



Can differentiated value-added tax rates promote healthier diets? The case of Costa Rica

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ABSTRACT

In February 2023, Costa Rica reformed its basic value-added tax basket on which a reduced rate applies to “guarantee a balanced diet”. This paper assesses *ex-ante* the impact of the reform on nutrient availability and household spending across income groups. Price elasticities are estimated using pooled National Household Income and Expenditure Survey data and a two-step censored quadratic almost ideal demand system model accounting for price and total expenditure endogeneity. Nutritional information is derived from food composition tables. Food items are grouped by processing level as a proxy to explore differences in own- and cross-price effects between ‘healthier’ and ‘less healthy’ items. The demand for ultra-processed sweet and savoury foods is price-inelastic (-0.74 and -0.81 , respectively). Lower-income households’ demand is more price-sensitive. The reform applies a reduced rate to a significant number of ultra-processed savoury food items and is associated with an increase in household purchases of calories (0.7%), sugar (0.4%), and saturated fat (1.2%). A counterfactual scenario with a basic tax basket defined based on the Pan American Health Organization nutrient profile model criteria is associated with the largest reductions in calories (-0.2%), sodium (-1.0%), and saturated fat (-0.6%), with higher benefits for lower-income households. It results in minor decreases in household spending (-0.2%). While an increasing number of countries contemplate the taxation of foods high in fat, salt, or sugar, Costa Rica is unique in mandating the consideration of nutritional aspects in determining value-added tax rates. However, the recently adopted basic tax basket may not fulfil this potential.

1. Introduction

Unhealthy diet and obesity are major risk factors for non-communicable diseases such as cardiovascular diseases, cancers, and diabetes. These diseases impose substantial direct treatment costs, as well as indirect costs to both society and individuals, such as loss of income and productivity. They represent a threat to socioeconomic development (Malik, Willett & Hu, 2013; Tremmel et al., 2017). In Costa Rica, more than six out of ten adults are overweight or obese (defined as having a body mass index greater than or equal to 25 kg/m^2). This prevalence has more than doubled over the last four decades, representing one of the most rapid increases in Latin America (WHO, 2017). Costa Rican children (between five and 19 years old) also have the highest prevalence of overweight in Central America, at 31.7 % (UNICEF & Ministerio de Salud, Costa Rica, 2023).

Costa Ricans’ diet is characterized by a significant consumption of

foods high in fat, salt, or sugar (HFSS). The average sodium availability in foods purchased by households (4.6 g/person/day in 2013) exceeds the World Health Organization (WHO) guideline of two grams per person per day (Blanco-Metzler et al., 2017). Daily intake of sugar-sweetened beverages (SSBs) among Costa Rican adults represents more than twice the global average (Singh et al., 2015). Approximately 80 % of urban adults exceed WHO’s recommended limit for total energy intake from added sugars (10 % of total energy intake), among the highest rates in Latin America (Fisberg et al., 2018).

Globally, several policies have been implemented to reduce the consumption of HFSS foods and beverages, including fiscal policies, front-of-package label warnings, and marketing restrictions (OECD, 2019). Consumption taxes levied on the manufacture of HFSS foods can play a key role in accounting for the negative externalities and internalities generated by their consumption. Negative externalities are social costs, including to non-consumers, arising from healthcare costs¹

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¹ In Costa Rica, government or compulsory health spending represents 74.4% of total health expenditure. Source: Organisation for Economic Co-operation and Development, *Health spending (indicator)* (Accessed 15 May 2024).

and productivity losses (e.g., those linked with obesity). Negative externalities represent own associated harms and costs that are not, or only partially, internalised by consumers (biased inter-temporal utility maximisation) due to imperfect information, present bias, or addictive behaviours (Allcott, Lockwood & Taubinsky, 2019). Said otherwise, fiscal policies can “encourage people to avoid acting against their own self-interest” (Adam et al., 2011).

Numerous countries apply excise taxes targeting SSBs with a health rationale, particularly in Latin America (Sandoval et al., 2021).² There is robust evidence supporting the effectiveness of such taxes in reducing SSB sales (Andreyeva et al., 2022a). However, only a small number of countries have implemented taxes on HFSS foods, with limited scope, targeting either specific food categories (e.g., sweets, ice creams, snacks, or animal fat products) or one or two critical nutrients (Pineda et al., 2024). For example, despite having a wider tax base than in other countries, the excise taxes adopted in Hungary on selected processed foods high in sodium and sugars, and in Mexico on non-essential energy-dense foods, cover only 12 % of total food expenditures and 14 % of total caloric intakes, respectively (Batis et al., 2017; Bfó, 2015). Two recent systematic reviews found that such taxes were associated with reduced sales of taxed products (Andreyeva et al., 2022b; Pineda et al., 2024). There is increasing interest from policymakers in introducing health taxes on food as Colombia recently adopted an excise tax on HFSS foods and policy proposals have been discussed in Brazil,³ Chile,⁴ and the Netherlands⁵ (Burki, 2023).

Most countries already apply value-added taxes (VAT) or sales taxes on foods and beverages. While many apply tiered rates, no country systematically differentiates VAT rates based on the relative nutritional impact of food items (Pineda et al., 2024).⁶ Such countries could consider the adoption of a nutrient profile model (NPM) as a basis to align existing tax rate differentiation with public health objectives. An NPM is a tool to classify foods and beverages in excess of critical nutrients. One example is the Pan American Health Organization (PAHO)’s NPM for the Region of the Americas, which includes nutrient content thresholds relative to total energy for processed foods (including sodium, free sugars, other sweeteners, total fat, saturated fat, and trans fat) (Pan American Health Organization, 2016). PAHO’s and other NPMs are increasingly used in nutrition policies, including front-of-pack label warnings and marketing restrictions (Labonté et al., 2018; Crosbie et al., 2023). Work by others has estimated fiscal policy scenarios based on nutrient content (Harding & Lovenheim, 2017; Härkänen et al., 2014; Smed, Jensen & Denver, 2007), including based on NPMs (Caro et al., 2017b; Colchero, Paraje & Popkin, 2021; Cornelsen, Mazzocchi & Smith, 2019; Valizadeh & Ng, 2024). However, evidence is lacking

outside of high-income settings.

Costa Rica applies a general VAT rate of 13 % on most goods and services, including the majority of food and beverage items. Since 13 March 2019, a reduced VAT rate of 1 % has been applied to a basic tax basket (*Canasta básica tributaria*, CBT for its abbreviation in Spanish). Items included in the CBT are determined by the Ministry of Finance and the Ministry of Economy, Industry and Commerce based on the purchasing patterns of the 20 % poorest households to decrease the tax burden on the most vulnerable population. The CBT includes HFSS foods like sausages or sweet doughnuts (Executive Decree 41615-H-MEIC).

On 19 November 2020, Law 9914 was passed mandating that any future updates of the CBT must be revised by the Ministry of Health and account for nutritional aspects to improve Costa Ricans’ dietary balance. In March 2021, in partnership with the United Nations Food and Agriculture Organization (FAO), the Ministry of Health proposed a new list of food and non-alcoholic beverage items to replace the CBT, named CBTEN (*Canasta básica tributaria con elementos nutricionales*, CBTEN for its abbreviation in Spanish), which accounts for nutritional aspects (Ministerio de Salud, Costa Rica, 2021). This list included or removed food and beverage items from the CBT based on several quantitative nutritional, cultural, and economic criteria (Ministerio de Salud, Costa Rica, 2020). After public consultation and several rounds of concertation across government sectors, a revised list was adopted by decree on 9 November 2022, differing significantly from the proposed CBTEN. This list, called CBTBIF (*Canasta básica tributaria para el bienestar integral de las familias*, CBTBIF for its abbreviation in Spanish), is defined based on the consumption patterns of the 30 % poorest households and has for objective to “guarantee a balanced diet” (Executive Decree 43790-H-MEIC-S).⁷ It has been criticised for lacking explicit nutritional criteria and transparency in the decision process.⁸⁹ It entered into effect on 1 February 2023. Fig. S1 illustrates the timeline of events and legislations regarding the basic tax basket and the criteria for inclusion in the CBTBIF.

The objectives of this study are threefold. First, it aims to estimate how prices impact the demand for foods and non-alcoholic beverages across Costa Rican income groups and food processing levels. Secondly, it assesses *ex-ante* the impact of the newly adopted CBTBIF on household expenditure and nutrient availability. Finally, it investigates how the CBTBIF would compare with the non-adopted CBTEN based on explicit nutritional criteria and differentiated VAT rates based on PAHO’s NPM.

Measuring price elasticities of demand (i.e., the percentage change in demand following a one per cent change in price) is essential to anticipate the extent to which food demand is sensitive to price changes and estimate the potential impact of alternative fiscal policies. Using a two-step censored quadratic almost ideal demand system accounting for price and total expenditure endogeneity, this study provides the first estimates of the price elasticity of demand for food by income group in Costa Rica. As there is increasing evidence of the association between higher levels of food processing and weight gain and the risk of non-communicable diseases (Askari et al., 2020; Fiolet et al., 2018; Rico-Campà et al., 2019; Srouf et al., 2020), this analysis uses processing levels as a proxy to explore own- and cross-price effects between healthier and less healthy food items. As such, it participates in

² Costa Rica applies an excise tax to non-alcoholic beverages, including SSBs. However, the tax also applies to bottled water and is not based on sugar content, thus not optimized to reduce sugar intake from SSBs nor to incentivise the consumption of healthier alternatives (Sandoval et al., 2021).

³ Peoples Dispatch. The urgency of taxing ultra-processed foods in Brazil, 28 March 2024 (Accessed 14 May 2024).

⁴ El Mercurio. Salud anticipa ejes de impuestos saludables y surge idea de graver nutrientes y alimentos con sellos (In English: The Ministry of Health envisages additional health taxes and the idea arises of taxing nutrients), 19 May 2023 (Accessed 15 May 2024).

⁵ Ned Tijdschr Geneesk. Hagenaars L, Waterlander W. Gezondheidsbelastingen in Rutte IV: Van ambities naar concreet beleid (In English: Health-related food taxes and the new Dutch government: from ambitions to real measures), 7 March 2022 (Accessed 4 July 2024).

⁶ Some countries differentiate VAT rates applied to beverages with a higher rate on SSBs (e.g., India, Spain). However, Pineda et al. (2024) show that countries applying a higher tax burden on HFSS foods have done so using import duties (e.g., French Polynesia, Tonga) or excise taxes (e.g., Colombia, Hungary, Mexico) and not differentiated VAT rates. The exception is St. Vincent and the Grenadines which applies a higher VAT rate only on brown sugar to encourage a reduction in sugar consumption.

⁷ Delfino. Mary Munive Angermuller. La canasta básica tributaria y las políticas públicas de salud preventiva (In English: The basic tax basket and preventive public health policies), 19 June 2023 (Accessed 4 July 2024).

⁸ Crhoy.com. Alexander Ramirez. Proponen ampliar la cantidad de bienes con IVA reducido (In English: They propose expanding the number of goods with reduced VAT), 26 August 2023 (Accessed 29 October 2024).

⁹ Sinart Digital. Andra Castro Ruiz. Cambios en la canasta básica: Desde decirle adiós a la cerveza a incorporar libros y productos de cuidado personal (In English: Changes in the basic tax basket: From saying goodbye to beer to incorporating books and personal care products), 18 April 2024 (Accessed 28 October 2024).

advancing the literature on the evaluation of health taxes on foods in low- and middle-income settings where detailed retail scanner or consumer panel data are rarely available. The *ex-ante* evaluation of the CBTBIF impact and the simulation of counterfactual scenarios contribute to informing future reforms of the CBT to improve nutrition among the Costa Rican population. While other countries are contemplating the use of consumption taxes to promote healthier diets, Costa Rica is the first to attempt a broad alignment of differentiated VAT rates with nutritional objectives. Consequently, the results of this study also contribute to the wider regional and global discussion on the use of this policy.

2. Materials and methods

2.1. Data

This study uses data from the National Household Income and Expenditure Survey (*Encuesta Nacional de Ingresos y Gastos de los Hogares*, ENIGH for its abbreviation in Spanish) from the National Institute of Statistics and Census (INEC). The ENIGH is nationally representative and has a probabilistic, stratified, two-stage sample design. Each household is surveyed for ten days. Data collected on the frequency of use for each item is utilised by the INEC team to estimate and report monthly expenditure and quantity purchased.¹⁰ The survey also provides household socioeconomic and demographic information. In the absence of detailed retail scanner or consumer panel data, household budget surveys, like the ENIGH, have been used to estimate demand systems in low- and middle-income countries, including Costa Rica (Dal et al., 2022). Household budget survey food purchase data also often serve as a proxy for food intake in nutrition studies (Fiedler et al., 2012), including in Costa Rica (Blanco-Metzler et al., 2017; Roselló-Araya et al., 2022).

To increase the sample size and estimate demand, this study uses both the latest 2018–2019 wave and the previous 2012–2013 wave and treats them as a pooled cross-section. The ENIGH 2018–2019 took place between February 2018 and February 2019 with a total sample size of 7,046 households distributed in 468 primary sampling units spread across the country.¹¹ The ENIGH 2012–2013 took place from October 2012 to October 2013 and included 5,705 households. Expenditure values are adjusted for inflation with base August 2018 (mid-point of ENIGH 2018–2019) using the consumer price index for food and non-alcoholic beverages.¹²

Nutritional information on energy (kcal) and key nutrients (sodium, total sugar, saturated fat, and total fat) is derived from the 2018 Food Composition Table for Central America from the Institute of Nutrition of Central America and Panama (INCAP). The INCAP table contains detailed nutrient content information per 100 g for 2,657 individual food and beverage items (Instituto de Nutrición de Centro América y

Panamá, 2018). This information is matched with each of the 713 off-trade food and non-alcoholic beverage survey items from ENIGH 2018–2019, adjusting for their respective edible fraction. The mean of specific products available in the table which matched the respective survey item description was used to estimate nutrient content for survey items where direct matches with INCAP table items were not one-to-one due to their variability in nature or type. **Table S1** shows the weighted average nutrient content per 100 g and the number of ENIGH items included in each of the food groups considered in the analysis.

2.2. Variables construction

Food and non-alcoholic beverage survey items are sorted into mutually exclusive groups. These groups are to be sufficiently large to obtain reliable price elasticity estimates given the relatively small sample size and reduce the number of households with zero purchases but sufficiently disaggregated to observe meaningful substitutions and complementarities among them. Broad categorisations, such as the often-used United Nations Classification of Individual Consumption According to Purpose (UN COICOP), only allow the assessment of cross-price effects between relatively wide aggregates without accounting for the relative healthiness of food and beverage items. This study uses the NOVA classification to further disaggregate food groups according to the level of processing of food items. This disaggregation enables the identification of potential price-induced complementarities and substitutions between ‘healthy’ and ‘less healthy’ foods, as proxied by their processing level, with an emphasis on ultra-processed (UP) foods.

UP foods are industrially manufactured and go through multiple processing steps. They often contain ingredients not typically found in home cooking such as artificial additives, flavour enhancers, emulsifiers, and colourants. Their consumption is rapidly increasing, particularly in middle-income countries (Vandevijvere et al., 2019). Diets high in UP foods have been associated with weight gain (Askari et al., 2020), as well as cancer (Fiolet et al., 2018), diabetes (Srouf et al., 2020), and all-cause mortality (Rico-Campà et al., 2019). The NOVA classification ranks foods and beverages based on the nature, extent, and purpose of their level of processing. Processing can be physical, biological, or chemical processes to transform foods from their natural state before being consumed or used to prepare a dish (Monteiro et al., 2018, 2019). This classification is broadly used in the nutrition literature and by governments and international organisations to set food-based dietary guidelines (Martinez-Steele et al., 2023; Sneed et al., 2023; Pan American Health Organization, 2016). It is made of four categories: 1) unprocessed or minimally processed (natural foods or those altered by processes such as drying, roasting, or freezing, which do not involve the addition of substances; e.g., fresh, dry or frozen fruits, vegetables or nuts, plain or powdered milk, fresh or frozen meat), 2) processed culinary ingredients (extracted from natural foods through processes like pressing or grinding and typically used for seasoning or cooking; e.g., oils, butter, table sugar and salt), 3) processed (simple industrially manufactured foods made by adding some group 2 ingredients to group 1 foods and using preservation methods, such that versions of the original foods are still recognizable; e.g., bread, cheese, dried fish, fruits in syrup, salted nuts), and 4) UP foods (industrially manufactured foods made up of several ingredients including fats, salt, and sugar and food substances of rare to no culinary use including hydrogenated oils, high-fructose corn syrup, additives, colourants, or emulsifiers, with group 1 foods absent or representing only a small portion of the formulation; e.g., carbonated soft drinks, confectionery, reconstituted meats, sweet or savoury packaged snacks) (Monteiro et al., 2019; Martinez-Steele et al., 2023).

The ten off-trade food and non-alcoholic beverage groups used in this analysis are 1) cereals; 2) dairy; 3) animal meat (including fish, seafood, and eggs); 4) fruits and vegetables (F&V); 5) UP sweet foods (e.g., pastries, ice creams); 6) UP savoury foods (e.g., cold cuts and sausages, salty snacks, ready-made foods); 7) other foods (condiments, oils, sugar, and other culinary ingredients); 8) SSBs; 9) non-SSBs (water, coffee, tea,

¹⁰ The record periods for expenditure in the ENIGH are the week of the interview, the previous month, the last three months, the last six months, and the last twelve months. INEC processes the expenditure data and releases it publicly for a standardised estimation period. This period is an “average month,” so that each expenditure is converted into monthly values: for daily-use goods and services a multiplicative factor is applied (4.33); quarterly, biannual and annual expenditures are divided by 3, 6 and 12, respectively; and monthly expenditures are kept unchanged (see Section 1.3.2. of INEC Costa Rica, *National Household Income and Expenditure Survey ENIGH 2018, Methodology*) (Accessed 7 October 2024).

¹¹ More details on the survey methodology and the distribution of the sample per region and zone (urban vs. rural) are available from National Institute of Statistics and Census (INEC), *Encuesta Nacional de Ingresos y Gastos de los Hogares 2018, Resultados Generales* (In English: National Household Income and Expenditure survey 2018, General Results) (Accessed 20 May 2024).

¹² Source for consumer price index data: INEC, *Economic Statistics* (Accessed 20 May 2024).

and diet soft drinks); and 10) milk (unsweetened) (Table S1). SSBs and UP food groups 5 and 6 encompass six of the seven unhealthy food groups (all except ‘white roots and tubers’) of the Global Diet Quality Score developed by Bromage et al. (2021), while groups 1, 3, 4, and 7 include the six food groups forming the Healthy Diet Basket used by FAO and the World Bank to measure the affordability of healthy diets globally (Herforth et al., 2022).

For each food group, the household budget shares are calculated by adding expenditures on all items within the group and dividing them by the total expenditure over all groups. Quantities purchased for items consumed in a reconstituted form are adjusted following Crovetto and Uauy (2014) (e.g., from powders, mixed preparations, or concentrates).¹³ The analysis accounts for household composition using adult equivalent units by dividing the recommended dietary allowance for energy of each household member (according to age and sex) by the energy recommended dietary allowance for an average adult (2,550 kcal) (FAO, United Nations University, & WHO, 2004). Finally, clusters with less than two households reporting positive purchases for any given food group are dropped. The final sample size for the demand estimation is 12,186 households.

2.3. The quadratic almost ideal demand system model

The demand for foods and non-alcoholic beverages is estimated using a quadratic almost ideal demand system (QUAIDS) model (Banks, Blundell & Lewbel, 1997). This model is an extension to the almost ideal demand system model (AIDS) derived by Deaton & Muellbauer (1980), adding a quadratic term in the logarithm of expenditure to allow for more flexibility over the income-expenditure (Engel) curves. In this utility-based structural model, goods are heterogeneous, and households choose the quantity and quality of a given good as a function of its price, the price of other goods, household income, and household socio-demographic characteristics. Below is a summary of the QUAIDS model in its budget share form.

$$w_i = \alpha_0 + \sum_{k \in K} \rho_{ik} z_k + \sum_{j=1}^I \gamma_{ij} \ln p_j + \beta_i (\ln x - \ln P) + \frac{\lambda_i}{\prod_{i=1}^I \beta_i} (\ln x - \ln P)^2 \quad (1)$$

where I represents the set of all food and non-alcoholic beverage goods, w_i the household budget share for good i (i.e., the share of household total expenditure in foods and non-alcoholic beverages spent on good i , $w_i = p_i q_i / x$, with q_i representing the quantity of good i purchased by the household), p_j the price of good j , x the household total expenditure in foods and non-alcoholic beverages (i.e., on all I goods), z a K -vector of household sociodemographic characteristics, and P the price aggregator index defined as follows.

$$\ln P = \alpha_0 + \sum_{j=1}^I \alpha_j \ln p_j + \frac{1}{2} \sum_{j=1}^I \sum_{l=1}^I \gamma_{jl} \ln p_j \ln p_l \quad (2)$$

Following Deaton and Muellbauer (1980), some restrictions are imposed to enable the identification of parameters and make the model consistent with consumer demand theory:

- Adding up: the sum of all budget shares equals one, $\sum_{i=1}^I w_i = 1$
- Symmetry: the direction and magnitude of compensated cross-price effects between goods are symmetric
- Homogeneity of degree zero in total expenditure and prices: the demand is not affected by proportional changes in total expenditure and prices.

Together, they imply the following constraints: $\sum_{i=1}^I \alpha_i = 1$,

$$\sum_{i=1}^I \beta_i = 0, \sum_{i=1}^I \lambda_i = 0, \sum_{i=1}^I \gamma_{ij} = \sum_{j=1}^I \gamma_{ji} = 0, \text{ and } \gamma_{ij} = \gamma_{ji} \text{ for } i \neq j.$$

2.4. Endogeneity, censoring, and estimation strategy

2.4.1. Endogeneity in prices derived from unit values

Price endogeneity is typically present in demand systems. To solve this issue, Deaton and Muellbauer (1980) propose to assume spatially varying prices. At a given time, households in the same village or cluster are assumed to face the same price, which differs from the price faced by households in other villages or clusters. The survey's primary sampling units are used as clusters for the analysis. Within a cluster, each household is surveyed during the same one-week period. The average cluster size is 13.6 households, which is relatively small, increasing the likelihood that households are geographically close and face the same price for a given good while providing enough variability to run the analysis with cluster-level prices. Factors affecting price changes across geographical regions implicitly serve as instruments (e.g., transportation costs), as they are correlated with prices but uncorrelated with unobserved demand shocks. This assumption, common to the use of AIDS-type models in low- and middle-income countries (Deaton, 2018), is credible in Costa Rica. Road freight transport costs (representing most of the domestic commodity transportation) are relatively higher in Central America than in other middle-income countries (Osborne, Pachon & Araya, 2013). In addition, Costa Rica historically has some of the highest fuel prices among Central American countries.¹⁴

Since the ENIGH survey does not contain price data, the analysis uses unit values as a proxy. This may introduce measurement errors. In addition, differences in prices and quality are confounded when using unit values. This could lead to a ‘quality shading’ effect (Deaton, 1988). Following Capacci and Mazzocchi (2011), this potential source of endogeneity is accounted for by estimating quality-adjusted prices, specifying the following unit value equation:

$$\ln v_{ih}^c = \eta_{i0} + \sum_{k \in K} \eta_{ik} z_{kh}^c + \ln p_{ih}^c + \mu_i \ln q_{ih}^c + u_{ih}^c \quad (3)$$

where v_{ih}^c , q_{ih}^c , and p_{ih}^c are respectively the unit value, the quantity, and the actual unobserved price of good i purchased by household h from cluster c , η_{i0} is a non-identifiable good-specific constant, u_{ih}^c a stochastic error term, and z_{kh}^c a set of household sociodemographic characteristics used as a proxy for unobserved household preferences. Such characteristics include household size, the age, sex, and level of education of the household head (defined as a dummy variable for completion of primary school),¹⁵ as well as the proportion of employed working-age household members (between 15 and 65 years old). Equation (3) decomposes unit values into a price effect (through p_{ih}^c), a quantity effect (through q_{ih}^c), and a quality effect (through the term $\eta_{i0} + \sum_{k \in K} \eta_{ik} z_{kh}^c$). It is estimated demeaning values at the cluster level, imposing the assumption $p_{ih}^c = \bar{p}_i^c$ (i.e., spatially varying prices). Quality-adjusted prices $\hat{p}_{ic}$ are recovered from estimated coefficients.

$$\hat{p}_{ic} = \eta_{i0} + \ln \bar{p}_i^c = \ln \bar{v}_i^c - \sum_{k \in K} \hat{\eta}_{ik} \bar{z}_k^c - \hat{\mu}_i \ln \bar{q}_i^c \quad (4)$$

2.4.2. Total expenditure endogeneity

Endogeneity also arises from simultaneity bias since total expenditure is both an independent variable and the denominator of the dependent variable in the model (i.e., the budget share). Following Banks, Blundell and Lewbel (1997), disposable household income is used as an instrument in a two-stage control function approach. The first

¹³ 10% and 15% conversion ratios, respectively, for powdered milk or dairy items and non-dairy-based beverages, powders, and concentrates.

¹⁴ World Bank. Pump price for gasoline (US\$ per litre) – Costa Rica, El Salvador, Nicaragua, Honduras, Panama, Belize, Guatemala (Accessed 4 July 2024).

¹⁵ Completion of primary school is proxied by at least six years of education, based on InterNations, A guide to education & International Schools in Costa Rica (Accessed 20 May 2024).

stage consists of regressing total expenditure on disposable income and a vector of household sociodemographic characteristics $\mathbf{z}$. The latter includes the household size, the age, sex, and level of education of the head of household, the proportion of employed working-age household members, the household zone (i.e., urban or rural), a dummy for the ENIGH wave to which the household belongs (i.e., 2012–2013 or 2018–2019), as well as dummy variables indicating the geographic region of the household. In the second stage, the residuals from the first stage are added to the model.

2.4.3. Censoring nature of expenditure data

Household budget surveys contain a significant proportion of households that do not report any purchases in certain categories of foods and beverages. This can be due to households' optimal choice given their budget constraint, non-availability, or the fact that some households never consume specific items or did not consume such specific items in the period during which the survey took place. Reported zero-purchases are likely selective and it is important to account for them to estimate a full demand system and avoid selection bias. For this, this analysis uses Shonkwiler and Yen (1999)'s two-step approach, following their main result:

$$w_{ih}^* = \Phi(\mathbf{r}_h' \boldsymbol{\theta}_i) w_{ih} + \zeta_i \phi(\mathbf{r}_h' \boldsymbol{\theta}_i) + \epsilon_{ih} \quad (5)$$

where w_{ih}^* denotes the unobserved latent budget share, Φ and ϕ stand respectively for the cumulative and probability distribution functions of the standard normal distribution, and $\mathbf{r}_h$ is a vector of regressors which includes the estimated quality-adjusted prices and the household socio-demographic characteristics included in the demand system. The residuals $[\vartheta_i, \epsilon_i]'$ are assumed bivariate normal with $\text{cov}(\vartheta_i, \epsilon_i) = \zeta_i$. First, $\boldsymbol{\theta}_i$ is estimated via the following probit regression:

$$d_{ih} = \mathbf{r}_h' \boldsymbol{\theta}_i + \vartheta_{ih} \quad (6)$$

where d_{ih} is a binary variable equal to one if household h has a non-zero expenditure for good i and zero otherwise, such that $w_{ih} = d_{ih} w_{ih}^*$. The second step consists of using the estimated $\hat{\boldsymbol{\theta}}_i$ to obtain $\Phi(\mathbf{r}_h' \hat{\boldsymbol{\theta}}_i)$ and $\phi(\mathbf{r}_h' \hat{\boldsymbol{\theta}}_i)$ and calculate the estimated latent budget shares w_{ih}^* using Equation (5). This two-step approach yields consistent estimators and is less computationally burdensome than other maximum likelihood methods in estimating censored demand systems (Shonkwiler & Yen, 1999). It has been used widely in the literature (Akabay, Boz & Chern, 2007; Caro et al., 2017a, 2017b).

2.4.4. Estimation strategy

The household size, the age and level of education of the head of household, as well as a dummy for the ENIGH wave to which the household belongs, are used to allow for heterogeneity in the demand system. The model is estimated for two sub-samples based on income distribution: low-income households (the lowest three national income deciles) and mid-high-income households (the highest seven national income deciles). This stratification corresponds to the classification used by the Ministry of Finance and the Ministry of Economy, Commerce and Industry to estimate purchasing patterns and define the list of items to be included in the CBTBIF (Fig. S1). Following Banks, Blundell and Lewbel (1997), α_0 is set to be equal to the highest integer lower than the lowest observed value of $\ln x$. The adding-up restriction is relaxed in the second stage as the latent budget shares of the QUAIDS model are no longer bound to add up to one when controlling for households' likelihood of having positive demand (Yen, Kan & Su, 2002).

The two-step censored QUAIDS model correcting for endogeneity in prices and total expenditure is hereafter referred to as the main model specification. For this study, the outcomes of interest of the demand model are the uncompensated (Marshallian) own- and cross-price elasticities ϵ_{ij}^u . Under the two-step censoring correction, the main model specification's price elasticities account for the direct effect of price

changes on the demand for foods and non-alcoholic beverages conditional on positive demand and the indirect effect of the change in the likelihood of having positive demand. Their expression has been derived by Boysen (2016):

$$\epsilon_{ij}^u = -\delta_{ij} + \frac{1}{w_i^*} \left[\Phi_i \left(\gamma_{ij} - \left(\beta_i + \frac{2\lambda_i}{\prod_i p_i^{\beta_i}} \ln \left(\frac{x}{p} \right) \right) \left(\alpha_j + \sum_i \gamma_{ij} \ln p_i \right) - \frac{\lambda_i \beta_j}{\prod_i p_i^{\beta_i}} \left[\ln \left(\frac{x}{p} \right) \right]^2 \right) + \tau_j \phi_i (w_i - \zeta_i d_i^*) \right] \quad (7)$$

where δ_{ij} represents the Kronecker delta (equal to one if $i = j$ and zero if $i \neq j$), τ_j the coefficient estimated in the probit equations for the quality-adjusted prices, and d_i^* is the latent dependent variable related to the binary variable d_i in Equation (6).

Models are estimated using Stata v.17 and iterative feasible generalized nonlinear least-squares via non-linear seemingly unrelated regressions using a modified version of Poi (2008)'s *nlsur* command derived by Caro et al. (2021). Standard errors are obtained through bootstrapping with 300 repetitions.

2.5. Fiscal policy scenarios

The estimated average own- and cross-price elasticities are used to simulate three fiscal policy scenarios. These scenarios are 1) CBTBIF: 1 % VAT reduced rate on the items listed in the CBTBIF as adopted by Executive Decree N° 43790-H-MEIC-S on 9 November 2022 (implemented as of 1 February 2023) and 13 % general rate for others; 2) CBTEN: 1 % VAT reduced rate on the items listed in the CBTEN as proposed by the Ministry of Health in 2020 (Ministerio de Salud, Costa Rica, 2021) and 13 % general rate for others (see Table S2 for a detailed list of survey items included in the baseline CBT, the proposed CBTEN, and the adopted CBTBIF); and 3) NPM: 1 % VAT reduced rate on a newly defined basket of foods and non-alcoholic beverages not exceeding any of the nutrient content thresholds of PAHO's NPM (displayed in Table S3) and 13 % general rate for others. Table S4 provides the number of discounted survey items (i.e., taxed at a VAT rate of 1 %) and their respective share of total baseline quantities for each food group and scenario.

Fig. S1 presents the regulatory criteria for items to be eligible for inclusion in the CBTBIF. These include a minimum of a 2 % share of the 30 % poorest households consuming the item and at least 6.25 % of the national total expenditure on the item being spent by the 30 % poorest households. The Ministry of Health then proposes amendments to the list of eligible items based on their suitability for daily consumption from a nutritional perspective, without explicit criteria. The final decision on the inclusion or exclusion of items is made in concertation with the Ministry of Finance and the Ministry of Economy, Industry and Commerce. On the other hand, an item is considered for inclusion in the CBTEN if at least 30 % of the national total expenditure or quantity consumed is by the 30 % poorest households or if the item is part of the 50 % most consumed items by the 30 % poorest households (Ministerio de Salud, Costa Rica, 2021). A weighted index is then calculated based on nutritional criteria – including healthy food groups, processing levels, traditional Costa Rican foods, and the content of key nutrients (e. g., protein, sodium, fat, fibre, calcium) and vitamins – and items above a minimum threshold are included (Ministerio de Salud, Costa Rica, 2020).¹⁶

Since Costa Rica has not defined a national NPM, this analysis uses the Pan American Health Organization (PAHO)'s NPM. This NPM discriminates between foods based on their nutritional quality using

¹⁶ See section 7 in Ministerio de Salud, Costa Rica (2020) and section 5.4 of Ministerio de Salud, Costa Rica (2021) for a more detailed description of the methods used by the Ministry of Health to select the CBTEN items.

thresholds relative to total energy content for sodium, free sugars,¹⁷ other sweeteners, total fat, saturated fat, and trans fat. These thresholds only apply to processed and ultra-processed foods (i.e., NOVA groups 3 and 4) (Pan American Health Organization, 2016). Due to data limitations, this analysis assumes free sugars to be equal to total sugars and does not account for the presence of other sweeteners or trans fat. PAHO's NPM has been used in other countries to design front-of-pack label warnings (e.g., Argentina and Mexico) (Crosbie et al., 2023). As of May 2024, a legislative proposal is being debated to adopt a similar policy in Costa Rica.¹⁸

For each fiscal policy scenario, results display relative changes in the average quantity purchased, household expenditure, and availability of energy and nutrients for each food group compared to baseline (i.e., ENIGH 2018–2019). Results also include absolute changes and final post-scenario total energy and nutrient availability per adult equivalent unit per day for the full population and two income groups. While results for total fat are displayed along with saturated fat, they should not be considered equally harmful (Mozaffarian, 2020). WHO recommends limiting the intake of total fat to 30 % of total energy intake to prevent weight gain but recognizes that small amounts of fat are an important part of a healthy diet and the importance of substituting saturated fat with unsaturated fat to prevent high lipoprotein cholesterol and cardiovascular diseases (World Health Organization, 2023).

3. Results

Table 1 presents sociodemographic descriptive statistics by income group for ENIGH 2012–2013 and 2018–2019. The sample contains mostly urban households (71–73 %), with a significantly larger share of rural households in the low-income group than in the mid-high-income group. Household size also decreases with income. On the other hand, the number of years of education of the household head and the proportion of employed working-age household members increase with income. Noticeably, household heads are older, and households have a lower share of employed adult members in ENIGH 2018–2019 than in ENIGH 2012–2013.

Table 2 reports household monthly expenditure statistics for the two ENIGH waves and by income group. Animal meat represents the highest share of spending on average followed by F&V and cereals. Cereals and 'other foods' represent a higher portion of total expenditure for lower-income households, who spend a lower share on F&V and UP foods (both sweet and savoury). Dairy, animal meat and UP sweet foods represent the groups with the highest unit value per 100 g and beverages (SSBs, non-SSBs, and milk) the lowest (Table S5). Several food groups have a large proportion of households without expenditure. More than half of the households in the sample did not purchase any non-SSBs, while more than 80 % purchased F&V, cereals, UP savoury foods, and animal meat.

Table 3 shows the baseline average nutrient availability by adult equivalent unit per day for each food group and as a total among all food items. UP foods and SSBs represent 18.4 % of total energy availability. UP savoury foods represent the second source of daily sodium availability after the 'other foods' group (which includes condiments, oils, and salt) and the third for saturated fat availability after the 'other foods' and animal meat groups. UP sweet foods represent the third source of daily sugar availability after the 'other foods' group (which includes sugar and honey) and F&V. Table S6 shows the baseline average

nutrient availability by income group. On average, mid-high-income households have a higher baseline availability than low-income households for calories and all nutrients. The average daily availability of sodium, sugar, and total fat per adult equivalent unit exceeds WHO's daily recommendations for both income groups.¹⁹

Table 4 presents the estimated average uncompensated own- and cross-price elasticities from the main model specification. All groups have an inelastic demand (i.e., an own-price elasticity lower than one in absolute value). The demand for the 'other foods' group (principally condiments and other culinary ingredients) is the most sensitive to price changes with a price elasticity of -0.98 . On the other hand, the demand for cereals (staple foods) is the least sensitive to price changes with -0.57 . The price elasticity of demand for UP foods is -0.74 and -0.81 for sweet and savoury, respectively. Among beverages, the demand for SSBs (-0.72) is less price-elastic than the demand for non-SSBs (-0.84) and milk (-0.80). Results highlight limited substitution and complementarity patterns between groups. Cereals and non-SSBs appear to complement each other (i.e., negative cross-price elasticities). Non-SSBs also represent a complement for dairies. Table S7 presents the estimated average expenditure elasticities.

Table S8 and Table S9 show the uncompensated own- and cross-price elasticity results for the low- and mid-high-income groups, respectively. Fig. 1 illustrates these findings in a bar graph. Low-income households have higher own-price elasticity estimates than mid-high-income households (in absolute terms) for all food groups (the difference is not significant for F&V, 'other foods', and non-SSBs), except for animal meat. Regarding cross-price elasticities, similar complementarity effects are observed between cereals and non-SSBs.

The impact of each fiscal policy scenario on quantities purchased, household expenditure, and energy and nutrient availability for the full sample is reported in Table 5. The CBTBIF scenario is associated with an increase in quantities purchased for all food groups, except UP sweet foods and SSBs. The CBTEN and NPM scenarios are associated with reduced quantities purchased of both UP sweet and savoury foods as well as SSBs and cereals. In addition, the CBTEN reduces quantities for the 'other foods' group and the NPM scenario for dairy. The latter also results in a significant increase in the purchase of F&V (3.3 % [CI: 2.0 %; 4.6 %]). In terms of relative changes in total household expenditure on foods and non-alcoholic beverages, all scenarios are associated with decreases (from -0.4 % [CI: -0.8 %; 0.0 %] for the CBTBIF scenario to -0.2 % [CI: -0.3 %; -0.1 %] for the NPM scenario). Low-income households may benefit from relatively larger reductions in household spending, although non-statistically significant for the NPM scenario (Table S10 and Table S11).

The CBTEN and NPM scenarios are associated with reductions in the availability of nutrients, except for sugar. The NPM scenario would lead to the most significant reductions in the availability of sodium (-1.0 % [CI: -1.4 %; -0.6 %]), saturated fat (-0.6 % [CI: -0.8 %; -0.4 %]), and total fat (-0.7 % [CI: -0.9 %; -0.4 %]). Both the CBTEN and NPM scenarios would lead to limited reductions in calories (-0.1 % [CI: -0.2 %; 0.1 %] and -0.2 % [CI: -0.4 %; -0.1 %], respectively) due to increased sugar availability (0.2 % [CI: 0.1 %; 0.4 %] and 0.4 % [CI: 0.4 %; 0.5 %], respectively) (Table 5). The higher increase in sugar availability for the NPM scenario is driven by the higher quantity purchased for the 'other foods' group (which contains honey and sugar) as this scenario increases the number of items in the VAT-discounted basket from that group (Table S4). On the other hand, the CBTBIF is associated with increased availability of calories (0.7 % [CI: 0.2 %; 1.1 %]), sugar (0.4 % [CI: 0.1 %; 0.7 %]), saturated fat (1.2 % [CI: 0.6 %; 1.7 %]), and total fat (0.9 % [CI: 0.5 %; 1.4 %]) (Table 5). Fig. 2 illustrates findings for the low- and mid-high-income groups. Both would incur an increase in the

¹⁷ Free sugars are added to food and drink or naturally present in honey, syrups, and fruit juices and concentrates. They differ from sugar present in the cells of food products (e.g., raw fruits).

¹⁸ El Mundo. Costa Rica Saludable hace llamado a diputados a aprobar proyecto para etiquetado frontal de los alimentos (Healthy Costa Rica calls representatives to approve the bill for the introduction of front-of-pack labelling of food products), 13 May 2024 (Accessed 14 May 2024).

¹⁹ WHO recommends adults limit the daily intake of sodium to two grams, sugar to less than 10% of total energy intake, saturated fat to less than 10% of total energy intake, and total fat to less than 30% of total energy intake.

Table 1
Household sociodemographic descriptive statistics.

Variable	ENIGH 2012–2013			ENIGH 2018–2019		
	Low-income (N = 1,986)	Mid-high income (N = 3,532)	Total sample (N = 5,518)	Low-income (N = 2,453)	Mid-high income (N = 4,592)	Total sample (N = 7,045)
Area (rural = 1)	0.42 (0.03)	0.20 (0.02)	0.27 (0.02)	0.45 (0.01)	0.22 (0.00)	0.29 (0.00)
Size	4.01 (0.05)	3.12 (0.03)	3.39 (0.03)	3.80 (0.05)	3.00 (0.02)	3.24 (0.02)
Head sex (female = 1)	0.36 (0.01)	0.35 (0.01)	0.35 (0.00)	0.39 (0.01)	0.37 (0.00)	0.38 (0.00)
Head age (years)	45.96 (0.45)	48.64 (0.40)	47.83 (0.31)	49.98 (0.40)	51.38 (0.35)	50.96 (0.28)
Head completed primary school ^a	0.66 (0.01)	0.86 (0.00)	0.80 (0.00)	0.67 (0.01)	0.86 (0.00)	0.80 (0.00)
Employed adults (all employed = 1) ^b	0.49 (0.00)	0.66 (0.00)	0.61 (0.00)	0.40 (0.00)	0.63 (0.00)	0.56 (0.00)
Total monthly expenditure (CRC, base August 2018) ^c	115,559.86 (2,600.39)	164,051.45 (3,481.14)	149,348.62 (2,816.13)	113,941.17 (2,464.22)	148,661.03 (2,478.99)	138,243.32 (2,084.55)

Notes: ENIGH: national household income and expenditure survey (Encuesta Nacional de Ingresos y Gastos de los Hogares, in Spanish); CRC: Costa Rican Colón (USD 1 = CRC 587, in 2019), base August 2018 CRC (mid-point of ENIGH 2018–2019). Low-income: the lowest three national income deciles; Mid-high income: the highest seven national income deciles. ^a At least 6 years of education; ^b Proportion of occupied adults (≥ 15 years old and < 65 years old); ^c Monthly total expenditure on all foods and non-alcoholic beverages. Standard deviations in parenthesis. Survey weighted.

availability of calories and nutrients (except sodium) from the CBTBIF scenario while they would both benefit from reductions in the availability of sodium, saturated fat, and total fat from the CBTEN and NPM scenarios. The nutritional benefits would be larger for low-income households than for mid-high-income households (in relative terms) under both the CBTEN and NPM scenarios.

4. Discussion

Results for baseline average nutrient availability are comparable to findings in the Costa Rican literature (Fisberg et al., 2018; Roselló-Araya et al., 2022).²⁰ As expected, baseline average daily energy availability overestimates intake (Kovalskys et al., 2018). This may particularly be driven by food waste.²¹ Nevertheless, the distribution of energy sources is aligned with results from dietary recall surveys (Kovalskys et al., 2018). Although no previous study has characterized food intake in Costa Rica using the NOVA processing level categorisation, this study indicates a similar proportion of total calories purchased from UP foods and SSBs (18.4 %) as found in other Latin American countries, like Brazil (Levy et al., 2022).

Overall, compared to the other fiscal policy scenarios, reforming the CBT based on the PAHO NPM nutrient thresholds is linked with the highest reduction in the availability of targeted nutrients, except sugar. Low-income households would benefit from relatively larger reductions than mid-high-income households. Nevertheless, these would not be substantial enough to bring the average daily nutrient availability per capita below WHO-recommended levels for sodium and total fat.

²⁰ For total sugars (this study estimates 115.8g per adult equivalent unit per day), Fisberg et al. (2018) found an average total sugar intake of 95.8g per capita per day among urban Costa Rican adults in 2015. However, it is important to differentiate nutrient intake and the availability of nutrients, as the latter only accounts for nutrients from purchased quantities and not consumed quantities and therefore tends to overestimate consumption (e.g., it does not account for food waste). For sodium, this analysis estimates a similar baseline average availability as Roselló-Araya et al. (2022), which used similar ENIGH data (4.6g vs. 4.4g).

²¹ Kovalskys et al. (2018) used 24-hour dietary recall survey data and estimated the energy intake of Costa Rican adults (15–65 years old) at 1,893 kcal in 2015. This represents 315 kcal less than this study's estimate for energy availability by adult equivalent unit. This difference could well be explained by food waste, which is estimated at 91kg per year per capita in Costa Rica (United Nations Environmental Programme, 2024).

These results are based on the estimates from a QUAIDS model, addressing the potential endogeneity in prices (as unit values) and total expenditure, following Capacci and Mazzocchi (2011) and Banks, Blundell and Lewbel (1997), respectively. Using Shonkwiler and Yen (1999)'s two-step approach, the main model specification also accounts for censoring, which can be significant in some food groups (Table 2). Table S12 compares the price and expenditure elasticity estimates obtained in this analysis with the literature in Latin America and selected middle-income countries. Elasticity estimates for food groups other than F&V cannot be directly compared with the literature, except for Pereda et al. (2024) in Brazil, which represents the only other study estimating a demand model using processing level to disaggregate food groups. The estimated own-price and expenditure elasticities for F&V are similar to Dal et al. (2022), which used ENIGH 2018–2019 and a QUAIDS model employing a different strategy to mitigate the price endogeneity and censoring problems by aggregating Costa Rican households in 200 income groups. Estimated own-price elasticities for other food groups are in line with results from the literature in other middle-income countries (Green et al., 2013).²² While also not directly comparable, the range of expenditure elasticity estimates for other food groups is in line with the literature in Latin America (Dal et al., 2022; Alfonso & Peterson, 2006). Regarding SSBs, results show an own-price elasticity of -0.72 , which is in the lower range (in absolute terms) of estimates found in the literature in Latin America (Claro et al., 2012; Paraje, 2016; World Bank & Pan American Health Organization, 2020). A 2019 report from the World Bank & PAHO found a price elasticity of -1.12 for Costa Rica (World Bank & Pan American Health Organization, 2019). This report used ENIGH 2012–2013 data and employed Deaton (1990)'s AIDS model controlling for differences in the quality of purchased goods but not correcting for the potential endogeneity in total expenditure. Not accounting for such endogeneity may bias elasticity estimates upwards (in absolute terms).²³ In addition, this World Bank & PAHO report omitted solid foods from the demand model, which represent potential substitutes or complementary goods, and thus may have overestimated the

²² Green et al. (2013) find the following predicted mean own-price elasticities for middle-income countries: -0.55 for cereals vs. -0.57 in this study; -0.72 for dairy vs. -0.78 in this study; and -0.72 for meat and -0.73 for fish vs. -0.72 in this study for both aggregated.

²³ A sensitivity analysis ran using a QUAIDS model without accounting for the endogeneity of prices (as unit values) and total expenditure and for the censoring correction shows this upward bias (in absolute terms). Results are available upon request.

Table 2
Household monthly expenditure statistics.

	ENIGH 2012–2013			ENIGH 2018–2019		
	Low-income	Mid-high income	Full sample	Low-income	Mid-high income	Full sample
Quantity purchased (100 g)						
Cereals ⁺	218.5 (7.6)	164.0 (5.6)	180.6 (4.8)	207.4 (6.9)	151.7 (4.0)	168.4 (3.8)
Dairy ⁺	12.6 (0.6)	20.1 (0.6)	17.8 (0.5)	14.3 (0.6)	18.6 (0.4)	17.3 (0.3)
Animal meat ⁺	82.8 (2.8)	109.1 (2.6)	101.1 (2.2)	81.5 (2.2)	98.5 (1.9)	93.4 (1.6)
F&V ⁺	204.2 (7.6)	330.3 (10.8)	292.1 (8.5)	223.9 (7.9)	313.8 (7.9)	286.8 (6.2)
UP sweet foods	45.0 (3.2)	72.7 (4.8)	64.3 (3.5)	44.8 (2.3)	58.2 (2.0)	54.2 (1.6)
UP savoury foods	50.5 (1.9)	72.0 (2.2)	65.5 (1.8)	49.2 (1.6)	68.5 (1.7)	62.7 (1.3)
Other foods ⁺	115.5 (5.1)	85.2 (2.9)	94.4 (2.8)	108.2 (4.2)	75.8 (2.5)	85.5 (2.4)
SSBs	74.5 (3.2)	124.0 (4.5)	109.0 (3.5)	81.2 (3.4)	100.9 (3.4)	95.0 (2.7)
Non-SSBs	83.7 (3.8)	83.4 (3.3)	83.5 (2.7)	87.2 (3.3)	75.2 (2.5)	78.8 (2.2)
Milk	95.7 (5.3)	118.4 (4.0)	111.5 (3.2)	101.5 (4.2)	101.5 (3.1)	101.5 (2.7)
Expenditure (CRC, base August 2018)						
Cereals ⁺	22,205.8 (634.8)	19,026.7 (478.3)	19,990.6 (402.3)	19,733.4 (618.2)	15,746.3 (366.0)	16,942.6 (350.7)
Dairy ⁺	3,433.2 (171.3)	6,760.3 (270.1)	5,751.5 (210.8)	4,390.5 (183.3)	6,903.0 (197.6)	6,149.1 (150.9)
Animal meat ⁺	22,758.7 (751.9)	35,824.4 (929.0)	31,862.8 (755.9)	22,541.8 (677.3)	31,569.5 (639.7)	28,860.7 (530.1)
F&V ⁺	16,412.1 (527.3)	28,483.3 (873.7)	24,823.3 (689.4)	18,486.9 (562.8)	29,713.5 (718.8)	26,345.0 (557.8)
UP sweet foods	9,740.1 (570.7)	18,334.0 (670.9)	15,728.3 (541.2)	9,622.1 (411.2)	16,722.8 (480.5)	14,592.3 (377.4)
UP savoury foods	13,855.9 (488.4)	22,056.5 (677.5)	19,570.1 (531.4)	13,588.1 (414.1)	21,642.8 (518.6)	19,226.0 (410.8)
Other foods ⁺	10,260.7 (428.7)	8,549.5 (268.0)	9,068.3 (238.4)	8,839.2 (329.6)	6,978.3 (221.4)	7,536.7 (210.2)
SSBs	5,993.9 (248.9)	10,797.9 (348.0)	9,341.3 (277.2)	5,515.9 (219.0)	7,458.8 (210.2)	6,875.8 (172.7)
Non-SSBs	5,538.2 (225.0)	6,575.7 (243.3)	6,261.1 (187.5)	5,342.4 (209.3)	5,460.8 (180.5)	5,425.3 (149.3)
Milk	5,360.7 (251.2)	7,642.7 (259.0)	6,950.8 (201.0)	5,880.5 (229.4)	6,464.7 (188.1)	6,289.4 (158.8)
Budget share (%)						
Cereals ⁺	20.0	13.3	15.3	18.1	11.8	13.7
Dairy ⁺	3.3	4.2	3.9	4.0	4.9	4.6
Animal meat ⁺	18.6	20.3	19.8	19.4	21.0	20.5
F&V ⁺	14.8	17.2	16.5	16.3	20.1	19.0
UP sweet foods	8.0	10.9	10.0	7.7	10.5	9.6
UP savoury foods	11.4	12.6	12.3	11.4	13.4	12.8
Other foods ⁺	7.9	4.6	5.6	7.4	4.3	5.2
SSBs	5.7	7.8	7.1	4.9	5.6	5.4
Non-SSBs	4.6	3.7	4.0	4.7	3.4	3.8
Milk	5.3	4.9	5.0	5.5	4.5	4.8
Households with positive expenditure (%)						
Cereals ⁺	86.7	82.2	83.5	89.7	80.8	83.5
Dairy ⁺	44.5	54.7	51.6	45.7	52.6	50.5
Animal meat ⁺	79.1	79.0	79.0	82.2	80.9	81.3
F&V ⁺	80.7	83.4	82.6	84.7	86.5	86.0
UP sweet foods	64.2	73.4	70.6	65.0	72.4	70.2
UP savoury foods	80.3	82.5	81.8	79.8	82.7	81.8
Other foods ⁺	66.7	55.9	59.2	68.4	54.2	58.5
SSBs	57.7	68.2	65.0	57.8	60.4	59.7
Non-SSBs	51.5	49.1	49.8	56.4	46.3	49.3
Milk	51.7	58.6	56.5	55.3	55.2	55.3

Notes: ENIGH: national household income and expenditure survey (Encuesta Nacional de Ingresos y Gastos de los Hogares, in Spanish). CRC: Costa Rican Colón (USD 1 = CRC 587, in 2019), base August 2018 CRC (mid-point of ENIGH 2018–2019). Low-income: the lowest three national income deciles; Mid-high income: the highest seven national income deciles. F&V: fruits & vegetables; SSBs: sugar-sweetened beverages; UP: Ultra-processed (as per NOVA classification group 4). ⁺ By construction, these groups do not contain UP food items (no item with NOVA classification group 4). The NOVA classification is used to rank foods and beverages based on the nature, extent, and purpose of their level of processing. It is made of four categories: 1) unprocessed or minimally processed, 2) processed culinary ingredients, 3) processed, and 4) ultra-processed (Monteiro et al., 2018). Standard deviations in parenthesis. Survey weighted.

Table 3

Baseline average daily nutrient availability by adult equivalent unit, full sample, ENIGH 2018–2019.

Food group	Energy (kcal)	Sodium (mg)	Sugar (g)	Saturated fat (g)	Total fat (g)
Cereals ⁺	719.8	212.1	3.2	1.4	6.9
Dairy ⁺	58.8	128.7	0.5	2.8	5.0
Animal meat ⁺	175.8	132.2	0.2	3.5	10.7
F&V ⁺	272.8	56.7	15.5	0.9	2.7
UP sweet foods	140.5	110.9	14.0	1.7	4.7
UP savoury foods	212.9	729.9	3.0	3.3	13.3
Other foods ⁺	513.8	3,138.1	60.6	5.3	30.6
SSBs	52.0	6.6	12.2	0.0	0.0
Non-SSBs	1.7	2.8	0.1	0.0	0.0
Milk	60.5	60.7	6.5	1.2	2.0
Total	2,208.6	4,578.7	115.8	20.1	76.1
Total (% of energy)	.	.	21.0	8.2	31.0

Notes: ENIGH: national household income and expenditure survey (Encuesta Nacional de Ingresos y Gastos de los Hogares, in Spanish). F&V: fruits & vegetables; SSBs: sugar-sweetened beverages; UP: Ultra-processed (as per NOVA classification group 4). ⁺ By construction, these groups do not contain UP food items (no item with NOVA classification group 4). The NOVA classification is used to rank foods and beverages based on the nature, extent, and purpose of their level of processing. It is made of four categories: 1) unprocessed or minimally processed, 2) processed culinary ingredients, 3) processed, and 4) ultra-processed (Monteiro et al., 2018). Based on the 713 off-trade food and non-alcoholic beverage survey items from ENIGH 2018–2019. Survey weighted.

Table 4

Uncompensated price elasticities for the main model specification, full sample, pooled periods.

Change in quantity	Change in price									
	Cereals ⁺	Dairy ⁺	Animal meat ⁺	F&V ⁺	UP sweet foods	UP savoury foods	Other foods ⁺	SSBs	Non-SSBs	Milk
Cereals ⁺	−0.569*** (0.191)	−0.053 (0.161)	0.001 (0.182)	−0.044 (0.338)	−0.041 (0.095)	0.013 (0.095)	−0.029 (0.054)	0.029 (0.061)	−0.092** (0.036)	0.182 (0.146)
Dairy ⁺	−0.001 (0.170)	−0.783*** (0.161)	−0.101 (0.108)	0.106 (0.108)	0.051 (0.102)	0.055 (0.124)	−0.015 (0.032)	0.054 (0.102)	−0.039 (0.039)	0.018 (0.087)
Animal meat ⁺	−0.036 (0.121)	−0.097 (0.076)	−0.725*** (0.087)	−0.165 (0.140)	−0.091 (0.057)	−0.138 (0.095)	−0.011 (0.023)	−0.078 (0.061)	−0.033 (0.022)	−0.046 (0.046)
F&V ⁺	−0.049 (0.206)	0.041 (0.068)	−0.049 (0.115)	−0.853*** (0.179)	0.038 (0.054)	−0.004 (0.095)	0.010 (0.048)	−0.059 (0.073)	−0.002 (0.029)	−0.058 (0.041)
UP sweet foods	0.004 (0.059)	0.058 (0.077)	−0.018 (0.092)	0.110 (0.071)	−0.742*** (0.097)	0.013 (0.047)	−0.000 (0.033)	0.085 (0.120)	0.035 (0.041)	−0.012 (0.045)
UP savoury foods	0.180* (0.094)	0.148 (0.164)	0.003 (0.248)	0.053 (0.208)	0.022 (0.089)	−0.814*** (0.080)	−0.005 (0.032)	0.049 (0.180)	0.079 (0.049)	−0.124 (0.115)
Other foods ⁺	−0.340 (0.368)	−0.165 (0.120)	−0.120 (0.112)	−0.046 (0.183)	−0.120* (0.063)	−0.005 (0.063)	−0.984*** (0.074)	−0.052 (0.085)	−0.058 (0.061)	−0.065 (0.055)
SSBs	0.052 (0.060)	0.025 (0.027)	0.015 (0.054)	−0.021 (0.096)	0.028 (0.062)	0.019 (0.089)	0.020* (0.012)	−0.717*** (0.071)	0.005 (0.027)	0.051 (0.038)
Non-SSBs	−0.263** (0.111)	−0.099** (0.039)	−0.038 (0.071)	0.026 (0.089)	−0.002 (0.058)	0.082 (0.064)	−0.031 (0.052)	−0.005 (0.046)	−0.837*** (0.065)	−0.060 (0.057)
Milk	0.085 (0.069)	0.006 (0.020)	0.006 (0.025)	−0.012 (0.040)	−0.005 (0.024)	−0.043 (0.045)	−0.006 (0.012)	0.008 (0.020)	−0.006 (0.014)	−0.799*** (0.045)

Notes: Main model specification: Two-step censored QUAIDS with corrections for endogeneity in prices (as unit values) and total expenditure. Pooled sample periods including ENIGH 2012–2013 and ENIGH 2018–2019. ENIGH: national household income and expenditure survey (Encuesta Nacional de Ingresos y Gastos de los Hogares, in Spanish); QUAIDS: Quadratic Almost Ideal Demand System; F&V: fruits and vegetables; SSBs: sugar-sweetened beverages; UP: Ultra-processed (as per NOVA classification group 4). ⁺ By construction, these groups do not contain UP food items (no item with NOVA classification group 4). The NOVA classification is used to rank foods and beverages based on the nature, extent, and purpose of their level of processing. It is made of four categories: 1) unprocessed or minimally processed, 2) processed culinary ingredients, 3) processed, and 4) ultra-processed (Monteiro et al., 2018). Bold denotes own-price elasticities; Bootstrapped standard errors with 300 repetitions; *p < 0.1, **p < 0.05, and ***p < 0.01.

own-price elasticity for SSBs (in absolute terms).

One of the main contributions of this study is the aggregation of food items accounting for their level of food processing using the NOVA classification. UP foods tend to be more energy-dense and contain more fat, sodium, and sugar. Their intake is associated with weight gain and related cardiometabolic outcomes (Askari et al., 2020; Poti, Braga & Qin, 2017). This serves as a proxy to investigate differences in the price-sensitivity of demand and cross-price effects between ‘healthier’ (less processed) and ‘less healthy’ (more processed) items. The demand for UP foods is found to be price-inelastic with own-price elasticity

estimates in line with Pereda et al. (2024).²⁴

This analysis provides the first price elasticity estimates by income group in Costa Rica. In line with Green et al. (2013)’s meta-analysis, results show that lower-income households’ demand tends to be more price-sensitive than higher-income households’ demand. Only animal meat does not follow this pattern, which is consistent with results for meat and fish products from other studies, for example in Chile, Colombia, and Turkey (Akabay, Boz & Chern, 2007; Caro et al., 2017a, 2017b).

²⁴ Pereda et al. (2024)’s own-price elasticity estimates for UP foods are −0.83 for UP foods covered by the non-essential energy-dense food tax in Mexico and −0.61 for other UP foods (vs. −0.74 for UP sweet foods and −0.81 for UP savoury foods in this study).

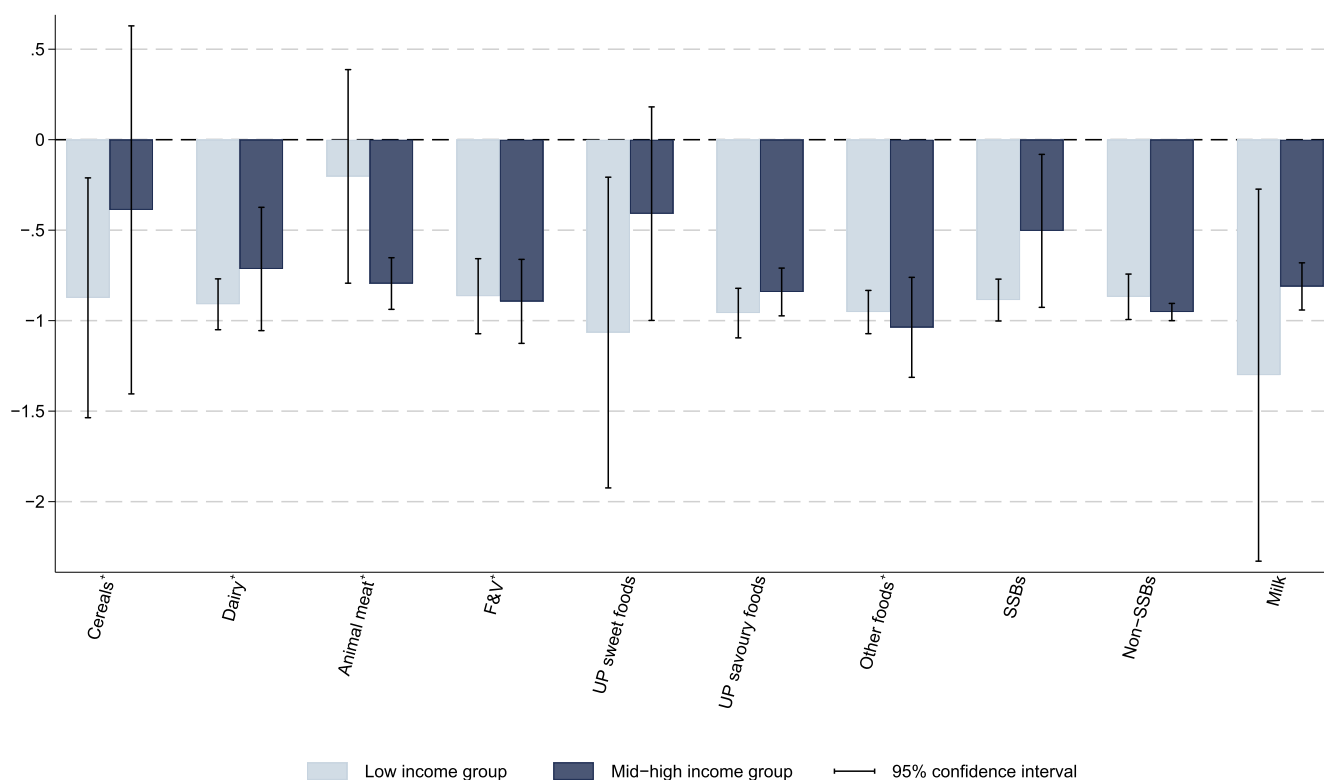


Fig. 1. Uncompensated own-price elasticities for the main model specification, by income group, pooled periods. Notes: Main model specification: Two-step censored QUAIDS with corrections for endogeneity in prices (as unit values) and total expenditure. Pooled sample periods including ENIGH 2012–2013 and ENIGH 2018–2019. ENIGH: national household income and expenditure survey (Encuesta Nacional de Ingresos y Gastos de los Hogares, in Spanish); QUAIDS: Quadratic Almost Ideal Demand System; F&V: fruits and vegetables; SSBs: sugar-sweetened beverages; UP: Ultra-processed (as per NOVA classification group 4). ⁺ By construction, these groups do not contain UP food items (no item with NOVA classification group 4). The NOVA classification is used to rank foods and beverages based on the nature, extent, and purpose of their level of processing. It is made of four categories: 1) unprocessed or minimally processed, 2) processed culinary ingredients, 3) processed, and 4) ultra-processed (Monteiro et al., 2018). Low-income group: the lowest three national income deciles; Mid-high-income group: the highest seven national income deciles. Vertical black segments represent the 95% confidence interval; Bootstrapped standard errors with 300 repetitions.

4.1. Policy implications

With the passing of Law 9914, Costa Rica has become the first country to mandate the alignment of differentiated VAT rates applied to foods based on their relative nutritional impact. However, findings show that the adopted CBTBIF may not lead to any improvements in the availability of key nutrients, and even a slight worsening from the baseline CBT in terms of calories, sugar, saturated fat, and total fat. This study's results participate in informing policymaking in the context of the recent reform of the CBT, by assessing the adopted CBTBIF in terms of nutritional outcomes and household expenditures, while also providing robust price elasticity estimates and an assessment of counterfactual scenarios to inform future reforms.

The CBTBIF and CBTEN encompass a higher number of survey items (210 and 171, respectively) but a lower share of baseline total quantities purchased (63.2 % and 63.8 %, respectively) than the baseline CBT (124 items representing 69.4 % of baseline total quantities purchased). This is particularly driven by the introduction of additional healthy food items with low baseline purchasing levels into the VAT-discounted basket, including a more than two-fold increase in F&V. However, only 29 food items are removed from the basic tax basket in the CBTBIF, and the CBTBIF includes more than 67.7 % of total baseline quantities purchased of UP savoury food items (e.g., crackers, sauces, sausages), representing an increase from 40.8 % in the baseline CBT (Table S2 and Table S4). Consequently, the tax burden on the majority of less healthy food items remains unchanged under the CBTBIF scenario, and even decreases for some UP savoury foods. The objective of health taxes on foods or the alignment of existing differentiated VAT rates with nutrition objectives

is to reduce the excessive consumption of less healthy foods. Therefore, establishing exemptions on the grounds of widespread consumption, like in the CBTBIF, contradicts the rationale for the taxation approach from a nutritional perspective.

On the other hand, the CBTEN and NPM-based scenarios result in more exhaustive price increases for less healthy food groups. While the CBTEN removes more UP items from the basic tax basket than the CBTBIF, it includes 12.1 % and 16.0 % of baseline UP sweet and savoury foods quantities, respectively, compared to 0.5 % and 6.1 % for the NPM-based scenario (Fig. S1 and Table S4).²⁵ These differences drive the simulation results and explain the relatively higher nutritional benefits from the NPM-based scenario over the CBTEN scenario, particularly for sodium and for lower-income households whose demand for UP foods is more price-sensitive.

All three simulated VAT scenarios are associated with minor reductions in total household expenditure on foods and non-alcoholic beverages, stronger for lower-income households. Thus, under both

²⁵ In addition to the nutritional criteria described in section 7 of [Ministerio de Salud, Costa Rica \(2020\)](#), the CBTEN proposed by the Ministry of Health also includes minimum consumption level criteria. An item is considered for inclusion in the CBTEN if at least 30% of the national total expenditure or quantity consumed is by the 30% poorest households or if the item is part of the 50% most consumed items by the 30% poorest households ([Ministerio de Salud, Costa Rica, 2021](#)). This is why, for example, even though the CBTEN includes 96.2% of the baseline quantity consumed of F&V, it only accounts for 85 F&V items compared to 168 F&V items (97.6% of the baseline quantity consumed) for the NPM-based discounted tax basket.

Table 5

Fiscal policy scenario simulation results for changes in quantity purchased, expenditure, and average daily nutrient availability per adult equivalent unit, full sample.

<i>Fiscal scenario: CBTBIF</i>							
	Quantity (%)	Expenditure (%)	Energy (kcal)	Sodium (mg)	Sugar (g)	Saturated fat (g)	Total fat (g)
Cereals ⁺	0.12%	−0.14%	0.81	0.57	0.00	0.00	0.01
	[−0.26%; 0.49%]	[−0.54%; 0.26%]	[−1.90; 3.52]	[−0.44; 1.59]	[−0.01; 0.01]	[−0.00; 0.01]	[−0.02; 0.03]
Dairy ⁺	4.09%	−1.57%	2.70	8.68	0.02	0.12	0.21
	[2.28%; 5.90%]	[−3.16%; 0.03%]	[1.52; 3.89]	[4.98; 12.38]	[0.01; 0.03]	[0.06; 0.17]	[0.12; 0.31]
Animal meat ⁺	1.28%	−0.60%	1.90	1.10	0.00	0.03	0.10
	[0.84%; 1.71%]	[−1.01%; −0.20%]	[1.22; 2.58]	[0.66; 1.54]	[−0.00; 0.00]	[0.02; 0.04]	[0.06; 0.13]
F&V ⁺	2.26%	−0.45%	4.03	0.58	0.43	0.02	0.07
	[1.15%; 3.37%]	[−1.24%; 0.34%]	[1.88; 6.18]	[0.24; 0.92]	[0.22; 0.63]	[0.01; 0.03]	[0.04; 0.11]
UP sweet foods	−2.43%	−0.01%	−0.71	−0.36	−0.16	0.01	0.02
	[−2.98%; −1.88%]	[−0.15%; 0.14%]	[−0.79; −0.63]	[−0.38; −0.35]	[−0.19; −0.13]	[0.00; 0.01]	[0.01; 0.03]
UP savoury foods	2.24%	−0.78%	5.37	−9.43	0.14	0.07	0.32
	[1.58%; 2.91%]	[−1.24%; −0.33%]	[3.84; 6.89]	[−9.55; −9.31]	[0.10; 0.17]	[0.05; 0.09]	[0.23; 0.41]
Other foods ⁺	0.17%	−0.06%	0.50	−0.28	0.12	−0.00	−0.01
	[−0.04%; 0.39%]	[−0.32%; 0.19%]	[−0.55; 1.54]	[−6.16; 5.60]	[−0.01; 0.26]	[−0.01; 0.01]	[−0.07; 0.05]
SSBs	−1.28%	0.30%	−0.54	−0.00	−0.13	−0.00	−0.00
	[−1.43%; −1.12%]	[0.16%; 0.45%]	[−0.60; −0.48]	[−0.01; 0.01]	[−0.15; −0.12]	[−0.00; 0.00]	[−0.00; 0.00]
Non-SSBs	0.13%	−0.19%	0.00	0.00	0.00	0.00	0.00
	[0.02%; 0.24%]	[−0.37%; −0.01%]	[−0.00; 0.00]	[0.00; 0.01]	[−0.00; 0.00]	[−0.00; 0.00]	[−0.00; 0.00]
Milk	0.69%	−0.31%	0.31	0.36	0.04	0.00	0.00
	[0.56%; 0.81%]	[−0.45%; −0.17%]	[0.25; 0.38]	[0.29; 0.44]	[0.03; 0.05]	[0.00; 0.00]	[0.00; 0.00]
Total absolute change			14.37	1.22	0.46	0.24	0.72
			[5.15; 23.59]	[−10.10; 12.55]	[0.11; 0.81]	[0.13; 0.35]	[0.37; 1.07]
Total relative change (%)		−0.42%	0.65%	0.03%	0.40%	1.19%	0.94%
		[−0.84%; 0.01%]	[0.23%; 1.07%]	[−0.22%; 0.27%]	[0.09%; 0.70%]	[0.64%; 1.74%]	[0.49%; 1.40%]
Post-scenario total per AEU per day			2,223.0	4,579.9	116.3	20.3	76.8
			[2,213.8; 2,232.2]	[4,568.6; 4,591.2]	[115.9; 116.6]	[20.2; 20.4]	[76.4; 77.1]
<i>Fiscal scenario: CBTEN</i>							
	Quantity (%)	Expenditure (%)	Energy (kcal)	Sodium (mg)	Sugar (g)	Saturated fat (g)	Total fat (g)
Cereals ⁺	−0.13%	0.25%	−1.06	−1.90	−0.01	−0.02	−0.06
	[−0.23%; −0.03%]	[0.17%; 0.33%]	[−1.69; −0.44]	[−2.75; −1.04]	[−0.02; −0.01]	[−0.02; −0.01]	[−0.08; −0.03]
Dairy ⁺	4.47%	−1.72%	2.85	8.76	0.02	0.12	0.22
	[2.68%; 6.26%]	[−3.30%; −0.14%]	[1.71; 3.98]	[5.25; 12.26]	[0.01; 0.03]	[0.07; 0.17]	[0.14; 0.31]
Animal meat ⁺	0.60%	−0.32%	0.90	0.13	−0.00	0.01	0.05
	[0.43%; 0.77%]	[−0.44%; −0.19%]	[0.64; 1.17]	[0.06; 0.20]	[−0.00; −0.00]	[0.01; 0.02]	[0.03; 0.06]
F&V ⁺	3.18%	−0.75%	5.35	0.68	0.64	0.06	0.12
	[1.83%; 4.53%]	[−1.78%; 0.28%]	[3.03; 7.66]	[0.38; 0.98]	[0.37; 0.91]	[0.03; 0.08]	[0.07; 0.17]
UP sweet foods	−2.21%	0.06%	−1.20	−0.86	−0.18	−0.00	−0.01
	[−2.77%; −1.65%]	[−0.13%; 0.25%]	[−1.50; −0.90]	[−1.08; −0.64]	[−0.23; −0.14]	[−0.00; −0.00]	[−0.01; −0.00]
UP savoury foods	−2.26%	0.12%	−3.74	−37.53	−0.05	−0.09	−0.25
	[−2.57%; −1.95%]	[−0.26%; 0.50%]	[−4.20; −3.28]	[−43.84; −31.21]	[−0.06; −0.04]	[−0.11; −0.08]	[−0.29; −0.22]
Other foods ⁺	−0.50%	−0.11%	−4.24	−0.29	−0.05	−0.18	−0.46
	[−0.52%; −0.47%]	[−0.15%; −0.08%]	[−4.60; −3.87]	[−1.82; 1.25]	[−0.07; −0.02]	[−0.21; −0.16]	[−0.51; −0.40]
SSBs	−1.25%	0.33%	−0.53	0.00	−0.13	0.00	0.00
	[−1.51%; −0.99%]	[0.08%; 0.58%]	[−0.64; −0.42]	[0.00; 0.00]	[−0.16; −0.10]	[0.00; 0.00]	[0.00; 0.00]
Non-SSBs	0.09%	−0.16%	0.00	0.00	0.00	0.00	0.00
	[0.08%; 0.09%]	[−0.22%; −0.09%]	[0.00; 0.00]	[0.00; 0.00]	[0.00; 0.00]	[0.00; 0.00]	[0.00; 0.00]
Milk	0.62%	−0.30%	0.27	0.33	0.04	0.00	0.00
	[0.56%; 0.67%]	[−0.36%; −0.23%]	[0.24; 0.29]	[0.30; 0.36]	[0.04; 0.04]	[0.00; 0.00]	[0.00; 0.00]
Total absolute change			−1.40	−30.67	0.28	−0.10	−0.38
			[−4.53; 1.73]	[−32.62; −28.73]	[0.05; 0.50]	[−0.13; −0.07]	[−0.43; −0.34]
Total relative change (%)		−0.24%	−0.06%	−0.67%	0.24%	−0.52%	−0.50%
		[−0.44%; −0.04%]	[−0.21%; 0.08%]	[−0.71%; −0.63%]	[0.05%; 0.43%]	[−0.66%; −0.37%]	[−0.56%; −0.45%]

(continued on next page)

Table 5 (continued)

Post-scenario total per AEU per day			2,207.2 [2,204.1; 2,210.4]	4,548.0 [4,546.0; 4,549.9]	116.1 [115.9; 116.3]	20.0 [19.9; 20.0]	75.7 [75.6; 75.7]
Fiscal scenario: NPM							
	Quantity (%)	Expenditure (%)	Energy (kcal)	Sodium (mg)	Sugar (g)	Saturated fat (g)	Total fat (g)
Cereals ⁺	−0.72% [−1.14%; −0.30%]	1.01% [−0.12%; 2.14%]	−4.31 [−6.78; −1.84]	−9.35 [−15.38; −3.31]	−0.08 [−0.13; −0.03]	−0.02 [−0.04; −0.01]	−0.10 [−0.16; −0.04]
Dairy ⁺	−2.56% [−3.78%; −1.34%]	0.10% [−0.83%; 1.03%]	−0.97 [−1.47; −0.47]	−0.55 [−1.02; −0.08]	−0.02 [−0.03; −0.01]	−0.04 [−0.07; −0.02]	−0.09 [−0.13; −0.04]
Animal meat ⁺	1.44% [1.16%; 1.73%]	−0.94% [−1.10%; −0.78%]	2.33 [1.88; 2.79]	−0.60 [−0.81; −0.38]	−0.00 [−0.00; −0.00]	0.05 [0.04; 0.06]	0.15 [0.12; 0.17]
F&V ⁺	3.34% [2.04%; 4.64%]	−0.86% [−1.94%; 0.21%]	5.76 [3.60; 7.93]	0.85 [0.54; 1.16]	0.66 [0.40; 0.93]	0.07 [0.04; 0.09]	0.14 [0.08; 0.19]
UP sweet foods	−3.23% [−4.12%; −2.35%]	0.29% [−0.21%; 0.78%]	−1.98 [−2.56; −1.39]	−1.89 [−2.44; −1.35]	−0.25 [−0.32; −0.18]	−0.01 [−0.01; −0.00]	−0.02 [−0.03; −0.01]
UP savoury foods	−3.16% [−3.74%; −2.57%]	0.37% [−0.26%; 0.99%]	−7.59 [−9.01; −6.18]	−41.83 [−49.72; −33.95]	−0.06 [−0.07; −0.05]	−0.17 [−0.20; −0.13]	−0.65 [−0.77; −0.53]
Other foods ⁺	0.57% [0.51%; 0.62%]	−0.29% [−0.30%; −0.28%]	1.99 [1.57; 2.42]	7.95 [4.73; 11.17]	0.31 [0.27; 0.35]	0.01 [0.00; 0.01]	0.08 [0.05; 0.11]
SSBs	−1.23% [−1.54%; −0.92%]	0.34% [0.04%; 0.65%]	−0.52 [−0.66; −0.38]	0.00 [−0.00; 0.01]	−0.13 [−0.16; −0.09]	0.00 [0.00; 0.00]	0.00 [0.00; 0.00]
Non-SSBs	0.78% [0.72%; 0.85%]	−0.48% [−0.61%; −0.35%]	0.01 [0.01; 0.01]	0.05 [0.04; 0.05]	0.00 [0.00; 0.00]	0.00 [0.00; 0.00]	0.00 [0.00; 0.00]
Milk	0.69% [0.68%; 0.71%]	−0.31% [−0.34%; −0.28%]	0.32 [0.31; 0.32]	0.37 [0.36; 0.37]	0.04 [0.04; 0.04]	0.00 [0.00; 0.00]	0.00 [0.00; 0.00]
Total absolute change			−4.95 [−7.86; −2.03]	−45.01 [−63.07; −26.95]	0.48 [0.43; 0.52]	−0.11 [−0.16; −0.07]	−0.49 [−0.68; −0.31]
Total relative change (%)		−0.18% [−0.27%; −0.09%]	−0.22% [−0.36%; −0.09%]	−0.98% [−1.38%; −0.59%]	0.41% [0.37%; 0.45%]	−0.57% [−0.79%; −0.36%]	−0.65% [−0.89%; −0.40%]
Post-scenario total per AEU per day			2,203.7 [2,200.8; 2,206.6]	4,533.6 [4,515.6; 4,551.7]	116.3 [116.2; 116.3]	19.9 [19.9; 20.0]	75.6 [75.4; 75.8]

Notes: CBTBIF: basic tax basket of goods and services for the integral wellbeing of families (Canasta Básica Tributaria por el bienestar integral de las familias, in Spanish), two-tiered VAT (1% on CBTBIF items, 13% others); CBTEN: Basic tax basket of goods considering nutritional aspects (in Spanish: Canasta básica tributaria con elementos nutricionales), two-tiered VAT (1% on CBTEN items, 13% others); NPM: nutrient profile model, based on the PAHO model, two-tiered VAT (1% on items with nutrient content below NPM thresholds, 13% others); PAHO: Pan American Health Organization; VAT: value-added tax. F&V: fruits and vegetables; SSBs: sugar-sweetened beverages; UP: Ultra-processed (as per NOVA classification group 4). ⁺ By construction, these groups do not contain UP food items (no item with NOVA classification group 4). The NOVA classification is used to rank foods and beverages based on the nature, extent, and purpose of their level of processing. It is made of four categories: 1) unprocessed or minimally processed, 2) processed culinary ingredients, 3) processed, and 4) ultra-processed (Monteiro et al., 2018). 95% confidence intervals are in square brackets. Calculations are based on the main model specification and the 713 off-trade food and non-alcoholic beverage survey items from ENIGH 2018–2019. Survey weighted.

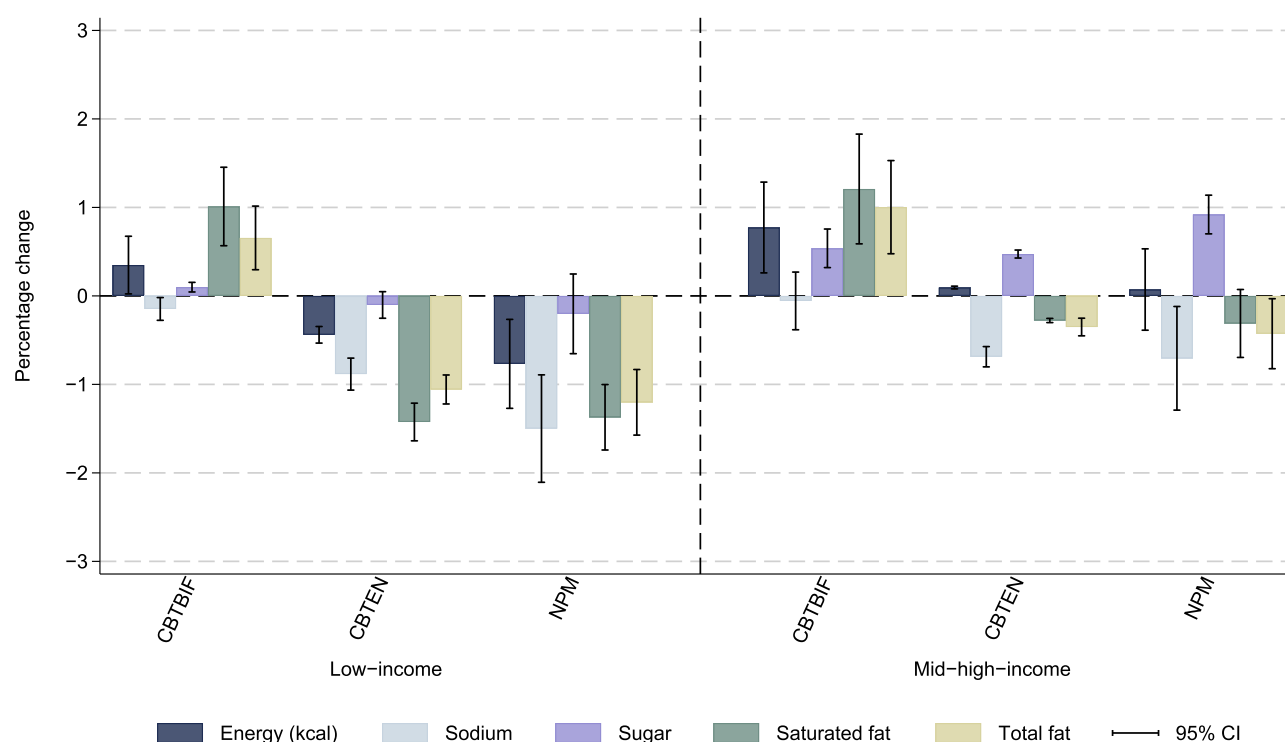


Fig. 2. Fiscal policy scenario simulation results for nutrient availability, by income group. Notes: CBTBIF: basic tax basket of goods and services for the integral wellbeing of families (Canasta Básica Tributaria por el bienestar integral de las familias, in Spanish), two-tiered VAT (1% on CBTBIF items, 13% others); CBTEN: Basic tax basket of goods considering nutritional aspects (in Spanish: Canasta básica tributaria con elementos nutricionales), two-tiered VAT (1% on CBTEN items, 13% others); NPM: nutrient profile model, based on the PAHO model, two-tiered VAT (1% on items with nutrient content below NPM thresholds, 13% others); CI: 95% confidence interval; PAHO: Pan American Health Organization; VAT: value-added tax. Low-income group: the lowest three national income deciles; Mid-high income group: the highest seven national income deciles. Calculations are based on the main model specification and the 713 off-trade food and non-alcoholic beverage survey items from ENIGH 2018–2019. Survey weighted.

the CBTEN and NPM scenarios, lower-income households may benefit from relatively larger improvements in both nutrient outcomes and household spending than richer peers. Finally, the CBTBIF and the other counterfactual scenarios simulated in this study could lead to significant changes in tax revenue, which should be assessed.

This study's findings show that reforming existing differentiated VAT rates between all foods and beverages according to their relative nutritional impact based on an NPM may yield the highest nutritional benefits. This is in line with previous studies in Chile and the United Kingdom (Caro et al., 2017b; Cornelsen, Mazzocchi & Smith, 2019). This analysis contributes to this literature, producing the first modelling study of NPM-based fiscal policies outside a high-income setting. NPM-based differentiated tax rates are less likely to apply high rates to healthier foods or incentivise negative substitutions from 'healthy' to 'less healthy' foods (Thow, Downs & Jan 2014). Nevertheless, taxing foods based on their nutritional content at product-level, rather than based on a defined list of item categories (as is the case with the CBTBIF or CBTEN), may require a strong tax administration capacity and lead to non-negligible compliance costs (World Health Organization, 2024). To date, only Hungary has used NPM nutrient thresholds to define a health tax on solid foods. However, this approach is gaining interest among policymakers. Colombia recently adopted a major fiscal reform including the introduction of an excise tax on HFSS foods based on PAHO's NPM thresholds for sodium, sugar, and saturated fat (Burki, 2023).

While this study shows that the CBTEN and NPM scenarios are associated with nutritional improvements, they are expected to lead to minimal impacts on total calorie availability. This is in line with the scarce observational evidence to date on changes in total energy intake in response to fiscal policies aimed at promoting healthier diets. This could be due to the limited availability of longitudinal consumption data

compared to sales data (Pineda et al., 2024). Evidence from sales data suggests compensatory shifts in energy intake, such as substitutions between taxed and untaxed items, as seen following Mexico's excise taxes on sugary drinks and non-essential energy-dense foods (Aguilar, Gutierrez & Seira, 2021). Furthermore, energy intake is influenced by unconscious biological and physiological factors. The food environment as well as the quality and diversity of diets can impact energy balance through complex hormonal and neurological pathways regulating satiety (Hall et al., 2012). Aside from energy, the high intake of specific nutrients, such as sugar, sodium, and saturated fat, is directly linked to health risks, particularly non-communicable diseases (Afshin et al., 2019). Given this, future research could enhance demand models by holding total energy intake constant to better capture the price sensitivity of diet quality and composition, ideally using dietary intake panel data.

Excise taxes are considered the preferred fiscal instrument to target well-defined unhealthy commodities, such as tobacco, alcoholic beverages, and SSBs (Powell & Chaloupka, 2023). However, HFSS foods represent a larger tax base, thus introducing an excise tax on such items without lowering the tax burden applied to healthier alternatives may raise equity concerns as expenditure on HFSS foods represents a higher share of total spending for the poorest (except if compensated by targeted subsidies or welfare programmes). This is particularly important in settings where healthy diets are relatively costly like Costa Rica (FAO et al., 2023).²⁶ In most countries, VAT or sales taxes are already applied to foods and beverages. Where such taxes apply differentiated rates, there is an opportunity to align existing rates with nutritional objectives

²⁶ The cost for an adult daily healthy diet in Costa Rica is estimated at USD 4.11, the second highest in Latin America (FAO et al., 2023).

(without adding new tiers). The European Parliament recently supported “giving Member States more flexibility to differentiate in the VAT rates on food with different health and environmental impacts, and enable them to choose a zero VAT tax for healthy and sustainable food products such as fruits and vegetables, [...] and a higher VAT rate on unhealthy food and food that has a high environmental footprint” (European Parliament, 2022, p.25). Although, the recent institutional frictions following the Dutch government’s attempt at reducing the VAT rate on F&V to zero per cent highlight the conflicting perspectives between fiscal and public health experts around the use of VAT to improve diets, specifically regarding food healthiness classifications (Hagenaars, Fazzino & Mackenbach, 2024). The impact of such an approach on VAT revenue generation efficiency should also be assessed.

In the context of Costa Rica, this study shows that the demand for UP foods and SSBs is price inelastic. This highlights the potential limitations of the use of differentiated VAT rates to promote healthier diets in this setting. Applying an additional excise tax on HFSS foods may further disincentivize their consumption. However, the distributional impact of such an approach should be carefully assessed. Other complementary policies that may participate in shifting the culture of eating, such as front-of-pack labelling schemes and marketing restrictions, could be considered.

4.2. Limitations

This study has several limitations. It suffers from the common challenge in demand estimation known as the aggregation problem as it assumes a generalizable utility function that applies across the population (and between two income groups) under which unexplained variation in demand is treated as random error (Blundell & Stoker, 2005). This study attempts to attenuate this problem by using a rank three demand model allowing non-linear Engel curves and accounting for heterogeneity in household characteristics through demographic controls and geographic differences through spatial clustering. The QUAIDS demand model additionally imposes standard restrictions in economic demand theory. In this analysis, the positivity of prices, monotonicity, and negativity conditions are satisfied (Table S5), while the adding-up restriction is relaxed in the second stage. However, symmetry and homogeneity are not necessarily expected to be satisfied empirically (Keuzenkamp & Barten, 1995). Their rejection is often due to model specification rather than the true nature of the data (Haag, Hoderlein & Pendakur, 2009). Nevertheless, the price elasticity estimates obtained in this analysis are in line with the literature in Latin America and other middle-income countries (Table S12). The F-statistics of variance tests support the main identifying assumption of spatially varying unit values for all food groups (rejecting the null hypothesis of no spatial variation in unit values at $p < 0.01$).²⁷ Finally, while household disposable income is a relevant instrument for total expenditure (first-stage F-statistic = 235, $p < 0.01$),²⁸ there may be concerns about the exclusion criteria. As noted by Attanasio and Lechene (2014), while being widely used in the literature, this instrument may only be valid if labour supply is weakly separable from consumption. A sensitivity analysis is run using a QUAIDS model without accounting for the endogeneity of prices (as unit values) and total expenditure and for the censoring correction. Results show that it biases estimates upwards (in absolute values), leading to more price-elastic estimates.²⁹

While the food group aggregation used in this analysis allows to proxy substitution effects between ‘healthy’ and ‘less healthy’ items, it may not provide an optimal representation of food purchasing behaviour. A sensitivity analysis is performed using the UN COICOP aggregation, which classifies food by purpose (ubiquitous in the food demand

estimation literature). Table S13 shows that the results of this study are robust to the choice of aggregation scheme as own-price and expenditure elasticity estimates are within similar ranges and only limited cross-price effects are found in both specifications. While this analysis considers between-group substitution effects, all items in each food group are assumed to share the same demand elasticity. Additionally, the limited sample size of the ENIGH survey waves and the large portion of non-purchasing households do not allow the disaggregation of food groups to a greater extent to further examine the price sensitivity of certain categorical subgroups (e.g., for meat: poultry vs. beef, for dairy: yoghurt vs. milk) or subgroups defined by processing levels (e.g., UP cereals vs. cereals, UP animal meat vs. animal meat). This has implications for the fiscal scenario modelling outcomes, as cross-price effects between such subgroups cannot be accounted for. If detailed consumer panel data with product-level information becomes available in Costa Rica, future research could overcome this issue and estimate demand systems using more disaggregated groups. Additionally, longitudinal consumer panel data would enable the use of event-study methods to assess the *ex-post* impact of fiscal policy reforms like the adoption of the CBTBIF. Instead, this analysis relies on *ex-ante* simulations based on price elasticities estimated using pooled cross-sectional household budget survey data. While demand estimates derived from spatial price variations provide useful insights, they are suboptimal representations of consumer responses to tax-induced price changes over time.

The simulations assume symmetry in response to own-price changes. However, households’ relative purchasing response may differ for a price increase (e.g., a tax) compared to a price decrease (e.g., a subsidy or a decrease in tax rate), although not substantially (Biondi et al., 2020). It is also important to acknowledge that the fiscal scenario simulations do not account for any type of industry behaviour. They do not model the potential tax-induced reformulation of foods and non-alcoholic beverages by the industry. Full and uniform tax passthrough to retail prices is assumed in the main analysis. However, firms may enter into strategic behaviours in under- or over-shifting the tax to consumers (Bonnet & Réquillart, 2013). In the case of VAT, passthrough levels may also differ for tax increases compared to tax decreases. Results are robust to the use of lower tax passthrough rates, specifically 82 % for tax increases – based on Andreyeva et al. (2022a)’s meta-analysis of studies evaluating real-world SSB taxes³⁰ – and 50 % for tax decreases – based on Benzarti, Garriga & Tortarolo (2024)’s analysis of a VAT cut on food necessities in Argentina.³¹

Demand elasticities are estimated based on the 2018–2019 and 2012–2013 ENIGH surveys and used to assess the impact of the CBTBIF introduced in February 2023. While these represent the most reliable and up-to-date data available for Costa Rica, it is important to note that the COVID-19 pandemic, alongside other macroeconomic shocks and disruptions to food systems, may have influenced consumer preferences and purchasing behaviours. Consumption, as measured using household budget survey data, does not account for kitchen and plate waste. However, recent evidence shows that the demand for food waste may be price elastic (Landry & Smith, 2019). The estimated policy-induced changes in nutrient availability may thus represent an upper bound on actual change in intake.

There are also limitations associated with the food processing classification and the nutrient content information used in this study. Food processing classifications have been criticized for their oversimplifying nature, inconsistencies, and sole focus on processing levels over diet quality (e.g., disregarding the presence of healthy ingredients such as

²⁷ Analysis of variance (ANOVA) test results are available upon request.

²⁸ First-stage results are available upon request.

²⁹ Results are available upon request.

³⁰ Andreyeva et al. (2022a)’s review includes mostly passthrough rates for excise taxes. Evidence is scarcer regarding VAT increases on foods and beverages. Nevertheless, a recent evaluation of the 2021 VAT increase on SSBs in Spain revealed a tax passthrough slightly above 100% (Martinez & Martinez, 2023). Thus, using an estimate of 82% may be conservative.

³¹ Results are available upon request.

F&V). While NOVA represents the most applied food processing classification system in the literature (Martínez-Steele et al., 2023), it is not exempt from such criticisms (Braesco et al., 2022; Petrus et al., 2021). The United States Department of Agriculture 2017–2018 Food and Nutrient Database for Dietary Studies and the University of Costa Rica School of Nutrition ValorNUT database are used as proxies for the survey items for which no match is found in the 2018 INCAP Food Composition Table for Central America, respectively 67 and 39 items (United States Department of Agriculture, 2019; Universidad de Costa Rica, 2018). Nevertheless, this represents only 6.6 % of the total baseline quantities purchased. Given the lack of disaggregated information on the type of sugar, this analysis assumes free sugar content to be equal to total sugar. The number of items categorized as HFSS under PAHO's NPM may thus be overestimated.³² Alternatively, the analysis may also be underestimating the number of food items identified as HFSS by PAHO's NPM as it is unable to account for the presence of other sweeteners or trans fats.³³ Estimating the content of free sugars, other sweeteners, and trans fat would require product-level information from nutrient fact panels. Finally, this study only investigates changes in the availability of calories, sodium, sugar, saturated fat, and total fat. However, the VAT scenarios may lead to significant changes in other critical nutrients (e.g., fibre).

4.3. Conclusion

An increasing number of countries are contemplating the taxation of HFSS foods. Costa Rica is unique in mandating the consideration of nutritional aspects when reforming the basic VAT tax basket (Law 9914, November 2020). This represents an opportunity to use fiscal policies more broadly to impact the relative price of foods and beverages based on their nutritional impact, thus taking an important step toward improving diets in the country. However, this study has shown that the recently adopted CBTBIF may not fulfil this potential. It includes many UP savoury foods and is expected to lead to non-significant changes in the availability of sodium and an increase in the availability of calories, sugar, saturated fat and total fat. Defining the basic VAT tax basket based on clear nutrient content thresholds may instead lead to dietary improvements, with higher nutritional benefits for low-income households while not increasing household spending. Nonetheless, the tax administration complexity and revenue impact of such an approach should be carefully assessed.

CRediT authorship contribution statement

Maxime Roche: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

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³² In the absence of information on free sugar content, Panel D of PAHO's NPM recommends assuming the content of free sugars to be equal to the declared total sugar content if “the product is part of a group of foods with no or a minimal amount of naturally occurring sugars” (Pan American Health Organization, 2016), which is the case for the majority of UP sweet food products.

³³ However, the use of trans fatty acids has significantly decreased over the past decade in Latin America, including in Costa Rica, such that the number of food items with a trans fat content above PAHO's recommended levels is expected to be close to zero (Monge-Rojas et al., 2017).

Declaration of competing interest

The author declares having no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.foodpol.2025.102824>.

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