Welfare impacts of fuel pricing policy in Brazil

by

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Abstract

Fossil fuels represent a large share of expenditure for Brazilian households. Demand is inelastic in the short-term, and pricing is mostly under control of Petrobras. Frequent price changes affect families well-being, and do so heterogeneously. To understand these heterogeneous effects, a Quadratic Almost Ideal Demand System (QUAIDS) is estimated and the results used to compute money-metric welfare effects of the Import Parity Price (IPP) policy for families of varying characteristics. It is found that the increase in price as caused by the IPP policy was regressive. It is also found that the number of adults significantly affect the welfare effects, whereas the number of children is only relevant under assumed economies of scale. The gender of the head of the household, and whether it is situated in a rural or urban area have negligible effects, especially among lower-income families. This suggests welfare programs that consider family composition may be adapted to counteract the negative effects of the price increase.

Keywords: *demand systems*, *welfare*, *fuel prices*

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List of abbreviations

ACPI Ample Consumer Price Index

AIDS Almost Ideal Demand System

BIGS Brazilian Institute of Geography and Statistics

BRL Brazilian Real

DQUAIDS Demographically-Scaled Quadratic Almost Ideal Demand System

ECID Economic Domain Intervention Contribution

FBS Family Budgets Survey

GHG Greenhouse effect Gases

GSFT Goods and Services Flow Tax

IPP Import Parity Price

LA-AIDS Linear Approximate Almost Ideal Demand System

MIQ Minimum Income Question

NSCPI National System of Consumer Price Indices

NSHS National Sample Household Survey

OECD Organisation for Economic Co-operation and Development

OPEC Organisation of the Petroleum Exporting Countries

PIGLOG Price-Independent Generalized Logarithmic

PSU Primary Sampling Unit

QUAIDS Quadratic Almost Ideal Demand System

USD American Dollar

Chapter 1

Introduction

According to the 2017-2018 FBS run by the Brazilian Institute of Geography and Statistics (BIGS) (IBGE, 2021), transportation was on average the second largest group of expenses for Brazilian families, corresponding to 18,1% of their monthly budget (IBGE, 2019a). Aggregate demand for gasoline in Brazil is generally estimated to be price-inelastic (Cardoso et al., 2019b), especially in the short run (Bastos and Sant Anna, 2016).

Having a low price-elasticity of demand and representing a large share of expenditure means the impact of gasoline price fluctuations is severe on consumers' well-being. Reflecting that relevance, since its inception the petroleum industry in Brazil has been the target of several important policy interventions. Section 2.1 provides a brief history of these interventions. In particular, in 2016, the Brazilian national petroleum company, Petrobras, implemented a new pricing policy, ending a long-term implicit subsidy on the price of oil that had kept it up to 20% lower for national distributors than the international average price (Ramalho, 2021). The IPP policy[1] included the prices in the international market for oil into the formula used to define the prices practiced by Petrobras. The resulting increase in fuel prices increased Petrobras' revenue, but generated discontent among the population. In 2023, the policy was reversed and price controls were put back in place.

Besides Petrobras' pricing, temporary fiscal policies are often applied by government – from municipal to federal levels – in response to popular demands, such as tax reductions or targeted subsidies. The truck driver strike of 2018 and the government response is a notable example, but politicians may also use gas price regulations as a popularity tool, especially near elections.[2]

It is also likely we will see an increase in fuel consumption interventions in the near future, as countries strive to reduce their carbon footprints. A better understanding of the determinant factors of demand for fuels, and of welfare effects of fuel price changes can yield more effective policies. As for the 2016 IPP policy, the benefits (lower imports of oil, an increase in government revenue and in profit for stock owners) can be weighted against a detailed account of the costs in consumer welfare loss.

From a methodological standpoint, previous work on the impact on welfare of gas prices follow three major metrics: dead-weight loss (e.g. Moreira (2017), Fernandes and Peixoto (2017)), regressivity measures (e.g. Carvalho (2014), Poterba (1991)),

[1]The Brazilian media uses the acronym "PPI" along with a variety of phrases such as "International Parity Price", "International Parity Policy" and "International Prices Parity". The Government webpage that tracks import prices of fossil fuels uses the name "Import Parity Prices". In the text, I use "the IPP policy" when referring to the policy implemented in 2016.

[2]For example, Vasconcelos et al. (2013) and Nakaguma and Bender (2006) find evidence of "rational political business cycles" in Brazil after the redemocratization of the 1980s. The rationale is that governments deviate from usual budget patterns in the periods before an election to signal competence, spending more on public goods or welfare programs, and reducing taxation. These measures tend to boost the domestic product and employment temporarily, and lead to contractionary measures after elections. In a survey run in July 2022 among Brazilian voters, the Exame magazine queried respondents on their perception of recent fuel price changes, as a potential explanatory factor for vote intentions (Dias, 2022).

and individual measures of welfare subject to some level of aggregation (e.g. Jorgenson and Slesnick (1987a), Nikodinoska and Schröder (2016)). Chapter 3 summarizes these approaches and the concept of equivalence scales for welfare comparisons among households.

Besides the costs for Petrobras, it has been argued that the price control policy is regressive, because it benefits people with higher incomes, who are more likely to own vehicles, more than people with lower incomes.[3] This argument is muddied by the fact that fuels impact consumers of all levels of income indirectly, as inputs of production and transportation of other goods. For policymakers that promote progressive values, it is important to know whether the price control aligns with those values, and if so, to what degree.

Properly identifying "winners" and "losers" from a policy change, and the magnitude of their outcomes, should make it easier for the government to decide whether the change should happen and, if so, whether further action must be taken to counteract negative effects on protected groups. In this essay, I investigate how fuel prices affect different population groups to support future decisions.

[3]For example, Exame (2022) reports that a reduction on gasoline prices benefitted the middle class more than lower-income families, due to the fraction of income spent on transportation being higher for higher-income families.

Chapter 2

Background

The majority of economic activity depends on electricity or thermal energy sources. Despite initiatives toward decarbonization, renewables and sustainability in general, petroleum derivates still dominate the energy market in most countries.

The Brazilian petroleum company Petrobras is partially nationalized – 51% of its stock is owned by the Brazilian federal government and it is responsible for over 65% of the petroleum market in the country. It is subject to a lot of political influence, as the company's president is appointed by the government, and has faced multiple corruption investigations over the years.

Price distortions in otherwise competitive markets lead to dead-weight loss. By maintaining domestic prices artificially low, Petrobras subsidizes consumption implicitly through forgone revenue and directly when it needs to import fuel to satisfy the domestic demand.

Between 2011 and 2014, imports of petroleum derivates by Petrobras increased significantly to meet the domestic demand. This represented large losses to the company: according to Almeida et al. (2015), between 2011 and 2014, the cost of imports by Petrobras was of Brazilian Real (BRL) 21 billion, while the losses in revenue were of BRL 98 billion.

The increase in Petrobras' debt led to the adoption, in 2016, of the IPP policy. The IPP policy redefined the composition of prices effected by Petrobras to include the cost of imports, the BRL-American Dollar (USD) exchange rate and a "risk fee". The policy also determined that prices could be adjusted monthly.

In 2023, the IPP policy was reversed with the purpose of "nationalizing" prices. The argument is that the abundance of oil and gas in Brazilian territory warrants an expansion of domestic refining, and should result in easier access to fuels to citizens and national industries regardless of international trends in oil prices (Elias et al., 2022).

While the IPP policy is the most notable, many other policy changes over fuels prices have been effected by the federal government. Section 2.1 provides a brief history of relevant interventions.

With the end of the IPP policy, unless the domestic demand for fuels can be satisfied by domestic production, there will be a new round of increased imports and losses to Petrobras, with accompanying lower government revenue. Other factors that may affect the fuels market in the near future are described in Section 2.2.

Figure 2.1 shows average monthly retail prices of gasoline, ethanol, and diesel in Brazil, as well as the Organisation of the Petroleum Exporting Countries (OPEC) crude oil monthly prices between 2003 and 2023, all in BRL and normalized to 1 in the first time period. The relative changes over time show that Petrobras' price policy before 2016 cushioned national fuel prices against international market price variations, and led also to a divergence between national and international prices – made even larger due to the devaluation of the BRL relative to the USD. Between the

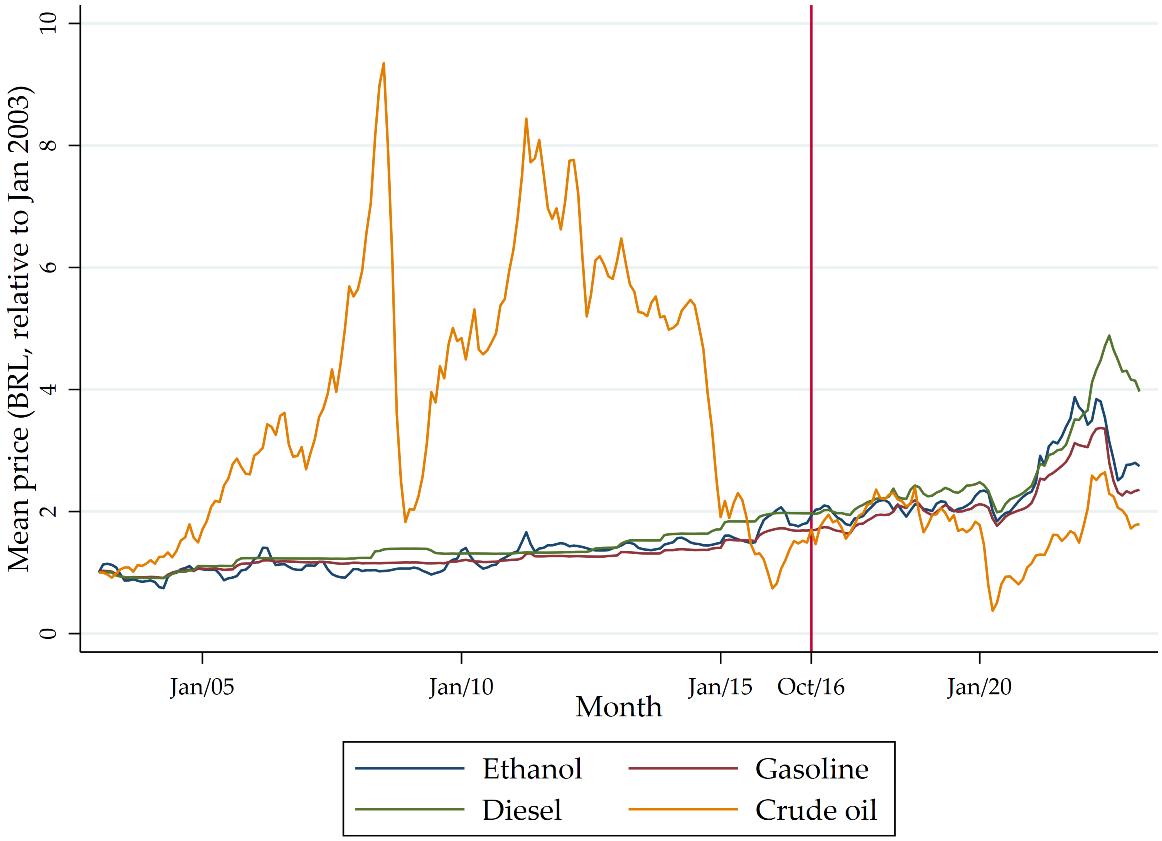

Figure 2.1: Fuel and crude oil prices over time in Brazil

policy change and 2022, prices followed crude oil price trends, increasing over time and becoming more volatile.

It is also visible in Figure 2.1 how the price of ethanol follows the price of gasoline, although with more fluctuation due to harvest seasons. Section 2.3 provides more information on the use of ethanol as fuel in Brazil.

2.1 Fuel price interventions

The Brazilian national petroleum extraction and refining company Petrobras was founded in 1953, establishing a state monopoly of the petroleum market. In 1967, Brazil reached self-sufficiency in almost all fuels used in the country. During the military regime installed in 1964, fuel prices were under state control and were set low as a way to reduce inflation.

With the end of the military regime, the market for fuels was progressively deregulated in the country. In 1995, a constitutional amendment enabled the state to hire private companies for oil extration. The Law of Petroleum, proposed in 1997 and installed in December 31st of 2001, mandated the state to outsource extraction and refining operations. Nevertheless, Petrobras still controlled oil prices, and Costa and Burnquist (2016) argue this was used to reduce inflation and to indirectly stimulate the domestic ethanol industry.

After the implementation of the IPP policy in 2016, the higher volatility of fuel prices, and overall increases in prices produced unrest among consumers. Diesel price increases culminated in a ten-day strike by truck drivers in 2018, which led the federal government to subsidize a reduction in diesel prices by Petrobras; to eliminate the Economic Domain Intervention Contribution (ECID) tax on diesel until 2020; and to change the rules of toll payments for trucks.

In 2021, a surge in soy prices led the government to temporarily change the mandated amount of biodiesel in retail diesel from 13% to 10%, to prevent "an excess increase" in the price of diesel to consumers (Andreia Verdélio, 2021). As part of an attempt to reduce inflation, in June of 2022, Brazilian president Jair Messias Bolsonaro sanctioned a bill setting the ceiling for the consumption tax on fuels (Goods and Services Flow Tax (GSFT)), to a maximum of 18%.

Finally, in May 2023, Petrobras announced the end of the IPP policy, in alignment with Brazilian president Luiz Inácio Lula da Silva's (elected in 2022) campaign suggestions (Sant'Ana and Rodrigues, 2023).

2.2 Additional prospects for fuels markets

Apart from changes in existing tax schedules and Petrobras' pricing, three factors will affect the market for fuels in the near future: changes in the supply of refined products of oil, environmental concerns, and changes in the number and type of vehicles in Brazil.

Fuels are inputs for most economic activity, either directly in production, or indirectly in distribution and for thermal power plants. Fuels are also responsible for a large fraction of pollution and associated climate issues. Therefore, governments face tradeoffs between economic development and environmental goals.

In 2013, crude oil reservoirs were found in the Amazon region. Since then, Petrobras has studied the risks and environmental impact of extraction, contacted neighbouring countries that might be affected by oil spills. Extraction is expected to begin in 2024. With the end of the IPP policy, Petrobras may use the increase in its supply of crude oil to justify a reduction in prices.

In June 2023, the government announced temporary measures to stimulate vehicle production and lower vehicle prices (BRASIL, 2023).[1] The combined growth in the vehicle fleet and potential reduction in fossil fuel prices would increase demand, which *ceteris paribus* would cause imports to continue to rise and increase costs to Petrobras.

In contrast, concern with climate change grows and Brazil slowly follows the trend of large economies in attempting to reduce GHG emissions. In May 2022, the Ministry of the Environment and Climate Change (then called "Ministry of the Environment") announced a decree to regulate a voluntary market of carbon dioxide and methane

[1]This echoes similar policies implemented during the first presidential mandates of Partido dos Trabalhadores (Worker's Party) in the 2000s, which resulted in significant growth in private vehicle ownership and usage (Carvalho and Pereira, 2012).

credits in Brazil (MMA, 2022). In December 2023, congress approved a new bill to regulate a mandatory market for GHG credits (Roberto Peixoto, 2023).

Another, if lukewarm, initiative to reduce GHG emissions was announced in 2023: law proposal 4.516/2023 determines an increase in the mandatory fraction of ethanol added to gasoline from 22% to 27%, and that the fraction of biodiesel added to diesel (currently at 15%) must reach 20% by 2030 (Conteúdo, 2024).

Additionally, with respect to electrical vehicles, in November 2023 the government announced increased taxes on imported electrical vehicles (MDICS, 2023). The measure aleggedly aims to encourage development of national technology in electrical vehicles, but in the meantime discourages consumers from replacing vehicles powered by fuel.

2.3 The role of ethanol

Sugarcane is a major agricultural commodity in Brazil since the XVI century, and typically over 50% of the annual harvest is used for ethanol production (UNICA, 2024).

Following the 1973 oil crisis, president Ernesto Geisel (formerly president of Petrobras) created the Proálcool program, with the aim of reducing reliance on fossil fuels by replacing them with ethanol. The program started in 1975 and fostered this substitution through technology development on ethanol production plants, and on the motors to be powered by it (Cortez, 2016, p29). While the Proálcool program was officially closed with the end of the military regime in 1985, the term "Proálcool" continued to be used to refer to the set of private, governmental and academic initiatives to develop and promote the use of ethanol as fuel (Cortez, 2016, p63).

There was a period of decline with the decrease of oil prices in the 1990s and a shortage of ethanol influenced by a rise in international sugar prices. However, the deregulation of the ethanol market in the following years and the introduction of *flex-fuel* vehicles in 2003 marked the beginning of a period of increased use of ethanol.

As a rule of thumb, ethanol is considered to yield 70% of the mileage of the same volume of gasoline, so popular sources recommend that drivers buy ethanol when its price is 70% of the price of gasoline or less. Cardoso et al. (2019a) show, from data ranging between 2001 and 2014, that ethanol prices are more often favourable (i.e. lower than 70% of the price of gasoline) in the southern region, near locations that produce the majority of the fuel. Iootty et al. (2009) estimates that demand for gasoline has a cross-price elasticity of 1.5 with respect to ethanol, while the demand for ethanol has a cross-price elasticity of 8.09 relative to gasoline.

Ethanol remains relevant in the Brazilian fuel market: in 2022, Brazilians consumed 15.5 billion litres of ethanol and 43 billion litres of gasoline (ANP, 2022). The majority of vehicles sold in the country are *flex-fuel*, i.e. can run on any combination of gasoline or ethanol, making ethanol and gasoline close short-run substitutes. In 2021, for example, of the 2,104,461 new vehicles licensed, 1,633,245 or 77.6% were *flex-fuel*. The share is even larger, 83.3%, if considering only light vehicles (ANFAVEA, 2023). Moreover, recent legislation to increase the percentage of ethanol in the gasoline sold within the country will likely affect relative prices between ethanol and gasoline.

Chapter 3

Literature Review

Assuming that governments, especially representative ones, must work to improve or maintain the well-being of their citizens, policy development requires some measure of that well-being (Adler and Posner, 1999). In the decision-making process, the consequences of the prospective policies on the well-being are compared and, ideally, the option that produces the highest level of well-being is implemented.

This task requires first a model of individual well-being, and second a way to aggregate the information on individuals into a criterion that can rank outcomes by their effects on social well-being.

On the second half of the XIX century, the "Marginal Revolution" introduces the concept of *utility* as the well-being that individuals aim to maximize under budget constraints. As well-being is hardly measurable, the concept evolved over time into an ordinal representation of preferences rather than a unit of well-being. Given that consumption is limited by budget and supply, the choices that consumers make within these constraints can reveal a structure for their preferences (Moscati, 2020).

Individual preferences can be inferred from individual behaviour, but the decision process still requires aggregating information on preferences into an index that allows the policymaker to fully rank the possible states of the world. The Pareto principle provides a starting point: if between states A and B of the world one individual prefers state A to state B and the others are indifferent between them, it is fairly straightforward to presume state A is preferred to state B. However, policies rarely produce pure Pareto improvements: if we introduce an individual that prefers state B to state A, it is not immediately clear which state should be preferred from a decision-maker point of view.

Within the ordinalist framework, in 1939 John Hicks and Nicholas Kaldor introduce the Hicks-Kaldor criterion, that allows for "winners" and "losers" of a change, as long as the winners could potentially compensate the losers and still be better off (Boardman et al., 2018, p. 33, 53).

To evaluate the hypothetical compensation for the losers and whether the winners would be better off after the compensation transaction, one needs a comparable, cardinal, measure of gains and losses. To that end, Hicks (1939, p. 40-41) introduces two money-metric measures of welfare change, based on indifference curves: the *compensating variation* and the *equivalent variation*.

Consider a price change situation such as the fuel price policy change by Petrobras. Compensating variation is the change in income that would restore the utility of an individual to the level it was before the change (hence "compensating" the individual for the change). It can be described as the amount of money the individual would pay to effect the change, in the case of a change that increases their utility, or the amount the individual would require to accept the change, in the case of a change that decreases their utility.

Formally, define $e(p, u)$ as the minimum expenditure needed to achieve utility u

under prices p.[1] In Equation 3.1, the compensating variation (CV) is the difference in expenditure that would allow the individual to afford u_0 under the new prices p_1 (Deaton and Muellbauer, 1980b, p. 186).

$$CV = e(p_0, u_0) - e(p_1, u_0) \tag{3.1}$$

Equivalent variation is the monetary value that would be "equivalent", in terms of utility change to the individual, as the price change. It can be described as the amount of money the individual would accept to forgo the change, in the case of a change that increases their utility, or the amount the individual would be willing to pay to avoid the change, in the case of a change that decreases their utility. In Equation 3.2, the equivalent variation (EV) is the difference in expenditure that would allow the individual to afford u_1 under the original prices p_0 (Deaton and Muellbauer, 1980b, p. 186).

$$EV = e(p_1, u_1) - e(p_0, u_1) \tag{3.2}$$

According to the Hicks-Kaldor criterion, a positive sum of all CVs (or EVs) means the change is socially desirable, as once the change was effected the "winners" would be willing to pay the "losers" enough to compensate them for the change and still be better off (or, for EVs, in order for the "winners" to be as well off as they would with the change, they would have to be paid more than the "losers" were willing to pay to prevent the change).

Willig (1976) showed that for small enough variations in income elasticities of demand and price changes, EV and CV can be closely approximated by the difference

[1] Also referred to as the "cost function", as in "the cost of achieving u".

in compensated demand following the price change. Social surplus measured that way is often used as a measure of welfare, and Section 3.1 covers research on this.

Welfare changes may vary systematically over population groups. If, within a utilitarian framework, we consider that income has diminishing marginal utility (Adler, 2019, p. 35), or otherwise taking into account social aversion to inequality (Banks et al., 1996); we shall want to distinguish how price changes will affect poorer families relative to richer families, and how the policy affects the overall wealth distribution. Section 3.2 covers research on such distributional effects and the framing of policies as regressive or progressive.

The change in utility following a price change of a certain good or service depends also on the consumer's willingness or ability to substitute for other goods and services. In consumer surplus analysis, substitution effects are typically averaged, often due to a lack of detailed individual data. Banks et al. (1996) show this may lead to overestimation of the social welfare effect of a price change. More importantly, Banks et al. (1996) show that it imposes implausible assumptions on consumer preferences and produce systematic errors. Section 3.3 discusses demand system methods that use micro data to improve welfare approximations.

Finally, household characteristics other than income affect demand. Children of different ages, working-age adults, retired adults and the elderly have different needs. Family composition also affects economies of scale in consumption, and policymakers may have targets for groups based on other protected characteristics, such as gender or race identities. Section 3.4 describes the concept of *equivalence scales* to further improve welfare comparisons between households.

3.1 Demand elasticities, efficiency and consumer surplus

With Petrobras being partly nationalized, the loss incurred by consumers from increased prices can be counteracted by a reduction in the tax burden accounting for the government increased revenue. Moreira (2017) uses a static open economy macroeconomic model of Brazil to estimate the impact of removing fuel subsidies on output, aggregate consumption and labour demand for the years 2011-2014. Moreira (2017) finds that if accompanied by an equivalent reduction on major taxes, the removal of the subsidy increases output, consumption and employment.

Demand models used to estimate dead-weight loss typically use a representative consumer approach: the preferences of the entire population are “averaged out” into the demand function. Fernandes and Peixoto (2017) use such a model to estimate dead-weight loss from collusion among retailers in the state of Minas Gerais. Fernandes and Peixoto (2017) estimate average losses of 11.73% of total yearly revenue from gasoline sales in the state of Minas Gerais between 2008 and 2010.

The welfare loss measured by this method reflects efficiency losses, which the author considers to be insufficient for policy analysis because needs, access and ability to pay vary a lot among families.

3.2 Income, Engel curves, and regressivity analysis

One way to incorporate income differences into the analysis is to use regressivity measures. If fuels comprise a larger share of the expenditure of families with lower income, a tax on them is considered regressive as it disproportionately affects those families. Similarly, a subsidy will be progressive.

Engel's work on food expenditure showed that the fraction of income spent on food decreased with total income. This evolved into the the classification of goods as luxuries or necessities according to the income elasticity of demand. A luxury good has income elasticity of demand larger than one. In Brazil, income elasticity of demand for gasoline are typically smaller than one. It's worth noting, however, that these estimates are for aggregated demand.

Carvalho (2014) analyses expenditure patterns by *per capita* income on public transportation, and on private vehicles and fuels, for families in urban areas in Brazil. Using the 2008-2009 FBS, Carvalho (2014) estimated the income-elasticity of expenditure on public transportation to be positive for lower income families and negative for higher income families; on the other hand, expenditure on vehicles and fuels increase with income at all levels, and have elasticity larger than one.

While income is often used as the explanatory variable for demand, and income distribution is used to produce inequality measures, it is worth noting that consumption need not be equivalent to income, and the difference tends to be higher the shorter the period under analysis is. Goods purchased in one period may be consumed over many subsequent periods, income received in one period may be saved for future use, and credit lines may allow consumption in one period to be paid for in the future. In this context, Poterba (1991) suggests that using income leads to overestimating the regressivity of a gasoline tax. Poterba (1991) considers that consumption is affected by expected lifetime earnings, life-cycle patterns and general backward- or forward-looking behaviours, and also that poverty is often temporary; which means income at any point in time is an imperfect, noisy measure of living standards. Expenditures during periods of lower income may reflect either existing assets and savings, or the expectation of a higher income in the near future; in particular, this results in gasoline purchases representing a larger share of income for households in the lower income deciles, than of total expenditure for households in the lower expenditure deciles. Moreover, because income may be indexed by price indices (e.g. transfers to low income families or social security recipients), the tax burden for lower income households tends to be partly offset by higher income. Taking indexing into account, Poterba (1991) finds that households in the lowest three deciles of total expenditure bear a lower tax burden than the higher expenditure deciles.

World Bank (2022, p. 88) estimates "transient poverty"[2] reached 10% of the Brazilian population in 2019, while OECD (2018) shows income mobility is higher in Brazil relative to Organisation for Economic Co-operation and Development (OECD) countries, which is likely to produce the type of bias described by Poterba (1991).

Teixidó and Verde (2017) show that wealth has the opposite effect. Between two similar families with the same level of income but different levels of wealth, the demand of the more wealthy family is likely to be less elastic to prices due to wealth providing a "safety net" in the event of income losses. By omitting this factor, the price-elasticity of demand of the wealthier family will be biased upwards, thus overstating their welfare losses in the case of a price increase. Teixidó and Verde (2017) thus include wealth as a measure of ability to pay and find that taxes are more regressive than estimated by Poterba (1991).

Sterner (2012) argues that whether a tax is regressive will vary among countries and in particular that cars in developing countries are luxury goods. The findings in Carvalho (2014) support that argument; however, it must be taken into consideration

[2]Transient poverty is the condition of households that have a low income but do not fall into "poverty traps" due to lack of education or infrastructure, making them more likely to be poor only temporarily.

that fuels have also a large impact on industry costs and output. For example, in Brazil, the transportation of consumer goods is largely made by trucks powered by diesel, so a tax on diesel can increase the prices of all goods. In this case, even if vehicles and fuels are luxuries, the tax may be regressive if the price of goods consumed by low-income families is more sensitive to transportation costs than the price of goods consumed by high-income families.

Freitas et al. (2016) analyse the distributional effects of taxing Greenhouse effect Gases (GHG) in Brazil using an input-output model of the production chains and find that food and transportation bear the largest changes in output. Because low-income households also spend the greatest shares in these goods, a fuel tax is found to be regressive.

3.3 Demand systems, other sources of heterogeneity and welfare computation

The regressivity evaluation in Poterba (1991) is done over a partial equilibrium analysis, and comes with the caveat that gasoline (as other fuels) is also used as an input in the production and transportation of many other consumer goods. A more complete evaluation, as suggested in Poterba (1991), would use I/O tables and a general equilibrium model to compute the effects of a change in gasoline prices on all production sectors. Freitas et al. (2016) analysis does just that, but using "representative households" of per capita income decile.

Jorgenson and Slesnick (1987b) combines both sides of this approach into an evaluation of the welfare effect of price controls on natural gas in the United States. Jorgenson and Slesnick (1987b) uses a complete demand system from disaggregated data on household expenditures together with a general equilibrium model of the impact of a change in natural gas prices . Households money-metric welfare changes are then aggregated by means of a social welfare function that accounts for efficiency and distribution effects. Jorgenson and Slesnick (1987b) conclude that decontrol of natural gas prices would increase efficiency and decrease equity.

Demand systems such as the one estimated by Jorgenson and Slesnick (1987b) approximate any general demand function of income and preferences and allow the estimation of detailed substitution effects, an advantage that is evaluated in Banks et al. (1996). Banks et al. (1996) analyse the bias present in first-order approximations of welfare effects from a price change. The bias increases in magnitude the larger the price change in question — Figure 2.1 suggests the price change caused by the IPP policy in Brazil may be quite large. Moreover, the bias also varies with own-price elasticity of demand, which may vary across demographic groups, and it varies systematically over the logarithm of income; both of these factors raise distribution concerns.

An alternative demand system form is defined by Deaton and Muellbauer (1980a): the Almost Ideal Demand System (AIDS) models the share of a household's total expenditure devoted to each good (or group of goods) as a function of the household's total expenditure on all goods and the prices of all goods (or groups of goods). In Equation 3.3, w_i is the expenditure share on good i, p_n is the price of good n and x is total expenditure on all goods.

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln \left[\frac{x}{a(p)} \right] + \frac{\lambda_i}{b(p)} \tag{3.3}$$

Deaton and Muellbauer (1980b) also propose a linear approximation of the AIDS model: the Linear Approximate Almost Ideal Demand System (LA-AIDS) model is used by Almeida et al. (2016) with monthly aggregate consumption of gasoline, diesel and ethanol over the state of Pernambuco in Brazil, and they find that demand for gasoline and diesel is price-inelastic, while demand for ethanol is price-elastic. This approach, however, precludes differentiating demographic groups, as consumption is aggregated over consumers, and regressivity analysis, as demand is modelled as a function of expenditure only on fuels, which is itself affected but not fully determined by income.

The AIDS model was expanded into QUAIDS by Banks et al. (1997). The QUAIDS model includes a quadratic term that allows for goods to be luxuries at low levels of income and necessities at higher levels of income, or vice-versa, as shown in Equation 3.4.

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i \ln \left[\frac{x}{a(p)} \right] + \frac{\lambda_i}{b(p)} \left[\ln \frac{x}{a(p)} \right]^2 \tag{3.4}$$

Banks et al. (1997) demonstrate that in data from family budget surveys from the United Kingdom between 1970 and 1986, expenditure on alcohol and clothing exhibit non-linear relationships to the logarithm of expenditure, whereas fuel and food exhibit linear decreasing relationships. On the other hand, Waleed and Mirza (2020) finds that for Pakistani families, while the coefficient of the linear log income term is negative for fuels, consistent with goods that are necessities, the coefficient of the quadratic log income term is significant and positive. The authors suggest this is due to families with higher income increasing expenditure on fuels to power luxuries such as air conditioning and heating. For Brazil, Carvalho (2014) findings suggest public transportation characterizes as a normal good for lower income families and as an inferior good for higher income families, so that QUAIDS would be a better model than AIDS.

Besides income, other household attributes affect demand. In particular, the age of a household member often translates into different needs and preferences. For example, children in general do not consume alcohol and tobacco, and may require specific goods such as disposable diapers and baby formula. Models of "the cost of the child" incorporate the number and age of children in a household into the demand estimation. This is done by Ray (1983) through what Pollak and Wales (1981) refer to as scaling: the number of children z enters the expenditure share equations of the standard AIDS model through the β_i parameters, which are redefined as shown in Equation 3.5.

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i^* \ln \left[\frac{x}{a(p)} \right] + \frac{\lambda_i}{b(p)} \tag{3.5}$$

$$\beta_i^* = \beta_i + \eta_i z \tag{3.6}$$

Besides scaling, Pollak and Wales (1981) describe three other methods of including demographic information into demand systems: translating, the Gorman specification (which applies scaling then translation) and its reverse (translating first, then scaling), and the Modified Prais-Houthakker procedure, which defines demographic scales for each good (or group of goods) in the system.

Spiller et al. (2017) consider that households in rural areas do not have access to public transportation, reducing their ability to substitute driving. Demand for gasoline is found to be more price-elastic among rural households than urban households, but because they also drive more these households face bigger losses than urban households from an increase in the gasoline tax rate. The tax is also found to be regressive.

Nikodinoska and Schröder (2016) use a model that incorporates both the quadratic extension of QUAIDS and the scaling of Ray (1983): the Demographically-Scaled Quadratic Almost Ideal Demand System (DQUAIDS). Nikodinoska and Schröder (2016) analyse the welfare effects of fuel taxes in Germany, including the number of adults and children below 15 years of age in a family, and whether it is located in a rural or urban area. Demand is also found to be more price-elastic for rural households.

Asano and Fiuza (2003) estimate an AIDS using a subsample of the 1986 and the 1995 FBSs, comprised of households headed by married men under 60 years of age, and aggregating over per capita expenditure 20^{th} quantiles. Elasticities computed at mean sample values for total expenditures suggest food and housing are necessities; furnishings, clothing, transportation, health care and personal experiences are found to be luxuries. Asano and Fiuza (2003) note that purchases of private vehicles may be driving up the price-elasticity of the transportation group.

3.4 Equivalence scales

When using models of disaggregated demand, either within a regressivity framework or a demand system, the issue of comparability among households arises. For example, total household income, if used as a measure of welfare, will underestimate the well-being of a family of two adults relative to that same family with a child at the same level of income, as satisfying the needs of the child will reduce the consumption of the parents.

A common correction to this issue is to use the income *per capita* of the household instead. In fact, the FBS provides in all its expense datasets a column with the per capita income of the household, and this is the chosen explanatory variable in the income-elasticity models of Carvalho (2014). However, per capita income disregards that members may have different needs and that there are economies of scale in consumption. Children, for example, consume less food than adults in general. Demand for goods such as lighting and water does not increase proportionally to the number of people in a household. Family members will usually share appliances and vehicles, and can purchase larger quantities of goods at a discount.

In 1895, Ernst Engel studies food expenditure patterns in Belgium and finds that richer families tend to spend lower fractions of their income on food than poorer families (Stigler, 1954). This suggests the fraction of income spent on food can be used as an approximation of welfare, which is the starting point of behavioural equivalence scales, see Section 3.4.1.

Engel is also responsible for introducing the concept of *adult equivalents* in 1883, following from his investigation of the "cost of the child"(Stigler, 1954). If we determine how children's consumption must be relative to an adult so that they achieve the same level of well-being, it becomes possible to compare households based on the number of adult equivalents (Deaton, 1997, p. 242).

Taking this further and incorporating a measure of economies of scale so that additional members require less consumption to reach the same level of well-being yields the number of *effective adult equivalents*. This number can be used as a deflation factor for family income or wealth, so that the transformed values are comparable among families of different compositions (Deaton, 1997, p. 242).

Formally, assume that utility is comparable between households, so that it is possible to say that two households at utility level u experience the same level of well-being. Assume also that households with the same characteristics d require the same expenditure to reach any level u of utility, so that the expenditure function of households differs only with respect to d. Then the equivalence scale between two households is the ratio

$$\frac{m_1}{m_2} = \frac{e(p, \bar{u}, d_1)}{e(p, \bar{u}, d_2)}$$

.

By choosing an array d_R of characteristics as the reference (e.g. an array of ones for binary variables), the equivalence scale for any household k will be

$$m_k = \frac{e(p, \bar{u}, d_k)}{e(p, \bar{u}, d_R)}$$

(Lewbel, 1989).

3.4.1 Types of equivalence scales

Mancero (2001) classifies equivalence scales into four categories according to the method of construction: behavioural scales, parametric scales, expert scales and subjective scales. Hagenaars et al. (1994) produces a somewhat similar classification: parametric and expert scales as "normative" scales, to "behavioural scales" as "based on consumption", and to "subjective scales" as "based on direct welfare measurement". Sections 3.4.1 to 3.4.1 contain a summary of each approach and, as we shall see, the methods can be combined.

Hagenaars et al. (1994) consider additionally "social security scales", which are implied in eligibility criteria for assistance programs or in transfer amounts dependent on family composition.[3] This cannot be considered as a method of construction,

[3] See for example the varying transfer amounts of the Canada Carbon Rebate for each household member in Newfoundland and Labrador (CRA, 2023).

however, as the equivalence criteria must have been defined prior to or along with the regulation. As Hagenaars et al. (1994) point out, accepting such scales (as inferred from the regulation rather than the original method of construction) results in a circular definition. Moreover, transfer programs are subject to budget constraints and political influences of their own, whereby the implicit scales may not allow a direct interpretation as living cost differences.[4]

Expert scales

Expert scales are developed for particular purposes by "experts" of a field. This description is a general way of describing the common approach of using minimum dietary needs in the construction of poverty lines. As such needs vary with age and sex, family composition will affect the total nutrition requirements. Food prices also vary among regions, so that the cost of satisfying the requirements of otherwise identical families will vary with region. Finally, home production of food (in rural areas, for example), may partially offset the necessary expenditure.

This information can be used to produce food expenditure equivalence scales by estimating the cost of achieving dietary adequacy for a family with d_h attributes relative to a reference family d_R.

For non-food goods and services, there is no exogenous way to determine adequate minimum consumption.[5] Some authors or programs may still produce minimum consumption baskets not restricted to food to determine poverty lines. The official poverty

[4]For example, Tronco and Ramos (2017) note that the poverty line used to evaluate the program Brasil Sem Miséria, which aimed to erradicate extreme poverty in Brazil, was linked to the transfer program Bolsa Família. The eligibility criteria for the Bolsa Família program are updated according to federal budget constraints, but were then used to measure poverty rates for the Brasil Sem Miséria Program, which was convenient in practice but added a layer of arbitrariness to the measure.

[5]Presumably for this reason, Vaz (2012) mentions the classification in Mancero (2001), but does not refer to general "expert" scales, using "nutritional scales" instead.

measure in Canada, for example, derives poverty thresholds from the localized cost of acquiring a predefined set of necessities that includes food, transportation, clothing and shelter (Heisz, 2019). However, it does not actually yield expert *scales*: rather than complete baskets for all possible family compositions, a single basket is defined for a reference family of two adults and two children, and the corresponding cost is then extrapolated to different family compositions by using a square root equivalence scale, which is parametric.[6]

Rocha (2000) notes that while it is possible to calculate the minimum cost of achieving adequate nutrition, families food purchase choices are typically not consistent with it. The method proposed by Rocha (2000) finds instead the minimum observed food expenditure at which families reach the minimum per capita caloric intake, by region. Then, to establish a poverty line, the average fraction of income spent on food is used to establish the minimum expenditure on non-food goods and services.

Clearly, this procedure does not yield "expert scales" either, but rather combines "expert" nutrition standards with a behavioural approach (see Section 3.4.1). It also does not differentiate family members with respect to sex or age (as it uses per capita caloric needs).

Subjective scales

Subjective scales are constructed from surveys that ask direct questions on well-being, happiness or income adequacy. These questions may be qualitative, "economic ladder" types of questions, where families rate their well-being (in general or financial) on an ordinal scale; or money-metric questions, where respondents provide money amounts

[6]See Section 3.4.1.

(Ravallion, 2012).

For example, the Leyden method as described by Vaz (2012) utilizes the Minimum Income Question (MIQ): asking respondents what they believe is the minimum income y^{min} needed to "make ends meet". The collected values are used to estimate a model of $\ln y^{min}$ as a function of actual income and household characteristics.

A key assumption of the Leyden method is that the answers to the MIQ are distorted by respondents' reference point: very poor families are likely to underestimate their minimum income, whereas richer families are likely to overestimate it (Vaz, 2012, p. 348). The poverty line is thus chosen at the intercept of (logarithm) actual family income y and the self-assessed (logarithm) y^{min}. In this case, equivalence scales can be derived as the ratio between the estimated poverty line for a household with a set d_h of characteristics and the poverty line for a reference household with set d_R of characteristics.

This distortion of the self-assessed minimum income is related to the more general issue of bias in subjective surveys. As discussed by Ravallion (2012), individuals' evaluation of their economic well-being often includes a "relative deprivation" component, so that answers are anchored by a perceived norm (for example, the living standards of neighbours, which may result in spatial autocorrelation). Respondents are also found to be highly sensitive to variations in the way questions are posed, and may have different understandings of terms like "income" or "adequate" than intended by the survey creator. These and other issues warrant careful crafting of surveys to minimize bias.

The FBS includes a well-being questionnaire that can be used to estimate subjective scales for Brazil. Vaz (2012) does so using the Leyden method and two other subjective methods (namely Antwerp and Minimum Income). Vaz (2012) finds that all three yield implausibly high economies of scale, including occasional *negative* values for the "cost of the child". While surely children can be a blessing, these results undermine the validity of the scales.

Behavioural scales

Behavioural scales are constructed from observed consumption patterns of families, and originate in the work of Ernst Engel. After observing that families with higher income tend to spend a lower fraction of it on food, Engel hypothesized that this fraction could be used as an indicator of well-being common among households (Stigler, 1954). Considering this hypothesis, data on family expenditures can be used to estimate, for example, how much income m_1 brings a family of three people to spend the same fraction of income on food as a family of two people with an income m_2, and the ratio m_1/m_2 is the equivalence scale between the two families.

The Rothbarth method uses instead the concept of "adult goods": goods such as alcohol are not purchased by children, so when a family has a child, the "cost of the child" can be estimated as the additional income necessary to restore the consumption of said "adult goods" to their initial levels. Rothbarth scales are less general than the Engel scales in that they can only be used to estimate the cost of children, so that families with different numbers of adults cannot be compared (Vaz, 2012).

Vaz and Vaz (2007) use the Engel and Rothbarth methods to estimate equivalence scales for Brazil from the 2002-2003 FBS. The estimates are in general non-significant but Vaz and Vaz (2007) find that children are "cheaper" than adults. Alonzo and Mancero (2011) estimate Engel and Rothbarth equivalence scales for Latin American countries, finding high variability in the marginal cost of a child, ultimately recommending the use of parametric equivalence scales instead.

Two generalizations of the Engel method allow for commodity-specific equivalence scales: the Prais and Houthakker approach and the Barten approach. The main difference between them is that the Barten method allows demographic variables to enter demand both by scaling the quantities demanded and by affecting the substitutability between commodities through “effective prices” faced by the household (Vaz, 2012).

Vaz (2012) estimates the Barten scales for Brazil from the 2002-2003 FBS and perform a test with the hypothesis of food being a normal good. As the estimated scales imply occasional negative elasticities for the demand of food, the Barten method is rejected.

Vaz (2012) also estimates Prais and Houthakker scales for Brazil, and finds that the “cost of a child” is lower for families in rural areas than for families in urban areas, for children between zero and nine years old, including the specific cost of transportation.

Jorgenson and Slesnick (1987a) uses the Barten method on United States data. Their translog demand system includes fuel expenses into a commodity group “Energy”, that also accounts for electricity, and incorporates the number of members of the household into the demand functions. Jorgenson and Slesnick (1987a) find that households in rural areas require less energy than households in urban areas; and find economies of scale in consumption of energy, with larger families requiring lower “effective” consumption of energy.

It should be noted the general “identification” issue with behavioural equivalence scales described by Pollak and Wales (1979), that suggests they are not appropriate for welfare comparisons. These scales assume demographic parameters are fixed, which may be true for attributes such as gender and race but not so for others like the number of children or the location of the household. Consumption patterns thus do not reveal the "direct" utility contribution of children or location and are instead conditional on the demographic parameters being fixed, whereas equivalence scales used for welfare comparisons should be unconditional. Pollak and Wales (1979) mention that their estimates of equivalence scales from observed consumption in the UK would suggest that larger families require less money than smaller families to reach the same level of utility (a similar result to the subjective scales estimated by Vaz (2012)), as an example of how the use of conditional equivalence scales may lead to spurious results.

Fisher (1987) points out that even if we accept that the utility function is the same for all households (with all relevant differences as parameters); due to the ordinal character of utility, it does not actually mean households with the same value of u experience the same level of well-being. This should stress out that treating them as such is an assumption but, as Fisher (1987) recognises, it is one necessary for the analysis.

More pertinent to the choice of which demographic characteristics to include, Fisher (1987) raises the issue of how preferences may be shaped by previous experiences in such a way that makes comparisons ethically "repugnant":

> Suppose that rich whites like caviar and poor blacks like pork and beans but that differences in preferences can be expressed in terms of household equivalence scales as before. Then [...] the implicit ethical judgment under consideration will require us to give symmetric treatment to rich whites faced with a high price of caviar and poor blacks faced with a high price of pork and beans. While poor blacks will usually be counted as having less income than rich whites, we will not be able to treat pork and beans for poor blacks as more important than caviar for rich whites. Indeed, if rich whites face a high enough price of caviar, we can be forced to treat

> them as being worse off than poor blacks facing a high price for pork and beans. This sort of treatment is required by the proposition that poor blacks would like caviar if only they were rich and white. Marie Antoinette would have approved, but I suspect she would be in the minority.

A related concern arises if we consider studies that show significant differences between the expenditure patterns of men and women. As Carvalho and Alves (2012) observe, public policy that assumes women "spend better" from observed behaviour and thus gives them preference for the control over transfer benefits, may inadvertently reinforce the role of women as the main caretakers of children.

Parametric scales

Parametric scales use a predefined functional form that allows the incorporation of economies of scale and/or differences in members' needs according to their attributes through parameters. A common scale in older OECD works is the Oxford scale: $1\times$ First adult $+ 0.7\times$ additional adults $+ 0.5\times$ children. Another common form is exponential, which accounts only for economies of scale, e.g. the square root scale: $\sqrt{M}$ where M is the number of individuals in the household (Maia and Sakamoto, 2016).

It could be argued that such scales are constructed both by behavioural and expert methods, as the parameters are informed by empirical observations of the "cost of the child" and economies of scale. The OECD modified scale, for example, was introduced by Hagenaars et al. (1994) following behavioural studies that suggested the Oxford scale[7] attributed too much weight to additional family members. Nikodinoska and Schröder (2016) use the OECD modified equivalence scale for their welfare analysis.

[7] Also known as the "old" OECD scale.

Besides simplicity, parametric scales have the advantage of functioning as standards of comparison between studies in different countries. This, however, may be misleading. Considering that it is not common to estimate equivalence scales in Brazil, the weights in the OECD scale might require different modifications than those applied by Hagenaars et al. (1994).

Hagenaars et al. (1994) concludes its survey of equivalence scales by saying there is no ultimate choice of scale and that the best one can do is compare the results (in their case, headcount poverty rates) from using different scales.

Chapter 4

Methodology

In this essay, consumer demand for six commodity groups is characterized across households of different compositions and attributes, and the results are used to estimate the welfare effects of a subsidy policy change. The commodity groups and household characteristics selected are described in Section 4.3. Section 4.4 explains the procedure to obtain welfare measures.

Demand is modelled with QUAIDS, the system is estimated with the **aidsills** package (Lecocq and Robin, 2015) over data from the 2017-2018 FBS[1]. Section 4.1 shows the model and the estimation method, with Section 4.2 containing the assumptions involved and restrictions imposed on the model.

4.1 Econometric Model

Assume that households behave as individuals when it comes to maximizing utility and that households with the same attributes have an indirect utility function of the

[1]See Chapter 5.

QUAIDS form shown in Equation 4.1 (Banks et al., 1997).

$$\ln v(x,p) = \left(\left[\frac{\ln x - \ln a(p)}{b(p)} \right]^{-1} + \lambda(p) \right)^{-1} \tag{4.1}$$

Assume also that the families allocate their budget into separable commodity groups. Then, applying Roy's identity onto Equation 4.1 yields a system of budget share equations. The expenditure share of each commodity group i is given by Equation 4.2

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i(\ln x - \ln a(p)) + \lambda_i \frac{(\ln x - \ln a(p))^2}{b(p)} + e_{ih} \tag{4.2}$$

, where $\ln x$ is the natural logarithm of total expenditure, and $\ln a(p)$ and $b(p)$ are price aggregators given by Equations 4.3 and 4.4.

$$\ln a(p) = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \ln p_i \ln p_j \tag{4.3}$$

$$\ln b(p) = \prod_{i=1}^{n} p_i^{\beta_i} \tag{4.4}$$

Let d_h be the vector of demographic variables for household h. Translation of demographic variables is done through α_i, which is modelled as a linear function of demographic attributes as shown in Equation 4.5. Each commodity group has a vector A_i of parameters estimated.

$$\alpha_{ih} = \alpha_{i0} + A_i \cdot d_h \tag{4.5}$$

Following Banks et al. (1997) the total expenditure of households is instrumented by their reported income. This, as well as ignoring certain categories of purchases, such as vehicles, mitigates the impact of unusually large expenses.

Following Deaton and Muellbauer (1980a); Banks et al. (1997); Poi (2012), α_0 is predefined as the lowest total expenditure in the dataset.

4.2 Assumptions and restrictions

Demand theory and regularity imply a few restrictions on the parameters of Equation 4.2.

4.2.1 Separability

Instead of making each purchase decision with full information all the time, families may allocate income into groups like "food", "housing" and "transportation" and treat each as a separate optimization problem.

Aggregating goods into groups has the additional advantages of improving the statistical power of the model and avoiding censoring issues. Because the number of goods consumed observed by the FBS is very large relative to the number of observations in the 2017-2018 survey, families will have zero expenditure on the majority of individual available goods, but are unlikely to have zero expenditure on major frequent expense categories such as food and transportation.

Grouping requires assuming *separability*: a group is separable when the ordering of consumption of goods within the group is independent of consumption of goods outside the group. This implies effects of substitutability or complementarity between goods in different groups only happen through the substitutability or complementarity of the groups themselves (Deaton and Muellbauer, 1980b, p. 124).

4.2.2 Consistency with the theory of demand

Demand is subject to a budget constraint, which in the model of Equation 4.2 becomes the *adding-up* constraint: the expenditure shares of all goods for any given family must add up to 1. This will be true if Conditions 4.6 are satisfied (Deaton and Muellbauer, 1980a).

$$\sum_{i=1}^{n} \alpha_i = 1 \qquad \sum_{i=1}^{n} \gamma_{ij} = 0 \qquad \sum_{i=1}^{n} \beta_i = 0 \tag{4.6}$$

Adding-up is enforced on estimation of the AIDS and its extensions by dropping one of the share equations and computing its parameters such that they satisfy these conditions.

Additionally, families are expected to not have money illusion, which translates into the property of *homogeneity*: changing prices and total expenditure by the same rate should not change quantities demanded. This will be true of the system if Condition 4.7 is satisfied (Deaton and Muellbauer, 1980a).

$$\sum_{j} \gamma_{ij} = 0 \tag{4.7}$$

Finally, there are the *negativity* and *symmetry* restrictions that are best explained in light of the Slutsky matrix definition. The Slutsky matrix is formatted as follows:

$$S(p,w) = \begin{pmatrix} S_{11} & S_{12} & \cdots & S_{1n} \\ S_{21} & S_{22} & \cdots & S_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ S_{n1} & S_{n2} & \cdots & S_{nn} \end{pmatrix}$$

Each element in the matrix is a sum $S_{ij} = \frac{\partial x_i}{\partial p_j} + \frac{\partial x_i}{\partial x} x_j(p,x)$ that represents the substitution effect of a price change if the consumer was compensated just enough to afford their initial bundle.

If demand satisfies Walras' law and the weak axiom of revealed preferences, the Slutsky matrix will be *negative semidefinite*, which implies that $\forall v \in \mathrm{R}, v \cdot S(p,x)v \leq 0$ (Mas-Colell et al., 1995, p. 34).

Mas-Colell et al. (1995, p. 70) show that the Slutsky substitution matrix is equivalent to the matrix of derivatives of the Hicksian compensated demand, which in turn is equivalent to the second-derivative matrix of the total expenditure function. This implies that the Slutsky matrix should be *symmetrical*, a property necessary for the recovery of the expenditure function (Deaton and Muellbauer, 1980b, p. 50; Mas-Colell et al., 1995, p. 80), which will be used to estimate welfare effects. Symmetry in the AIDS and its extensions requires Condition 4.8 (Deaton and Muellbauer, 1980a).

$$\gamma_{ij} = \gamma_{ji} \tag{4.8}$$

4.3 Study Variables

4.3.1 Cohort Attributes

Taking into consideration the demographic attributes used by Slesnick (2000); Nikodinoska and Schröder (2016); Spiller et al. (2017), I use the following for translation of demand in the QUAIDS model: the number of adults and the number of children in the household, the sex of the head of the household, and the type of residence.

The cut-off age for a household member to be considered a "child" varies in the literature. However, the age can be as low as 10 years (Mariano and Figueiredo, 2010), as high as 18 (Ray, 1983), or the "child" category may be subdivided into younger and and older children (Ray, 1983; Hagenaars et al., 1994). I defined "children" as members under 16 years of age, and "adults" as members 16 years old or higher.

"Type of residence" refers to whether the family resides in an urban or rural area. Slesnick (2000) uses "farm or nonfarm", while Jorgenson (1990) uses "urban or rural". The FBS classifies households as "urban or rural", so I use this classification.

See Appendix B for the variables used to capture each of these attributes.

4.3.2 Commodity Groups

In the literature, the choice of groups of goods and services also vary. Food is present in all the reviewed articles that aim to estimate demand systems for all or most of households' spending (Jorgenson, 1990; Banks et al., 1997; Asano and Fiuza, 2003; Menezes et al., 2008); housing and clothing are often present (Asano and Fiuza, 2003; Menezes et al., 2008); and "adult goods" such as tobacco and alcohol sometimes appear as their own groups (Banks et al., 1997; Menezes et al., 2008). Vehicle fuels may be present in “fuel”, “energy” or “transportation” groups (Jorgenson, 1990; Banks et al., 1997; Menezes et al., 2008).

For the present analysis, the following groups compose the first stage of the budget: fuels, housing and maintenance services, adult goods, services, and other goods. Vehicle and real estate purchases are excluded to avoid “spurious volatility” (Poterba, 1991). “Adult goods” such as alcohol and cigarettes are its own group, following from the considerations of Banks et al. (1997) and Rothbarth (Ray, 1983).

Some authors separate groceries from restaurant expenses, which is likely not applicable for the Brazilian population. The Brazilian government subsidises food programs for workers that often consist in meal vouchers for exclusive use in restaurants.

4.4 Welfare measurement

The welfare effects of the IPP policy are measured as the equivalent variation of the change in the price of the “Transportation” group for the households. Equivalent variation is the change in total expenditure that would place the household at the same utility level as the price change, better understood with Equation 3.2, reproduced below. After the price change, the household faces prices p_1 and is at utility level u_1, and the difference between the cost of achieving u_1 under the old prices p_0 and the new prices p_1 is the equivalent variation, in money terms.

$$EV = c_k(u_1, p_0) - c_k(u_1, p_1)$$

Rearranging the (logarithm) indirect utility function $\ln v(x, p)$ of QUAIDS shown in Equation 4.1 yields the (logarithm) cost function $\ln c(u,p)$ in Equation 4.9 (Chang and Serletis, 2012).

$$\ln c(u,p) = \ln a(p) + \frac{b(p)\ln v(x,p)}{1-\lambda(p)\ln v(x,p)} \tag{4.9}$$

With the estimated cost of attaining the reference level of utility before and after the price change, it is possible to estimate the aggregate losses faced by consumers; to evaluate the regressivity of the change through the relative burden of the change, and also through an inequality measure such as the Gini index; and to observe how the burden changes according to family characteristics.

The interpersonal comparisons of the effects are refined through the use of two equivalence scales. Studies estimating behavioural and subjective scales for Brazil are scarce and the results not particularly reliable. Moreover, the only actual "expert scales" are nutritional, which are only potentially useful in this context as a starting point for more comprehensive scales. Considering this, the scales chosen are parametric: the modified OECD and square root scales.

Chapter 5

Data

5.1 Data Source

For the demand system estimation, data from the 2017-2018 FBS was used. The FBS provides detailed data on individual household expenditure on particular goods and services, as well as the cohort attributes mentioned in Section 4.3.1. It both the levels of expenditure as recorded at the time of the survey and the expenditure values deflated to the baseline date of January 23rd 2018.

The FBS is meant to be used as cross-sectional data and does not contain the dates each household was surveyed,[1] while other surveys run in Brazil that follow population and economic trends more frequently do not include family expenses in the level of detail required by the model. However, estimating a demand system requires price variation. To obtain some price variation information, I exploit the fact that the FBS data was collected over a period of 12 months and that the dataset includes the deflation factors used for each recorded expense.

[1] Waleed and Mirza (2020), for example, match their family budget survey data to the weekly Pakistan Bureau of Statistics price index using the date of collection.

The grouping was done as follows. First, the type of expense that was present more frequently among the households surveyed was identified: in the case of the 2017-2018 FBS this was rent or estimated rent, from the $58,039$ surveyed, $50,849$ or 87.61% of households recorded a value. The second step is done under the assumption that two households that paid rent on the same date and location, or were interviewed on the same date and location, would have the same deflator value. Under this assumption, households that have the same deflator value for rent were grouped and treated as facing the same prices. Third, a Stone price index was produced from all expenses reported by all households in each group.

This exploitation made it possible to obtain estimates but, given that the procedure by which the deflators are generated and mapped onto observations is not transparent and I did not have the dates of collection, the results are not reliable. The reader should take the estimates, their discussion and conclusions as an example of the use of the method to address the question rather than an actual answer.

If the deflator values had been solely determined by the date of the payment or the survey, we would expect to find at most 395 different values (365 for each day of the survey plus 30 for the days prior to the first day of the survey). Instead, $4,905$ values were found, and the FBS documentation informs us that location and time period are both used to produce the deflator values. This means the groups do not reflect only a time dimension. Additionally, even though inflation records for housing were positive every month in the period of the survey, the absence of definitive information on the deflator source leaves open the possibility that households surveyed at different periods and locations would have the same deflator value.

5.2 Population sample description

The 2017-2018 FBS surveyed $58,039$ households. Table 5.1 shows how observations are distributed by gender of household head, and by residence type . Overall, the majority of the sampled households are headed by men and located in urban areas.

Table 5.1: Sample distribution by gender and residence type

	Gender	
	Male	Female
Type of residence		
Urban	24,344	20,530
	(41.94%)	(35.37%)
Rural	9,592	3,573
	(16.53%)	(6.16%)

Table 5.2 shows the distribution of the sample with respect of the number of children and the number of adults. The most common configuration is two adults with no children. One unit reported no adults and a single child. A small fraction of households (1.85%) reported having four children or more, up to ten. The number of adults varies up to 14, but more than four is rare (4.04%).

In the 2010 census data, 18% of the households surveyed were in a rural area, while the percentage in the 2017-2018 FBS is of 22.68%. In 2010, 38.74% of households were headed by a woman, versus 41.53% in 2017-2018.

BIGS uses a master sample framework to select households for surveys, including the FBS. The master sample is a sample of the census sectors drawn using stratification and probability weighted by the number of households in the sector, and grouped into Primary Sampling Units (PSUs) so that each PSU has at least 60 households (IBGE, 2008). The FBS uses a subsample of the master sample in two stages: first drawing PSUs randomly from each strata, then drawing households randomly

Table 5.2: Sample distribution by number of adults and children

	Adults				
	1	2	3	4	≥ 5
Children					
0	8,093	13,741	6,865	3,013	1,085
	(13.94%)	(23.68%)	(11.83%)	(5.19%)	(1.87%)
1	1,253	7,422	3,542	1,431	614
	(2.16%)	(12.79%)	(6.10%)	(2.47%)	(1.06%)
2	592	4,628	1,399	604	357
	(1.02%)	(7.97%)	(2.41%)	(1.04%)	(0.62%)
3	184	1,337	427	213	162
	(0.32%)	(2.30%)	(0.74%)	(0.37%)	(0.28%)
≥ 4	87	525	200	137	127
	(0.15%)	(0.90%)	(0.34%)	(0.24%)	(0.22%)

from each PSU. See Appendix A for more details.

Of the original $3,153,534$ purchases recorded, $129,483$ were excluded from the analysis as the amount spent was not informed.

Some expenses on services like renting of clothes or appliance repairs have been included in the "Other Goods" group, as they are likely not separable from the goods associated.

The periods of reference vary by purchase group, with food registry being done over a period of seven days, income and health expenses done over the previous 30 days, durable goods over the last twelve months and other expenses over the previous 90 days. Total expenses reported were extrapolated or averaged into 30-day periods, as formal income is usually paid monthly.

The distribution of income and total expenditure is strongly right-skewed: Figure 5.1

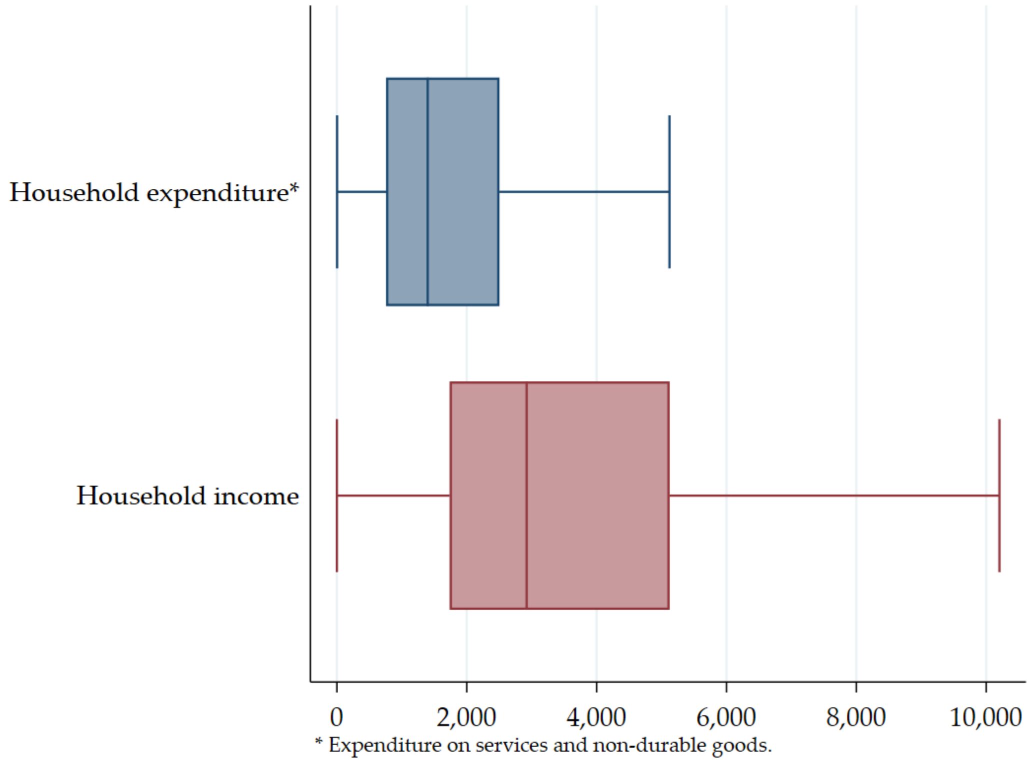

Figure 5.1: Boxplots of monthly total income and expenditure by Brazilian households from the 2017-2018 FBS

shows the boxplots for monthly total income and total expenditure. The skewness score of total expenditure is 9.19, and the skewness score of total income is 28.10.

23, 927 of the households surveyed, or 41.23%, report owning one vehicle. A small number, 25, or 0.04%, of households, report purchasing gasoline for domestic use.

5.3 Expenditure patterns on fuel and transportation

Figure 5.2 shows the fractions of households' total expenditures spent on gasoline. For households that consumed any gasoline during the period of the survey, the clusters' shapes suggest Engel curves linear on the logarithm of total expenditure, which is

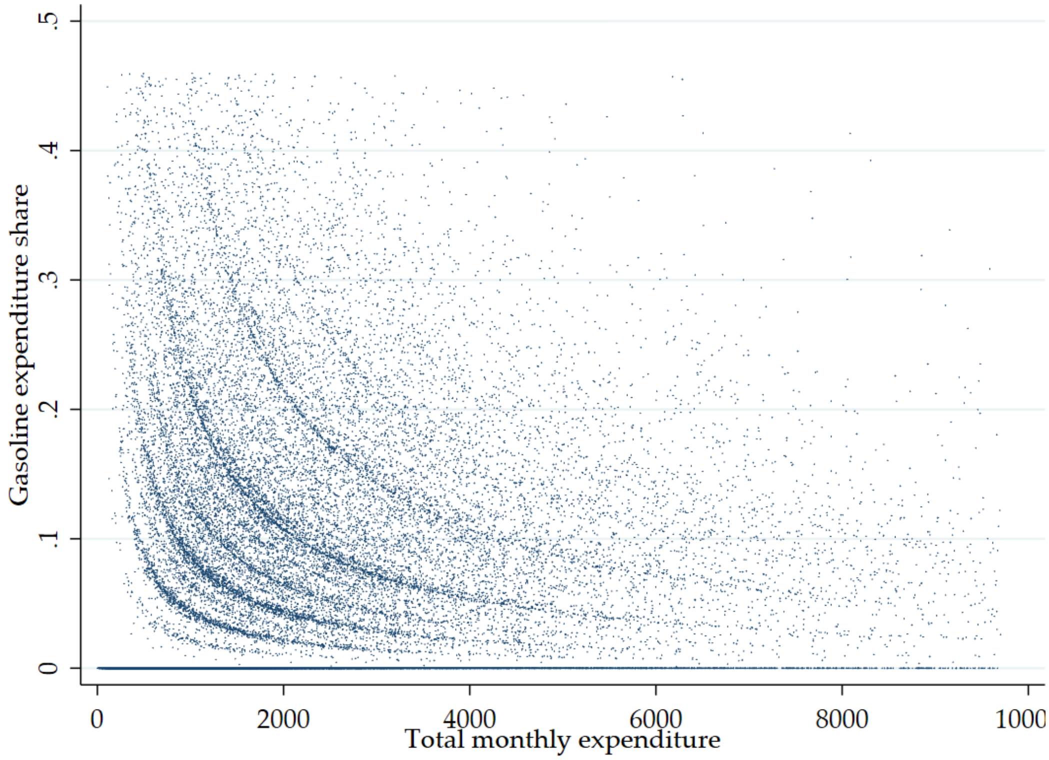

Figure 5.2: Expenditure share on gasoline of Brazilian households by total expenditure from the 2017-2018 FBS

expected of goods that are not luxuries.

Figure 5.3 shows concentration curves of expenditure on fuels and public transportation in Brazil based on the 2017-2018 FBS. The horizontal axis is the cumulative proportion of total expenditure on fuels and public transportation by each household in the sample, sorted by their total expenditure, and the vertical axis is the cumulative proportion of the total expenditure by all households in the sample. Families with higher expenditure, presumably wealthier, are responsible for a larger proportion of the total expenditure on all three main vehicle fuels (gasoline in blue, ethanol in green and diesel in purple), while families with lower expenditure are responsible for a larger proportion of expenditure on public transportation (in orange).

If price elasticity of demand for fuels does not vary significantly across expenditure

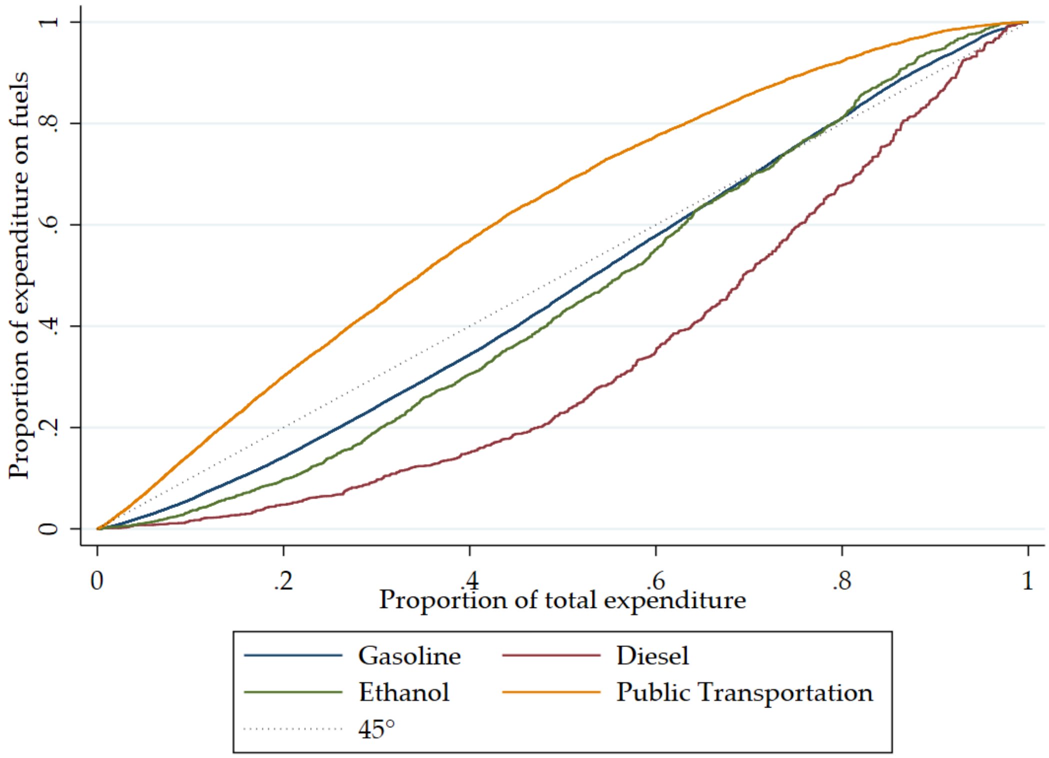

Figure 5.3: Cumulative proportion of expenditure on fuels and public transportation of Brazilian households by cumulative proportion of total expenditure from the 2017-2018 FBS

levels, Figure 5.3 suggests a subsidy is regressive. On the other hand, the price of public transportation depends heavily on fuel prices and subsidies to public transportation are uncommon in Brazil (Carvalho, 2016). Until the COVID-19 pandemic only the city of São Paulo significantly subsidised urban public transportation in Brazil (Carvalho, 2016; Ferraz, Jorge, and Scheller, Ferraz et al.). From that perspective, a subsidy on fuels, in particular diesel, indirectly subsidises public transportation.

Chapter 6

Results

Table 6.1 shows estimates for an AIDS, an unconstrained QUAIDS, a QUAIDS with homogeneity enforced, and a QUAIDS with homogeneity and symmetry enforced.

Table 6.1: Demand system estimates for the Brazilian population

	QUAIDS	AIDS	Homogeneity	Symmetry
w_{Food}				
γ_{Food}	0.338***	0.357***	0.288***	0.223**
$\gamma_{FuelsTransportation}$	−0.230***	−0.223***	−0.194***	−0.103***
γ_{Goods}	0.211***	0.179**	0.204***	0.127*
$\gamma_{Services}$	−0.364*	−0.506**	−0.711***	−0.153
$\gamma_{Housing}$	0.746***	0.747***	0.684***	−0.00920
$\gamma_{AdultGoods}$	−0.155	−0.143	−0.271***	−0.0861
$\beta_{\ln x}$	0.0260***	−0.0513***	0.0260***	0.0247***
$\lambda_{\ln x^2}$	−0.0226***		−0.0225***	−0.0225***
ρ_{v_x}	0.0849***	0.0993***	0.0848***	0.0861***
α_{Adults}	0.00375***	0.00623***	0.00373***	0.00417***
$\alpha_{Children}$	0.0121***	0.0135***	0.0121***	0.0122***
α_{Male}	0.00153	0.00202	0.00149	0.00109
α_{Rural}	0.00358**	0.00251*	0.00359**	0.00338**
α_{i0}	0.284***	0.325***	0.285***	0.294***
$w_{FuelsTransportation}$				

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6.1 Continued:

	QUAIDS	AIDS	Homogeneity	Symmetry
γ_{Food}	-0.00762	-0.0217	-0.0415	-0.103^{*}
$\gamma_{FuelsTransportation}$	0.0133	0.0107	0.0375^{*}	0.00240
γ_{Goods}	-0.00925	0.0115	-0.0143	-0.0173
$\gamma_{Services}$	0.502^{***}	0.585^{***}	0.268^{***}	-0.0125
$\gamma_{Housing}$	-0.341^{***}	-0.341^{***}	-0.383^{***}	0.102
$\gamma_{AdultGoods}$	0.212^{***}	0.204^{***}	0.134^{**}	0.0282
$\beta_{\ln x}$	-0.0716^{***}	-0.0258^{***}	-0.0716^{***}	-0.0710^{***}
$\lambda_{\ln x^2}$	0.0134^{***}		0.0134^{***}	0.0134^{***}
ρ_{v_x}	-0.0241^{***}	-0.0326^{***}	-0.0242^{***}	-0.0248^{***}
α_{Adults}	0.0107^{***}	0.00924^{***}	0.0107^{***}	0.0105^{***}
$\alpha_{Children}$	0.000310	-0.000520	0.000290	0.000254
α_{Male}	0.0136^{***}	0.0133^{***}	0.0136^{***}	0.0138^{***}
α_{Rural}	0.00519^{***}	0.00582^{***}	0.00520^{***}	0.00525^{***}
α_{i0}	0.203^{***}	0.179^{***}	0.204^{***}	0.199^{***}
w_{Goods}				
γ_{Food}	0.0190	0.00979	0.0207	0.127^{**}
$\gamma_{FuelsTransportation}$	0.0110	0.00587	0.00977	-0.0173
γ_{Goods}	0.190^{***}	0.208^{***}	0.191^{***}	0.201^{***}
$\gamma_{Services}$	0.147	0.229	0.159^{*}	-0.112
$\gamma_{Housing}$	-0.411^{***}	-0.412^{***}	-0.409^{***}	-0.188^{***}
$\gamma_{AdultGoods}$	0.0253	0.0184	0.0293	-0.0108
$\beta_{\ln x}$	0.0237^{***}	0.0678^{***}	0.0237^{***}	0.0241^{***}
$\lambda_{\ln x^2}$	0.0129^{***}		0.0129^{***}	0.0129^{***}
ρ_{v_x}	-0.0523^{***}	-0.0605^{***}	-0.0523^{***}	-0.0528^{***}
α_{Adults}	-0.0118^{***}	-0.0133^{***}	-0.0118^{***}	-0.0120^{***}
$\alpha_{Children}$	-0.0163^{***}	-0.0171^{***}	-0.0163^{***}	-0.0164^{***}
α_{Male}	-0.0113^{***}	-0.0115^{***}	-0.0113^{***}	-0.0111^{***}
α_{Rural}	-0.0109^{***}	-0.0103^{***}	-0.0109^{***}	-0.0109^{***}
α_{i0}	0.0956^{***}	0.0725^{***}	0.0956^{***}	0.0920^{***}
$w_{Services}$				
γ_{Food}	-0.145^{*}	-0.137^{*}	-0.0757	-0.153^{*}
$\gamma_{FuelsTransportation}$	0.0429	0.0455	-0.00665	-0.0125
γ_{Goods}	-0.201^{***}	-0.215^{***}	-0.190^{***}	-0.112^{*}
$\gamma_{Services}$	-0.372^{*}	-0.431^{**}	0.108	0.158
$\gamma_{Housing}$	0.0393	0.0393	0.125	0.0736
$\gamma_{AdultGoods}$	-0.120	-0.115	0.0401	0.0454
$\beta_{\ln x}$	0.0240^{***}	-0.00797^{***}	0.0240^{***}	0.0240^{***}

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6.1 Continued:

	QUAIDS	AIDS	Homogeneity	Symmetry
$\lambda_{\ln x^2}$	-0.00934^{***}		-0.00938^{***}	-0.00942^{***}
ρ_{v_x}	-0.0239^{***}	-0.0180^{***}	-0.0237^{***}	-0.0237^{***}
α_{Adults}	0.00456^{***}	0.00558^{***}	0.00459^{***}	0.00459^{***}
$\alpha_{Children}$	0.0115^{***}	0.0120^{***}	0.0115^{***}	0.0115^{***}
α_{Male}	-0.0215^{***}	-0.0213^{***}	-0.0215^{***}	-0.0215^{***}
α_{Rural}	-0.00319^{**}	-0.00363^{***}	-0.00321^{**}	-0.00319^{**}
α_{i0}	0.322^{***}	0.339^{***}	0.321^{***}	0.321^{***}
$w_{Housing}$				
γ_{Food}	-0.144^{**}	-0.149^{***}	-0.120^{**}	-0.00920
$\gamma_{FuelsTransportation}$	0.144^{***}	0.142^{***}	0.127^{***}	0.102^{***}
γ_{Goods}	-0.180^{***}	-0.172^{***}	-0.176^{***}	-0.188^{***}
$\gamma_{Services}$	-0.0199	0.0167	0.144^{*}	0.0736
$\gamma_{Housing}$	-0.0657	-0.0659	-0.0364	0.00540
$\gamma_{AdultGoods}$	0.00720	0.00407	0.0620	0.0164
$\beta_{\ln x}$	0.00124	0.0211^{***}	0.00123	0.00144
$\lambda_{\ln x^2}$	0.00579^{***}		0.00577^{***}	0.00579^{***}
ρ_{v_x}	0.0108^{***}	0.00717^{***}	0.0109^{***}	0.0106^{***}
α_{Adults}	-0.00679^{***}	-0.00742^{***}	-0.00678^{***}	-0.00686^{***}
$\alpha_{Children}$	-0.00467^{***}	-0.00502^{***}	-0.00465^{***}	-0.00468^{***}
α_{Male}	0.0111^{***}	0.0109^{***}	0.0111^{***}	0.0111^{***}
α_{Rural}	0.00674^{***}	0.00701^{***}	0.00673^{***}	0.00680^{***}
α_{i0}	0.0655^{***}	0.0551^{***}	0.0652^{***}	0.0643^{***}
$w_{AdultGoods}$				
γ_{Food}	-0.0600^{**}	-0.0600^{**}	-0.0709^{**}	-0.0861^{***}
$\gamma_{FuelsTransportation}$	0.0191^{*}	0.0193^{*}	0.0269^{***}	0.0282^{***}
γ_{Goods}	-0.0116	-0.0118	-0.0133	-0.0108
$\gamma_{Services}$	0.107^{*}	0.107^{*}	0.0320	0.0454
$\gamma_{Housing}$	0.0327	0.0328	0.0193	0.0164
$\gamma_{AdultGoods}$	0.0310	0.0311	0.00590	0.00692
$\beta_{\ln x}$	-0.00327^{***}	-0.00375^{***}	-0.00326^{***}	-0.00327^{***}
$\lambda_{\ln x^2}$	-0.000142		-0.000135	-0.000138
ρ_{v_x}	0.00454^{***}	0.00463^{***}	0.00451^{***}	0.00453^{***}
α_{Adults}	-0.000389	-0.000373	-0.000393	-0.000387
$\alpha_{Children}$	-0.00287^{***}	-0.00286^{***}	-0.00288^{***}	-0.00287^{***}
α_{Male}	0.00659^{***}	0.00659^{***}	0.00658^{***}	0.00658^{***}
α_{Rural}	-0.00136^{***}	-0.00137^{***}	-0.00136^{***}	-0.00136^{***}
α_{i0}	0.0293^{***}	0.0296^{***}	0.0294^{***}	0.0295^{***}

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6.1 Continued:

	QUAIDS	AIDS	Homogeneity	Symmetry

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 6.2 shows the results of Hausman specification tests for the quadratic specification, and of endogeneity tests of the logarithm of total expenditure. The hypothesis of a linear specification is rejected at the usual significance levels. The hypothesis of exogeneity of $\ln x$ is also rejected at the usual levels.

Table 6.2: Joint tests of the quadratic model specification and endogeneity tests

	Quadratic terms		Endogeneity of $\ln x$	
	χ^2	Two-sided p-value	χ^2	Two-sided p-value
QUAIDS (unconstrained)	2613.78	0.0000	2576.38	0.0000
AIDS			3377.66	0.0000
QUAIDS (homogeneous)	2616.06	0.0000	2576.19	0.0000
QUAIDS (symmetric)	2614.64	0.0000	2627.34	0.0000

6.1 Welfare effects estimation

The demand system estimates in Section 6 provide the necessary information for the derivation of each household's cost function, which can then be used to compute the equivalent variation measure described in Section 3.

Choosing u_1 and p_1 as the prices and utility level of households at the base period for the 2017-2018 FBS, the cost of achieving u_1 is equal to the total expenditure of household k at the base period, so that Equation 3.2 can be computed as in Equation 6.1.

$$EV = c_k(u_1, p_0) - x \tag{6.1}$$

Even though it is not possible to determine how much of the increase in fuel prices was directly caused by the IPP policy, the index used for the welfare effects computation is estimated as follows. First, the weight of each fuel is obtained from the ratio of the aggregate expenditure on the fuel by the aggregate expenditure on all items in the Fuels and Transportation group. Then, the price change of each fuel is estimated as the difference between the accumulated increase in the price of each fuel and the accumulated inflation as measured by the ACPI between October 2016 and September 2019 (to avoid potential effects of the COVID-19 pandemic) (IBGE, 2019b). Finally, the price change for the Fuels and Transportation group is computed as the weighted sum of the differences not accounted by inflation. This procedure yields an accumulated change of 15.73%.

Aggregate losses to consumers due to the price increase are shown in Figure 6.1. Higher income deciles show bigger losses, which is expected as transportation is not an inferior good.

Figure 6.2 shows the mean ratio of EV to total expenditure by total expenditure decile. Despite the fact that higher income families consume more fuels than lower income families, the price increase is found to be regressive up until the 9th total expenditure decile, as the increase in consumption is not large enough to offset the price increase.

Alternatively, the distributional impact of the price change can be evaluated through the Gini index before and after the change. Applying the modified OECD equivalence scale to the sample, the Gini index is calculated at 46.45 after the price increase, and estimated at 46.53 before the price change. A similar result is found by applying the square root equivalence scale, with the Gini index is calculated at 46.21 after the price increase, and estimated at 46.27 before the price change. Both point

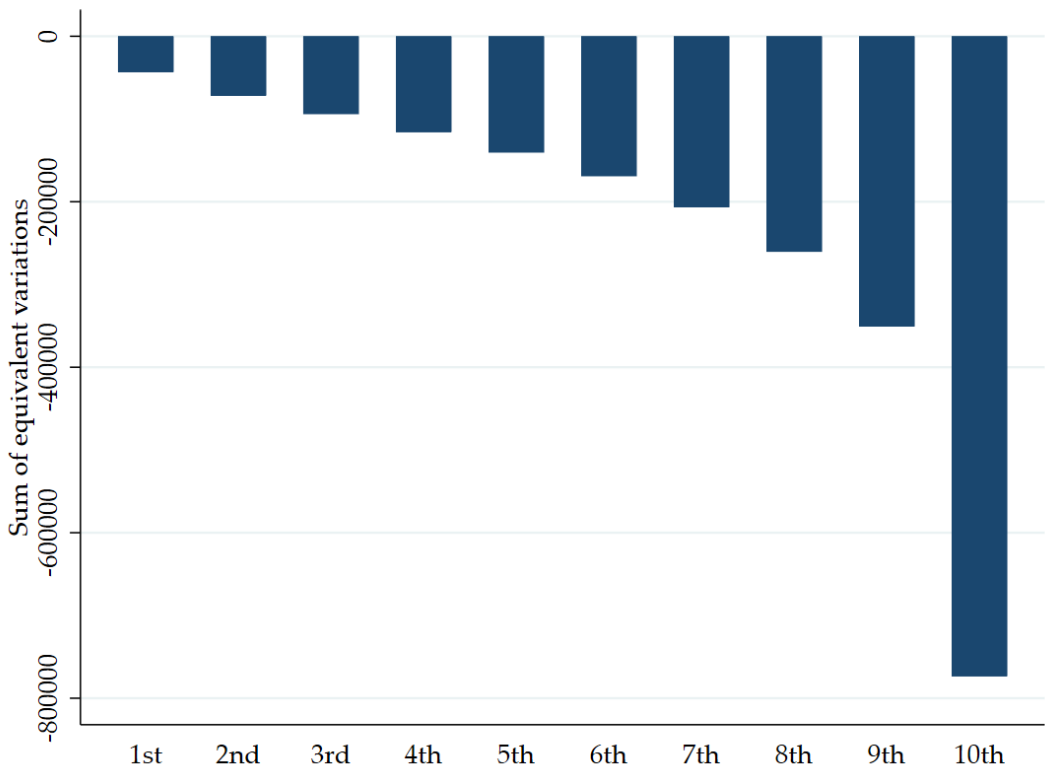

Figure 6.1: Sum of EVs by total expenditure decile

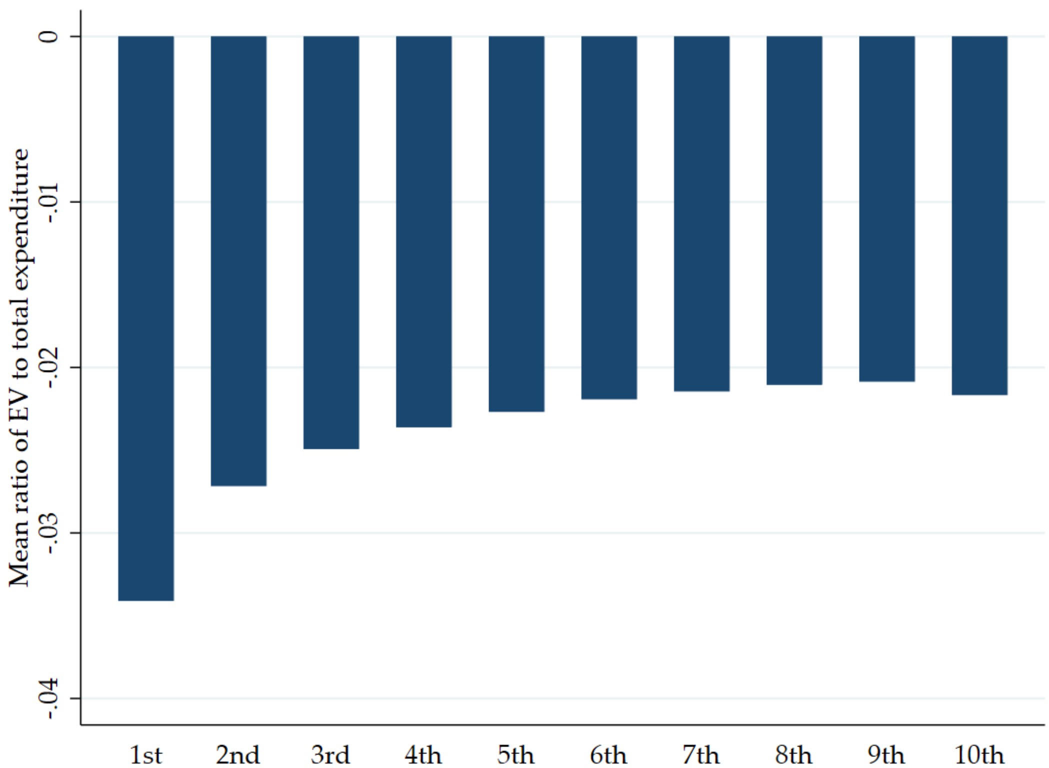

Figure 6.2: Mean ratio of EVs to total expenditure, by total expenditure decile

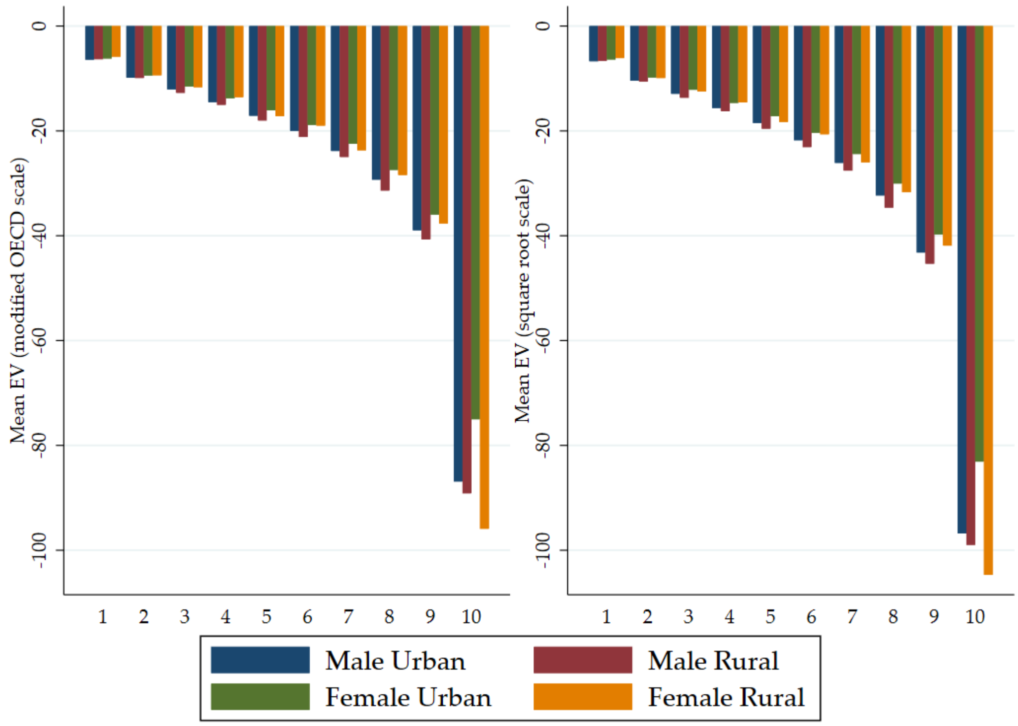

Figure 6.3: Mean EV by gender and residence type, by total expenditure decile, scaled with the modified OECD and the square root scales

to an increase in inequality.

The estimated α_{rural} and α_{male} are significant but small in magnitude for the $w_{FuelsTransportation}$ equation. This is reflected in the small differences found in the estimated EVs between households headed by women and men, or between households in rural and urban areas, shown by total expenditure decile in Figure 6.3. Households headed by women show sligthly smaller losses than households headed by men, and households in urban areas show slightly higher losses than households in rural areas.

Figure 6.3 also shows that EVs scaled with the square root scale tend to be larger in magnitude than those scaled with the modified OECD scale.

With respect to the number of adults and children in the household, the estimated $\alpha_{Children}$ is much smaller than α_{Adults}. As a result, Figure 6.4 shows roughly

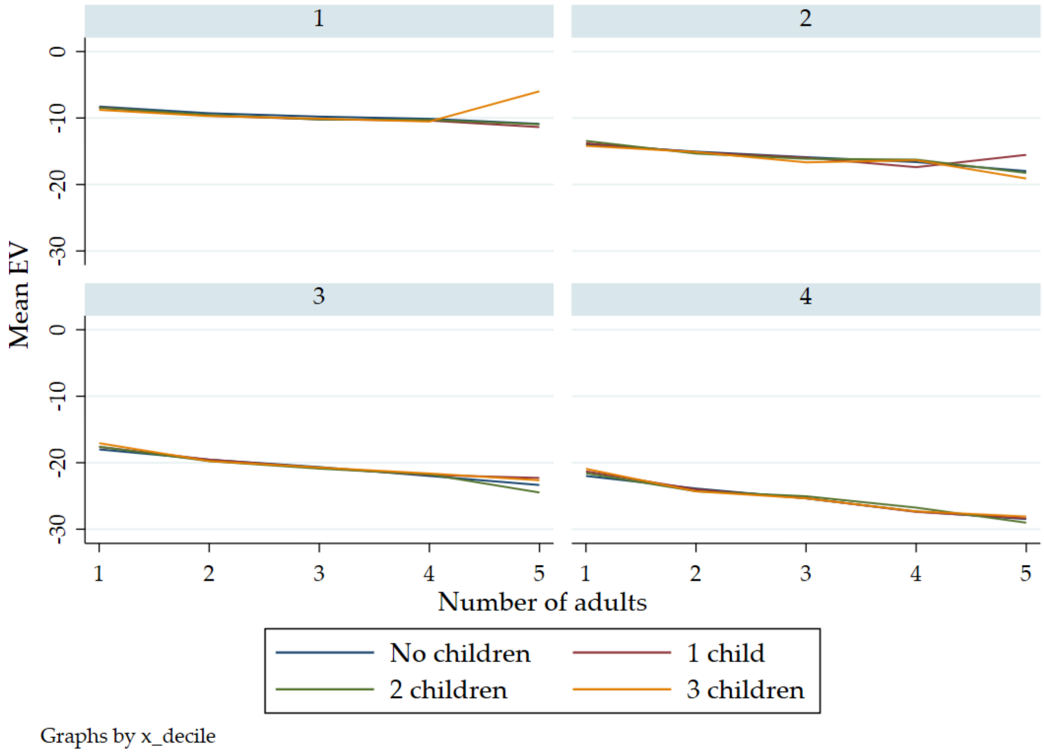

Figure 6.4: Mean EV by number of children and adults, by total expenditure decile

equal mean EVs among households with 0-3 children, while more adults imply higher losses.[1]

Applying equivalence scales, it is assumed that larger households benefit from economies of scale. Since the non-scaled EVs do not vary significantly with the number of children, scaling results in families with more children showing lower equivalent losses, as shown in Figure 6.5. The scaling also changes the relationship between the number of adults and the size of the losses: families with more adults also display lower equivalent losses.

[1]Only the first four expenditure deciles are represented, but the trend is the same present on all deciles.

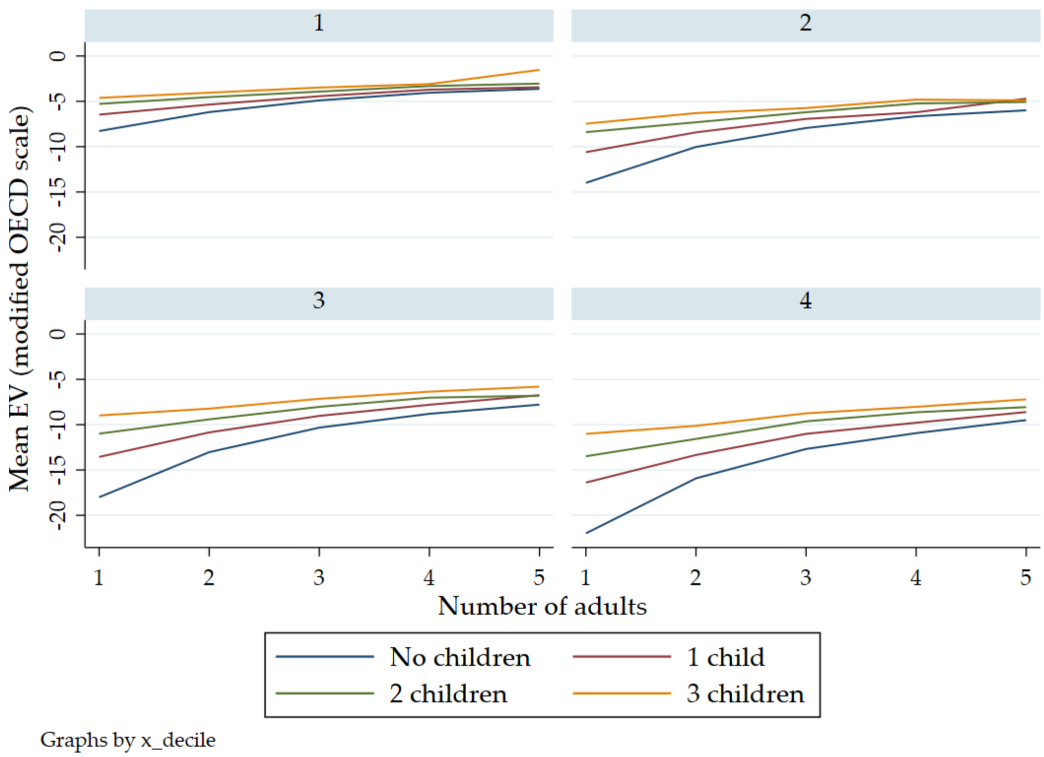

Figure 6.5: Mean EV by number of children and adults, by total expenditure decile, scaled with the modified OECD scale

6.2 Limitations

As mentioned in Section 5.1, the QUAIDS estimates are obtained by using unofficial price variation information, which renders the results not reliable.

The price variation matter introduces another issue. Having zero expenditure in one or more commodity groups does not ordinarily require that a household not be included in the estimation. However, due to the procedure described in Section 5.1, if within a household's price group there was no aggregate expenditure on the commodity group in question, there will also be no price index for said commodity group. The absence of price index information does mean the household data will be discarded.

Figure 6.6 shows that the mean count of commodity groups with zero expenditure is higher for lower income households. This is likely due to "corner solutions" at low levels of income, and potentially to sparse purchases that fall outside of the survey period.[2] It also means lower income families are more likely to be ommited from the sample, as shown in Figure 6.7.

Finally, the model with enforced symmetry must be used for the welfare computations, but the symmetry and homogeneity hypotheses are rejected.

[2]For example, the survey registers food purchases for seven days. If the household typically buys groceries in bulk once a month, their (adjusted) monthly expenditure would be incorrectly represented as zero.

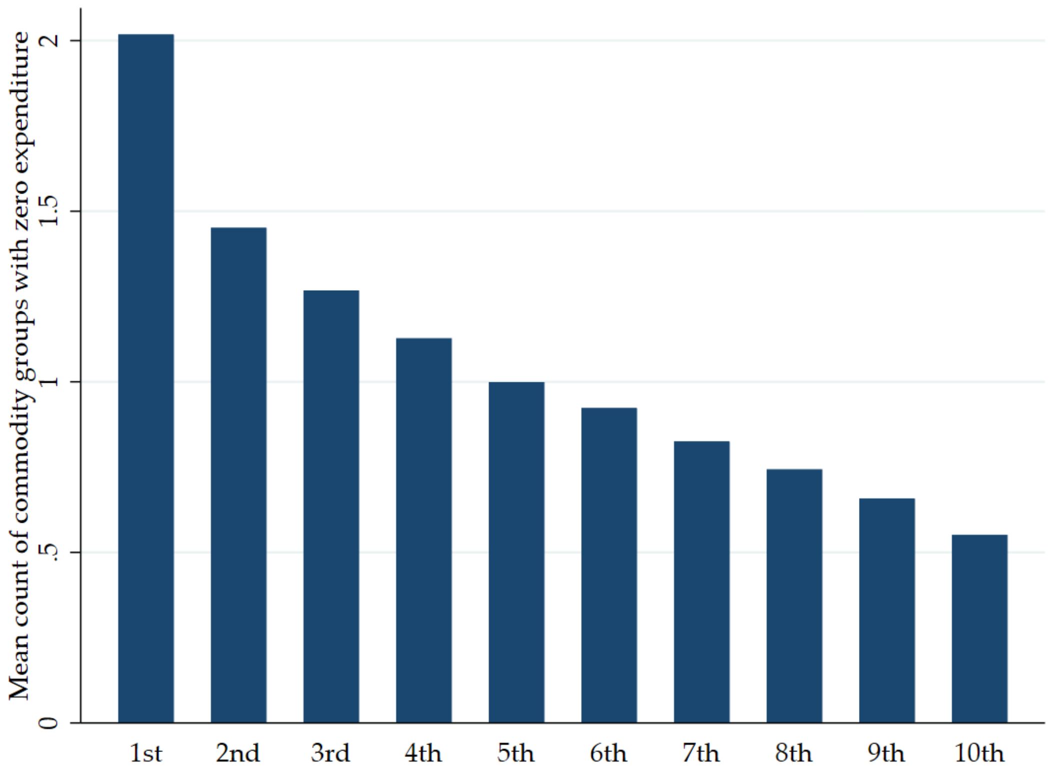

Figure 6.6: Mean count of commodity groups with zero expenditure by total expenditure decile

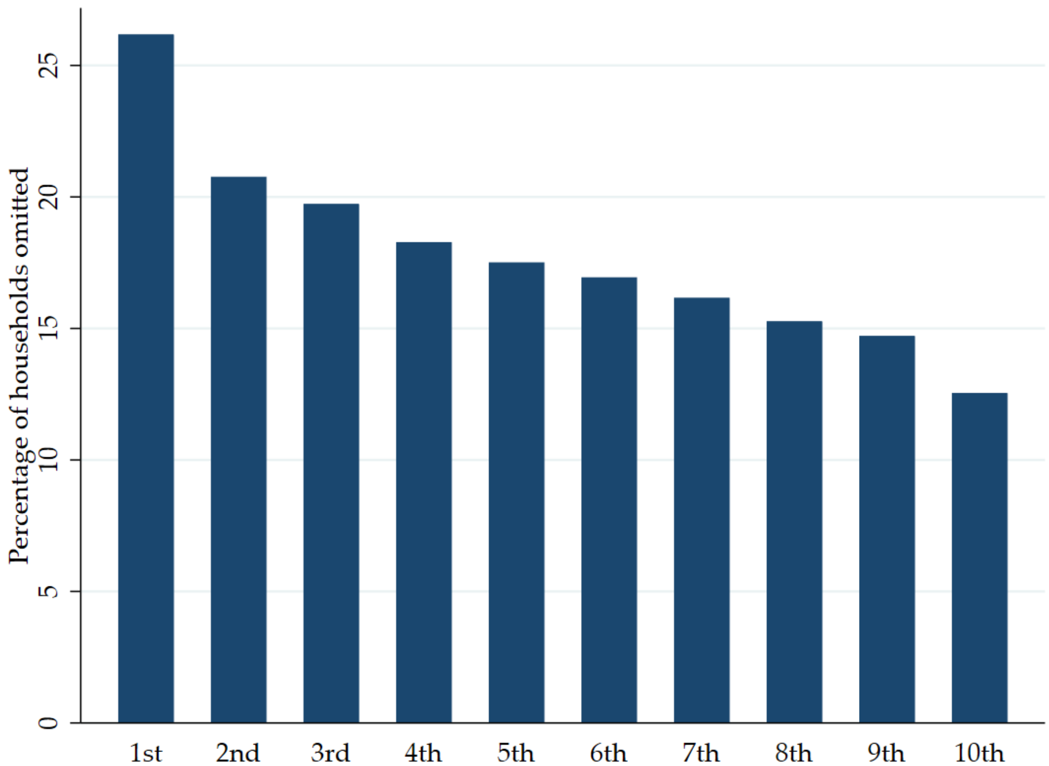

Figure 6.7: Percentage of households omitted from the estimation by total expenditure decile

Chapter 7

Conclusions

A complete demand system was estimated for the Brazilian population, from the 2017-2018 FBS. The demand estimates were used to compute equivalent variations for each household in the sample, taking into consideration the number of adults and children in the household, whether it is located in a rural or urban area, and the gender of the head of the household.

From the rates of equivalent variations following the price increase due to the IPP policy, the policy is found to be regressive, even considering only effects on the cost of transportation. With the accompanying increase in profits for Petrobras and hence of government revenue, there is an opportunity to reduce this impact by applying this revenue into counteracting measures such as subsidies targeted towards lower income families, or through income tax changes that reduce the tax burden for lower income families.

In particular, families are more affected the larger the number of adults, but in a diminishig schedule. Given that the Bolsa Família transfer program already has information on the number of adults and children in each household, the per capita transfer amounts could be changed following this schedule, with the first adult receiving an increase of close to BRL 8 and each additional adult receiving progressively lower amounts. Alternatively, taking into account the findings of Carvalho (2014), the revenue could be directed towards a national program of subsidies of urban public transportation.

With respect to other demographic characteristics, it was found that the number of children, the gender of the the head of the household, and whether it is situated in an urban or rural area, made little difference on the welfare effect of the price increase, relative to the total expenditure and the number of members.

Additionally, estimation of complete demand systems requires better data than currently provided by BIGS. This could be achieved by including, on the dataset, the date of collection — to the extent that this does not produce a privacy breach hazard — so that price variation can be obtained from the National System of Consumer Price Indices (NSCPI). Another possibility would be to include a simplified budget questionnaire into existing yearly population surveys, so that yearly price changes could be linked to expenditure pattern changes.

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Appendix A

Sampling of the FBS

The FBS uses BIGS's master Sample. The master sample is a set of households selected as follows. First, BIGS divides the Brazilian territory into census sectors following three sets of criteria: the number of residences, the number of agricultural and livestock facilities, and the number of days needed to collect data in one sector. For urban areas, there is a subdivision between urbanized and non-urbanized areas, and the criterion for rural and non-urbanized areas includes a range of agricultural and livestock facilities. Table A.1 shows the minimum, average and maximum number of residences or facilities for each category, and the number of days allocated to the data collection.

The sectors are then stratified for sampling as follows: first by federative unit,[1] then by municipality within the federative unit, then by the type of residence[2] and finally by income levels, determined within the stratum. BIGS groups the census

[1] A "federative unit" is a state or the Federal District of Brazil, where the capital Brasília is located.

[2] Usually referred to in BIGS documents as "household situation".

Table A.1: Sector size definition criteria

Area type		Number of residences			Number of facilities			Days for collection	
		min	avg	max	min	avg	max	counting	large agricultural territories
Urban	urbanized area	250	300	400				30	
	non-urbanized area	150	200	250	100	150	200	45	
Rural		150	200	250	100	150	200	45	60

sectors into PSUs, aiming to have at least 60 permanent residences in each PSU, although some PSUs may not reach that number (Freitas and Antonaci, 2014). The PSUs are then drawn from the strata into the master sample with weighted probabilities according to the size of the PSU. The number of PSUs drawn is chosen so that the number of individuals 14 years of age or older who are not employed or students — this is a relevant indicator of another survey, the National Sample Household Survey (NSHS) — can be estimated with a predefined precision level (Freitas and Antonaci, 2014). When of the execution of the 2017-2018 FBS, the number of PSUs in the master sample was 15,096 (IBGE, 2019a).

For the FBS, the number of PSUs sampled from the master sample is chosen so that the total income of the head of the households can be estimated under a predetermined precision level. The coefficient of variance was determined for each federative unit, ranging from 6% to 15%. The final size of the sample was of 5,504 FBS, containing 69,660 households (IBGE, 2019a).

The master sample excludes the following areas: military bases, camping sites, prisons, orphanages, hospitals, nunneries and elderly rest homes (IBGE, 2019a).

Appendix B

Demographic attribute variables in the FBS

Table B.1 shows the variable in the FBS datasets for each attribute used to translate demand in the QUAIDS.

[1] This font indicates names of variables as provided in the raw dataset.

Attribute	**Source**
Number of Adults	The dataset `MORADOR`[1] contains one row per household member, and the variable `V0403` with each member's age. I count the rows in each household where the age is ≥ 16.
Number of Children	The dataset `MORADOR` contains one row per household member, and the variable `V0403` with each member's age. I count the rows in each household where the age is < 16.
Type of Residence	Variable `TIPO_SITUACAO_REG` in `MORADOR` classifies households as "urban" or "rural".
Gender of Head of the Household	Variable `V0404` in `MORADOR` classifies the head of the household as "male" or "female".

Table B.1: Source variables of household attributes in the 2017-2018 FBS

Appendix C

Mapping of ACPI groups to commodity groups

Table C.1 shows the structure of groups, subgroups, items and subitems of goods and services used by the ACPI (Freitas and Antonaci, 2020, p. 20), with the respective commodity group. Less aggregated levels of the structure have been omitted when the entire parent category was mapped into a single group, for example the ACPI group "Communication" is entirely included in the "Services" commodity group, so it is represented by a single row in the table, whereas each subgroup of the "Health Goods and Services" was mapped to a different commodity group, occupying a separate row.

Table C.1: ACPI group to commodity group mapping

Group	**Subgroup**	**Item**	**Subitem**	**Commodity Group**
Food and Beverages	Groceries	Beverages	Alcoholic beverages†	Adult Goods
			All others†	Food

Table C.1 Continued:

Group	**Subgroup**	**Item**	**Subitem**	**Commodity Group**
		All others†		Food
	Eating out	Eating out	Alcoholic beverages†	Adult Goods
			All others†	Adult Goods
Housing	Fees and Maintenance	Rent and Fees		Housing and Maintenance
		Repairs		Housing and Maintenance
		Cleaning Products		Other Goods
	Domestic Fuels and Electricity			Fuels and Transportation
Appliances and Furniture				Other Goods
Clothing				Other Goods
Transportation	Transportation	Public Transportation		Fuels and Transportation
		Private Vehicle		-
		Vehicle Fuels		Fuels and Transportation
Health Goods and Services	Pharmaceutical and Optical Goods			Other Goods
	Health Services			Services
	Personal Care			Other Goods
Personal Expenses	Personal Services			Services
	Recreation and Smoking	Recreation	Musical Instrument	Other Goods
			Bicycle	Other Goods
			Toys	Other Goods

Table C.1 Continued:

Group	**Subgroup**	**Item**	**Subitem**	**Commodity Group**
			Fishing Materials	Other Goods
			Sports Materials	Other Goods
			Pet Food	Other Goods
			All others[†]	Services
		Smoking		Adult Goods
Education				Other Goods
Communication				Services

[†]These are not item names in the BIGS registry, but groupings of convenience named by me to avoid listing many items.