.62
2015	97.46	54.32	0.32	40.56
2016	96.39	51.58	0.38	39.53
2017	114.73	68.15	0.25	41.84
2018	117.91	83.61	0.19	43.56
2019	114.27	74.07	0.14	43.45
2020	121.80	82.97	0.82	46.85
2021	138.86	86.11	0.86	47.78

Source: FAOstat (2022) & ABIOVE (2022)

After 2013, the next catalyst to Brazil's growth in both production and exports of soybean is the trade war between China and the United States in 2018. According to Miranda (2018), it all started in March 2018 when the US announced a 25 per cent tariff over Chinese goods. China, in turn, announced the same tariff over imported US goods including soybeans and meat. However, China is the largest soybean importer in the world accounting for more than 60 per cent of the oilseed world trade. Since US soybeans became more expensive, the Chinese demand shifted towards Brazil. Between January and April 2018, China imported 1.26 million tons less than in the same period in 2017, however, the situation changed drastically between May and November 2018 when China imported 14.5 million tons more in comparison to the same period in 2017.

The impacts of the biodiesel policy on the soybean market in Brazil becomes more apparent in the soybean oil market since it is the main raw material for the biofuel accounting for almost 70 per cent of the total (ANP, 2022a). It is worth highlighting that to produce one liter of biodiesel, 1.3 liters of soybean oil are required (Elgharbawy et al., 2021). Table 5 presents the soybean oil market between 2000 and 2021 which was five years before biodiesel started being produced, so that it is possible to have an idea of the growth in the market before the biodiesel program.

Table 5: Brazilian Soybean Oil Market

Year	Production	Exports	Imports	Consumption
		thousand metric tons		
2000	4,058	1,120	105	2,997
2001	4,411	1,596	73	2,972
2002	4,939	2,030	113	2,900
2003	5,286	2,357	36	2,971
2004	5,507	2,448	27	3,044
2005	5,736	2,645	3	3,111
2006	5,429	2,360	25	3,198
2007	6,045	2,384	84	3,617
2008	6,267	2,222	27	4,102
2009	5,896	1,517	27	4,454
2010	6,928	1,490	16	5,404
2011	7,340	1,782	0	5,528
2012	7,013	1,764	1	5,328
2013	7,075	1,383	5	5,723
2014	7,443	1,295	0	6,109
2015	8,074	1,665	25	6,521
2016	7,885	1,257	66	6,580
2017	8,433	1,340	58	7,094
2018	8,833	1,416	35	7,457
2019	8,791	1,041	48	7,909
2020	9,557	1,110	199	8,530
2021	9,638	1,651	107	8,017

Source: ABIOVE (2022)

Between 2000 and 2004, exports had the most significant increase of 118 per cent, followed by the production and consumption which increased 35 and 1.5 per cent respectively. Imports, on the other hand, reduced by 74 per cent. Between 2005 and 2010, the situation changed significantly, imports increased by 433 per cent followed by consumption and production with an increase of 73 and 20 per cent, respectively. Exports, on the other hand, reduced by 43 per cent. Then between 2010 and 2020, imports increased by a massive rate of 1143 per cent followed by consumption and production whose increase was 57 and 38 per cent, respectively. Exports reduced by 25 per cent. In 2020, Brazil imported a record of 199,000 tons of soybean oil – this represents an increase of 314 per cent from 2019. The last time the country imported more than that was in 1994 when 254,000 tons were imported – the highest amount ever since the measurements began in 1961 (FAOstat, 2022). Between 2020 and 2021, the situation changed as soybean oil exports and production increased by 48 and 0.8 per cent, respectively. Imports reduced drastically by 46 per cent followed by consumption with a reduction of 6 per cent.

Focusing on the consumption of soybean oil following the biodiesel policy and regulation dates. Between 2000 and 2004 there was no production of biodiesel, the consumption of soybean oil increased 1.5 per cent. The production of biodiesel started in 2005, the consumption of soybean oil increased 2.2 per cent from 2004 to 2005. Between 2005 and 2008, adding biodiesel in diesel became mandatory and the biodiesel content increased from 2 to 3 per cent as shown in table 3. The consumption of soybean oil increased 31.8 per cent. Between 2008 and 2019 the biodiesel content in diesel went from 3 to 11 per cent, the consumption of soybean oil increased 92.8 per cent. Between 2019 and 2021 the biodiesel content in diesel went from 11 to 13 and was then reduced to 10, the consumption of soybean oil increased 1.36 per cent.

2.5 – Diesel and Biodiesel

One of the objectives of the biodiesel program was to reduce imports of diesel as well as its consumption offering a green substitute. However, biodiesel has only been sold as a diesel additive. Table 6 summarizes the diesel market in Brazil from 2000 to 2020. Between 2000 and 2004, production increased by 24 per cent followed by consumption and exports with an increase of 11 and 6 per cent respectively. Since the increase in production was higher than the increase in consumption, imports reduced by 53 per cent.

Table 6: Brazilian Diesel Market

Year	Production	Exports	Imports	Consumption
		million cubic meters		
2000	30.98	0.06	5.80	35.15
2001	33.25	0.07	6.59	37.02
2002	33.21	0.02	6.37	37.67
2003	34.39	0.12	3.82	36.85
2004	38.51	0.06	2.69	39.23
2005	38.75	0.30	2.37	39.17
2006	39.12	0.60	3.55	39.01
2007	39.58	1.05	5.10	41.56
2008	41.13	0.65	5.83	44.76
2009	42.90	1.22	3.52	44.30
2010	41.43	0.67	9.01	49.24
2011	43.39	0.60	9.33	52.26
2012	45.50	0.32	7.97	55.90
2013	49.54	0.36	10.28	58.57
2014	49.68	0.39	11.28	60.03
2015	49.46	0.08	6.94	57.21
2016	45.37	0.48	7.92	54.28
2017	40.63	0.50	12.96	54.77
2018	41.96	0.95	11.65	55.63
2019	41.00	0.04	13.01	57.30
2020	42.22	0.32	11.99	57.47
2021	42.85	0.04	14.44	62.11

Source: ANP, 2022b

Between 2005 and 2015, imports increased by 192 per cent followed by consumption and production whose increase was 46 and 27 per cent respectively. Exports reduced by 73 per cent. Between 2015 and 2021, exports reduced by 54 per cent followed by production whose reduction was 13 per cent. Both imports and consumption increased by 108 and 8 per cent, respectively. The consumption volumes for diesel in table 6 included an optional addition of biodiesel between 2005 and 2007 which became mandatory in 2008. To analyze the real volumes of diesel consumed, the biodiesel content displayed in table 3 must be subtracted from the consumption volumes in table 6.

In 2005, Brazil produced only 736 cubic meters as illustrated in table 7. However, the production increased considerably from one year to another reaching more than 6,7 million cubic meters in 2021. The production volume overcame 1 million cubic meters for the first time in 2008 when the addition of 2 per cent biodiesel in diesel became mandatory. The production volume reduced only once from one year to another in 2016 when Brazil produced 135,000 fewer cubic meters than in the year before.

Table 7: Biodiesel Production Volumes

Year	**Production** million cubic meters
2005	0.0007
2006	0.069
2007	0.404
2008	1.17
2009	1.61
2010	2.39
2011	2.67
2012	2.72
2013	2.92
2014	3.42
2015	3.94
2016	3.80
2017	4.29
2018	5.34
2019	5.90
2020	6.43
2021	6.75

Source: ANP, 2022b

There seems to be a relationship between the production of biodiesel and the consumption of soybean oil, especially when the content of biodiesel in diesel higher than 10 per cent. Therefore, it should come as no surprise that the government reassessed the regulation and reduced the biodiesel content in diesel for the two last months in 2021 and all 2022.

The next chapter presents some background on consumer theory, government intervention, commodity markets and related literature.

3 – Theory

3.1 – Consumer Theory

Whelan & Msefer (1996) define demand as the rate at which consumers want to buy a good depending on their taste and ability to buy. Taste is the desire for the good and it determines the willingness to buy the good at a given price whereas ability to buy is related to the level of income or wealth consumers have so that they can afford the good at a certain price. The demand curve shows the relationship between prices and quantities demanded, that is, the quantity of a product that is demanded at various price levels in a given time. The demand curve slopes down showing that there is a negative relationship between prices and quantities demanded – if the price of the good decreases, people are more willing to buy it (Varian, 2014). It is affected by consumer's preference, consumer's purchasing power, price of substitute and complementary goods, price of the good itself, quality of the good, consumer's expectations towards income and prices and etc. (Sandroni, 1999).

Marques et al. (1999) express a typical demand equation for agricultural products as on equation 1:

(1) $Q_t = f(p_t, y_t, ps_t, pc_t, E_t, O_t)$,

where Q_t is quantity demanded; p_t is price of the good; y_t is income; ps_t is the price of substitute goods; pc_t is the price of complementary goods; E_t is Expectations; O_t is Others.

It is common to estimate how responsiveness demand is to changes in its factors, especially prices and income. Each of those factors is expressed in different units which makes it harder to estimate how demand behaves in relation to them. However, there is the possibility of using the percentage change of quantities demanded by the percentage change of any other factor – known as the elasticity (Varian, 2014).

The price elasticity of demand is defined to be the percentage change in quantity divided by the percentage change in price. A 10 per cent increase in price is the same percentage increase in US dollars or pounds; thus, measuring in percentage terms makes the estimation unit-free. If a good has an elasticity greater than one in absolute value, it has an elastic demand. Elastic demand implies that consumers are very responsive to prices, so if the price increases by one per cent the quantity demanded reduces by more than one per cent. Similarly, if the elasticity is less than one in absolute value, we say it is price inelastic. Inelastic demand is not responsive to prices, so if prices increase by 1 per cent the quantity demanded reduces by less than 1 per cent. Lastly, if it has an elasticity of exactly 1 in absolute value, we say it has unit elastic demand. Unit elastic demand means that an increase of 1 per cent in prices the quantity demanded reduces by the same 1 per cent (Varian, 2014).

The income elasticity of demand is used to describe how the quantity demanded responds to a change in income. It is defined by the percentage change in quantity divided by the percentage change in income. When an increase in income leads to an increase (decrease) in demand, i.e., the income elasticity of demand is positive, the good is said to be a normal (inferior) good (Varian, 2014).

The cross-price elasticity of demand is the ratio of the percentage change of the quantity of one good demanded with respect to the percentage change in the price of another good. When the cross-price elasticity is negative, the goods are complements. If the price of one increases, then the demand for the other decreases. When the cross-price elasticity is positive, the goods are substitutes. If the price of one good increases, then the demand for the other increases – this phenomenon is called substitution effect (Besanko & Braeutigam, 2011).

One of the objectives of the biodiesel program was to the use of different types of oilseeds and animal fats as raw materials so that they could work as substitutes to one another. When the price of soybean oil was high, producers could easily switch to another raw material. However, the dominance of soybean oil prevented the substitution effect from happening. Soybeans have a better performance in terms of yield and costs.

3.2 – Government Intervention in the Market

The Office of Fair Trading (OFT, 2009) provides a detailed overview of the main instruments of intervention government has at its disposal, and they are:

- Regulation: consists of a set of rules administered by the government to influence the behavior of business and the economic activity. It captures primary legislation setting the market frameworks to detailed regulations imposed in specific sectors. It provides rules for health and safety of workers as well as consumers through licensing of approved suppliers.
- Subsidies and Taxation: subsidies are governmental support that provides economic advantage, and they can take place in the form of direct grants, tax exemptions, soft loans, guarantees and etc.. Taxes are a source of revenue for the government to fund public goods. Taxes can be indirect such as VAT which is levied on transactions or direct such as the income tax. Subsidies and taxes affect competition by changing the costs and profits of businesses, and thus influencing their behavior and decisions.

- Government as an influencer: it happens when the government tries to influence consumer behavior and businesses' actions indirectly through policy statements, information campaigns and discussions with key parties. This tool is used to change behavior that has adverse effects on society, such as, excessive consumption of alcohol or sugar or to encourage changes in consumption, e.g., in favor of biofuels.
- Government as a market maker: refers to the government playing a role in market design, supervision, and enforcement. It provides the necessary incentives for goods and services to be provided efficiently while keeping competitive pressure between buyers and sellers. The three most common mechanisms are competitive tendering, user choice, and tradable permits.
- Public procurement: happens when the government is a major buyer in a market, and its purchasing decisions can have significant effects on competition. Government can use its buyer power to enhance competition among suppliers. Government can also help shaping markets for example through supporting new technologies or products. Public procurement plays a vital role in how the whole economy works as it accounts for 20 per cent of OECD countries' GDP.
- Government as a supplier: it is a situation where the government is the direct provider of services or goods. The public sector used to be a direct provider of several goods and services which has changed over time due to privatization and growing use of public-private partnerships. In such a circumstance, the government is responsible for instigating competition by giving fair treatment to both private firms and public bodies and by making it easier for private firms to access public sector information.

The use of different instruments of governmental intervention depends on the objectives of public policies. The main objectives of the biofuel program were creating a second market for soybeans, reducing imports of diesel, including a green fuel in the Brazilian fuel matrix, supporting family farming and regional development, and selling Brazil's image as world leader in green energy production. To achieve those, the government used all the instruments listed. Regulation came in the form of blending mandates to ensure demand for biodiesel, and thus, creating a market for it. The government implemented a series of tax breaks and subsidies especially focused on family farming and regional development. The government also acted as the only buyer and supplier in the biodiesel market through the biodiesel auctions where refineries would sell biodiesel to *Petrobrás* which would then resell it to fuel distributors. The auctions gave the government control over supply, demand, and prices. The government worked as an influencer with campaigns to increase awareness of the environmental, economic, and social benefits of biodiesel.

3.3 – Commodity Market

A commodity is a homogenous good that is identical or a very close substitute to another good of the same type. Commodities are raw materials or agricultural products that are non-product differentiable, and they are used as inputs in the production of finished goods (Carter, 2017). In practice, commodities are associated with non-specialized goods produced and transported in large volumes (Matias et al., 2005).

Pereira (2009) defines a commodity as a type of product that has no qualitative differences in terms of quality wherever it is traded – thus it refers to a standardized product. It is often attributed to raw materials with no or very little industrial processing. When a product is processed, it develops specific and differentiating characteristics which no longer has standardization.

Commodities can be divided in different types according to their characteristics and used. A common way is to separate them into primary and secondary commodities. Primary commodities are those extracted or produced directly from natural resources such as farms, mines, and wells. As primary commodities are natural products coming out of the ground, they are non-standard meaning that their characteristics can vary widely. Secondary commodities are those produced from primary commodities and therefore there may be minor variations in quality depending how they are produced. However, standardization is possible (Buchan & Errington, 2008).

Commodities can also be split into two types: hard and soft. Hard commodities are usually natural resources that must be mined or extracted, such as, energy and metal and mineral. Soft commodities are those that need to be produced or raised, such as, agricultural products (James, 2016). Energy commodities include coal, crude oil, natural gas, diesel, biodiesel among others. Metal and mineral commodities include iron ore, aluminum, copper, gold, silver etc. Agricultural commodities include maize, wheat, soybeans, cotton, coffee, sugar, and many others (Buchan & Errington, 2008).

According to Carter (2017), commodity markets are an important part of the global economy as they work as a barometer of supply and demand. They reflect shifts in supply and demand before even the general economy responds to those shifts. A fundamental economic contribution of commodity futures markets is their ability to establish prices across time – intertemporal price discovery.

The biodiesel program has had an impact on the market of different commodities. The market of energy commodities is affected by the introduction of biodiesel as a fuel which works as complementary to diesel because it is only sold blended with diesel. The market of agricultural commodities is affected by the increase in domestic soybean demand to produce soybean oil, which in turn increase the supply of soybean meal. This also influences other related agricultural commodities, such as, maize, wheat, and cotton.

3.4 – Related Literature

There are several studies about the Brazilian soybean market. However, most of them are focused on prices and exports of soybeans. In fact, there is a shortage of studies that deal with the domestic consumption of soybeans in Brazil. Papers about the domestic soybean oil consumption in Brazil were found neither in English nor in Portuguese.

The most relevant paper is presented by Freitas et al. (2019) because it links the production of biodiesel to the soybean market in Brazil. The authors look into the relationship between the production of biodiesel and the price of soybean in the Brazilian market from 2005 to 2015. The study involves an estimation of biodiesel and soybean by state in Brazil. They use a Generalized Least Squares (GLS) estimation with random effects to identify the relationship between the production of biodiesel and the price of soybeans. The regression equation includes the dependent variable as the price soybeans which is regressed on the explanatory variables biodiesel's production volume, soybean's planted area, soybean's production volume, soybean's ending stocks, oil price, international soybean prices, and the blending mandates. The results show that the production of biodiesel has an effect of 0.01 per cent and the blending mandates has an effect of 0.13 per cent over soybean prices at the 5 per cent significance level. According to the authors, the production of biodiesel has a small effect on soybean price because the volume of soybeans used is still small when compared to the total soybean volume produced in Brazil. The blending mandates have a positive influence on the prices of soybeans which can be explained by the lack of diversification in the raw materials used to produce biodiesel. This paper sheds some light over relevant variables to be included when analyzing biodiesel influence on soybean markets in Brazil as well as suggests an effective way of dealing with the blending mandates of biodiesel in diesel as a dummy variable to assess the regulation to support the sector.

Hirakuri et al. (2010) study the relationship between soybeans and the production of biodiesel in Brazil. The study is divided into four different factors: the supply and demand for biodiesel, the soybean market and its development, the logistics for soybeans as raw-material, and the raw materials to produce biodiesel. When it comes to the supply and demand for biodiesel, the authors divide the delivery volumes by the production capacity of the biodiesel factories obtaining the delivery efficiency of each plant for 2009. They also investigate whether Brazil would be able to produce enough biodiesel to meet the demand when the regulation increased to 5 per cent in 2010. The results show that the factories had, then, capacity to produce more than 1 million m^3 above the volume needed to for the increase in the content of biodiesel in diesel. The analysis of the raw materials is done using OLS regression with monthly data from October 2008 to December 2009 where the growth rate of each raw material is estimated. The results show that the volume of biodiesel produced increases by 3.64 per cent and its production was dependent on soybean oil as raw-material accounting for 78.2 per cent of the total. The growth rate of soybean oil is 3.31 per cent in the period. This paper draws a relationship between the production of biodiesel and the demand for soybean oil.

Souza et al. (2019) analyze the factors that influence the domestic demand for soybeans in Brazil using monthly data from 2005 to 2015. A Vector Error Correction Model (VECM) is used, and the regression equation includes the dependent variable as the domestic soybean demand which is regressed on the explanatory variables: wholesale price of soybeans, price index of soybean oil and soybean meal, FOB exporting price of soybean meal, quantity of slaughtered pigs, quantity of slaughtered chickens, and national income. The authors use the log and the first difference of those variables. The results show that the national income is the variable with the highest influence on the domestic soybean demand. Other variables highly influenced by the national income are the quantity of slaughtered pigs and chickens. This paper provides a domestic soybean demand equation and some relevant variables for its estimation in Brazil, highlights the importance of national income as a driver of domestic soybean demand.

Rhoden et al. (2020) focus on the domestic soybean demand in Brazil. They look into the trends for the supply and demand of soybean, soybean meal and soybean oil in Brazil and the main global players. The authors use annual data of production, export, consumption and import of soybeans, soybean meal and soybean oil between the crop-years of 1998/1999 and 2017/2018. The trends and growth rates are estimated using the econometric model of trends and growth rates where the R-squared is determined using Ordinary Least Squares. Focusing on the results for the domestic demand for soybean and soybean oil in Brazil, the growth rates are 3.63 and 5.68 per cent, respectively. The authors highlight that the increase in the domestic demand for soybeans is highly affected by the domestic demand for soybean meal and soybean oil whose main markets are in Brazil. The growing soybean meal demand in Brazil comes from the production of livestock, especially pigs and chicken. The rising demand for soybean oil in Brazil comes as a result of its industrial uses, especially to produce biodiesel, which has reduced gradually the ending stocks of the oil. This paper corroborates that the domestic demand for soybeans and the domestic demand for soybean oil increased between 1998/1999 and 2017/2018 and that the production of biodiesel played a role in such change and consequently affected its domestic price.

4 – Data and Methodology

4.1 – Data

The theoretical model proposed to estimate the demand for soybean oil is on equation 2:

$$\text{(2)} \quad Doil_t = f\,(Prodbio_t, Poil_t, Pdiesel_t, Begoil_t, Y_t, Reg),$$

where, Doil represents the demand for soybean oil; Prodbio represents the production of biodiesel; Poil represents the price of soybean oil; Pdiesel represents the price of diesel; Y represents national income; Reg represents the regulation.

The dataset consists of 168 monthly observations from January 2008 to December 2021. Even though the production of biodiesel began in March 2005, it was preferred to use data starting in 2008 because it was the year that the addition of biodiesel to diesel became mandatory and the volume of biodiesel produced overcame 1 million metric cubes for the first time.

The variable demand for soybean oil is the total volume of soybean oil consumed in Brazil in metric tons. It includes both refined and unrefined soybean oil sold for food, chemical and biodiesel industries. The data source is the Brazilian Association of Vegetable Oils Industries (ABIOVE, 2022).

The variable production of biodiesel is the volume of biodiesel produced in Brazil in cubic meters. The data source is the Brazilian Association of Vegetable Oils Industries (ABIOVE, 2022). This is the variable representing the impact of the biodiesel policy on the demand for soybean oil.

The variable price of soybean oil is the monthly wholesale average prices for unrefined soybean oil in the state of Paraná. It is in Brazilian reais per metric ton. The data source is the Department of Rural Economics of the state of Paraná (DERAL, 2022). The prices were deflated using the General Price Index – Domestic Availability (IGP-DI) whose source is the Getulio Vargas Foundation (FGV, 2022).

The variable price of diesel is the monthly average price for diesel for fuel distributors in Brazil. It is in Brazilian reais per cubic meter. The data source is the Brazilian Association of Vegetable Oils Industries (ABIOVE, 2022). The price series for consumers was found, but it was chosen not to use it due to missing observations. The prices were deflated using the General Price Index – Domestic Availability (IGP-DI) whose source is the Getulio Vargas

Foundation (FGV, 2022). This variable is expected to influence the demand for soybean oil because biodiesel is only sold blended with diesel.

The variable beginning stocks of soybean oil is the volume of soybean oil in metric tons that the industry has in stock in the beginning of each month. The data source is the Brazilian Association of Vegetable Oils Industries (ABIOVE, 2022). This variable is expected to influence the demand for soybean oil as suggested in Freitas et al. (2018). The authors used the ending stocks of soybeans as one of the explanatory variables to estimate the impact of the production of biodiesel on the soybean prices.

The variable national income is monthly gross domestic product in Brazil in Brazilian reais. The data source is the Central Bank of Brazil (BCB-DEPEC, 2022). Income is often used to estimate demand as suggested on equation 1. Souza et al (2019) found it to be a relevant variable when estimating the demand for soybeans in Brazil.

The variable regulation is a dummy variable. It is set to 1 when the content of biodiesel in diesel is more than 10 per cent, i.e., the period between March 2019 and October 2021. This is variable representing the impact of regulation above 10 per cent on the demand for soybean oil.

4.2 – OLS regression with time series data

Time series data consists of a collection of observations on the values that a variable takes at different time intervals, such as, monthly, quarterly, annually etc. Ordinary Least Squares (OLS) regression is commonly used for estimating linear regression models for time series data. OLS is a method for estimating the parameters of a multiple linear regression model by minimizing the sum of squared residuals (Wooldridge, 2013).

The OLS regression for time series follows six assumptions: 1) the stochastic process follows a linear model; 2) no collinearity among the independent variables; 3) Zero conditional mean of the disturbances, i.e., the explanatory variables are exogenous; 4) the error terms are homoscedastic; 5) the errors in two different time periods are uncorrelated, i.e., no serial correlation; 6) the errors are normally distributed. When the conditions 1-3 hold, the OLS estimators are unbiased. Adding the conditions 4 and 5, the OLS estimators are the best linear unbiased estimators (BLUE). In case all six assumptions hold, everything used for estimation and inference for cross-sectional data applies to time series (Wooldridge, 2013).

The first step for time series analysis is the test for stationarity, i.e., when the mean and the variance of the time series do not vary systematically over time. Time series can be trend stationary – when it has a deterministic trend, or difference stationary – when it has a variable, or a stochastic, trend. Regressing a nonstationary time series on one or more nonstationary time series can lead to misleading results called a spurious regression. To avoid such a problem, it is common to transform nonstationary time series to make them stationary depending on its type. For difference stationary time series, the solution is to take its first differences. For trend stationary time series, the common practice is to include the time or trend variable in the regression model to detrend the data. Dickey-Fuller (DF) test is commonly used to test for stationarity (Gujarati, 2003).

The Dickey-Fuller test is estimated in three different ways: i) a random walk as on equation 3; ii) a random walk with a drift as on equation 4; iii) a random walk with a drift around a stochastic trend as on equation 5:

$$(3)\ \Delta Y_t = \delta Y_{t-1} + u_t$$

$$(4)\ \Delta Y_t = \beta_1 + \delta Y_{t-1} + u_t$$

$$(5)\ \Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + u_t$$

where β_1 is the drift, and t is the trend variable. The null hypothesis is that $\delta = 0$, i.e., there is a unit root, and the time series is nonstationary. The alternative hypothesis is that δ is less than zero, i.e., the time series is stationary. If the null hypothesis is rejected, it means that Y_t is stationary with zero mean in the case of equation 3; Y_t is stationary with a nonzero mean in the case of equation 4; and Y_t is stationary around a deterministic trend in case of equation 5. It is important to keep in mind that the critical values of the tau test to test the hypothesis are different under different specifications (Gujarati, 2003).

After the regression is performed, there are other assumptions to be checked. Multicollinearity happens when there is correlation among the independent variables in a multiple regression model. Serial correlation refers to correlation between the errors in different time periods. Heteroskedasticity is when the variance of the error term, given the explanatory variables, is not constant. Normality refers to the assumption that the error (or dependent variable) has a normal distribution (Wooldridge, 2013). To test for multicollinearity, the Variance Inflator Factor (VIF) test is used. The Breusch-Godfrey test is the one used to test for serial correlation. To test for heteroskedasticity, the Breusch-Pagan test is used. Kernel Density is the test used for normality.

The VIF test quantifies how much the variances of the estimated coefficients are inflated. The VIF is the ratio of the variances, and it measures how much the variance of the estimated regression coefficient is inflated by the presence of correlated regressors in the model. It identifies correlation between independent variables and the strength of that correlation. A value of 1 indicates that there is no correlation between this independent variable and any others. VIF greater than 10 indicates significant multicollinearity (Das, 2019).

The Breusch-Godfrey is a test for serial correlation that allows non-stochastic regressors such as the lagged values of the regressand; higher-order autoregressive schemes, such as AR(1), AR(2), etc.; and simple or higher-order moving averages of white noise error terms. The test uses two hypotheses. The null-hypothesis is that there is no autocorrelation up to p (Gujarati, 2003).

To perform Breusch-Pagan test for heteroskedasticity, first we need to estimate the model using OLS to obtain the predicted values of the dependent variable. Then, we estimate the auxiliary regression using OLS and retain the R^2. Based on estimated R^2, calculate the F statistic or the chi-squared statistic. The null hypothesis that the error variances are all equal whereas the alternative hypothesis is that the error variances are a multiplicative function of one or more variables. Alternatively, the test can be specified to give corrected standard errors in the presence of heteroskedasticity which reduces the standard errors and provides reasonably accurate p values without affecting the estimated coefficients (Das, 2019).

The Kernel density is a technique for estimation of a probability density function (pdf). It is considered an improved version of histograms because it produces smooth estimate of the pdf, uses all sample points' locations, and suggests multimodality (Węglarczyk, 2018).

4.3 – The Model

The regression model to estimate the demand for soybean oil follows equation 2. To interpret the coefficients as elasticities, all variables are transformed into logarithm as on equation 6:

$$(6)\ \ln Doil_t = \alpha + \beta_1 lnProdbio_t + \beta_2 lnPoil_t + \beta_3 lnPdiesel_t + \beta_4 lnBegoil_t + \beta_5 lnY + \beta_6 Reg + u_t$$

The coefficient β_1 is expected to be positive because the production of biodiesel increases the demand for soybean oil. The coefficient β_2 is expected to be negative following the economic theory that there is a negative relationship between prices and quantities demanded. The coefficient β_3 is expected to be negative as biodiesel is blended with diesel, and therefore, the higher the price of diesel the lower the demand for biodiesel. The coefficient β_4 is expected to be negative considering that the higher the beginning stock levels of soybean oil, the lower its demand. The coefficient β_5 is expected to be positive since the higher the income, the higher the demand for fuels. This was the result found for soybean demand in Brazil by Souza et al. (2019). The coefficient β_6 is expected to be positive considering that more biodiesel is demanded when the regulation is above 10 per cent increasing the demand for soybean oil. Lastly, there is u_t which represents the error term.

The estimation is performed using *Stata* software and the results are presented in the next chapter. The estimation happens in the following steps: 1) Dickey Fuller Test for Stationarity; 2) Regression; 3) VIF test for Multicollinearity; 4) Breusch-Godfrey Test for Serial Correlation; 5) Breusch-Pagan Test for Heteroskedasticity; 6) Kernel Density Test for Normality. To make sure the OLS regression assumptions hold, the model is adapted and the variables are changed throughout the estimation process.

5 – Results

5.1 – Model Specification

The regression equation to be estimated is shown on equation 6:

$$(6)\ \ln Doil_t = \alpha + \beta_1 lnProdbio_t + \beta_2 lnPoil_t + \beta_3 lnPdiesel_t + \beta_4\, lnBegoil_t + \beta_5 lnY + \beta_6 Reg + u_t$$

where, Doil is the demand for soybean oil; Prodbio is the production of biodiesel; Poil is the price of soybean oil; Pdiesel is the price of diesel; Y is national income; Reg is regulation. The descriptive statistics is shown in table8.

Table 8: Descriptive Statistics

Variable	Obs	Mean	Std. dev.	Min	Max
lnDoil	168	13.15075	0.235315	12.56867	13.62936
lnProdbio	168	12.54817	0.521423	11.06162	13.37399
lnPoil	168	7.927743	0.352001	7.433814	8.991822
lnPdiesel	168	7.787667	0.268478	7.452119	8.520085
lnBegoil	168	12.79633	0.203207	12.18653	13.27389
lnY	168	19.93717	0.307282	19.26217	20.4488
Reg	168	0.190476	0.393851	0	1

All variables have 168 observations. Each variable is transformed into logarithm form to help make them unit-free and stationary and to be able to interpret the results as percentage change. Income has the highest mean value followed by the demand for soybean oil. The production of biodiesel establishes around its mean of 12.5.

The next step is to perform the Dickey-Fuller test for Stationarity. The default test is a random walk as on equation 3. According to the results in table9, the variables price of soybean oil, production of biodiesel, price of diesel and income are non-stationary. However, all of them are stationary in their first difference. The non-stationary variables are also tested using the Dickey-Fuller test with a trend as on equation 5 and the results are in table10.

Table 9: Dickey-Fuller Test for Stationarity

Variable	Test Statistic	p-value	Interpretation
lnDoil	-3.466	0.0089	Stationary at the 1% level
lnPoil	1.257	0.9964	Non-stationary
ΔlnPoil	-8.688	0.0000	Stationary at the 1% level
lnProdbio	-2.263	0.1841	Non-stationary
ΔlnProdbio	-14.484	0.0000	Stationary at the 1% level
lnPdiesel	1.817	0.9984	Non-stationary
ΔlnPdiesel	-8.481	0.0000	Stationary at the 1% level
lnBegoil	-4.521	0.002	Stationary at the 1% level
lnY	-1.436	0.5648	Non-stationary
ΔlogY	-15.230	0.0000	Stationary at the 1% level

Critical values: 1% = –3.43; 5% = –2.86; 10% = –2.57 in Wooldridge (2013)

The results show that the price of soybean oil and the price of diesel are non-stationary, so their first difference is used for the estimation. However, both the production of biodiesel and the national income are trend stationary and whether these variables are used for the estimation, or their first difference, depends on the results of the regressions and the tests.

Table 10: Dickey-Fuller Test with a Trend for Stationarity

Variable	Test Statistic	p-value	Interpretation
lnPoil	-0.649	0.9763	Non-stationary
lnProdbio	-4.635	0.0009	Stationary at the 1% level
lnPdiesel	-0.454	0.9851	Non-stationary
logY	-3.931	0.0110	Stationary at the 5% level

Critical values: 1% = –3.96; 5% = –3.66; 10% = –3.12 in Wooldridge (2013)

Considering the results of the Stationarity Tests, the regression is shown on equation 7 and it includes the first difference of price of soybean oil and price of diesel. Both production of biodiesel and income are used.

(7) $\ln Doil_t = \alpha + \beta_1 lnProdbio_t + \beta_2 \Delta lnPoil_t + \beta_3 \Delta lnPdiesel_t + \beta_4 \, lnBegoil_t + \beta_5 lnY + \beta_6 Reg + u_t$

The regression on equation 7 has a good explaining power with R^2 and Adjusted R^2 of 0.87. However, there is multicollinearity issue on the production of biodiesel and income. Then, we try the first difference of both variables, and the new regression is on equation 8.

(8) $\ln Doil_t = \alpha + \beta_1 \Delta lnProdbio_t + \beta_2 \Delta lnPoil_t + \beta_3 \Delta lnPdiesel_t + \beta_4 \, lnBegoil_t + \beta_5 \Delta lnY + \beta_6 Reg + u_t$

The regression on equation 8 has a low explaining power with R^2 and Adjusted R^2 of about 0.36. Even though the regulation variable is statistically significant, the production of biodiesel is not. No conclusions can be drawn about the policy if this regression is used. Next step is to use only the difference of the production of biodiesel as on equation 9.

(9) $\ln Doil_t = \alpha + \beta_1 \Delta lnProdbio_t + \beta_2 \Delta lnPoil_t + \beta_3 \Delta lnPdiesel_t + \beta_4 \, lnBegoil_t + \beta_5 lnY + \beta_6 Reg + u_t$

The regression on equation 9 has a good explaining power with R^2 and Adjusted R^2 of 0.84. Both the production of biodiesel and the regulation variable are statistically significant. The multicollinearity test does not detect any multicollinearity issues. However, serial correlation is detected.

A way to solve such a problem is to include a lagged dependent variable as a regressor (Wooldridge, 2013). Having that said, the lag variable is created as the lagged value of the demand for soybean oil, and the new regression is on equation 10.

$$(10)\ \ln Doil_t = \alpha + \beta_1 \Delta \ln Prodbio_t + \beta_2 \Delta \ln Poil_t + \beta_3 \Delta \ln Pdiesel_t + \beta_4 \ln Begoil_t + \beta_5 \ln Y + \beta_6 Reg + \beta_7\, lag + u_t$$

The regression on equation 10 has a good explaining power with R^2 and Adjusted R^2 of 0.88. Both the production of biodiesel and the regulation are statistically significant. The multicollinearity test does not detect any multicollinearity issues. However, serial correlation is still detected. However, the results of the serial correlation test show a much lower level of serial correlation than in the regression on equation 9. The next step is to regress using only the difference of income. As the lag variable is statistically significant and improved the explaining power of the regression and reduced serial correlation, it is also included in the new regression as shown on equation 11.

$$(11)\ \ln Doil_t = \alpha + \beta_1 \ln Prodbio_t + \beta_2 \Delta \ln Poil_t + \beta_3 \Delta \ln Pdiesel_t + \beta_4 \ln Begoil_t + \beta_5 \Delta nY + \beta_6 Reg + \beta_7\, lag + u_t$$

The regression on equation 11 has great explaining power with an R^2 and Adjusted R^2 of 0.91. The production of biodiesel is statistically significant, but the regulation is not. The tests do not detect any issues with multicollinearity, serial correlation, heteroskedasticity or normality. However, if the regression on equation 11 is used – no conclusions can be drawn about the influence of regulation. Considering that regulation is a dummy variable representing the blending of biodiesel with diesel higher than 10 per cent, it is possible to use an interaction term which is a product of a dummy variable and another explanatory variable to estimate the simultaneous impact of both variables on the dependent variable (Wooldridge, 2013). Therefore, an interaction between the production of biodiesel and the regulation is added to the regression on equation 11 so that it is possible to estimate the impact of the production of biodiesel alone and its impact under the regulation. The new regression is shown on equation 12.

$$(12)\ \ln Doil_t = \alpha + \beta_1 \ln Prodbio_t + \beta_2 \Delta \ln Poil_t + \beta_3 \Delta \ln Pdiesel_t + \beta_4 \ln Begoil_t + \beta_5 \Delta \ln Y + \beta_6 Reg + \beta_7\, lag + \beta_8 Reg\ln Prodbio_t + u_t$$

The regression on equation 12 has a great explaining power with an R^2 and Adjusted R^2 of about 0.92. Both the production of biodiesel and the interaction term are statistically significant. The coefficient of the production of biodiesel is 0.2385 in the regression on equation 11 and in the regression on equation 12 it is 0.2326 meaning that both regressions estimate a very similar impact of the production of biodiesel on the demand for soybean oil. However, the multicollinearity test detects multicollinearity issues with the regulation variable and the interaction variable. Considering that the regression on equation 11 has no problems with multicollinearity and the regression on equation 12 is the same regression with the interaction term, the multicollinearity issue arises from estimating the interaction between both variables. Also, all other independent variables have a VIF lower than 10. The multicollinearity issue with the interaction term and the regulation variable does not invalidate the results. There are no issues with serial correlation, heteroskedasticity or normality. The regression on equation 12 appears to be the best at explaining the impacts of both the production of biodiesel and the regulation on the demand for soybean oil.

Before presenting the results of the tests and the regression on equation 12, other potential model specifications are run and briefly discussed. The first one is to estimate the impact of time on the regression on equation 12. The second one is to estimate the impact of dropping one of the independent variables.

The influence of time is of paramount importance when estimating regressions with time series data and to avoid running a spurious regression. In the case of the regression on equation 12, the dependent variable is stationary meaning that the regression should not be spurious. To make sure that assumption holds, a time variable is added to the regression on equation 12 to investigate the impacts on time on the results. The R^2 and Adjusted R^2 are 0.92. The time variable is not statistically significant. The coefficient for the production of biodiesel reduces from 0.2326 to 0.2016 whereas the coefficient for the interaction term increases from 0.2666 to 0.2714. The change in the coefficients is small. The multicollinearity test detects multicollinearity issues for both the time variable and the production of biodiesel. Lastly, to estimate the impact of time on the dependent variable, another regression is performed in which the demand for soybean oil is regressed on the time variable alone. The coefficient for time is 0.0043 showing that time has a very small impact on the demand for soybean oil. Therefore, the regression on equation 12 appears to be a better model without the time variable. Another reasonable assumption is that the lag variable already controls for the influence of time in the regression.

To investigate how the results change when one of the dependent variables is dropped, the regression on equation 12 is performed again without the variable beginning stocks since it is not a statistically significant in that regression. However, the R^2 and Adjusted R^2 are slightly smaller when the beginning stocks variable is dropped. The same happens when any of the other independent variables are dropped. Therefore, we stick to the regression on equation 12.

5.2 – Model Estimation and Results

The estimation is performed according to equation 12:

(12) $\ln Doil_t = \alpha + \beta_1 \ln Prodbio_t + \beta_2 \Delta \ln Poil_t + \beta_3 \Delta \ln Pdiesel_t + \beta_4 \ln Begoil_t + \beta_5 \Delta \ln Y + \beta_6 Reg + \beta_7 lag + \beta_8 Reg\ln Prodbio_t + u_t$

The results of the multicollinearity test are shown in table11. All independent variables have a VIF below 10. However, the interaction term and the regulation variable have a high level of multicollinearity. This might be due to the interaction imposed in the regression considering that no multicollinearity is detected when the same regression is performed without the interaction term.

Table 11: VIF Test for Multicollinearity

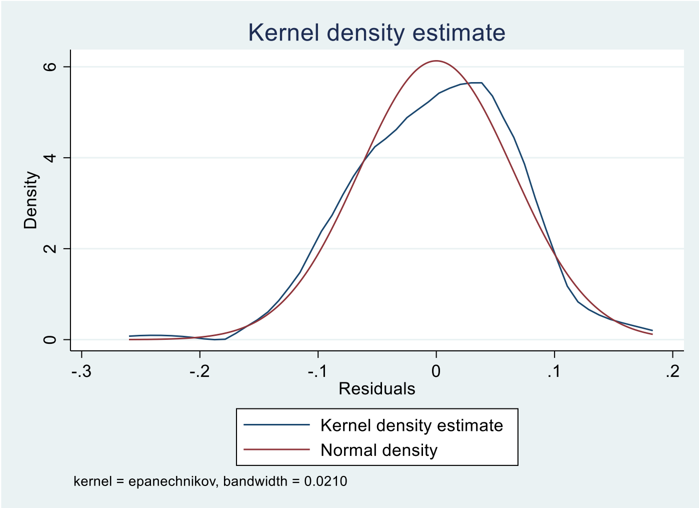
Variable	**VIF**	**1/VIF**
lnProdbio	7.89	0.126672
ΔlnPoil	1.18	0.850485
ΔlnPdiesel	1.16	0.862505
lnBegoil	1.11	0.904572
ΔlnY	1.20	0.834299
Reg	16163.03	0.000062
lag	8.04	0.124384
ReglnProdbio	16.196.80	0.000062

The results for the Breusch-Godfrey test for serial correlation show a chi-squared of 1.335 and a p-value of 0.2478. Thus, the null hypothesis of no serial correlation is not rejected meaning that serial correlation is not an issue.

The results for the Breusch-Pagan test for heteroskedasticity show a chi-squared of 10.99 and a p-value of 0.2020. Thus, the null hypothesis is of no heteroskedasticity is not rejected meaning that heteroskedasticity is not an issue either. This result does not come as a surprise because the results are the same when the same regression is performed with robust standard errors.

Lastly, the results for the Kernel Density test for normality test are shown on figure 1 which includes the normality curve for comparison. The normality test checks whether the errors are normally distributed which seems to be true according to figure 1.

Figure 1:Kernel Density test for Normality



After all those tests, the regression on equation 12 follow all the OLS assumptions for time series data which means that estimators are the best linear unbiased estimators (BLUE) and the inference, and everything used for estimation and inference for cross-sectional data applies here.

The regression results are shown in table12.

Table 12: Regression Results

Variable	**Coefficient**	**Standard Error**	**T-Statistics**
lnProdbio	0.2326923	0.0283467	8.21***
ΔlnPoil	-0.292451	0.1046172	-2.80***
ΔlnPdiesel	-0.5284387	0.2159749	-2.45**
lnBegoil	-0.0215666	0.0267152	-0.81
ΔlnY	1.267281	0.1538548	8.24***
1.Reg	-3.49213	1.667202	-2.09**
lag	0.4368274	0.0623278	7.01***
ReglnProdbio	0.2666764	0.1265468	2.11**
Constant	4.756018	0.5409631	8.79***

** 5% level of significance. *** 1% level of significance
Number of observations: 167
F (8, 158) = 231.52
Prob > F = 0.0000
R-squared = 0.9214
Adjusted R-squared = 0.9174
Root MSE = 0.0667

The results in table12 show that there are 167 observations, and the independent variables can explain about 92 per cent of the changes of the demand for soybean oil since the R-squared is 0.92. The variables production of biodiesel, price of soybean oil, national income, the lag and the constant are statistically significant at the 1% level. The fact that the lag variable is significant means that the past values of the demand for soybean oil help explaining its current values. The variables price of diesel, the regulation and the interaction term are statistically significant at the 5% level. However, regulation does not show significance when there is no interaction term as on equation 11, and the result in table12 is only when the regulation is 1 so that the interaction can be estimated. Therefore, the result for the regulation variable does not seem consistent. Only the beginning stocks variable does not show any level of statistically significance.

Turning towards the coefficients in table12. The price of soybean oil has a coefficient of -0.29. This means that if the price of soybean oil increases by 10 per cent, the demand for soybean oil reduces by 2.9 per cent. This negative result is expected and in accordance with consumer theory which states that there is a negative relationship between prices and quantities demanded. The price of diesel has a coefficient of -0.52. This means that if the price of diesel increases by 10 per cent, the demand for soybean oil reduces by 5.2 per cent. This negative result is expected and in accordance with consumer theory. Biodiesel is only sold blended with diesel, and soybean oil is the main raw material used to produce biodiesel, accounting for about 70 per cent of the total. The relationship between biodiesel and diesel is comparable to complementary goods. If the price of diesel increases, consumers buy less diesel which reduces the demand for biodiesel and consequently the demand for soybean oil. Income has a coefficient of 1.26. This means that if income increases by 10 per cent, the demand for soybean oil also increases by 12.6 per cent. This positive result is expected and in accordance with consumer theory. The higher the income, the higher the consumption for fuels, and consequently, for soybean oil.

The production of biodiesel has a coefficient of 0.23. This means that if the production of biodiesel increases by 1 per cent, the demand for soybean oil increases by 0.23 per cent. This positive result is expected and according to economic theory. However, it was expected a higher impact of the production of biodiesel on the demand for soybean oil because soybean oil is the main raw material used to produce biodiesel, accounting for about 70 per cent of the total and to produce one liter of biodiesel, 1.3 liters of soybean oil are required (Elgharbawy et al., 2021). This small result can be explained by the fact that the data representing the demand for soybean oil account for both refined and unrefined soybean oil used for food, chemical and biodiesel industries. To sum up, the biodiesel policy has a positive impact on the demand for soybean oil which increases 0.23 per cent given a 1 per cent increase in the production of biodiesel.

The interaction term has a coefficient of 0.26. It is the interaction between the production of biodiesel and a regulation when the content of biodiesel in diesel is more than 10 per cent. The coefficient 0.26 means that the production of biodiesel has an impact 0.26 higher on the demand for soybean oil when the regulation is in place. To estimate the total impact of the biodiesel policy on soybean oil, we can add the coefficient from the production of biodiesel, 0.23, and the coefficient from the interaction term, 0.26, totaling 0.49. To sum up, the impact of the biodiesel policy on the demand for soybean oil increases from 0.23 to 0.49 per cent when the regulation is in place. This positive result is expected because under the regulation more biodiesel is demanded as more of the diesel sold is biodiesel. The result also goes in accordance with the government decision to reduce the content of biodiesel in diesel from 13 to 10 per cent in September 2021.

6 – Conclusion

This study comes to provide some insights into the impact of the biodiesel policy and regulation on the demand for soybean oil in Brazil. The thesis aimed at investigating whether the governmental decision to reduce in three per cent the biodiesel content in diesel made sense considering the impact of the biodiesel policy and regulation on the demand for soybean oil. According to the government, the decision was to avoid an increase in diesel prices led by high soybean oil prices which is the main raw material for the production of biodiesel.

To draw the relationship between the biodiesel policy and regulation with the demand for soybean oil, (OLS) regression is performed using monthly data from January 2008 to December 2021. The explanatory variables include the production of biodiesel representing the biodiesel policy, real prices of soybean oil, real prices of diesel, soybean oil beginning stocks, monthly GDP representing income in Brazil, and a dummy variable for regulation which takes the value of 1 when biodiesel content in diesel is above 10 per cent. The model is adapted and changed throughout the estimation process to make sure all assumptions hold and to obtain relevant results. The results show that the biodiesel policy has a positive impact on the demand for soybean oil which increases 0.23 per cent given a 1 per cent increase in the production of biodiesel. When the regulation is in place, the impact of the biodiesel policy increases from 0.23 to 0.49 per cent.

The decision to reduce the biodiesel content in diesel in three per cent makes sense to avoid an increase in the prices of diesel driven by high soybean oil prices. The regulation has a clear impact on the dynamics of the market since the impact of the production of biodiesel increases from 0.23 to 0.49 per cent. Given the dependence Brazil has on fuels for transportation and the rampant inflation the country has been facing in the last two years, an increase in fuel prices would only make matters worse. It would also help mitigate the problem to encourage the production and use of other raw materials to produce biodiesel as well as increasing soybean processing capacity in the country.

It is worth mentioning that defining the content of biodiesel in diesel is a comprehensive decision involving different sectors of the Brazilian economy. However, reducing the content of biodiesel in diesel is taking a step behind in the environmental efforts to reduce the use of fossil fuels like diesel.

6.2 – Limitations and Recommendations for Future Research

The limitations of this study are mostly related to data. The biodiesel policy started in 2005, but only observations from 2008 were used. The demand for soybean oil included both refined and unrefined soybean oil for food, chemical and biodiesel industries which might have impacted the results. There might be other relevant variables not included in the model which might have impacted the results due to omitted variable bias.

The recommendations for future research go in line with the limitations of this study. Using only unrefined soybean oil data, or data excluding food use, to estimate the impact of the biodiesel policy. Including more potentially relevant variables in the model, such as, the number of cars running on diesel, other competing fuels, other raw materials used to produce biodiesel. Estimating the impact of the regulation separately according to the content of biodiesel in diesel so that the impact of the regulation could be quantified for each percentage change of biodiesel in diesel.

Bibliography

ABIOVE (2022). Associação Brasileira das Indústrias de Óleos Vegetais. Estatísticas. https://abiove.org.br/estatisticas/

ANP (2021). Agência Nacional do Petróleo, Gás Natural e Biocombustíveis. *CNPE mantém percentual de 10% de biodiesel no diesel em 2022*. https://www.gov.br/anp/pt-br/canais_atendimento/imprensa/noticias-comunicados/cnpe-mantem-percentual-de-10-de-biodiesel-no-diesel-em-2022

ANP (2022a). Agência Nacional do Petróleo, Gás Natural e Biocombustíveis. *Painel Dinâmico de Produtores de Biodiesel*. https://app.powerbi.com/view?r=eyJrIjoiOTlkODYyODctMGJjNS00MGIyLWJmMWItNGJlNDg0ZTg5NjBlIiwidCI6IjQ0OTlmNGZmLTI0YTYtNGI0Mi1iN2VmLTEyNGFmY2FkYzkxMyJ9&pageName=ReportSection8aa0cee5b2b8a941e5e0%22

ANP (2022b). Agência Nacional do Petróleo, Gás Natural e Biocombustíveis. *Dados Estatísticos*. https://www.gov.br/anp/pt-br/centrais-de-conteudo/dados-estatisticos

Azevedo, L. & Neto, R. (2020). Instabilidade no cenário socioeconômico e político no Brasil a partir de 2014: contrachoque do petróleo, mudanças no marco regulatório e operação Lava Jato. *Cadernos do Desenvolvimento Fluminense: Retomada econômica pós-pandemia: abordagens a partir dos territórios para o desenvolvimento do estado do Rio de Janeiro*. Edition 19 (2020), 11-42. https://doi.org/10.12957/cdf.2020.59048

BCB-DEPEC (2022). Banco Central do Brasil. Estatísticas. https://www.bcb.gov.br/

Besanko, D. & Braeutigam, R. (2011). *Microeconomics: International Student Version* (4th Edition). John Wiley & Sons (Asia) Pte Ltd.

Bregman, D. (2017). *A Petrobrás e as Atividades de Exploração e Produção no Brasil: Um Breve Histórico.* O Boletim Petróleo – Universidade Candido Mendes. https://royaltiesdopetroleo.ucam-campos.br/wp-content/uploads/2017/05/Bregman_Historia_da_Petrobras.pdf

Buchan, D. & Errington, C. (2008). *Commodities demystified: a guide to trading and the global supply chain* (2nd Edition). https://www.commoditiesdemystified.info/pdf/CommoditiesDemystified-en.pdf

Cachola, C., Andrade, A., & Peyerl, D. (2022).Tendências e Perspectivas para o Consumo de Combustíveis no Transporte Rodoviário Brasileiro entre 2020 e 2030. *Anais III Simpósio Interdisciplinar de Ciência Ambiental*, 167-176. https://doi.org/10.6084/m9.figshare.16766578.v2

Carter, C. C. (2017). *Futures and Options Markets: An Introduction*. Rebel Text.

Carvalho, L., Bueno, R., Carvalho, M., Favoreto, A., Godoy, A. (2013). Cana-de-açúcar e álcool combustível: histórico, sustentabilidade e segurança energética. *Enciclopédia Biosfera*, *9*(16), 530-543. https://www.conhecer.org.br/enciclop/2013a/agrarias/cana-de-acucar.pdf

CNPE (2018). Conselho Nacional de Política Energética. *Resolução Nº 16, de 29 de Outubro de 2018.* https://www.gov.br/mme/pt-br/assuntos/conselhos-e-comites/cnpe/resolucoes-do-cnpe/arquivos/2018/resolucao_16_cnpe_29-10-18.pdf

Contini, E., Gazzoni, D., Aragão, A., Mota, M., Marra., R. (2018). *Complexo Soja - Caracterização e Desafios Tecnológicos*. Embrapa. https://www.embrapa.br/documents/10180/0/COMPLEXO+SOJA+-+Caracteriza%C3%A7%C3%A3o+e+Desafios+Tecnol%C3%B3gicos/709e1453-e409-4ef7-374c-4743ab3bdcd6

Copesucar (2020). *Etanol*. Série CoperBooks. https://www.copersucar.com.br/wp-content/uploads/2020/09/01-E-book-Etanol-Web.pdf

Das, P. (2019). *Econometrics in Theory and Practice: Analysis of Cross Section, Time Series and Panel Data with Stata 15.1*. Springer Singapore. https://doi.org/10.1007/978-981-32-9019-8

DERAL (2022). Departamento de Economia Rural do Paraná. Relatório de Preços. https://www.agricultura.pr.gov.br/deral/precos

Ebghaei, F. (2017). OPEC and Its Role in Regulating Price of Petroleum. *Munich Personal RePEc Archive*. Paper n. 80156. https://mpra.ub.uni-muenchen.de/80156/1/MPRA_paper_80156.pdf

Elgharbawy, A., Sadik, W., Sadek, O., Kasaby, M. (2021). A Review on Biodiesel Feedstocks and Production Technologies. Journal of the Chilean Chemical Society vol.66 no.1 Concepción Jan. 2021. http://dx.doi.org/10.4067/S0717-97072021000105098

FAOstat (2022). Food and Agriculture Organization of the United Nations statistical database. https://www.fao.org/faostat/en/#data

FGV (2022). Fundação Getúlio Vargas. Índice Geral de Preços – Disponibilidade Interna (IGP-DI). https://extra-ibre.fgv.br/IBRE/sitefgvdados/default.aspx

Fishlow, A. (1986). A economia política do ajustamento brasileiro aos choques do petróleo: uma nota sobre o período 1974/84. *Pesquisa e Planejamento Econômico, 16*(3), 507-550. http://repositorio.ipea.gov.br/bitstream/11058/6028/1/PPE_v16_n03_Economia.pdf

Freitas, I., Rosa, M. & Dalfovo, W. (2018). Influência da produção de biodiesel no preço da soja no Brasil. *Revista de Economia da UEG*, 14(2), 45-65. https://doi.org/10.5281/zenodo.5248720

Gazzoni, D. & Dall'agnol, A. 2018. *A saga da soja: de 1050 a.C. a 2050 d.C.* Embrapa. https://www.embrapa.br/busca-de-publicacoes/-/publicacao/1093166/a-saga-da-soja-de-1050-ac-a-2050-dc

Gujarati, D. (2003). *Basic econometrics* (4th ed., pp. XXIX, 1002). McGraw-Hill.

Hirakuri, M., Lazzarotto, J. & Ávila, M. (2010). *Avaliação da relação entre soja e produção de biodiesel* [Conference presentation]. Congresso da Sociedade Brasileira de Economia, Administração e Sociologia Rural. http://ainfo.cnptia.embrapa.br/digital/bitstream/item/30053/1/167.pdf>.

IPEAdata, 2022. IPEAdata macroeconômico. http://ipeadata.gov.br/Default.aspx

James, T. (2016). *Commodity market trading and investment: A practitioners guide to the markets*. Palgrave Macmillan

Leite, R. & Cortez, L. (2008). O etanol combustível no Brasil. *Biocombustíveis no Brasil: Realidades e Perspectivas*. Ministério das Relações Exteriores. 60-75. https://www.agencia.cnptia.embrapa.br/Repositorio/etanol3_000g7gq2cz702wx5ok0wtedt3xdrmftk.pdf

Leite, R. & Leal, M. (2007). O biocombustível no Brasil. *Novos Estudos*, (78). https://doi.org/10.1590/S0101-33002007000200003

MAPA (2007). Ministério da Agricultura, Pecuária e Abastecimento. *Balanço Nacional da Cana-de-Açúcar e Agroenergia*. https://www.gov.br/agricultura/pt-br/assuntos/sustentabilidade/agroenergia/arquivos-balanco-nacional-da-cana-de-acucar-e-agroenergia-2007/balanco-nacional-da-cana-de-acucar-e-agroenergia-2007.pdf

MAPA (2019). Ministério da Agricultura, Pecuária e Abastecimento. Programa Nacional de Produção e Uso do Biodiesel (PNPB). https://www.gov.br/agricultura/pt-br/assuntos/agricultura-familiar/biodiesel/programa-nacional-de-producao-e-uso-do-biodiesel-pnpb

Marques, P. V., Mello, P. C. & Martines, J.G. *Mercados Futuros e de Opções Agropecuárias*. Departamento de Economia, Administração e Sociologia da Esalq/USP. Universidade de São Paulo. https://www.agencia.cnptia.embrapa.br/Repositorio/did-129_000fk725ekp02wyiv80sq98yqoy5hp4u.pdf

Matias, M., Silva, C., Vieira, L. (2005). Análise de padrões de comportamento de preços com fins de projeção de receita: testes estatísticos em uma série temporal de preços da commodity cobre. *Brazilian Business Review*, 2(2), 108–123. https://doi.org/10.15728/bbr.2005.2.2.2

ME (2020). Ministério da Economia. *Nota Técnica SEI nº 36442/2020/ME*. https://www.biodieselbr.com/pdf/18092020170924_NotaTecnica_MinisterioEconomia.pdf

Melo, I. E. (2008). *As crises do petróleo e seus impactos sobre a inflação do Brasil*. [Bachelor thesis]. Pontifícia Universidade Católica do Rio de Janeiro. http://www.econ.puc-rio.br/uploads/adm/trabalhos/files/Isabela_Esterminio_de_Melo.pdf

Michellon, E., Santos, A. & Rodrigues, J. 2008. *Breve Descrição do Proálcool e Perspectivas Futuras para o Etanol produzido no Brasil*. Congresso da Sociedade Brasileira de Economia, Administração e Sociologia Rural, Maringá. https://ageconsearch.umn.edu/record/109225/

Miranda, R., (2018). Guerra Comercial Estados Unidos x China e o impacto na soja e no milho brasileiro. *Boletim Informativo do Centro de Inteligência do Milho, 10*(95). https://ainfo.cnptia.embrapa.br/digital/bitstream/item/190626/1/Guerra-comercial.pdf

MME (2022). Ministério de Minas e Energia. *Biodiesel*. http://antigo.mme.gov.br/web/guest/secretarias/petroleo-gas-natural-e-biocombustiveis/acoes-e-programas/programas/biodiesel

Nunes, A. F. (2016). *O Choque do Petróleo de 1973: Estados Unidos, OPAEP e a Segurança Energética*. [Master thesis]. Universidade Federal do Rio de Janeiro. https://ppghc.historia.ufrj.br/index.php?option=com_docman&view=download&alias=199-o-choque-do-petroleo-de-1973-estados-unidos-opaep-e-a-seguranca-energetica&category_slug=dissertacoes&Itemid=155

OFT (2009). The Office of Fair Trading. *Governments in Markets*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/284451/OFT1113.pdf

Oliveira, T., Gouvêa, E., Mayumi, A., Shitsuka, R. (2017). Um Estudo de Matérias-primas para Fabricação de Biodiesel. *Educação, Gestão e Sociedade: revista da Faculdade Eça de Queirós*. 7(27). http://uniesp.edu.br/sites/_biblioteca/revistas/20170919090536.pdf

Pedroti, P. M. (2011). *Entre a Estrutura Institucional e a Conjuntura Política: O Programa Nacional de Produção e Uso do Biodiesel (PNPB) e a combinação inclusão social – participação*. [PhD thesis]. Fundação Getúlio Vargas. https://pesquisa-eaesp.fgv.br/sites/gvpesquisa.fgv.br/files/paula_maciel_pedroti.pdf

Pereira, L. M., (2009). *Modelo de Formação de Preços de Commodities Agrícolas Aplicado ao Mercado de Açúcar e Álcool*. [PhD thesis]. Universidade de São Paulo. https://teses.usp.br/teses/disponiveis/12/12139/tde-04062009-155921/publico/Tese_Doutorado_Leonel_20090421.pdf

Pfluck, B. (2016). *O valor do Petróleo para o Brasil: dos choques da década de 1970 ao Pré-Sal* [Bachelor thesis]. Universidade Federal do Rio Grande do Sul. https://lume.ufrgs.br/bitstream/handle/10183/166178/001026496.pdf?sequence=1&isAllowed=y

Pires, A., Oliveira, A. & Machado, C. (2010). Biodiesel: obtenção de biodiesel a partir de resíduos de gorduras animais e óleos vegetais com auxílio de catalisadores. *Revista de divulgação do Projeto Universidade Petrobras e IF Fluminense*, 1, 75-79. https://www.researchgate.net/publication/277120339_Biodiesel_obtencao_de_biodiesel_a_partir_de_residuos_de_gorduras_animais_e_oleos_vegetais_com_auxilio_de_catalisadores

Planalto. Lei nº 8.723 de 28 de outubro de 1993. http://www.planalto.gov.br/ccivil_03/leis/l8723.htm

Prates, C., Pierobon, E. & Costa, R. (2007). Formação de mercado de biodiesel no Brasil. *BNDES Setorial, Rio de Janeiro*, 25, 39-64. https://web.bndes.gov.br/bib/jspui/bitstream/1408/2528/1/BS%2025%20Forma%C3%A7%C3%A3o%20do%20mercado%20de%20biodiesel%20no%20brasil_P.pdf

Pugliese, L., Lourencetti, C., & Ribeiro, M. L. (2017). Impactos Ambientais na Produção do Etanol Brasileiro: Uma Breve Discussão do Campo à Indústria. *Revista Brasileira Multidisciplinar*, 20(1), 142-165. https://doi.org/10.25061/2527-2675/ReBraM/2017.v20i1.472

Rhoden, A., Costa, N., Santana, A., Oliveira, G., Gabbi, M. (2020). Análise das Tendências de Oferta e Demanda para o Grão, Farelo e Óleo de Soja no Brasil e nos Principais Mercados Globais. *Desenvolvimento em Questão*, *18*(51), 93–112. https://www.revistas.unijui.edu.br/index.php/desenvolvimentoemquestao/article/view/9139

Rico, J. (2007). Programa de Biocombustíveis no Brasil e na Colômbia: uma análise de implantação, resultados e perspectivas [Master thesis]. Universidade de São Paulo. https://teses.usp.br/teses/disponiveis/86/86131/tde-07052008-115336/publico/ultimaju.pdf

Rodrigues, G. & Ross, J. (2020). *A trajetória da cana-de-açúcar no Brasil: perspectivas geográfica, histórica e ambiental.* Editora da Universidade Federal de Uberlândia (EDUFU). http://www.edufu.ufu.br/sites/edufu.ufu.br/files/edufu_a_trajetoria_da_cana-de-acucar_no_brasil_2020_ficha_corrigida.pdf

Sallet, C. (2011). *Os Biocombustíveis no Brasil e a relação entre os mercados agrícolas e de energia.* [Master's thesis]. Pontifícia Universidade Católica do Rio Grande do Sul. https://repositorio.pucrs.br/dspace/bitstream/10923/2584/1/000431815-Texto%2BCompleto-0.pdf

Sallet, C., & Alvim, A. (2011). Biocombustíveis: uma análise da evolução do biodiesel no Brasil. *Revista Economia & Tecnologia*, 7(2). http://dx.doi.org/10.5380/ret.v7i2.26828

Sandroni, P. (1999). *Novíssimo Dicionário de Economia*. Editora Best Seller.

Senado Federal. (2021, September 30). *Comissão debate na terça porcentagem de biodiesel no óleo diesel*. https://www12.senado.leg.br/noticias/materias/2021/09/30/comissao-debate-na-terca-porcentagem-de-biodiesel-no-oleo-diesel

Silva, J. (2013). Avaliação do Programa Nacional de Produção e Uso do Biodiesel no Brasil – PNPB. Revista Política Agrícola. 23(3), 18-31. https://seer.sede.embrapa.br/index.php/RPA/article/viewFile/763/720

Souza, M., Bacchi, P. & Alves, L. (2019). Análise de Fatores que Influenciam o Processamento de Soja no Brasil. *Revista de Economia e Agronegócio*, 17(3), 485–506. https://doi.org/10.25070/rea.v17i3.7957

Terazono, E. & Jacobs, J. (2021, September 8). 'Diesel vs doughnuts': new biofuel refineries squeeze US food industry. *Financial Times*. https://www.ft.com/content/b5839a04-a06a-49c1-8622-2974cbb9a84a

Varian. (2014). Intermediate microeconomics: a modern approach (7th ed.). W.W. Norton & Co.

Veloso, F., Villela, A., Giambiagi, F. (2008). Determinantes do "milagre" econômico brasileiro (1968-1973): uma análise empírica. *Revista Brasileira de Economia*, *62*(2), 221-245. https://doi.org/10.1590/S0034-71402008000200006

Whelan, J. & Msefer, K. (1996). *Economic Supply and Demand*. MIT System Dynamics in Education Project. https://ocw.mit.edu/courses/sloan-school-of-management/15-988-system-dynamics-self-study-fall-1998-spring-1999/readings/economics.pdf

Węglarczyk, S. (2018). Kernel density estimation and its application. *ITM Web of Conferences*, 23, 1-8. https://doi.org/10.1051/itmconf/20182300037

Wooldridge, J. (2013). *Introductory econometrics: a modern approach* (5th ed., international ed., pp. XXVII, 878). South-Western, Cengage Learning.

Norges miljø- og biovitenskapelige universitet
Noregs miljø- og biovitskapelege universitet
Norwegian University of Life Sciences

Postboks 5003
NO-1432 Ås
Norway