

**JOÃO VITOR TSUYOSHI SATO**

**GASOLINE DEMAND AND TAX SALIENCE IN BRAZIL**

Dissertação apresentada à Universidade Federal de Viçosa, como parte das exigências do Programa de Pós-Graduação em Economia Aplicada, para obtenção do título de *Magister Scientiae*.

Orientador: Leonardo Chaves Borges Cardoso

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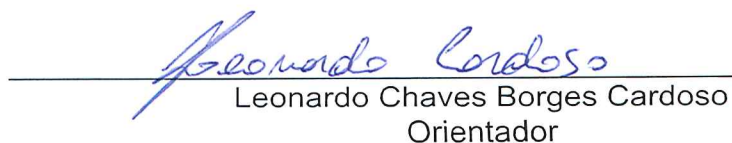
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## RESUMO

SATO, João Vitor Tsuyoshi, M.Sc., Universidade Federal de Viçosa, dezembro de 2020. **Demanda de Gasolina e saliência dos impostos no Brasil**. Orientador: Leonardo Chaves Borges Cardoso.

A gasolina é um dos principais combustíveis para veículos no Brasil e esta, sendo um combustível fóssil, também é uma das principais responsáveis pelo aquecimento global. Nesse sentido, essa dissertação faz um estudo relativo à demanda de gasolina no Brasil utilizando uma regressão de mínimos quadrados de dois estágios. Observou-se que ao utilizar os impostos da gasolina como variáveis instrumentais, estas tendem a aumentar o valor da elasticidade preço da gasolina, o que gera valores superestimados e geralmente implausíveis. Para contornar este problema foram adicionados *leads* e *lags* nas taxas da gasolina, uma vez que o comportamento antecipatório dos consumidores produz um problema de endogeneidade e acaba por invalidar a regressão por variáveis instrumentais. O resultado demonstra que o consumidor brasileiro possui comportamento antecipatório frente a aumentos nos impostos da gasolina. Para analisar em que medida o consumo de gasolina é afetado quando seu preço muda por fatores de precificação de mercado ou por meio de tributação governamental, foram estimadas, via mínimos quadrados ordinários, a elasticidade-preço e a elasticidade taxa da gasolina no período de janeiro de 2002 a dezembro de 2018. Essa análise é importante uma vez que o consumo de combustíveis fósseis é um dos principais causadores do aquecimento global. Os resultados mostraram que o consumidor brasileiro reage mais a aumentos nos impostos da gasolina do que aumentos nos preços de mercado desta. Esse resultado é importante pois possibilita maior eficácia na introdução de políticas públicas que almejam a redução de gases efeito-estufa.

Palavras-chave: Gasolina. Demanda. Saliência. Elasticidades. Emissões de Carbono.

## ABSTRACT

SATO, João Vitor Tsuyoshi, M.Sc., Universidade Federal de Viçosa, December, 2020. **Gasoline demand and tax salience in Brazil.** Adviser: Leonardo Chaves Borges Cardoso.

Gasoline is one of the main fuels for vehicles in Brazil and being a fossil fuel, is also one of the main responsible for global warming. In this sense, this dissertation makes a study on demand for gasoline in Brazil using a two-stage least square regression. It was observed that when using gasoline taxes as instrumental variables, they tend to increase the value of the gasoline price elasticity, which generates overestimated and generally implausible values. To circumvent this problem, leads and lags were added to the gasoline taxes, since the anticipatory behavior of consumers produces an endogeneity problem and ends up invalidating the regression by instrumental variables. The results demonstrates that the Brazilian consumer has an anticipatory behavior in the face of increases in gasoline taxes. To analyze the extent to which gasoline consumption is affected when its price changes due to market pricing factors or through government taxation, we estimated via ordinary least squares the elasticity-price and elasticity-tax of gasoline in the period from January 2002 to December 2018. This analysis is important since the consumption of fossil fuels is one of the main causes of global warming. The results showed that the Brazilian consumer reacts more to increases in gasoline taxes than increases in market prices for this gasoline. This result is important because it enables greater efficiency in the introduction of public policies that aim to reduce greenhouse gases.

Keywords: Gasoline. Demand. Salience. Elasticities. Carbon Emissions.

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## 1. INTRODUCTION

Global warming is one of the most pressing problems the World faces in the 21st century. According to the World Health Organization (WHO), climate change affects the social and environmental determinants of health like clean air, safe drinking water, sufficient food, and secure shelter. Also, from the WHO, between 2030 and 2050, it is expected that climate change causes approximately 250.000 additional deaths per year from malnutrition, malaria, diarrhoea, and heat stress.

The increase in the average temperature is caused by the massive increase of greenhouse gases (GHGs) in the atmosphere resulting from burning fossil fuels and deforestation (MASLIN, 2004). A higher concentration of GHGs leads to surface warming of the land and oceans and the resulting climate change, such as changes in temperature extremes, precipitations patterns, storm location, and water availability. All these changes can profoundly impact biological and human activities that are sensitive to the climate (NORDHAUS,2008).

The set of changes to the Earth's climate represents an unpredictable challenge to scientists. Dealing with this complex problem of mitigating climate change is the biggest challenge for science globally (NOBRE, REID, and VEIGA, 2012). The questions and methodology related to it are diverse in economic literature, but we can divide those into two main branches. The first aims to measure the impacts of climate change on main economic concerns such as growth, income, inequality, poverty, land use, and agricultural productivity (CLINE, 2007; DESCHÊNES and GREENSTONE, 2007; GASPER, BLOHM and RUTH, 2011; TOL, 2018, for example). The second aims to mitigate climate change's harmful effects (PEARCE, 1991; POTERBA, 1991; NORDHAUS, 2001, for example), trying to understand the best tools to deal with the problem. In this study, we try to contribute to the second branch.

Once the scientific consensus is that climate change is caused mainly by greenhouse gas emissions caused by the burning of fossil fuels (ORESQUES, 2004), to slow global warming, policy addressed to reduce GHGs emissions as biofuels subsidies and environmental taxes plays a key role (KYOTO PROTOCOL, 1998). To verify the effectiveness of these policies, price and tax elasticities are key variables. Here, we separated these two elasticities due to recent and growing literature, e.g. Rivers and Schaufele (2015) and Davis and Kilian (2011), indicating that the source of the price increase may have different effects on final demand. The same amount of price variation originated due to tax

changes would have a greater impact than those originating in other market movements. Therefore, the power of taxes to fight against greenhouse gases would be underestimated.

This study aims to analyse the impact of gasoline taxes on its demand and carbon emission. First, we estimate the gasoline demand using instrumental variables. Second, we report these results in terms of carbon emissions.

The master thesis is organized as follows. In Section 2, we do an overview of emissions in the World. It is followed by a discussion of fuel taxes in Brazil (Section 3) and carbon pricing (section 4). A review of the literature in gasoline demand and gasoline tax salience is presented in section 5. Section 6 is used to explain the methods and estimation strategy used here. After that, the results are showed (Section 7). Finally, we draw some important conclusions based on our analysis.

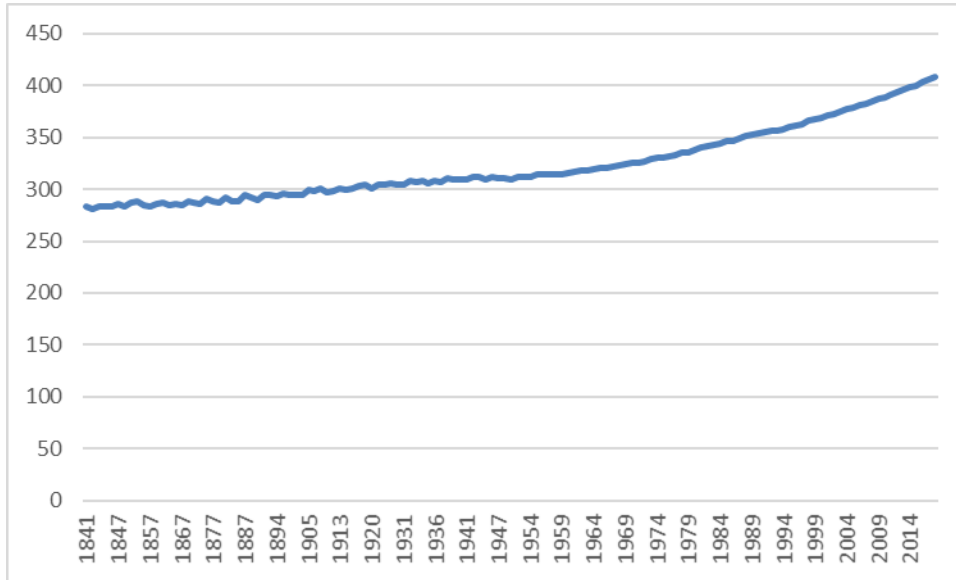
## **2 WORLD CARBON DIOXIDE EMISSION**

Carbon dioxide (CO<sub>2</sub>) is the primary gas emitted through human activities. The main source of human CO<sub>2</sub> emission is the combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation (EPA,2019). According to National Oceanic and Atmospheric Administration (NOAA), the quantity of CO<sub>2</sub> that human activity launched in the atmosphere have broken the natural balance of the carbon cycle, which is the CO<sub>2</sub> exchange between atmosphere and biosphere mainly through photosynthesis.

According to Houghton (2004), the Industrial Revolution disturbed this balance and since its beginning in about 1700, approximately 600 thousand million tonnes of carbon have been emitted into the atmosphere from fossil burning. This has resulted in a concentration of carbon dioxide in the atmosphere that has increased by about 44 percent, from 280 parts per million (ppm) around 1840 to 408 ppm in 2018.

As more CO<sub>2</sub> is pumped out, more is accumulating in the atmosphere than the plants and oceans can take it back. And add too much CO<sub>2</sub> traps heat causing the globe to warm up. Although gases like methane and nitrous oxide contribute to global warming, CO<sub>2</sub> is blamed to be the main factor causing the greenhouse effect because it is the most important anthropogenic greenhouse gas (IPCC,2007).

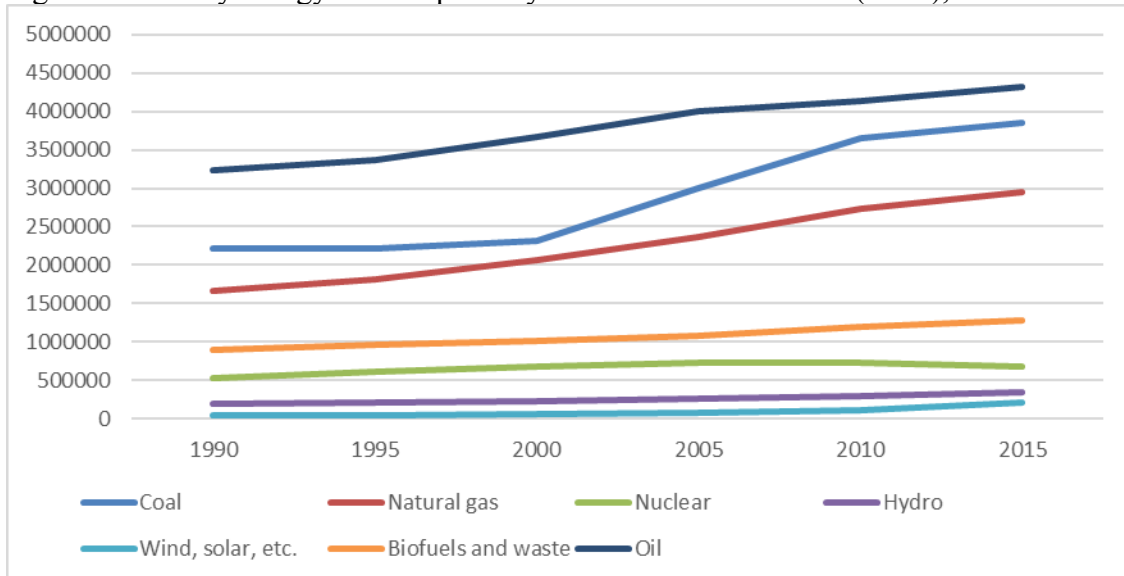
Figure 1: Concentration of CO<sub>2</sub> (ppm) in atmosphere



Source: Our world in data

Despite the threat of global warming, the global energy matrix is still based on fossil fuels. Natural gas, oil and coal are the leading primary energy consumption in the world:

Figure 2: Primary energy consumption by source in terawatt-hour (TWh), world

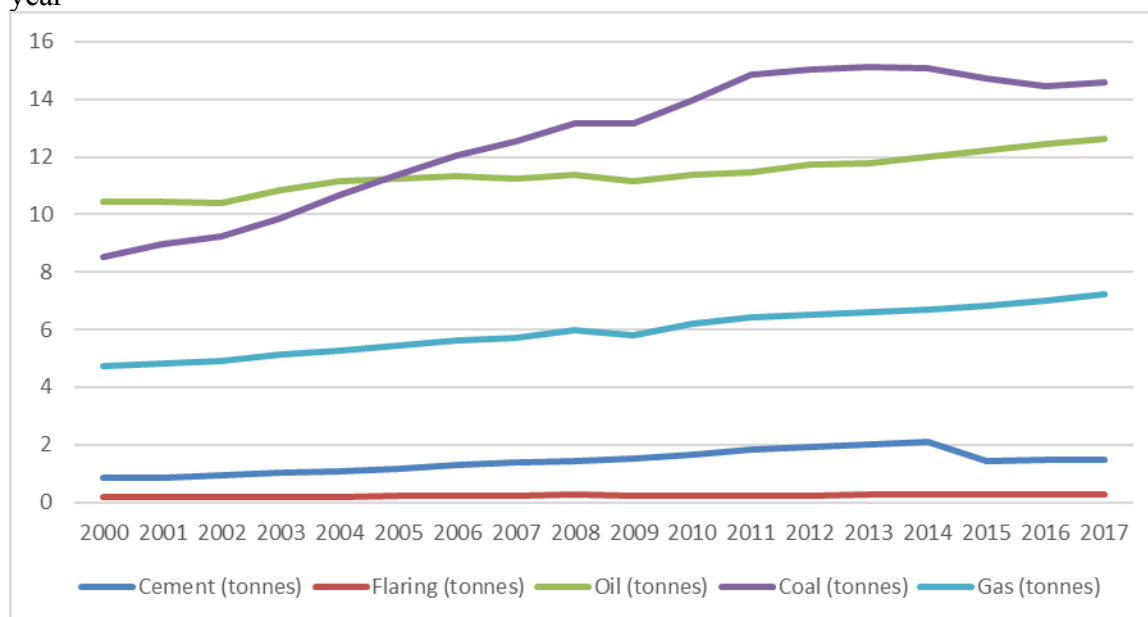


Source: BP Statistical Review of Global Energy. 2019

According to the BP Statistical Review of World Energy (2019), global primary energy grew by 2.9% in 2018, the fastest growth since 2010. Simultaneously, carbon emissions from energy use grew by 2.0%, the fastest expansion in many years, with emissions increasing by around 0.6 gigatonnes, equivalent to the carbon emissions associated with increasing the number of passenger cars on the planet by a third.

This growth was driven mainly by China, the United States, and India which together account for two-thirds of the growth. The strength in energy consumption was reflected across all the fuels but was particularly pronounced in natural gas demand, which increased 5.3%, one of its strongest growth rates for over 30 years, accounting for almost 45% of the entire growth in global energy consumption. Coal demand also increased by 1.4% in the second consecutive year. Despite all, renewable energy grew 14.5% and is the fastest-growing energy source in the World.

Figure 3: Annual carbon dioxide emissions from different fuel types, measured in tonnes per year

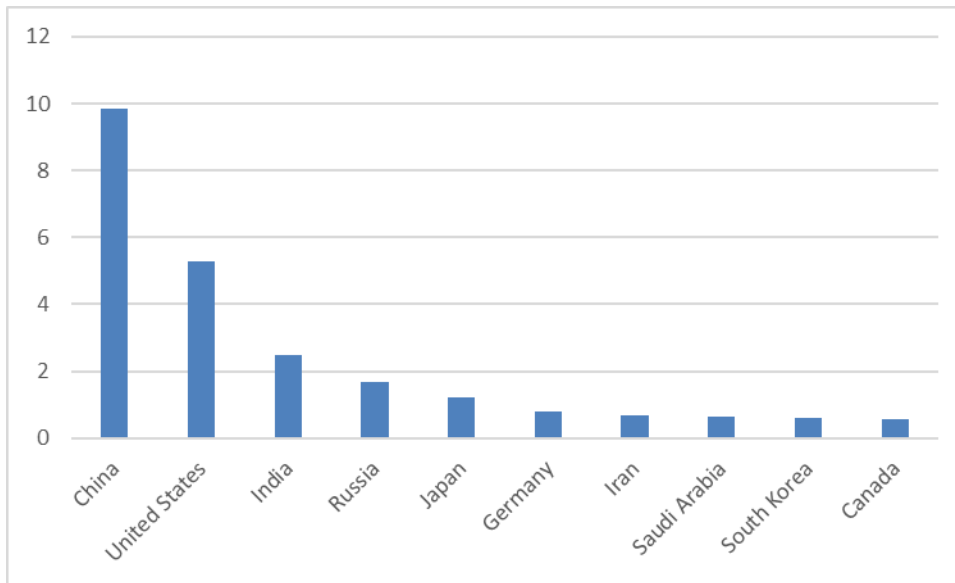


Source:

Global Carbon Project, 2019

Related to countries'  $\text{CO}_2$  emissions, China has become the largest polluter in the world. It emits nearly 10 billion tonnes each year, more than one-quarter of global emissions. The USA is the second-largest emitter at 18% of global emission, more than the entire Europe with 17%.

Figure 4: Carbon dioxide emission in measured in billion tonnes (2017)



Source: Global Carbon Project, 2019

Although China is the largest emitter, it is home to 1.38 billion people (WORLD BANK, 2019). When we divide its total emission by its population ( $\text{CO}_2$  emissions per capita), an average Chinese emitted around 7.12  $\text{CO}_2$  tonnes in 2017, much less than Qatar with a population of 2.64 million people and carbon emission of 0.13 billion tonne, a typical Qatari emitted 35.71  $\text{CO}_2$  tonnes. In fact, the world's largest per capita  $\text{CO}_2$  emitters are the major oil-producing countries with relatively low population size. Qatar had the highest per capita emission in 2017, followed by Trinidad and Tobago (30t); Kuwait (25t). United Arab Emirates (25t); Brunei (24t); Bahrein (23t) and Saudi Arabia (19t) (OUR WORLD IN DATA, 2019).

### 2.1 Brazil carbon dioxide emission

After an overview of the World's carbon emission, we are now presenting the carbon dioxide emission situation in Brazil.

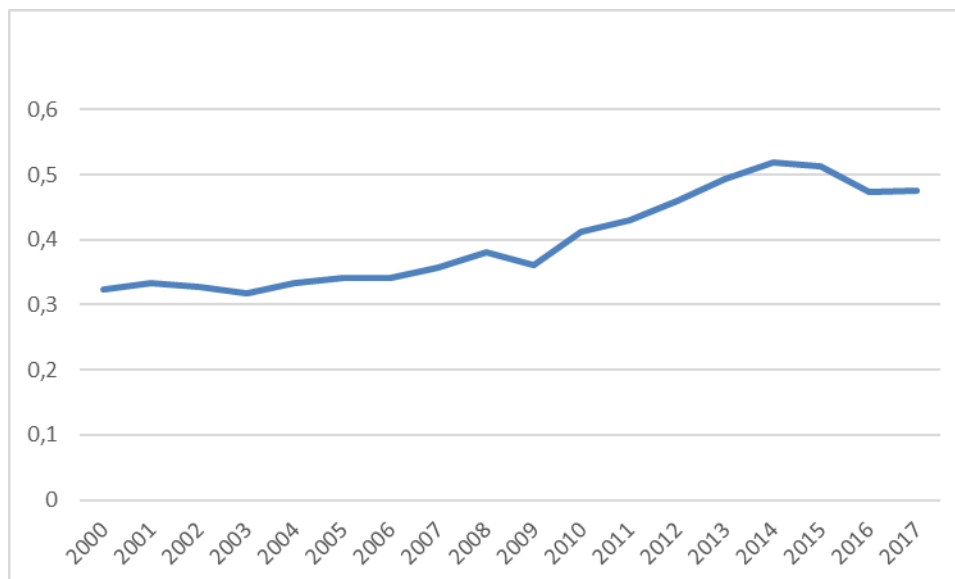
The largest Latin American country, Brazil stands out to have a strong presence of renewable sources, particularly sugarcane and hydropower in addition to traditional fossil fuels. According to the Brazilian Energy Balance (2018), the share of renewable energy in the Brazilian energy matrix increased from 40.7% in 2017 to 41.8% in 2018.

The crescent presence of renewable energy in the Brazilian energy matrix is not only useful to slow down the effects of global warming. It can also offer much broader benefits as contributing to economic and social development, greater access to energy, a safer electrical system, and reducing the negative impacts of the energy system on the environment and the

population's health. Their use also impacts social development by creating an emerging industrial sector and consequently, jobs and wealth (OLIVEIRA AND TRINDADE, 2018).

But, even with a favourable energy matrix, Brazil is one of the largest carbon dioxide emitters in the world, having emitted 476  $\text{CO}_2$  million tonnes in 2017.

Figure 5: Brazil  $\text{CO}_2$  emission per year (billion tonne)



Source: Global carbon project, 2019

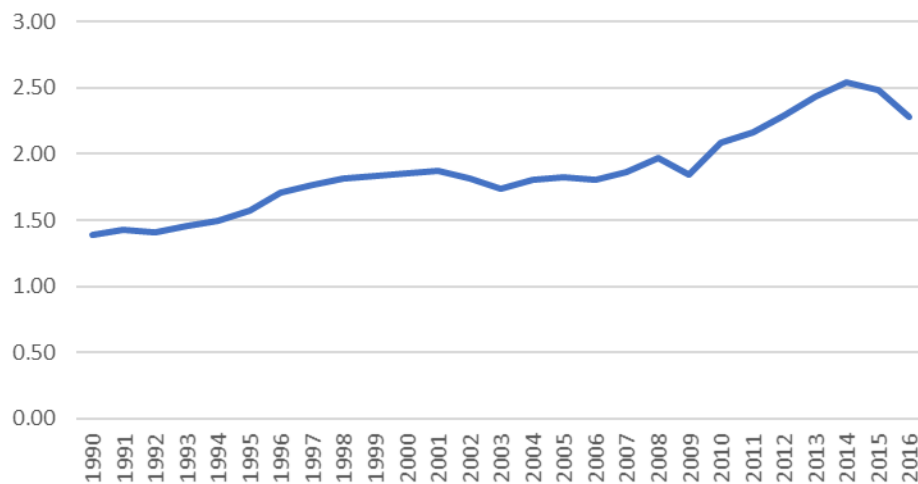
The main reason why Brazil occupied a high-rank level in  $\text{CO}_2$  emission is due to the agricultural sector. In fact, according to *Sistema de Emissões de Gases de Efeito Estufa* (SEEG), this sector responds to 47% of total  $\text{CO}_2$  emission in the country in the year of 2017. With the largest commercial beef herd in the world, if the Brazilian cattle sector was a country, it would rank 16<sup>th</sup> in league table countries with the highest GHG. A report from *Instituto de Manejo e Certificação Florestal e Agrícola (Imaflora)* and *Observatório do Clima (2015)* highlighted the double challenged Brazil is facing: stepping up its production to meet the needs of a growing population and reducing GHG emissions to mitigate global climate change.

It is important to stress that these challenges are also now nationally determined contributions, such as Brazil assumed during the 21<sup>st</sup> Conference of the Parties (COP 21) held in Paris in 2015, the ratification of the Paris Agreement.

Thus, the country pledged to reduce its GHG emissions by 37% below 2005 levels in 2025 and by 43% below 2005 levels in 2030. Sector-specific goals to be achieved by 2030 include: increasing the share of sustainable biofuels to 18%, zero illegal deforestation in the Brazilian Amazon, restore 12 million ha of forests, enhance sustainable native forest management, achieve 45% renewables in the energy mix and achieve 10% electricity

efficiency gains. However, report data from “*Emissões de GEE no Brasil e suas implicações para políticas públicas e a contribuição brasileira para o acordo de Paris*” showed that between 1990 and 2016 the gross GHG emissions increased 32% from 1.72  $\text{CO}_2$  billion tonnes to 2.27  $\text{CO}_2$  billion tonnes. An important point is that per capita emission has also increased. Data from the Global Carbon Project showed that while a Brazilian emitted around 1.70  $\text{CO}_2$  tonne per year, in 2016 that average jumped to 2.28 tonne per year.

Figure 6: Brazil  $\text{CO}_2$ (tonne) per capita emission



Source: Global Carbon Project, 2019

### 3 GASOLINE TAXATION IN BRAZIL

The Brazilian gasoline market is currently regulated by the *Agência Nacional de Petróleo* (ANP) and by the Federal Law 9478/97 (the Petroleum Act). This act added flexibility to the oil and natural gas market until held by Petrobras, opening the fuel market in Brazil. As such, in January 2002, gasoline imports were released, and the price went on to be defined by the market itself.

When consumers fill their car's tank up at a retail service station, the gasoline they purchase is a blend of grade "A" gasoline (ethanol-free) and anhydrous ethanol. The proportion of anhydrous ethanol in this blend is determined by the *Conselho Interministerial do Açúcar e do Alcool* (CIMA) that fixed in March 2015, 27% of ethanol in "A" gasoline (CIMA, 2015). This blend is called grade "C" gasoline and is sold through thousands of service stations throughout Brazil.

According to Petrobras (2020), the composition of consumer prices of C gasoline, based on the average price at the main cities are:

Box 1: "C" Gasoline price composition

"C" gasoline price composition	
12%	Distribution and retail
14%	Anhydrous alcohol cost
30%	ICMS
15%	CIDE PIS-COFINS
29%	Petrobras parcel

Source: PETROBRAS (2020)

There are two types of taxation in "C" gasoline. The state tax and the federal tax. The state tax is *Imposto sobre serviços e mercadorias* (ICMS) and it is calculated based on the average weighted price for the final consumer. Since state governments charge the gasoline average price on the sale of fuel between companies located in different states, the rates vary according to each unit of the federation and these rates range from 25% to 34%. The percentages are regulated by the *Conselho Nacional de Política Fazendária* (CONFAZ).

ICMS is an important revenue source and with the deepening of economic crisis, several states have chosen to change ICMS tax rates on various products and services. In 2015 for example, three states changed the ICMS rate on gasoline to increase their revenues. Minas Gerais had the biggest hike, whose rate went from 27% to 29%. The state of Rio de Janeiro has the highest ICMS rate for gasoline in the country, 34% in 2018, and the most expensive gasoline in the country (ANP,2018).

The federal taxes are *Programa de Integração Social e Contribuição para o financiamento da Seguridade Social (PIS/COFINS)* and *Contribuição Social de Intervenção no Domínio Econômico (CIDE)*.

PIS/COFINS are social contributions established by complementary law 07/1970, intended to finance federal social security. Specifically, the amounts collected by PIS are destined to finance salary allowance and unemployment insurance and COFINS has as purpose, financing the cost of social security.

CIDE was established by law 10.336/2001, which aims to ensure a minimum amount of resources for investment in transportation infrastructure, environmental projects related to the oil and gas industry, and subsidies for the transportation of ethanol fuel, natural gas, oil and oil products (AGÊNCIA DO SENADO, 2019). The tax had several changes and current is charged in R\$ 0.100 per liter of gasoline.

Box 2: Laws and decrees of *CIDE-combustíveis*

Year	Legislation	Abstract	Effect rates
2001	Law n° 10.336	Institutes CIDE with rate of R\$ 0.501 per litre of gasoline	01/01/02-29/12/02
2002	Law n° 10.636	Changes the CIDE rate to R\$ 0.860 per litre of gasoline	30/12/02-29/04/04
2004	Decree n° 5.060	Reduces the CIDE rate to R\$ 0.280 per litre of gasoline	30/04/04-01/05/08
2008	Decree n° 6.446	Reduces the CIDE rate to R\$ 0.180 per litre of gasoline	02/05/08-07/06/09
2009	Decree n° 6.875	Increases the CIDE rate to R\$ 0.230 per litre of gasoline	08/06/09-04/02/10
2010	Decree n° 7.095	Reduces the CIDE rate to R\$ 0.150 per litre of gasoline	05/02/10-30/04/10
2010	Decree n° 7.095 (2)	Rebound the CIDE rate to R\$ 0.230 per litre of gasoline	01/05/10-26/09/11
2011	Decree n° 7.570	Reduces the CIDE rate to R\$ 0.192 per litre of gasoline	27/09/11-31/10/11
2011	Decree n° 7.591	Reduces the CIDE rate to R\$ 0.091 per litre of gasoline	01/11/11-21/06/12
2012	Decree n° 7.764	Reset all gasoline CIDE rates to zero	22/06/12-30/04/15
2015	Decree n° 8.395	Restores the CIDE rate to R\$ 0.100 per litre of gasoline	01/05/15 – Current

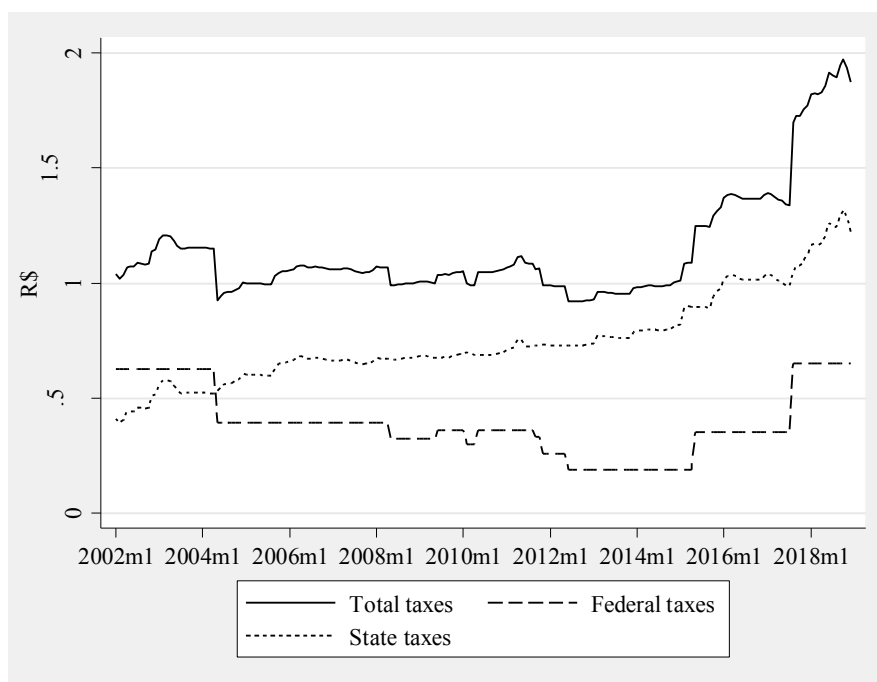
Source: Federal laws and federal decrees. Elaborated by author.

## Box 3: Gasoline taxation in Brazil (2019)

Gasoline taxation in Brazil	
Tax	Rate
ICMS (State tax)	25% to 34% the average weighted price
PIS/COFINS (Federal tax)	R\$ 0,7925/litre
CIDE (Federal tax)	R\$ 0,1000/litre

Source: *Fecombustíveis* (2019). Elaborated by the author

Figure 7: Brazil tax evolution 2002-2018



Source: Brazilian Legislation. Elaborated by the author

## 4 CARBON PRICING

Global warming can be viewed as a market failure. GHG emissions causes negative externality due to social and environmental costs and its impacts are not reflected in the market price of carbon-intensive goods and services and can be corrected by placing a price on carbon (ROSENBLOOM et al, 2020)

According to World Bank (2020) a price on carbon helps shifts the burden for the damage back to those who are responsible for it and who can reduce it. A carbon price gives an economic signal and polluters decide themselves whether to discontinue their polluting activity, reduce emissions, or continue polluting and pay for it. The carbon price also stimulates clean technology and market innovation, fuelling new, low-carbon drivers of economic growth.

There are two main types of carbon pricing: emissions trading systems (ETS) and carbon taxes.

An ETS, also known as “cap and trade”, is a cost-effective way of reducing greenhouse gas emissions. To incentivise firms to reduce their emissions, a government sets a cap on the maximum level of emissions and creates permits, or allowances, for each unit of their emissions allowed under the cap (LSE, 2018). The cap helps ensure that the required emissions reductions will take place to keep the emitters within their pre-allocated carbon budget.

An example of ETS is the European Union ETS that operates in all European Union countries plus Iceland, Liechtenstein, and Norway. It limits emissions from more than 11,000 heavy energy-using installations and airlines operating between these countries by setting a cap on the total amount of certain greenhouse gases that can be emitted, the cap is reduced over time so that total emissions fall. Within the cap, companies receive or buy emission allowances, which they can trade with one another as needed. After each year company must surrender enough allowances to cover all its emissions, otherwise heavy fines are imposed. If a company reduces its emissions, it can keep the spare allowances to cover its future needs or sell them to another company that is short of allowance (EUROPEAN UNION, 2015).

A carbon tax directly sets a price on carbon by defining a tax rate on greenhouse gas emission. Carbon taxes intend to reduce carbon dioxide emissions by increasing the price of fossil fuels and decreasing the demand for them.

An example of carbon tax is Chile that in October 2014 enacted the first climate pollution tax in South America. Part of a broad tax reform, Chile's carbon tax will target the power sector with installed capacity equal or larger than 50 megawatts. These installations

will be charged US\$ 5 per ton of carbon dioxide released in atmosphere. Thermal plants fuelled by biomass and smaller installations will be exempt (REUTERS, 2014).

Sweden is the country with the highest carbon tax in the world, charging US\$ 119 per dioxide carbon tone emission and was one of the first in the world, implemented in 1991. The Sweden carbon tax targets fossil fuels such as petrol, oil, and coal, used for heating purposes as well as motor fuels. The tax is calculated based on the estimated amount of CO<sub>2</sub> emissions covered energy products emit upon combustion. A measure that is based on the carbon content of fossil fuels (TAX FOUNDATION, 2020).

Box 4 shows the countries that have implemented carbon taxes and its rate in US\$/tonCO<sub>2</sub>.

Box 4: Countries that implemented carbon taxes

Carbon Taxes Implemented	
Country	Carbon price (US\$/tCO <sub>2</sub> )
Sweden	119
Switzerland	99
Liechtenstein	99
Finland (transport fuels)	68
Finland (other fossil fuels)	58
Norway	53
France	49
Iceland (fossil fuels)	30
Ireland (transport fuels)	28
Denmark (fossil fuels)	26
Slovenia (fossil fuels)	19
Spain	16
South Africa	7
Chile	5
Singapore	4
Japan	3

Source: World Bank: State and trends of Carbon pricing 2020

According to OECD (2018), there are no explicit carbon tax or an emission trading system in Brazil, otherwise there are specific taxes for electric sector and fuel sector. In the first, according to IDEC (2020), the consumers are charged on federal level, the taxes *PIS* and *COFINS*, on state level the *ICMS* and on the municipal level the *Custeio do Serviço de Iluminação Pública (CIP)*. Besides these costs, the consumers are still charged federal tariffs consisting of *Tarifa de Energia (TE)* and *Tarifa de Uso do Sistema de Distribuição (TUSD)*. In the second, according to ANP (2019), there are four taxes that apply on fuels: for gasoline

and diesel, the federal taxes charged are PIS/COFINS and CIDE and state tax is ICMS. Ethanol has the same taxation except CIDE.

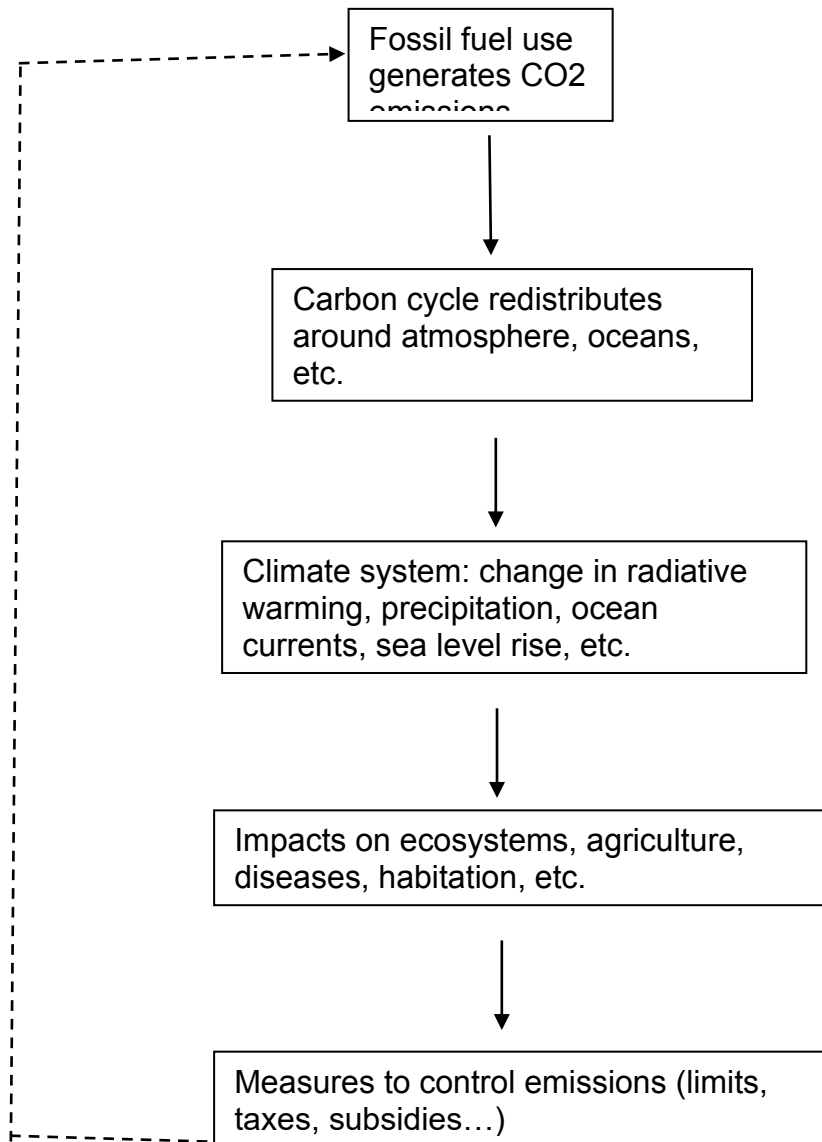
#### 4.1 The Social Cost of Carbon

The social cost of carbon (SCC) is an estimate, in dollars, of the economic damage that would result from emitting one additional ton of greenhouse gases into atmosphere. The SCC puts the effects of climate change into economic terms to help policy makers understand the economic decisions that would increase or decrease emissions (RENNERT AND KINGDON, 2019).

Nordhaus (2016) estimated that the SCC is US\$ 31 per ton of  $\text{CO}_2$ . The author came with that conclusion after an updated variables of a revised version of the Dynamic Integrated model of Climate and the Economy (DICE-2016R). The DICE model attempts to use the tools of modern economics to determine an efficient strategy for coping with the threat of global warming (NORDHAUS, 1992). The DICE model views the economic of climate change from the perspective of neoclassical economic growth theory, by including the concentrations of GHGs as negative capital end emissions reductions as investment that raise the capital. By devoting output to emissions reductions, economies reduce consumption today but prevent economically harmful climate change and thereby increase consumption possibilities in the future (NORDHAUS, 2013).

Figure 8 shows a schematic flow chart of the major modules and logical structure of the DICE model:

Figure 8: Structure of the DICE model:



Source: Nordhaus (2013)

Applying the SCC calculated by Nordhaus to the gasoline market in Brazil, the government should charge for every litre of gasoline type C (gasoline contain 27% of ethanol anhydrous) US\$ 0.05 as gasoline type C emits 1.679 kg/**CO<sub>2</sub>** in atmosphere.

## 5 LITERATURE REVIEW

There is a considerable amount of work in the literature regarding gasoline demand in Brazil and worldwide. This section aims to present several studies on the theme, introduce the concept of tax salience, and some work on the effects of taxes on reducing GHG emissions.

### 5.1 Empiric studies for gasoline demand

Dahl and Sterner (1991) made a survey of studies on gasoline demand classifying these studies by data type, countries, time periods, different functional forms, and econometric techniques. They separated these studies into 10 types of models, the simplest being the one in which the demand for gasoline ( $G$ ) is considered as a function of the real price of gasoline ( $P$ ) and the real income ( $Y$ ), as shown in equation (1). Models that did not consider some form of income or price were not disregarded.

$$G = f(P, Y) \quad (1)$$

The second set of models essentially used to capture the fact that adaptations take time are dynamic. If income or price changes in one year, but some consumers defer their reaction to a later year, then today's consumption is not the only function of today's income and price structure but of earlier income and prices as well. The model widely used to capture this dynamic dependence is the partial adjustment model. It gives the quantity of gasoline demanded ( $G$ ) as a function of the real price of gasoline ( $P$ ), real income ( $Y$ ) and the quantity of gasoline demanded in the last period ( $G_{t-1}$ ).

$$G = f(P, Y, G_{t-1}) \quad (2)$$

The third group considers the stock of vehicles ( $V$ ) as in the following model:

$$G = f(P, Y, V) \quad (3)$$

The fourth model considers beside the stock of vehicle, individual characteristics such as vehicle efficiency, average size and weight ( $CHAR$ ) which can be used as efficiency proxies. These models capture the long-run adjustments through the quantity and characteristics of the vehicle stock:

$$G = f(P, Y, V, CHAR) \quad (4)$$

The other models consider by the authors are variations and combinations of the models cited above. For example, models which include the vehicle price, other transport prices and lagged gasoline price and income.

Analysing the static models with yearly data, the elasticity estimates are 1.16 for income and -0.53 for price in the short run. For the dynamic models, the authors found short-run price elasticities in the range of -0.08 and -0.24 and long-run price elasticities in the range

of -0.23 and -1.05. In the short-run, income elasticities were found in the range of 0.14 and 0.5. In the long-run, income elasticities were found in the range of 0.60 and 1.31. The results indicate that the demand for gasoline is average inelastic for income and price.

Another way to measure gasoline demand is using integration techniques. Ramanathan (1999) estimated the short-run and long-run gasoline demand for India from 1972 to 1973 and from 1993 to 1994. The results of the study were a high-income elasticity (2.682) and a low-price elasticity (-0.319) in the long-run. In the short-run, the author has found income elasticity of 1.178 and price elasticity of -0.209.

Cheung and Thompson (2004) used the same technique to estimate the gasoline demand for China from 1980 to 1999. The authors have found in the long-run, income elasticity of 0.97 and price elasticity of -0.19, while for the short-run they have found income elasticity and price of 1.64 and -0.19 respectively.

Alves and Bueno (2003) estimated the gasoline demand for Brazil from 1974 to 1999 using cointegration techniques with the following model:

$$\ln C_t = \beta_0 + \beta_1 \ln Y_t + \beta_2 \ln P_t + \beta_3 \ln A_t + e_t \quad (5)$$

Where  $C_t$  is the yearly gasoline consumption measured in liters;  $Y_t$  is the yearly real GDP per capita;  $P_t$  is the yearly real gasoline price;  $A_t$  is the yearly real ethanol price and  $e_t$  is the residual.

The results show that gasoline price elasticity is inelastic in the long run and completely inelastic in the short run and ethanol is an imperfect substitute for gasoline even in the long run. The authors point out that any public policy that intends to replace gasoline as fuel must start long before oil reserves become scarce, otherwise the price of gasoline will rise sharply.

Cardoso et. al. (2019) estimated the elasticities of gasoline and ethanol, focusing on the changes caused by the introduction of flex-fuel cars in Brazil in 2003. The authors used monthly data from July 2001 to December 2014 and estimated a two-stage least square (2SLS).

The first stage to gasoline and ethanol are represented in equations (6) and (7) and the second stage are represented in equations (8) and (9):

First stage:

$$\ln P_{g_{it}} = \delta_{g0} + \delta_{g1} \ln Z_{j_{it}} + \delta_{g2} \ln \text{Income}_{it} + \delta_{g3} \ln \text{Fleet}_{it} + \delta_{g4} \ln P_{g_{it-1}} + v_{sit} \quad (6)$$

$$\ln P_{e_{it}} = \delta_{e0} + \delta_{e1} \ln Z_{j_{it}} + \delta_{e2} \ln \text{Income}_{it} + \delta_{e3} \ln \text{Fleet}_{it} + \delta_{e4} \ln P_{e_{it-1}} + v_{sit} \quad (7)$$

Gasoline second stage

$$\ln Q_{g_{it}} = \beta_{g0} + \beta_{g1} \ln \hat{P}_{g_{it}} + \beta_{g2} \ln \hat{P}_{e_{it}} + \beta_{g3} \ln \text{Income}_{it} + \beta_{g4} \ln \text{Fleet}_{it} + \varepsilon_{sit} \quad (8)$$

Ethanol second stage

$$\ln Q_{e_{it}} = \beta_{e0} + \beta_{e1} \ln \hat{P}_{e_{it}} + \beta_{e2} \ln P_{g_{it}} + \beta_{e3} \ln \text{Income}_{it} + \beta_{e4} \ln \text{Fleet}_{it} + \varepsilon_{sit} \quad (9)$$

Where  $\ln P_{g_{it}}$  and  $\ln P_{e_{it}}$  are the natural logarithm of real prices of gasoline and ethanol by state in Brazil.  $\ln Q_{g_{it}}$  and  $\ln Q_{e_{it}}$  are the natural logarithm of total amount of each fuel sold, measured in barrel of oil equivalent.  $\ln \text{Income}_{it}$  is the natural logarithm of income which in this paper was utilized as a proxy, the ICMS tax revenue.  $\ln \text{Fleet}_{it}$  is the natural logarithm of car fleet and  $\varepsilon_{sit}$  and  $v_{sit}$  are the residuals.

The results reached by the research showed that ethanol is an elastic good, with elasticity around -1.5. The income elasticity estimated for ethanol was slightly shorter than one, indicating that an income expansion has a great impact on ethanol demand. For gasoline demand price elasticity close to -0.78 was found, a higher value than those found in international markets. The reason is due to high arbitration of flex cars and a lower income in Brazil.

The results also show that the markets for gasoline and ethanol are fully integrated in Brazil. Every policy that potentially changes ethanol prices will have spillover effects on gasoline demand, and policies primarily designed to impact one fuel market can indeed affect other fuels' markets.

## 5.2 Tax Effects in Gasoline Demand and Carbon Emission

The second approach in our literature review is the set of empirical studies that measure the tax effects on gasoline demand and carbon emissions. This approach usually allows different effects on demand whether the price is changed due to tax or regular market movements.

In the United States, a third of carbon dioxide emissions are derived from the transportation sector, so the responsiveness of gasoline consumption to tax changes plays a significant role in determining the evolution of overall carbon dioxide emission in response to policy intervention. To measure how effective a gasoline tax increase would be in reducing gasoline consumption Davis and Killian (2010) used an instrumental variable specification, using monthly gasoline consumption at the national level from 1989 to 2008, and find a statistically significant price elasticity of -0.46.

The results indicate that gasoline consumption is more sensitive to gasoline taxes than would be implied by recent estimates of the gasoline price elasticity. A likely reason is that price changes inducted by tax changes are more persistent than the other price changes and thus induce larger behavioural changes.

With the econometrics results, the authors concluded that a 10-cent gasoline tax increase would reduce carbon emission in the United States by 0.48% a value that although not negligible is smaller than recent USA annual increases in carbon emission. To amplify the effects the authors, suggest a broad-based carbon tax on all sources of carbon dioxide rather than just gasoline and larger gasoline tax increases.

Kim, Han and Moon (2011) analyzed the introduction of the carbon tax for Korea using monthly data of national gasoline prices, gasoline consumption and taxes over the period 1999-2009 through an instrumental variable estimation, to measure the appropriate price elasticity and show how much gasoline consumption and GHG emission are reduced by carbon tax for different scenarios of the carbon tax rate

The authors used the natural logarithm of the real gasoline tax per liter as an instrument for gasoline price to control the endogeneity problem. The results of the IV estimation of the effect of price on gasoline consumption range from -0.4391 to -0.8764.

With these estimates, the authors measured the tax effects on carbon emissions. With an additional charge of 50,000 Korean won per  $\text{CO}_2$  ton, gasoline consumption is decreased by 5.16% and  $\text{CO}_2$  emissions are reduced by 1,090,325  $\text{CO}_2$  tons.

In 2008, the Canadian province of British Columbia (BC) enacted North America's first broad-based carbon tax designed to reduce greenhouse gas emissions. To evaluate the

impacts on gasoline demand and carbon emissions, Rivers and Schaufele (2015) used several econometric specifications such as variable instruments and robustness checks, covering the period of July 2007 to July 2012.

Their main result is that BC carbon tax generated demand response that is 4.9 times larger than is attributable to an equivalent change in the carbon tax-exclusive price. A five-cent increase in the market price of gasoline yields a 2.2 % reduction in the number of liters of gasoline consumed in the short run, while a five-cent increase in the carbon tax, a level approximately equal to a carbon price of \$25 per tonne, generates a 10.6% short-run reduction in gasoline demand.

The conclusion is that carbon tax is more salient than market determined price changes which means that carbon taxes produce larger demand responses than tax-exclusive price increases, the authors also find that the carbon tax was responsible for 2.4-million-ton carbon reduction in the Canadian province.

### 5.3 Tax Salience

According to Varela (2016) tax salience is a relatively new field of economic research that emphasises the way in which taxes are displayed can affect the behaviour of consumers. Particularly consumers are more likely to change their behaviour in response to highly visible and highly salient taxes.

There is a crescent literature that investigate the consumer's behaviour front to highly visible and highly salient taxes.

Chetty, Looney and Kroft (2009) tested the assumption that individuals optimize fully with respect to the incentives created by tax policies, using two empirical strategies. First an experiment at a large grocery store where they posted tax-inclusive prices for certain products and second, using data alcohol consumption from 1970-2003.

The authors find in the experiment test that taxes that are included in posted prices reduce demand significantly more than taxes that are not included in posted prices.

Sexton (2015) demonstrated that the introduction of automatic bill payment (ABP) eliminated the need to consumers to view electricity bills diminishing the perception and visibility of taxes charges. The results find by the authors showed an increase in residential electricity consumption by 4.0% and commercial electricity consumption by 8.1%.

Li, Linn and Muehlegger (2014) also find that tax increases have a larger effect in gasoline consumption than market prices increase.

The main explanation to consumers reacts different from tax increases is that changes in gasoline taxation receive a larger media attention than gasoline prices changes. Li,

Linn and Muehlegger (2014) tested whether gasoline taxes receive disproportionate levels of media attention and their results demonstrate that an increase in US\$ 0.01 change in retail gasoline price is associated with 805 words of newspaper coverage and 14 seconds of additional nightly news coverage, An increase of US\$ 0.01 in gasoline taxes is associated with 3,621 words of additional coverage and 129 seconds of additional network airtime.

## 6 METHODOLOGY

### 6.1 Gasoline Demand Estimation

The demand curve for gasoline is estimated from market data on the good quantity purchased at various prices over time. As each priced-quantity observation represents equilibrium market points, the model presents an identification problem. When an equation is not identified, it is not possible to estimate the underlying equation and when an equation is part of a simultaneous system of equations, such as the supply and demand for a product, direct estimates obtained from a linear regression will be biased (MCAULIFFE, 2014).

One way to circumvent this situation is to use instrumental variable methods. According to Cameron and Trivedi (2005) instrumental variable is a variable that satisfies two assumptions: (1) the variable is uncorrelated with the error term and (2) the variable is correlated with the regressor. The first assumption excludes the instrument from being a regressor in the model and the second requires that there is some association between the instrument and the variable being instrumented.

In this study, we addressed the endogeneity problem through instrument variables, using a similar approach to Davis and Killian (2010), that is the level of the federal taxes (CIDE and PIS-COFINS). As we are using the level of federal generate over grade “C” gasoline, we are considering just 73% of total tax charged legislation due to 27% addition of anhydrous ethanol. We are not considering the state tax (ICMS) due to its nature of ad valorem tax is functionally related to price, which invalidates the instruments.

To evaluate the gasoline demand we will use the econometric method of Two-Stage Least Square (2SLS) Regression. Specifically, we have:

Gasoline First Stage

$$\ln P_{g_{it}} = \delta_{g0} + \delta_{g1} \ln Tax_{it} + \delta_{g2} \ln Inc_{it} + \delta_{g3} \ln Pe_{it} + v_{eit} \quad (10)$$

Gasoline Second Stage

$$\ln Q_{g_{it}} = \beta_{g0} + \beta_{g1} \ln \hat{P}_{g_{it}} + \beta_{g2} \ln Pe_{it} + \beta_{g3} \ln Inc_{it} + \varepsilon_{eit} \quad (11)$$

Where  $Q_{g_{it}}$  is the gasoline consumption;  $Tax_t$  is federal tax of gasoline;  $P_{g_{it}}$  is the real price of gasoline without the federal taxes;  $P_{e_{it}}$  is the real price of ethanol;  $Inc_{it}$  represents an income proxy that in this case is the ICMS tax revenue  $\varepsilon_{it}$  and  $v_{eit}$  are the residuals.

As gasoline federal tax may not capture the effect of price variability between states, we are also including as an instrument the revenue margin of gasoline.

According to MME (2019) the fuel revenue margin are composed of revenues from the sales, deducted from the amount spent on their acquisition. In gasoline revenue margin is given by the distribution price practiced by the distributors less the resale price practiced by the gas stations.

## 6.2 Tax Effects and Price Effects

To compare the effects of gasoline taxes and tax-inclusive gasoline prices, we employed a similar empirical approach to Li et al (2012) and estimate the following linear equation, which decomposes the tax inclusive retail price into a tax-exclusive component and the excise tax rate.

$$\ln G_{it} = \alpha \ln (p_{it}) + \beta \ln (\delta_{it}) + X_{it}\theta + \lambda_i + \gamma_t + \varepsilon_{it} \quad (12)$$

Where  $G_{it}$  is the dependent variable, gasoline consumption by state (i) and month (t);  $p_{it}$  is the tax-exclusive gasoline price;  $\delta_{it}$  is given by the equation  $(1 + \frac{\text{total tax}}{\text{tax exclusive gasoline price}})$ , where total tax is the sum of state tax and federal tax;  $X_{it}$  is a vector of the state-level observables; and  $\lambda_i$  and  $\gamma_t$  are state and year fixed effects.

Following equation (12), we can derive the price and tax elasticities of demand from its coefficients. As Brazil opened his fuel market in 2002, Marion and Muehlegger (2011) demonstrate that under normal market conditions, any change in excise taxes is fully reflected in final prices. Under the assumption that consumers bear the entire tax, the tax-exclusive price is not affected by a change in the tax rate and equation (12) provides a direct test of whether taxes are more strongly correlated with behaviour than are tax exclusive prices. If consumers respond equally to changes in the gasoline tax and tax-exclusive price,  $\alpha$  should be equal to  $\beta$ . (LI ET AL, 2014).

To derive the price and tax elasticities starting from equation (12), we will estimate using ordinary least-squares, the following equations:

$$\ln G_{it} = \beta_{g1} \ln (P_{it}) + \beta_{g2} \ln (\delta_{it}) + \lambda_i + \gamma_t + \varepsilon_{it} \quad (13)$$

$$\ln G_{it} = \beta_{g1} \ln(P_{it}) + \beta_{g2} \ln(\delta_{it}) + \beta_{g3} \ln Pe_{it} + \beta_{g4} \ln Inc_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \quad (14)$$

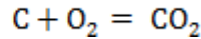
### 6.3 Carbon emission measure

The release of  $\text{CO}_2$  due to fossil fuel combustion causes impacts in the short-run (air pollution) and long-run (global warming). According to Natural Resources Canada (2014) gasoline is composed of hydrocarbons, which are hydrogen (H) and carbon (C). When gasoline burns, the carbon and hydrogen separate. Two hydrogen atoms combine with one oxygen atom to form  $\text{H}_2\text{O}$  and one carbon atom combines with two oxygen atoms in atmosphere to form  $\text{CO}_2$ .

To measure the carbon emissions impact due to variations via market prices and taxes in gasoline price, we used the equation below:

$$Q_{co2} = \text{Gasoline Consumption} \times \text{Emission Factor}_{co2} \left( \frac{\text{kgCO}_2}{\text{litre}} \right)$$

To calculate the emission factor of gasoline we used the  $\text{CO}_2$  reaction that can be expressed as:



The atomic weight of carbon atom is 12 and the atomic weight of oxygen atom is 16. Hence, each molecule of  $\text{CO}_2$  has an atomic weight of 44 which is 3.67 times heavier than carbon itself. Therefore, one litre of gasoline which contains about 0,63 kg of carbon, can produce about 2.3 kg of  $\text{CO}_2$ .

As gasoline type C contains 27% of ethanol in its composition and the emission carbon of ethanol made from sugarcane biomass is considered atmospheric carbon neutral, because as sugarcane grows, it absorbs  $\text{CO}_2$  which offset the  $\text{CO}_2$  produced when ethanol is burned (EIA,2019). Thus, the emission factor of gasoline type C is 1.679  $\text{kgCO}_2/\text{litre}$ , which means that the average Brazilian vehicle, which travels approximately 12.900 km per year and consumes an average of 12.5 litres of gasoline per km on the road (INMETRO,2014) emits 1.73  $\text{tonCO}_2$  every year.

#### 6.4 Data Set

In this study, we used data from different sources. From *Agência Nacional de Petróleo e Gás Natural* (ANP) we collected data on gasoline consumption and gasoline and ethanol prices sold in filling stations and gasoline price form distributors over the different Brazilian States. ANP provides state-level averages of both consumption and priced data. To get constant prices, we used the *Índice de Preço ao Consumidor Amplo* (IPCA) from the *Instituto Brasileiro de Geografia e Estatística* (IBGE) to convert all the prices to December 2018 Brazilian reais.

As an income proxy, we used the ICMS tax revenue from *Boletim de Arrecadação do Conselho Nacional de Política Fazendária* (CONFAZ). Another common proxy for income is electrical consumption, however, electrical consumption is not available at the state level and may not be a good proxy for long panels, since technological changes towards energy-savings and environmental concerns decrease the correlation between GDP and energy consumption (CARDOSO ET AL, 2019).

Data from state tax are from *Relatórios Anuais de Revenda – Fecombustíveis* and federal taxes are from Brazilian legislation.

The final data set is a panel (NT) where N equals 27 (the numbers of state in Brazil) and T equals 204 (the numbers of months in our sample), resulting in a panel with 5,470 observations. Our sample goes from January 2002 to December 2018.

## 7 RESULTS

Table 1 presents the results from the ordinary least square estimation of gasoline demand.

Dependent variable: Monthly Gasoline Consumption						
	Coef.	Std.Err.	t	P> t	95% Conf.	Interval
Gasoline price	-2.315***	0.079	-29.07	0	-2.471	-2.158
Income	0.605***	0.005	114.67	0	0.595	0.615
Ethanol price	0.155***	0.063	2.46	0	0.031	0.278
cons	13.12***	0.152	86.14	0	12.82	13.41

Source: Elaborated by the author

\*\*\*\_Significant at 1% level

Although the results are statistically significant, and the explanatory variables have signs in line with the literature, in this model we did not address the endogeneity problem and the results are biased, inconsistent and inefficient.

Table 2 presents the results from the two-stage least square model. Coefficient estimates and standard error for two models are shown in the lower section. The model uses monthly data and have log-log specification

Table 2: Two-stage least square results

Dependent Variable	Monthly gasoline consumption (litres)				95% Conf.	Interval
	Coef.	Std.Err.	z	P> z		
Gasoline price (without federal taxes)	-3.526***	0.438	-8.03	0	-4.387	-2.666
Income	0.591***	0.007	78.97	0	0.577	0.606
Ethanol price	0.472***	0.134	3.51	0	0.208	0.736
cons	14.409***	0.553	26.04	0	13.325	15.494
Instrumented	Gasoline price					
Instruments	Income	Ethanol price	Federal Tax			

Source: Elaborated by the author

\*\*\*\_Significant at 1% level

Table 2 reports the two-stage least square model that estimates the percent change in the number of liters gasoline consumed that results from a corresponding percentual increase in the gasoline market price. The results are statistically significant and the explanatory variables have signs in line with the literature: the gasoline price is negatively correlated with demand; income is positively correlated with demand and the cross elasticity is positive, indicating substitutability between gasoline and ethanol.

Table 3: Two-stage least square results adding revenue margin instrument.

Dependent Variable	Monthly gasoline consumption (litres)					Interval
	Coef.	Std.Err.	z	P> z	95% Conf.	
Gasoline price (without federal taxes)	-2.894***	0.117	-24.58	0	-3.125	-2.663
Income	0.599***	0.005	11.49	0	0.589	0.610
Ethanol price	0.300***	0.671	4.47	0	0.168	0.431
cons	13.625***	0.182	74.78	0	13.268	13.983
Instrumented	Gasoline price					
Instruments	Income	Ethanol price	Federal Tax	Revenue margin		

Source: Elaborated by the author

\*\*\*\_Significant at 1% level

Adding another instrument variable, the results preserve the statistical significance and the explanatory variables have signs in line with the literature, the remarkable change is the gasoline price coefficient that despite its high value, presents a more suitable value.

#### 7.1 Robustness Checks

To assess the quality of the instruments used in the regressions we did a weak test instrument.

Weak instruments can produce biased IV estimators and hypothesis tests with large size distortions. Stock and Yogo (2005) provided useful rules of thumb regarding the weakness of instruments based on a statistic due to Cragg and Donald. The null hypothesis ( $H_0$ ) is that the set of instruments is weak and the alternative hypothesis ( $H_a$ ) is that the set of instruments is strong. If the calculated value of the test statistic is greater than the critical tabulated value, then the null hypothesis that the set of instruments is weak is rejected.

Table 4: Endogenous test

Tests of endogeneity		
Ho: variables are exogenous		
Durbin (score) $\chi^2(1)$	7.1228	(p=0.0076)
Wu-Hausman F (1,5465)	7.1255	(p=0.0076)

Source: Elaborated by the author

As the result is statistically significant, we can reject the null hypothesis and consider the market price of gasoline, income, and ethanol price as endogenous.

It is important to salient that the solution to the problem of the endogeneity of gasoline prices tends to yield implausibly large price elasticities as our results have shown. According to Coglianesi et al (2015) the large elasticity price is due to the consumer anticipatory behaviour. The main concern is that gasoline purchases may adjust in anticipation of changes in gasoline taxes even before the tax changes takes effect.

The solution proposed by the authors consist in adding one lead and one lag of the change in tax as instrumental variable. The reason is that, in the presence of forward-looking behaviour, consumers increases their purchases during the lead month and decreases their purchases during the month of the tax increase, making their behavioural change apparently only in the month after the tax change.

Table 5 presents the IV regression results, adding one lead and one lag in the gasoline federal tax.

Table 5: Two-stage least square results with lead and lags

Dependent Variable	Monthly gasoline consumption (litres)				95% Conf.	Interval
	Coef.	Std.Err.	z	P> z		
Gasoline price (without federal taxes)	-2.948***	0.327	-9.01	0	-3.590	-2.307
Income	0.598***	0.006	91.16	0	0.585	0.611
Ethanol price	0.314	0.108	2.92	0.004	0.103	0.526
cons	13.704***	0.419	32.71	0	12.884	14.526
Instrumented	Gasoline price					
Instruments	Income	Ethanol price	Federal Tax	Lagged federal tax	Leaded federal tax	

Source: Elaborated by the author  
 \*\*\*\_ Significant at 1% level

Table 6: Endogenous test

Tests of endogeneity		
Ho: variables are exogenous		
Durbin (score) $\chi^2(3)$	2.9524	(p=0.0858)
Wu-Hausman F (1, 5416)	2.9513	(p=0.0859)

Source: Elaborated by the author

The results are statistically significant and the explanatory variables have signs in line with the literature: the gasoline price is negatively correlated with demand; income is positively correlated with demand and the cross elasticity is positive, indicating substitutability between gasoline and ethanol.

Table 7: Two-stage least square results with lead and lags and revenue margin instrument

Dependent Variable	Monthly gasoline consumption (litres)					95% Conf.	Interval
	Coef.	Std.Err.	z	P> z			
Gasoline price (without federal taxes)	-2.869***	0.116	-24.65	0		-3.097	-2.641
Income	0.599***	0.005	111.01	0		0.588	0.609
Ethanol price	0.294***	0.672	4.38	0		0.162	0.426
cons	13.603***	0.181	75.11	0		12.248	13.958
Instrumented	Gasoline price						
Instruments	Income	Ethanol price	Federal Tax	Lagged federal tax		Leaded federal tax	Revenue margin

Source: Elaborated by the author

\*\*\*\_Significant at 1% level

Adding another instrument variable, results are statistically significant and the explanatory variables have signs in line with the literature: the gasoline price is negatively correlated with demand; income is positively correlated with demand and the cross elasticity is positive, indicating substitutability between gasoline and ethanol. But now the gasoline price elasticity presents a more suitable result despite its values is still higher than recent studies that addressed the endogeneity problem as Davis and Killian (2011) with a price elasticity of -0.46 and Cardoso et al (2019) with a price elasticity of -0.78

## 7.2 Tax effects and price effects

Table 8 presents the percent change in the number of gasoline litters consumed that results from a corresponding one cent increase in the gasoline market price and in the gasoline tax.

Table 8: Least square results: Tax effects and price effects with ethanol price

Dependent variable: Monthly Gasoline Consumption						
	Coef.	Std.Err.	t	P> t	95% Conf.	Interval
Gasoline tax-exclusive price	-2.930***	0.123	-23.74	0	-3.183	-2.676
Tax ratio	-3.563***	0.167	-21.36	0	-3.905	-3.220
Ethanol price	0.793***	0.0935	8.480	0	0.601	0.985
cons	19.72***	0.254	77.62	0	19.20	20.24

Source: Elaborated by the author

\*\*\*\_Significant at 1% level

Table 9: Least square results: Tax effects and price effects with income

Dependent variable: Monthly Gasoline Consumption						
	Coef.	Std.Err.	t	P> t	95% Conf.	Interval
Gasoline tax-exclusive price	-0.704***	0.236	-2.98	0.006	-1.190	-0.218
Tax ratio	-0.912***	0.411	-2.22	0.036	-1.75	--0.066
Income	0.009	0.003	2.58	0.016	0.001	0.171
cons	17.273***	0.446	38.69	0	16.35	18.19

Source: Elaborated by the author

\*\*\*\_Significant at 1% level

Table 10: Least square results: Tax effects and price effects with income and ethanol price

Dependent variable: Monthly Gasoline Consumption						
	Coef.	Std.Err.	t	P> t	95% Conf.	Interval
Gasoline tax-exclusive price	-0.719***	0.227	-3.17	0.004	-1.18	-0.252
Tax ratio	-0.925***	0.389	-2.37	0.025	-1.725	-0.124
Ethanol price	0.019***	0.145	0.13	0.894	-0.280	-0.319
Income	0.009	0.003	2.64	0.014	0.002	0.170
cons	17.267***	0.462	38.69	0	16.35	18.19

Source: Elaborated by the author

\*\*\*\_Significant at 1% level

The least-square equation to measure the effect of the gasoline market price and gasoline tax was estimated using state fixed effects. The results have shown that an increase in tax provokes a larger gasoline demand effect than an increase in gasoline market price. This result opposes the neoclassical assumption that consumers formulate expectations consistently, and both responsiveness to market price and tax changes should be identical (RIVERS AND SCHAUFEELE,2015).

Table 10 we are considering a scenario where Brazil adopts a carbon tax. As calculated by Nordhaus (2016) the social carbon cost would be US\$ 31 per ton of CO<sub>2</sub> or US\$ 0,05 per litre of gasoline type C.

Considering the exchange rate of R\$ 3,8750 per dollar in December of 2018 (UOL, 2018), the government should charge their citizens a carbon tax of R\$ 0,19 per litre of gasoline type C.

Table 11: Least square results: Tax effects and price effects with income and ethanol price (scenario with a carbon tax)

Dependent variable: Monthly Gasoline Consumption						
	Coef.	Std.Err.	t	P> t	95% Conf.	Interval
Gasoline tax-exclusive price	-0.765***	0.244	-3.13	0.004	-1.268	-0.262
Tax ratio	-0.968***	0.409	-2.37	0.025	-1.809	-0.127
Ethanol price	0.019***	0.145	0.13	0.894	-0.280	-0.319
Income	0.009	0.003	2.64	0.014	0.002	0.170
cons	17.376***	0.506	34.33	0	16.33	18.41

Source: Elaborated by the author

\*\*\*\_Significant at 1% level

### 7.3 Carbon Emission Measure

In the period of January 2002 to December 2018 the total consumption of gasoline type C for Brazil was 547,526,146 m<sup>3</sup> as shown in box 5 bellow.

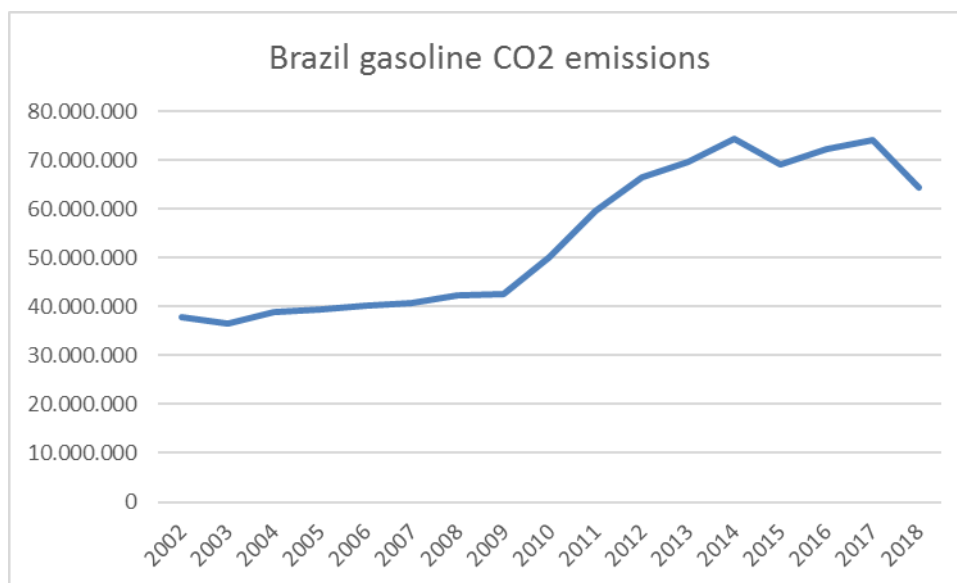
Box 5: Brazil Gasoline “C” consumption from 2002-2018

Year	Brazil gasoline "C" consumption
2002	22,610,257
2003	21,790,652
2004	23,173,878
2005	23,553,490
2006	24,007,633
2007	24,325,448
2008	25,174,782
2009	25,409,089
2010	29,843,664
2011	35,491,255
2012	39,697,714
2013	41,426,236
2014	44,364,246
2015	41,137,401
2016	43,019,081
2017	44,149,532
2018	38,351,779

Source: Agência Nacional do Petróleo (2019). Elaborated by the author

Multiplying the total gasoline consumption by 1.679 which is the carbon emission factor for gasoline type “C”, Brazil produced the total amount of 919 million tonnes of carbon dioxide.

Figure 9 shows the dioxide carbon emission released in atmosphere due to gasoline consumption.



Source: Agência Nacional do Petróleo (2019). Elaborated by the author

Box 6 presents the price and tax impact on the carbon emission on the several scenarios calculated in our work. Scenario 1 and scenario 2 shows the price and tax impact respectively, on carbon emission where the model considers the ethanol price and income. Scenario 3 and scenario 4 shows the price and tax impacts respectively, on carbon emissions, where the model considers the ethanol price, income, and the carbon tax.

Box 6 shows the several scenarios calculated in our work

Year	Brazil gasoline CO2 emissions	Scenario 1	Scenario 2	Scenario 3	Scenario 4
2002	37962621.5	37689670.25	37611467.25	37672207.45	37595143.33
2003	36586504.71	36323447.74	36248079.54	36306617.95	36232347.34
2004	38908941.16	38629185.88	38549033.46	38611287.76	38532302.61
2005	39546309.71	39261971.74	39180506.35	39243780.44	39163501.43
2006	40308815.81	40018995.42	39935959.26	40000453.37	39918626.47
2007	40842427.19	40548770.14	40464634.74	40529982.62	40447072.50
2008	42268458.98	41964548.76	41877475.73	41945105.27	41859300.30
2009	42661860.43	42355121.65	42267238.22	42335497.20	42248893.62
2010	50107511.86	49747238.85	49644017.37	49724189.39	49622471.14
2011	59589817.15	59161366.36	59038611.34	59133955.04	59012987.72
2012	66652461.81	66173230.61	66035926.53	66142570.47	66007265.98
2013	69554650.24	69054552.31	68911269.73	69022557.17	68881361.23
2014	74487569.03	73952003.41	73798559.02	73917739.13	73766529.37
2015	69069696.28	68573085.16	68430801.59	68541313.10	68401101.62
2016	72229037	71709710.22	71560918.41	71676484.87	71529859.92
2017	74127064.23	73594090.64	73441388.88	73559992.19	73409514.25
2018	64392636.94	63929653.88	63797005.05	63900033.27	63769316.22

Source: Agência Nacional do Petróleo (2019). Elaborated by the author

## 8 CONCLUSIONS

Throughout this dissertation, we sought to analyse how gasoline tax affects its demand and carbon emissions. Our results show that consumer behaviour has an essential role in this market. The ability to forward-looking the increase of gasoline price due to an elevation of a tax produces an endogeneity problem that invalidates the use of only tax as instrument. The fact that when correcting the endogeneity problem due to inserting leads and lags in gasoline taxes produces a much more plausible elasticity -price indicates that the Brazilian consumer has an anticipatory behaviour. One explanation for this behaviour is that changes in taxes are more persistent than price market changes and may induce larger behavioural responses (DAVIS AND KILLIAN, 2011). Another explanation resides in the fact that taxes are more salient than prices; as pointed by Li, Linn and Muehlegger (2014), taxes increases receive more media attention than gasoline prices increase.

Another important result in our work is the estimation of gasoline price market elasticity and gasoline tax elasticity.

The results demonstrated the importance of salience in public policies that aim to mitigate the increases in carbon emissions. We also estimated a scenario where Brazil adopts a carbon tax, based on the social carbon cost.

Further studies will be needed to understand better the role that taxes has in mitigating carbon emission. Even though an increase in gasoline tax has a larger effect in demand than an increase in gasoline price in Brazil, the tax nature is also important. For example, although an increase in the CIDE rate makes a decrease in gasoline consumption, its revenue is focused on the restoration of roads, which, in the long run, can serve as an incentive to the road transportation and increase the carbon emissions. In the scenario where Brazil adopts a carbon tax, is important to stress that policies that increases taxes are unpopular among population, which makes difficult for its implementation. Besides other factors should be take into account because Brazil is dependant of road transportation and increases in the gasoline price would harm the vulnerable population through inflation.

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