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Distributional Effects of Taxation of Processed Foods in Brazil

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Abstract

This paper examines the potential distributional effects of a tax increase on processed and ultra-processed foods. Using data from the most recent Brazilian consumption survey (POF 2017/2018), it analyzes the welfare changes that households would experience when facing increased costs for these products. Using an extended cost-benefit analysis model to assess net income effects, the paper considers three distinct dimensions: changes in product expenditure, changes in medical expenditure, and changes in years of life lost. The findings suggest that the tax increase would have a progressive impact, benefiting households at the lower end of the consumption distribution in all three dimensions. Overall, the study highlights the potential for targeted taxation policies as a "triple win" to address health concerns, promote greater equity, and increase fiscal revenues.

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Distributional Effects of Taxation of Processed Foods in Brazil

Bernardo D.P. Coelho[1]; Courtney Ivins[2]; Roberto Iunes[3]

1. Introduction

It is estimated that non-communicable diseases (NCDs) cause over 70% of deaths worldwide (WHO, 2022). Among these, an estimated 7.9 million deaths and 187.7 million disability-adjusted life-years (DALYs) were attributable to dietary risk factors in 2019 (Qiao et al., 2021). Unhealthy diets - linked to leading NCDs like diabetes, heart disease, stroke, and cancer - are characterized by low consumption of whole grains, fruit, vegetables, nuts and seeds, fiber, polyunsaturated fatty acids, omega-3 oils, calcium, or milk, and/or high consumption of sodium, trans-fats, processed and red meat, and sugary drinks (as classified by Global Burden of Disease studies) (PAHO, 2023).

Increased dietary risk has contributed to an unprecedented rise in overweight and obesity. The first report from the Lancet Commission on Obesity described this rise, together with undernutrition and climate change, as a "Global Syndemic", a synergy of epidemics sharing common societal drivers including food and agriculture, transportation, urban design, and land use systems (Swinburn et al., 2019). Due to factors such as limited political leadership, coordination, and public demand, and strong commercial lobbies, no country has managed to reverse the rise in obesity prevalence over the last four decades, despite three decades of World Health Assembly commitments and the UN designation of 2016-2025 as the "Decade of Nutrition" (Swinburn et al., 2019). The Americas is the World Health Organization (WHO) region with the highest prevalence of overweight and obesity, estimated at 62.5% and 28% respectively in 2016 (PAHO, 2023).

In addition to contributing to obesity and overweight (which in turn increases NCD risk), ultra-processed foods have been independently linked to a range of negative health outcomes, informing policy efforts to reduce their consumption to promote healthy diets and reduce the burden of diet related NCDs, as recommended by the Framework for Action from the Second International Conference on Nutrition (2014). Fiscal policies – both taxes and subsidies – have gained increasing traction as tools to influence healthier consumption. While more substantial research has been conducted on taxation of alcohol, tobacco, and sugar-sweetened beverage (so-called "health taxes" or "sin taxes"), studies on fiscal policies to influence healthy food consumption have been more limited. In particular, evidence on impacts of such

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policies on subpopulations is a notable and persistent gap in the literature, essential to ensure policies are assessed and designed with an equity lens.

Health taxes have been proposed in Brazil to address the country's growing burden of obesity and NCDs. More than half of Brazilian adults are overweight (60.3%, or 96 million people – including one in five teenagers aged 15-17), and 25.9% of adults is obese (41.2 million people), with higher prevalence among women (World Bank, 2022). This has been accompanied by Brazil's alarming rise in NCDs, now responsible for almost 75% of deaths in the country. Brazil's changing dietary profile is characterized by increased consumption of ultra-processed foods, which rose as a proportion of household caloric intake from 12.6% in 2002-2003 to 18.4% in 2017-2018 (Machado, 2022). Considering the established links of the consumption of ultra-processed foods in Brazil and globally with negative health outcomes, including mortality, obesity, and NCDs, policy measures to reduce consumption may effectively contribute to reduce premature mortality and promote health status, thus contributing more broadly to human capital development.

This study addresses gaps in the health tax literature by assessing equity impacts of a potential tax on ultra-processed foods in Brazil. Applying a statistical model to assess welfare changes in terms of net income effects, findings indicate that an ultra-processed food tax would have a progressive impact. Tax burdens increase among higher consumption deciles, whereas lower consumption deciles experience welfare gains in terms of product expenditure, and from reductions in years of life lost and medical expenditure resulting from reduced ultra-processed food consumption. Section 2 of the paper provides a review of the literature, including on the concepts of processed and ultra-processed foods, the evidence on their negative health impacts and their consumption and production in Brazil, international experiences on taxing unhealthy foods, and methodologies for assessing the progressiveness of taxation. Sections 3 and 4, respectively, describe the paper's methodology and provide an overview of the data and descriptive statistics it employs. Section 5 describes the study results in terms of elasticity and changes in product expenditure, medical expenditure, and years of life lost. Section 6 discusses policy implications of these findings.

2. Literature review

2.1. The concept of processed and ultra-processed food

A key challenge in analyzing and operationalizing fiscal policies to influence food consumption relates to how healthy and unhealthy foods are defined. Categories of "processed" and "ultra-processed" have been increasingly used. While definitions of these terms can vary, the NOVA classification, developed by the Center for Epidemiological Studies in Health and Nutrition (NUPENS) at the University of São Paulo in 2009, has been recognized by the WHO/Pan American Health Organization and the Food and Agriculture Organization, and utilized to assess impacts of the rapid increases in the sale of these foods, particularly in lower-middle-income and upper-middle-income countries (Global Panel on Agriculture and Food Systems for Nutrition, 2016; Monteiro et al., 2018). In high-income countries, ultra-processed foods already make up a significant share of energy intake (for example, reaching almost 58% in the United States, where they also represent an estimated 90% of the energy intake from added sugars) (Steele et al., 2016).

The NOVA classification divides foods into four distinct groups. The first group, referred to as "**unprocessed or minimally processed foods**", consists of natural, whole foods that have undergone little to no processing. This category includes fresh fruits and vegetables, nuts, seeds, and freshly prepared meats and seafood. These foods are considered the most nutritionally rich and provide essential nutrients, fiber, and antioxidants that are beneficial for maintaining a healthy diet. This group will be mentioned hereafter as "in-natura foods".

The second group encompasses "**processed culinary ingredients**" that are derived from unprocessed foods, such as oils, butter, salt, and sugar. Although these ingredients are extracted or refined from whole foods, they are typically used in small quantities to enhance the flavor or cooking process and are not consumed as standalone items.

Moving further along the processing spectrum, the third group comprises "**processed foods**." These products often contain a combination of processed culinary ingredients along with added substances such as preservatives, sweeteners, and flavor enhancers. Examples of processed foods include canned vegetables, cured meats, and bread. While these foods may still retain some nutritional value, they tend to have reduced amounts of essential nutrients and may also contain higher levels of salt, sugar, and unhealthy fats.

The final category within the NOVA classification is "**ultra-processed foods**." These foods are heavily modified and typically contain a multitude of ingredients, including additives, preservatives, artificial flavors, and other chemical substances. Examples of ultra-processed foods are soft drinks, packaged snacks, ready-to-eat meals, and sugary cereals.

Recent systematic reviews and meta analyses have summarized a wealth of accumulating evidence linking ultra-processed food consumption with negative health outcomes, which, in addition to weight gain, include increased risk of all-cause mortality, cardiovascular, cardiometabolic, and cerebrovascular diseases, low HLD-cholesterol levels, dyslipidaemia in children, hypertension, metabolic syndrome, irritable bowel syndrome, functional dyspepsia, cancer (breast and overall), gestational obesity, adolescent wheezing, frailty, and depression (Costa et al., 2018, Askari et al., 2020, Chen et al., 2020; Santos et al., 2020, Silva et al., 2020, Delpino et al., 2021; de Miranda et al., 2021, Lane et al., 2021, Pagliai et al., 2021; Suksatan et al., 2021; Louzada et al., 2022; Moradi et al., 2022), with more recent evidence also establishing an association with chronic kidney disease (Avesani et al., 2023). The evidence is particularly robust on the causal linkage with obesity (including a randomized control trial which controlled for the level of processing while matching intake of calories, energy density, macronutrients, sugar, sodium, and fiber) (Hall, 2019). While many existing studies on linkages with other chronic conditions are observational and cross-sectional, increasing possible confounding (particularly with obesity, which has multiple causal factors), large cohort studies have also maintained the link with NCDs like cardiovascular disease, diabetes, and cancer after controlling for obesity (Louzada et al., 2022).

This evidence also indicates that the pernicious health effects of ultra-processed foods go beyond their tendency to be more energy-dense, higher in added sugar, fat, and salt, and lower in fiber and nutritional value (Monteiro, et al., 2019). While the precise biological mechanisms still require further clinical studies, plausible causal links with obesity and NCDs are based on the use of additives and food matrix alterations that accompany industrial processing, which can induce increased caloric intake and negatively interfere with satiety signaling, while generating unfavorable gut microbiomes and hormonal imbalances (Crimarco, et al., 2021).

2.2. Consumption and production of ultra-processed foods and health outcomes in Brazil

According to estimations from Nilson et al. (2023), ultra-processed foods represent between 13% and 21% of total estimated energy intake of Brazilian adults across age and sex stratum, and their consumption was associated with 57,000 premature deaths in 2019 (10.5% of all premature deaths of adults from 30-69 years of age). Dos Passos et al. (2020) also found that the price of ultra-processed foods is inversely associated with the prevalence of overweight and obesity in Brazil, highlighting the role of these products in contributing to the country's obesity pandemic. A longitudinal study in Brazil also suggested a possible association between consumption of ultra-processed foods and cognitive decline (requiring additional research to ascertain causal mechanisms) (Gomes et al., 2023). It is projected that proportional consumption of ultra-processed foods will increase in Brazil, particularly among rural, poorer, and less educated population groups, reducing the current gap in consumption profiles characterized by higher ultra-processed foods consumption among urban, wealthier, and more educated population groups (Louzada et al., 2022). These trends have significant human as well as economic costs. Overweight and obesity alone represent an annual direct cost of R$ 1.5 billion for resulting NCD treatment within Brazil's public Unified Health System (SUS) (Ferrari et al., 2022). If no changes occur, it is projected that by 2030, the annual costs to SUS for NCD treatment will reach R$ 4.2 billion, with an additional R$ 45.5 billion in losses to the economy due to years of productive life cut short among the population with these conditions (Giannichi et al., 2023). As part of broader preventive measures, Brazil is among many Latin American countries that have advised against ultra-processed food consumption in national dietary guidelines (Monteiro, et al., 2019). These guidelines emphasize the importance of basing one's diet on fresh, minimally processed foods and culinary preparations, such as beans, rice, fruits, coffee, bread, cassava, and fish, while avoiding the consumption of ultra-processed foods like soda, cookies, packaged snacks, instant noodles, sausages, etc. (Brazil, 2014).

Arguments in support of these guidelines also point to the adverse environmental impacts of the production and consumption of ultra-processed foods, with the water footprint of those who consume them the most being 10% higher than those who consume them the least (Garzillo et al., 2022). The production of a single 500ml soda, for instance, requires an estimated 168 to 309 liters of water (Ercin et al., 2011; Hoekstra et al., 2007; Hoekstra, 2019). In Brazil, the prioritization of arable lands for the production of commodities like soy, corn, and sugarcane, driven by export incentives, has also resulted in a neglect of staple products for the domestic market. This shift in production focus has led to significant disruptions in the production and distribution chain, contributing to high levels of food waste and increased prices of these essential food items (Baccarin and Oliveira, 2021; Preiss, 2021). Moreover, specific tax incentives are also granted in regions like the Manaus Free Trade Zone (ZFM) which incentivize the production of soft drinks and other ultra-processed beverages. This arrangement allows companies to produce concentrated syrups without paying the Industrialized Products Tax (IPI), while receiving credits that can be used to offset their tax obligations. The Federal Revenue office estimated a resulting annual revenue loss of approximately R$ 4 billion for the country, despite the creation of a mere 762 jobs in the region (Brazil, 2018). Additionally, the inclusion of sausages, biscuits, and other ultra-processed foods in the Basic Food Basket, which grants tax benefits similar to those provided for staple foods like rice and beans, has raised concerns. This practice may inadvertently support unhealthy food choices while compromising efforts to promote the consumption of fresh and minimally processed foods (Campos and Carmélio, 2022).

2.3. International experience on taxation of ultra-processed foods

The literature on taxation of unhealthy foods is part of a growing body of evidence on health taxes, which originally focused primarily on tobacco, alcohol, and sugar-sweetened beverages. These taxes aim to improve health outcomes, reduce future health expenditure, and increase public revenue. These policy options can be particularly desirable in the context of budget constraints for low- or middle-income countries, where 70% of the global overweight and obese population reside (Shekar and Popkin, 2020).[4]

Several systematic reviews provide convincing evidence that taxes on unhealthy foods can effectively increase their prices and reduce their sale (used as a proxy for consumption, which is much more difficult to measure) (Andreyeva, et al., 2022, Andreyeva, et al., 2010; Green et al., 2013; Powell et al., 2013; Alagiyawanna et al., 2015; Afshin et al., 2017). There are significant gaps in the literature evaluating equity impacts of taxing unhealthy food products, and wide variations in approaches to implementing them, including, for example, a non-essential energy- dense food excise tax in Mexico; sales taxes on candy and unhealthy snack foods in different US states; a saturated fat excise tax in Denmark; snack and confectionery excise taxes in Denmark and Finland; and an excise levy on salt, sugar and caffeine content of pre-packaged foods which have healthier alternatives in Hungary (the "public health product tax") (Andreyeva, et al., 2022).

National and international commitments and recommendations, including the United Nations General Assembly's political declaration on NCDs in 2018, have emphasized the role of fiscal policies in promoting healthy eating habits. While global experiences on utilizing the level of processing as the basis for taxation are still incipient, there is ample evidence focused on taxing sugar-sweetened beverages, which have been implemented in 108 countries at the national level as of 2022 (WHO, 2023). Sugar-sweetened beverages can represent a significant share of the sugar intake through ultra-processed product consumption (Steele et al., 2016). Since 2016, the WHO has advocated for the adoption of taxes that increase the price of sugary beverages by 20% to effectively reduce their consumption and mitigate the impact of NCDs (WHO, 2017), an approach also endorsed by the International Task Force on Fiscal Policy for Health, composed of leaders, economic experts, and representatives from various governments worldwide (Bloomberg et al., 2019). A 2023 WHO Global Report highlights how the potential of these taxes for reducing consumption and preventing obesity, NCDs, and dental caries could be further harnessed through measures that ensure taxation is sufficiently high to affect affordability, while preventing substitution with nontaxed sugary beverages and incentivizing the production of healthier substitutes (WHO, 2023). However, as discussed further below, policy debates also highlight how single product or ingredient taxation that results in product reformulations or ingredient substitutions may have limited impacts on the broader tendency of increasing ultra-processed food consumption, and its resulting effects on food systems and health outcomes.

2.4. Progressiveness

Progressiveness is a characteristic that is mostly associated with income tax brackets. The definition in this context is that an income tax is progressive if the tax rate is higher for higher income brackets. In other words, richer individuals pay more taxes as a share of their income. This paper employs a slightly different definition and follows Fuchs and Meneses (2017), among others. This definition is related to consumption taxes and identifies taxes on foods and beverages as regressive if they proportionally reduce the consumption of poorer households more than they reduce that of richer households. Conversely, if the opposite happens, the tax is considered progressive. This characteristic is important considering that food represents a significant portion of expenses for poorer households. Estimating the impact of taxation on poorer households is also critical considering their greater socioeconomic vulnerability and related food and nutrition insecurity (Hassan, 2021; OPAS, 2020; OPAS, 2021).

[4] A study on estimation of obesity indicators by the World Obesity Federation (Okunogbe et al. 2022) suggests that most countries will experience obesity prevalence levels above 70% by 2060. For Brazil this prevalence is estimated at 88%.

3. Methodology

This paper aims to assess the net income effect of a tax on processed and ultra-processed foods in Brazil by considering three key factors: (i) change in product expenditure; (ii) change in medical expenditure; and (iii) change in years of productive life. The net income effect is calculated using the methodology developed by Fuchs and Meneses (2017, 2018) based on Pichón-Riviere et al. (2014) and Verguet et al. (2015). This has been applied in past literature on tobacco taxation in countries such as Chile (Fuchs and Meneses, 2017); Bosnia (Fuchs, Orlic and Cancho, 2019); Indonesia (Fuchs and Del Carmen, 2018); and South Africa (Fuchs, Del Carmen and Mukong, 2018). In Brazil, this methodology has been applied to estimate the impacts of taxes on tobacco, alcohol, and sugar-sweetened beverages by Coelho and Araújo (2023), showing that taxation of these goods has a progressive pattern.

Firstly, the assessment of changes in product expenditure assumes that consumption remains unchanged, but that the tax leads to a higher proportion of household expenditure allocated to specific products. Secondly, the paper suggests that the tax may result in a decrease in medical expenses due to a reduced incidence of diseases associated with the consumption of ultra-processed foods. Lastly, the paper estimates how potential increases in life expectancy contribute to extended income gains throughout lifetimes and positively impact household income. The overall impact of a tax policy on a specific product category, denoted as j = ($processed, ultra\text{–}processed$), can be estimated using the following approach:

$$Net\ Income\ effect_j = Change\ in\ Product\ expenditure_j\ (A) + Change\ in\ OOP\ spending\ on\ health\ care_j (B) + Change\ in\ years\ of\ productive\ life_j\ (C) \quad \text{Eq. 1}$$

3.1. Change in product expenditure

The impact of the price hike on household expenditures is evaluated by considering the variation in prices resulting from the tax, the income decile-specific price elasticity, and the proportion of household expenditure allocated to the product. The exercise assumes a price increase and does not investigate the tax structure that would lead to this increase. To estimate the change in household expenditures on a particular product category, $j = (processed, ultra - processed)$, the aggregated analysis is conducted at the decile level, employing the following formula:

$$\Delta Expenditure_{jd} = \left[\left(1 + \Delta P_j\right)\left(1 + \varepsilon_{jd} * \Delta P_j\right) - 1\right] * \frac{\omega_{jd}}{Total\ Expenditure_d} \quad \text{Eq. 2}$$

Where ΔP_j refers to the change in price, ϵ_{jd} to the price elasticity of product j for decile d, and ω_{jd} to the share of expenditures on product j and decile d. Price elasticities are estimated using the average unit prices. To ensure robustness and accuracy, any outliers beyond three standard deviations in terms of quantity and unit value were removed from the dataset. Subsequently, the price elasticities for the overall population were estimated using the following equation:

$$lnQ_{jid} = \beta_{j0} + \beta_{j1} P_j * D_i + \beta_{j3} X_{id} + \mu_{jid} \quad \text{Eq. 3}$$

In equation 3, Q_{ijd} represents the quantity of each product j consumed by household i in consumption decile d, with quantity in standard kilograms. The average price of the product, denoted by P_j, is calculated after removing outliers that deviate by three standard deviations from the average. D_i is the consumption decile of household i. Additionally, X_{id} is a vector that encompasses various household characteristics, such as urban or rural residence, household size, education level, gender, and race of household head.

3.2. Change in medical expenditure

The long-term change in spending on health care that would result from a reduction in the consumption of each product j is estimated using the static model described by equation 4. Estimates of the cost of treating diseases related to the consumption of each product are distributed proportionally to the number of households in decile d that consume product j. The list of diseases that are considered related to consumption comes from the Global Burden of Diseases dataset and will be explored in section 4.2.

To analyze the long-term impact on health care spending resulting from a reduction in the consumption of each product j, we employ a static model as outlined in equation 4. In this model, estimates are generated by attributing the public expenditures from administrative data on treating diseases associated with the consumption of each product to the number of households in decile d that engage in the consumption of said product j. The data source for the associated medical expenditure estimates is described in section 4.3.

$$\Delta Medical\ Expenditure_{jd} = \left[\left(1 + \varepsilon_{jd} * \Delta P_j\right) - 1\right] * \frac{Cost\ of\ treatment\ of\ related\ diseases_{jd}}{Total\ Expenditure_d} \qquad \text{Eq. 4}$$

3.3. Change in years of productive life

The impact of a reduction in the consumption of processed and ultra-processed foods on long-term income is derived from the reduction in years of life lost (YLL) and the associated loss of income in those years. The use of both processed and ultra-processed foods is due to a data limitation that will be explored in section 4.2.

Equation 5 provides an estimation of the average number of working years lost within decile d and is derived from the years of life lost due to diseases associated with product j. This estimation takes into account the proportional distribution based on the number of households in decile d that engage in the consumption of product j. The calculation is carried out as follows:

$$YLL_{jd} = \frac{YLL_j * Share\ of\ hh\ consuming\ product_{jd}}{Population_d} \qquad \text{Eq. 5}$$

In order to be able to compare the impact of years of life lost with the other two changes, we monetize the value of these years. To do so, we estimated the income loss due to the YLL in each decile using the average income of the decile. This estimation involves determining the average income level that would potentially have been attained by individuals within the decile if they had lived their full life expectancy. The exercise does not intend to estimate a complete income stream of individuals that died prematurely, it does not take into account the potential skill gains, economic growth or any potential changes. Instead, it aims to provide a simple and comparable impact of this hypothetical income to the actual income earned before premature death, allowing us to estimate the income loss caused by YLL.

$$\Delta Income_{jd} = \left[\left(1 + \varepsilon_{jd} * \Delta P_j\right) - 1\right] * \frac{YLL_{jd} * Average\ Income_d}{Total\ Expenditure_d} \qquad \text{Eq. 6}$$

4. Data, classification, and descriptive statistics

4.1. Brazil Consumer Expenditure Survey

Our research relies on the comprehensive Consumer Expenditure Survey (Pesquisa de Orçamento Familiar, POF) released in 2020, encompassing consumption data collected during 2017-18. The POF is a comprehensive survey conducted by the Brazilian Institute of Geography and Statistics (IBGE) that collects data on the purchasing habits and dietary intake of households across the country. It classifies food items into different groups based on their primary purpose and intended use, such as staple foods, beverages, dairy products, meats, and processed foods. Notably, the POF dataset offers extensive disaggregated data on a wide array of products, including over 8,000 food items, facilitating our identification of food groups based on the NOVA classification. In addition, this survey collects information on various aspects of household living standards, including consumption patterns, non-food expenditures, income, and socioeconomic variables.

To extract consumption data, we employed two distinct questionnaires from the POF. The first one is the "*Caderneta coletiva*" questionnaire, which captures shared household consumption and provides information on total expenditure and quantities consumed. The second one is the "*Despesa Individual*" database, which focuses on individual consumption, provides data on total expenditure for a limited number of items and does not include information on quantity. Food consumption is only included in the former. However, as we are also interested in the total consumption, we merge the two databases to obtain total household consumption, adding the shared component with the individual consumption of each household member.

To present the profile of the individuals in the database, Table 1 presents demographic statistics by consumption decile. These variables are important for the analysis, as they are included as controls in the estimation of price elasticity, described in section 5.1. The demographic statistics of POF are aligned with other household surveys, such as the Continuous National Household Sample Survey (*PNAD Contínua*), showing that the higher the consumption decile, the higher the incidence of educated white men as heads of household.

Table 1 - Demographic statistics

Consumption Decile	Woman head of household	White head of household	Literate head of household	Urban household	Years of schooling of head of household
1	49%	26%	81%	76%	6.25
2	47%	32%	85%	80%	6.78
3	43%	34%	86%	81%	7.31
4	42%	37%	88%	84%	7.69
5	41%	41%	92%	87%	8.29
6	42%	44%	92%	88%	8.78
7	39%	48%	94%	90%	9.37
8	39%	53%	96%	91%	10.1
9	38%	60%	97%	93%	11.4
10	37%	69%	99%	96%	13.3
Total	42%	44%	91%	86%	8.93

Source: POF 2017/2018

One central aspect of the study depends on the classification[5] of the more than 8,000 food items present in the POF database using the NOVA classification, described in section 2. Table 2 presents, for each consumption decile, the food consumption pattern of households following the classification describing the four food types: in natura; culinary ingredients; processed; and ultra-processed foods. The statistics show that in natura foods represent the most important food group for every decile and, with the exception of the top consumption decile, in natura represents over 50% of the total food consumption. More importantly, ultra-processed consumption is smaller for lower deciles and grows with household consumption decile, with the top decile having a 65% larger consumption than the bottom decile. This pattern is different from countries such as the United States, where consumption of ultra-processed foods is generally associated with poorer households (Baraldi et al, 2018). Consumption of processed foods follows an opposite pattern to ultra-processed, with consumption being higher at the bottom of the distribution. This group includes foods such as bread, cheese, canned food and in general foods that contain no more than three or four ingredients.

Table 2 - Consumption statistics of food

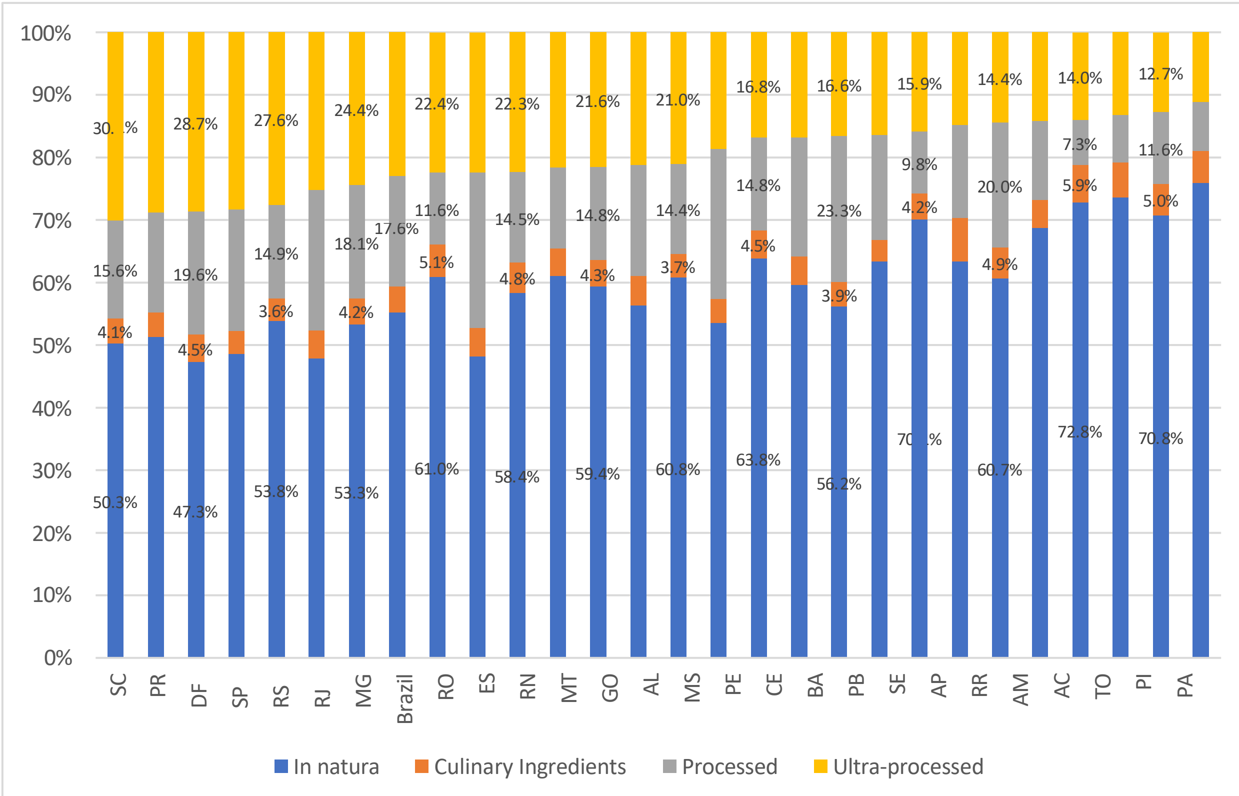
	Share of household food consumption by type			
Decile	In natura	Culinary Ingredients	Processed	Ultra-processed
1	54.0%	3.9%	24.4%	17.7%
2	58.5%	3.9%	19.3%	18.3%
3	58.6%	4.0%	17.0%	20.5%
4	58.2%	4.0%	17.3%	20.5%
5	56.6%	4.4%	16.6%	22.5%
6	56.0%	4.3%	16.2%	23.5%
7	54.8%	4.4%	15.8%	24.9%
8	53.0%	4.2%	16.6%	26.3%
9	52.4%	4.3%	16.3%	26.9%
10	49.6%	4.5%	16.8%	29.2%
Total	55.2%	4.2%	17.6%	23.0%

Source: POF 2017/2018

The analysis of food consumption types by federative unit/state shows a similar pattern. Richer states in the South and Southeast regions, as well as the Federal District (DF) show a higher percentage of consumption of ultra-processed foods, while poorer states have a much higher consumption of in natura foods. In Maranhão, the poorest Brazilian state in terms of GDP per capita, on average 11% of food consumption is of ultra-processed items, while in natura represents over three-quarters of food consumption. On the other hand, Santa Catarina households consume almost three times as much ultra-processed items (30% of the food consumption).

[5] The full classification is too lengthy for inclusion in this paper but can be shared by the authors upon request.

Figure 1 - Food consumption by Federative Unit (ordered by ultra-processed foods consumption)



Source: POF 2017/2018

Note: SC= Santa Catarina, PR= Paraná, DF= Distrito Federal, SP= São Paulo, RS= Rio Grande do Sul, RJ= Rio de Janeiro, MG= Minas Gerais, RO= Roraima, ES= Espírito Santo, RN= Rio Grande do Norte, MT= Mato Grosso, GO= Goiás, AL= Alagoas, MS= Mato Grosso do Sul, PE= Pernambuco, CE= Ceará, BA= Bahia, PB = Paraíba, SE= Sergipe, AP= Amapá, RR= Roraima, AM= Amazonas, AC= Acre, TO= Tocantins, PI= Piauí, PA= Pará, MA= Maranhão.

4.2. Global Burden of Disease

The POF database would be sufficient for the estimation of price elasticity if we were interested only in the change in product expenditure due to the implementation of a tax. However, as the consumption of ultra-processed foods is a risk factor related to several diseases, we also estimate changes in medical expenditure and in the number of years of productive life.

To accomplish this, we rely on data sourced from the Global Burden of Disease dataset (2019). This comprehensive dataset encompasses 25 diseases that are linked to the risk factor known as "dietary risks." It further provides estimations of the corresponding years of life lost (YLL) across different age groups. The complete list of diseases related to dietary risks and the years of life lost can be found in Table
3. Data for Brazil in the 2019 Global Burden of Disease estimates almost 3.7 million years of life lost due to diseases related to dietary risks, such as heart disease, strokes, and diabetes.

It is worth noting that the factor risk "dietary risks" are not strictly characterized by the consumption of processed and ultra-processed foods, encompassing a broader range of dietary patterns (such as low fruit intake, high sodium consumption, and increased consumption of sugar-sweetened beverages). However, considering their association, they can reasonably be considered as encompassing consumption of processed and ultra-processed foods. Because we are interested in the effect that years of life lost have on household income, we estimate income gains using household income per capita by consumption decile.

Table 3 - Years of life lost related to dietary risks in Brazil

Diseases related to dietary risks	Years of life lost
Ischemic heart disease	1,700,337
Intracerebral hemorrhage	371,371
Diabetes mellitus type 2	358,077
Total cancers	335,480
Ischemic stroke	281,207
Colon and rectum cancer	204,317
Subarachnoid hemorrhage	148,322
Hypertensive heart disease	60,017
Stomach cancer	39,746
Esophageal cancer	38,375
Breast cancer	32,387
Tracheal, bronchus, and lung cancer	20,656
Other cardiomyopathy	19,691
Chronic kidney disease due to hypertension	11,773
Chronic kidney disease due to diabetes mellitus type 2	11,361
Aortic aneurysm	11,041
Chronic kidney disease due to other and unspecified causes	11,022
Chronic kidney disease due to glomerulonephritis	10,726
Other cardiovascular and circulatory diseases	9,911
Atrial fibrillation and flutter	6,022
Non-rheumatic calcific aortic valve disease	3,035
Endocarditis	2,909
Chronic kidney disease due to diabetes mellitus type 1	2,733
Rheumatic heart disease	2,209
Peripheral artery disease	1,389
Total	3,694,114

Source: Global Burden of Disease 2019

4.3. Hospital Information System - SIH/SUS

The average expenditures for the treatment of each disease are derived from the Hospital Information System of the Brazilian Unified National Health System (SIH/SUS), which adheres to the International Classification of Diseases, 10th revision (ICD-10). It is important to note that these expenditures primarily reflect the public sector (based on reimbursement rates).

To establish the medical expenditures associated with each risk factor-related disease, we link them to the diseases outlined in the Global Burden of Disease dataset. For each specific disease, we deflate the monthly treatment expenditures incurred during 2018-2022 using Brazil's National Consumer Price Index and calculate the average, as shown in Table 4. Subsequently, the average medical expenditure associated with each disease related to the risk factor "dietary risks" is determined by computing the average cost across all related diseases and dividing it by the average number of approved Hospital Admission Authorizations (AIH). In other words, the average cost for each disease is calculated as the ratio between the total medical costs for that disease and the number of admitted patients due to that disease, using the ICD classification.

As the data for medical costs only consists of public expenditure, medical costs in the analysis cannot be understood as a direct household expenditure change. Instead, it offers an estimated reflection of the overall change in medical costs attributable to taxation. This encompasses the impact on patients in both the public and private sectors, with the public sector's cost data serving as the foundational reference point.

Table 4 - Medical expenditure related to dietary risks

Diseases related to dietary risks	2018	2019	2020	2021	2022	Average 2018-2022
Other heart diseases	173.06	169.51	129.86	122.58	149.26	148.85
Intracranial hemorrhage	121.89	124.07	121.75	116.90	123.61	121.64
Other peripheral vascular diseases	25.63	27.00	27.11	28.20	32.89	28.17
Malignant neoplasm of trachea, bronchus, and lung	37.74	40.03	36.77	34.09	38.27	37.38
Other hypertensive diseases	16.10	14.12	12.97	11.92	15.85	14.19
Other ischemic heart diseases	710.05	711.00	559.94	500.76	553.90	607.13
Conduction disorders and cardiac arrhythmias	279.89	291.49	249.04	238.26	225.23	256.78
Diabetes mellitus	100.56	104.30	99.55	95.91	104.32	100.93
Malignant neoplasm of the breast	148.18	152.16	137.79	136.29	146.14	144.11
Malignant neoplasm of the colon	109.23	113.33	111.49	110.72	114.07	111.77
Other liver diseases	199.15	202.69	183.55	166.64	165.39	183.48
Cerebrovascular disease, ischemic transient and syndromes	22.16	21.45	18.49	17.70	21.72	20.30
Chronic rheumatic heart disease	77.79	84.59	62.92	62.13	82.64	74.02
Neoplasms (tumors)	1,754.21	1,777.43	1,585.28	1,554.07	1,645.61	1,663.32
Malignant neoplasm of the esophagus	29.37	29.05	26.22	24.39	23.04	26.41
Other diseases of arteries, arterioles, and capillaries	141.59	150.32	125.75	123.28	152.97	138.78
Malignant neoplasm of the stomach	69.28	71.64	65.44	64.14	61.68	66.43
Other circulatory system diseases	10.51	10.15	8.91	8.81	10.46	9.77
Other cerebrovascular diseases	74.97	74.62	60.19	51.27	58.09	63.83
Total	4,101.36	4,168.95	3,623.03	3,468.04	3,725.13	3,817.30

Source: SIH/SUS (Sistema de Informações Hospitalares do Sistema Único de Saúde). Values in millions of Brazilian reais, deflated using INPC to 2018 average values.

5. Results

5.1. Elasticity

This paper employs three scenarios to estimate elasticity, including a medium-bound average, and lower and upper-bound elasticities calculated using the standard deviation and a 95% confidence level. To aid in understanding the results, we present the upper and lower bounds in terms of magnitude, with the upper-bound representing the most elastic estimates and the lower-bound the most inelastic estimates.

Table 5 presents estimates for price elasticity (i.e., responsiveness of demand to changes in price) for in natura; culinary ingredients; processed; and ultra-processed foods. A price elasticity of -1.5 indicates that a 20% price increase reduces consumption by 30%. When analyzing statistical data related to food categories and their price elasticity, the lower and upper bounds of estimates tend to be close to the medium estimates. This is primarily due to the small standard deviation observed across all food categories. The small standard deviation suggests that the price elasticity of demand for food items is relatively consistent, with minimal variation among the four food categories. As a result, the estimated effects of price policies such as taxation or subsidies on food consumption are similar across the entire range of estimates, indicating a robust relationship between price changes and demand for food.

Lower-bound estimates represent individuals with more rigid consumption patterns or a longer period of adaptation of preferences. Upper-bound estimates may be interpreted as a long-term effect, where the higher price level reduces the habit of consuming processed and ultra-processed foods.

All food categories present a progressive pattern and are “normal” goods, meaning they exhibit negative price elasticity (as prices increase, the demand for these goods decreases). Across income deciles, in natura foods are the most elastic. This implies that changes in prices, whether due to taxation or subsidies, have a substantial impact on the demand for fresh food. For instance, an increase in taxes on fresh produce might lead to a significant reduction in consumption, particularly among price-sensitive consumers. In particular, ultra-processed foods are the second group with the highest elasticity in magnitude, only behind in natura goods. This indicates a large potential for policy makers to affect the consumption of healthy foods by adopting a tax policy that inhibits consumption of ultra-processed foods. Conversely, subsidies on fresh food items could encourage their consumption by making them more affordable.

The results show that pricing policies, either to subsidize in natura foods or tax ultra-processed foods, will have the greatest impact on consumption among the poorest populations. Price elasticity is larger (in magnitude) in poorer deciles for all categories, but the difference in elasticity between the highest and lowest consumption deciles is larger for ultra-processed foods and in natura. As the poorest populations are also the most SUS-dependent, this has the potential of reducing public medical expenditure, as will be explored in section 5.4. Furthermore, increasing ultra-processed food prices can have potential long-term benefits for public health and life expectancy, as will be seen in section 5.3.