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

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# Disclaimer

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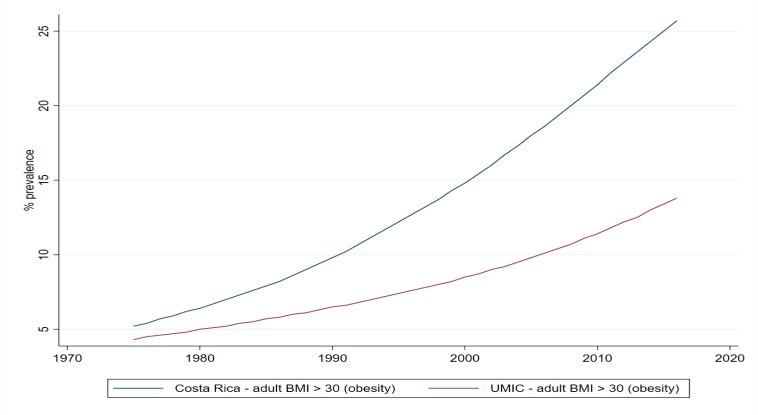
# MOTIVATIONS

# Motivations - Health




*Notes: BMI: Body mass index, UMIC: Upper-middle income countries*

*Source: WHO Global Health Observatory data*

# Motivations - Health

Unhealthy diets and obesity are major risk factors for non-communicable diseases such as cardiovascular diseases, cancers, and diabetes *(Malik, Willett & Hu, Nature RE, 2013)*.

Costa Rica:

- Prevalence **overweight/obesity** *(WHO, 2017; Ministerio de Salud, Costa Rica, 2017)*:
  - Adults: 6 out of 10, doubled in last 4 decades
  - Children (5-19 yo): 31.7%

⇒ **Threat to socio-economic development** *(Tremmel et al, IJERPH, 2017)*

# Motivations - Diet

Costa Rica:

- Average **sodium** availability in foods (4.6 g/person/day in 2013) largely exceeds WHO guideline (2 g) *(Blanco-Metzler et al, Nut, 2017)*
- Daily intake of **sugar-sweetened beverages (SSBs)** is twice the global average *(Singh et al, PLOS One, 2015)*
- 80% urban adults exceed WHO guideline for daily total energy intake from **sugar** intake *(Fisberg et al, Nut, 2018)*

# Motivations - Fiscal policies as one solution

**Consumption taxes** can play a key role in accounting for the negative:

- **externalities**: social costs arising from healthcare cost and productivity losses *(Allcott, Lockwood & Taubinsky, JEP, 2019)*
- **internalities**: own-harms and costs, not internalised; goal: "encourage people to avoid acting against their own interest" *(Adam et al, IFS, 2011)*

**Robust evidence** of the effectiveness of **excise taxes on SSBs** in reducing sales *(Andreyeva et al, JAMA, 2022)*.

Fewer countries have implemented **taxes on HFSS foods**, mostly excise taxes with limited scope (i.e., targeting specific food categories or one/two critical nutrients), e.g., Hungary, Mexico *(Pineda et al, FP, 2024)*.
$\Rightarrow$ **Reduced sales** *(Andreyeva et al, JAMA, 2022; Pineda et al, FP, 2024)*.

**Increased interest** with recent adoption in Colombia and proposals in Brazil, Chile, and the Netherlands

# Motivations - Fiscal policies as one solution

Most countries apply **value-added taxes (VAT)** on foods, and many apply **tiered rates**

**No country broadly differentiates VAT rates based on relative nutritional impacts** *(Pineda et al, FP, 2024)*.

⇒ A potential solution: **Nutrient profile modelling (NPM)**

- already used for front of pack nutrition labelling (FOPNL), marketing regulations, etc. *(Labonte et al, AN, 2018)*
- 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 et al, NR, 2014)*

Example: Pan American Health Organization (PAHO)' NPM NPM

# Literature

Food demand elasticities

- Global, and by income groups *(Green et al, BMJ, 2013)*
- Costa Rica, full sample *(Dal et al, FiN, 2022)*
- **Disaggregation by income group** is lacking in Costa Rica

Food tax simulations

- Fiscal policy scenarios based on nutrient content *(Harding & Lovenheim, JHE, 2017; Harkanen et al, FP, 2014; Smed, Jensen & Denver, FP, 2007)*
- Including NPM-based (Chile, UK, US) *(Caro et al, FP, 2017; Colchero et al, PLOS One, 2021; Cornelsen et al, SSM, 2019; Valizadeh & Ng, AJPM, 2024)*
- **Evidence is lacking outside of high-income settings**

# Motivations - Costa Rica's VAT

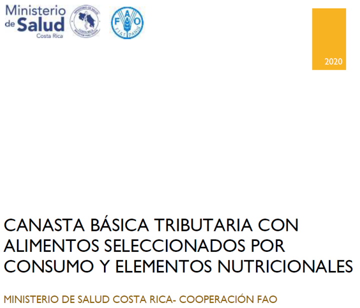
Excise on SSBs

Value-added tax (VAT) (until Jan 2023)

- **General rate 13%**
- **Canasta Básica Tributaria (CBT)**: **Reduced rate 1%** on selected basket of foods and non-alcoholic beverages, based on consumption patterns of **20% poorest HH**, and defined by Ministry of Economy, Industry, and Commerce (MEIC) and Ministry of Finance
- Revised after new iterations of national household budget survey
- CBT contains $\approx$ 124 items, which **also include HFSS foods** (e.g., sausages, sweet donuts)
- Nov 2020, **Law 9914**: future revisions of **CBT must acccount for nutritional aspects** and Ministry of Health must be involved

# Motivations - Costa Rican VAT reform

- In March 2021, Ministry of Health proposed a revised CBT, named **Canasta Básica Tributaria con Elementos Nutricionales (CBTEN)** accounting additionally for nutrition
- CBTEN was **never adopted**



2020

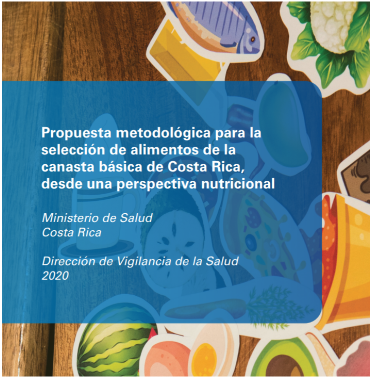
CANASTA BÁSICA TRIBUTARIA CON ALIMENTOS SELECCIONADOS POR CONSUMO Y ELEMENTOS NUTRICIONALES

MINISTERIO DE SALUD COSTA RICA- COOPERACIÓN FAO

# Motivations - Costa Rican VAT reform

**CBTEN: Point-based system**, criteria include:

- Food groups
- Traditional Costa Rican items
- Processing level
- Protein, Sodium, Fibre, Fat and Sat. fat content
- Others (calcium, iron, vitamine C, potassium, cholesterol)



# Motivations - Costa Rican VAT reform

Gobierno firma decreto para reglamentar Canasta Básica Tributaria que contemple dietas saludables

noviembre 9, 2022 Redacción Costa Rica

San José, 9 nov (elmundo.cr) – El presidente de la República, Rodrigo Chaves Robles, junto con el ministro de Hacienda, Nogui Acosta Jaén; el ministro de Economía, Industria y Comercio, Francisco Gamboa Soto y la ministra de Salud, Joselyn Chacón Madrigal, firmaron el decreto denominado "Reglamentación de la Lista de Bienes que confirman la Canasta Básica Tributaria por el Bienestar de las Familias" (CBTBIF).

- In 2022, MEIC and MoF proposed: **Canasta Básica Tributaria por el Bienestar Integral de las Familias (CBTBIF)**
- Based on consumption patterns of **30% poorest households and to "guaranty a balanced diet" $\neq$ CBTEN**
- **No quantitative nutritional criteria**, public consultation, and concertation across government
- Decreto Ejecutivo N° 43790-H-MEIC-S signed on 11 Nov 2022
- **Implemented on 1 February 2023**

Policy timeline | Criteria CBTBIF | Example CBT-CBTEN-CBTBIF

# Research questions

1. How do **prices impact the demand** for foods and non-alcoholic beverages across Costa Rican **income groups** and **food processing levels**?

2. How will the adopted **CBTBIF** impact **nutrient availability and household expenditure**?

3. How would the adopted CBTBIF compare with the non-adopted **CBTEN** based on explicit nutritional criteria and **differentiated VAT rates based on PAHO's NPM**?

# Main contributions

- Literature on broad NPM-based food taxes ⇒ **first modelling study in a non-high-income country**
- Novel approach to estimate price elasticities of demand **exploring own- and cross-price effects across food processing levels** as a proxy for healthiness (more appropriate for LMICs & NPM-based tax simulations)
- First price elasticity estimates of **food demand at income group level** in Costa Rica
- **Informing current and future national policy debates** around VAT on foods and the CBT
- Contribute to the wider regional and **global discussion on the use of HFSS taxation**

# DATA

# Data - Expenditure

HH sociodemographics

**National Household Income & Expenditure survey (ENIGH)**

- Nationally representative
- Expenditure data per item - monthly total spent and quantities purchased - but **NO price data** (713 off-trade foods & non-alcoholic beverages)
- HH socioeconomic and demographic information
- HH budget surveys often serve as proxy for food intake *(Fiedler et al, FNB, 2012)*, including in Costa Rica *(Dal et al, FiN, 2022; Blanco-Metzler et al, Nut, 2017)*
- Pooled waves:
  - Feb 2018 - Feb 2019, 7,046 HH in 468 PSUs
  - Oct 2012 - Oct 2013, 5,705 HH in 468 PSUs
- Expenditure values adjusted for inflation using CPI
- Low-income (3 poorest deciles), Mid-high-income (7 richest deciles)

# Data - Nutritional information

**INCAP 2018 Food Composition Table Central America**

- Nutritional information per 100g/ml (2,657 foods & beverages): energy, sodium, sugars, saturated fat
- Manual match with each of the 713 ENIGH survey items (off-trade foods & non-alcoholic beverages) using item descriptions, adjustment for edible fractions
- For missing items (106 survey items $\approx$ 6.6% quantities purchased), completed with nutrient information from:
    - USDA Food and Nutrient Database for Dietary Studies 2017-2018
    - University of Costa Rica, School of Nutrition's ValorNUT

Adult equivalent units (AEU) dividing recommended dietary allowance (RDA) for energy of each HH member (according to age and sex) by RDA for an average adult (2,550 kcal) *(FAO, UN & WHO, 2004)*

# NOVA classification

NOVA def details

In collaboration with INCIENSA, grouping foods according to the nature, extent, and purpose of the industrial processing they undergo *(Monteiro et al, PHN, 2018; Martinez-Steele et al, Nature F, 2023)*:

- Group 1: Unprocessed or minimally processed foods
- Group 2: Processed culinary ingredients
- Group 3: Processed foods
- Group 4: Ultra-processed foods

Ultra-processed food intake is associated with higher availability of fat, sodium, and sugars, weight gain *(Askari et al, IJO, 2020)*, cancer *(Fiolet et al, BMJ, 2018)*, diabetes *(Srour et al, JAMA IM, 2020)*, and all-cause mortality *(Rico-Campa et al, BMJ, 2019)*.

# Methods: Food/beverage grouping

Description

Based on **mix of UN COICOP categories and NOVA classification**:

1. Cereals
2. Dairy products
3. Animal meat
4. Fruits & Vegetables (F&V)
5. UP sweet foods
6. UP savory foods
7. Other foods
8. SSBs
9. Non-SSBs (e.g., water, coffee, tea)
10. Milk (unsweetened)

Proxy to investigate differences in the price- sensitivity of demand and cross-price effects between ‘healthier’ (less processed) and ‘less healthy’ (more processed) items

# HH expenditure statistics

| | ENIGH 2012-2013 | | | ENIGH 2018-2019 | | |
|---|---|---|---|---|---|---|
| | Low-income | Mid-high income | Full sample | Low-income | Mid-high income | Full sample |
| **Budget share (%)** | | | | | | |
| | 20.0 | 13.3 | 15.3 | 18.1 | 11.8 | 13.7 |
| | 3.3 | 4.2 | 3.9 | 4.0 | 4.9 | 4.6 |
| | 18.6 | 20.3 | 19.8 | 19.4 | 21.0 | 20.5 |
| | 14.8 | 17.2 | 16.5 | 16.3 | 20.1 | 19.0 |
| | 8.0 | 10.9 | 10.0 | 7.7 | 10.5 | 9.6 |
| | 11.4 | 12.6 | 12.3 | 11.4 | 13.4 | 12.8 |
| | 7.9 | 4.6 | 5.6 | 7.4 | 4.3 | 5.2 |
| | 5.7 | 7.8 | 7.1 | 4.9 | 5.6 | 5.4 |
| | 4.6 | 3.7 | 4.0 | 4.7 | 3.4 | 3.8 |
| | 5.3 | 4.9 | 5.0 | 5.5 | 4.5 | 4.8 |
| **HH pos exp. (%)** | | | | | | |
| | 86.7 | 82.2 | 83.5 | 89.7 | 80.8 | 83.5 |
| | 44.5 | 54.7 | 51.6 | 45.7 | 52.6 | 50.5 |
| | 79.1 | 79.0 | 79.0 | 82.2 | 80.9 | 81.3 |
| | 80.7 | 83.4 | 82.6 | 84.7 | 86.5 | 86.0 |
| | 64.2 | 73.4 | 70.6 | 65.0 | 72.4 | 70.2 |
| | 80.3 | 82.5 | 81.8 | 79.8 | 82.7 | 81.8 |
| | 66.7 | 55.9 | 59.2 | 68.4 | 54.2 | 58.5 |
| | 57.7 | 68.2 | 65.0 | 57.8 | 60.4 | 59.7 |
| | 51.5 | 49.1 | 49.8 | 56.4 | 46.3 | 49.3 |
| | 51.7 | 58.6 | 56.5 | 55.3 | 55.2 | 55.3 |

# Nutrient availability per AEU per day, full sample

Inc. groups

| | Energy (kcal) | Sodium (mg) | Sugar (g) | Sat 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 savory 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 (% energy)** | **.** | **.** | **21.0** | **8.2** | **31.0** |

# METHODS

# Methods: QUAIDS model (1)

**Quadratic Almost Ideal Demand System (QUAIDS)**: Utility-based structural demand model *(Banks, Blundell and Lewbel, REStat, 1997)*, where HH choose quantity and quality based on prices and HH income and sociodemographic characteristics. Derived from *Deaton & Muellbauer (AER, 1980)*'s AIDS model.

$$w_i = \alpha_0 + \sum_{k \in K} \rho_{ik} z_k + \sum_{j}^{I} \gamma_{ij} \ln p_j + \beta_i [\ln x - \ln P] + \frac{\lambda_i}{\prod_i^I p_i^{\beta_i}} [\ln x - \ln P]^2$$

$$\ln P = \alpha_0 + \sum_{j}^{I} \alpha_j \ln p_j + \frac{1}{2} \sum_{j}^{I} \sum_{k}^{I} \gamma_{jk} \ln p_j \ln p_k$$

QUAIDS derivation

# Methods: QUAIDS model (2)

Following *Deaton & Muellbauer (AER, 1980)* and consistent with microeconomic demand theory, I introduce the following restrictions:

- **Adding up**: $\sum_i w_i = 1$ (conditional on positive demand)
- **Slutsky symmetry**: cross-price derivatives of Hicksian (compensated) demand are equal
- **Homogeneity**: homogeneity of degree zero in prices and income
- **Positivity & monotonicity**: $p_i > 0$ and $w_i \geq 0$

$\Rightarrow \sum_i^I \beta_i = 0$, $\sum_i^I \lambda_i = 0$, $\sum_i^I \gamma_{ij} = \sum_j^I \gamma_{ij} = 0$, and $\gamma_{ij} = \gamma_{ji}$ for $i \neq j$

# Methods: Price & unit value endogeneity

Endogeneity issues ($p_i$): reverse causality, OVB

Main assumption for identification: **Spatially varying prices**, i.e., factors affecting price changes across clusters (e.g., transportation costs) implicitly serve as instruments *(Deaton & Muellbauer, AER, 1980)*.

This assumption is common to the use of AIDS-type models in low- and middle-income countries *(Deaton, World Bank, 2018)* and **credible** in Costa Rica:

- higher road-freight transportation costs than most middle- and high-income countries *(Osborne, Pachon and Araya, World Bank, 2013)*
- some of the highest fuel prices in Central America *(World Bank, 2016)*

No price data in ENIGH survey, so I rely on **unit values**: $\nu_i = \frac{w_i x}{q_i}$

Endogeneity issues ($\nu_i$): measurement errors, 'quality shading' effect.

Following *Capacci & Mazzocchi (JHE, 2011)*, estimating **quality-adjusted prices** assuming spatially varying prices at cluster level (468 PSUs):

$$\ln \nu_{ih}^c = \underbrace{\eta_{i0} + \sum_{k \in K} \eta_{ik} z_{kh}^c}_{\text{quality effect}} + \underbrace{\ln p_{ih}^c}_{\text{price effect}} + \underbrace{\mu_i \ln q_{ih}^c}_{\text{quantity effect}} + u_{ih}^c$$

HH sociodemographics used as **proxy for unobserved HH preferences (quality effect)**. Imposing $p_{ih}^c = \bar{p_i^c}$, demeaning at cluster level:

$$\left(\ln \nu_{ih}^c - \ln \bar{\nu_i^c}\right) = \mu_i \left(\ln q_{ih}^c - \ln \bar{q_i^c}\right) + \sum_{k \in K} \eta_{ik} \left(z_{kh}^c - \bar{z_k^c}\right) + \left(u_{ih}^c - \bar{u_i^c}\right)$$

$$\hat{p}_{ic} = \eta_{i0} + \ln \bar{p_i^c} = \ln \bar{\nu_i^c} - \sum_{k \in K} \hat{\eta}_{ik} \bar{z_k^c} - \hat{\mu}_i \ln \bar{q_i^c}$$

# Methods: Expenditure endogeneity

Total expenditure (as the sum of expenditure on all off-trade foods and non-alcoholic beverages) captures the sensibility of HH from changes in their budget.

Endogeneity issue ($x$): reverse causality

Solution: **Augmented regression technique** *(Banks, Blundell and Lewbel, REStat, 1997)*, similar to control function and 2SLS

$\Rightarrow$ **Instrumental variable (IV): total disposable income**

- 1st stage: OLS $\ln x = \mu_0 + \sum_{k \in K} \mu_k z_k + \tau \ln disp + e$
- Recovering the residuals: $\hat{e} = \ln x - \hat{\mu}_0 - \sum_{k \in K} \hat{\mu}_k z_k - \hat{\tau} \ln disp$
- 2nd stage: Add the residuals to the QUAIDS demand model

# Methods: Accounting for censoring

Issue: Reported zero values are likely selective.

Following *Shonkwiler & Yen (AJAE, 1999)*'s **two-step approach**:

$$w_{ih} = d_{ih} w_{ih}^{*} \qquad \text{with} \;\; d_{ih} = \begin{cases} 1 & d_{ih}^{*} > 0 \\ 0 & d_{ih}^{*} \leq 0 \end{cases}$$

1st step: Probit regression: $d_{ih} = \mathbb{1}_{d_{ih}^{*}>0} = \mathbf{r}_{ih}'\theta_i + \vartheta_{ih}$

2nd step: Actual budget shares calculation using $\hat{\theta}_{\mathbf{i}}$

$$w_{ih}^{*} = \Phi(\mathbf{r}_{ih}'\theta_i) w_{ih} + \zeta_i \phi(\mathbf{r}_{ih}'\theta_i) + \epsilon_{ih}$$

$\mathbf{r}_{ih}$ represents a vector of regressors including $\hat{p}_{ic}$ and HH characteristics.
Error terms $[\vartheta_{ih}, \epsilon_{ih}]$' assumed bivariate normal with $cov(\vartheta_i, \epsilon_i) = \zeta_i$
* for latent variables, $\Phi$ and $\phi$ for std. normal CDF and PDF

# Methods: Estimation (1)

**Z** contains the following **household characteristics**:

- Household size
- Household head:
    - age
    - education
- ENIGH wave dummy

Estimation: **Iterative Feasible Generalized Nonlinear Least-Squares (IFGNLS)** using modified version of *Poi (2008)*'s *nlsur* STATA command derived by *(Caro et al, 2021)*. Bootstrapped SE (300 repetitions).

# Methods: Estimation (2)

Uncompensated price elasticities (outcome of interest): $\varepsilon_{ij}^{u} = \frac{\partial \ln q_i}{\partial \ln p_j}$

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

Accounting for **direct effect** (price change) conditional on positive demand and **indirect effect** (purchasing likelihood change) on demand.

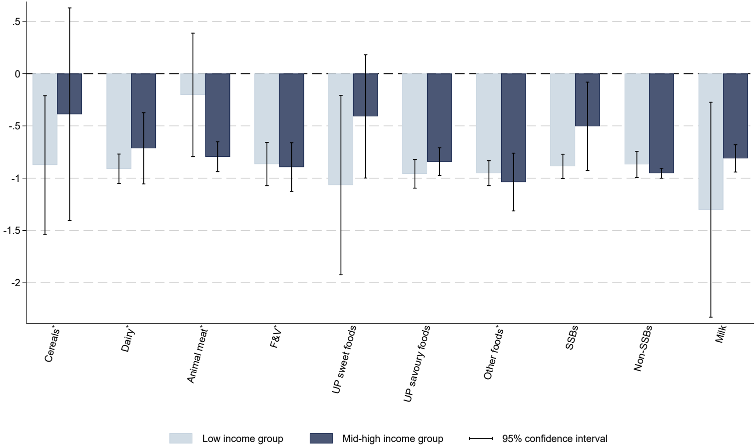
Formulae derivation

# RESULTS

# Results: Uncompensated price elasticities

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

# Results: Own-price elast. per income group



# VAT scenarios

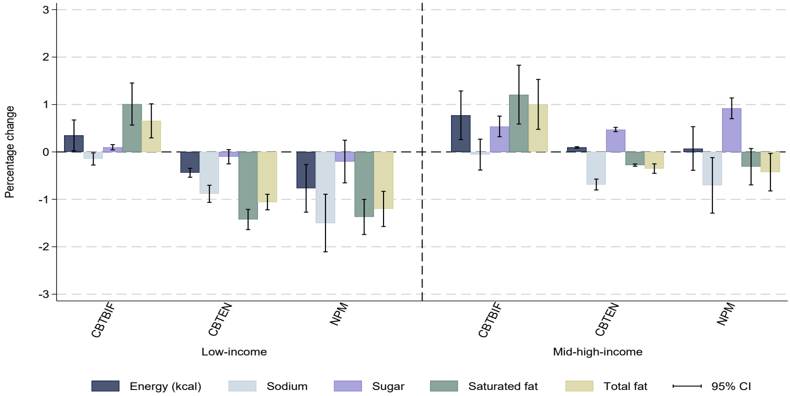
- 1) **CBTBIF scenario**, two-tiered VAT as adopted by decree N° 43790-H-MEIC-S on 11 Nov 2022 and **implemented as of 1 Feb 2023** (1% on CBTBIF, 13% on others)

- 2) **CBTEN scenario**, two-tiered VAT as **proposed by Ministry of Health in 2021** (1% on CBTEN, 13% on others)

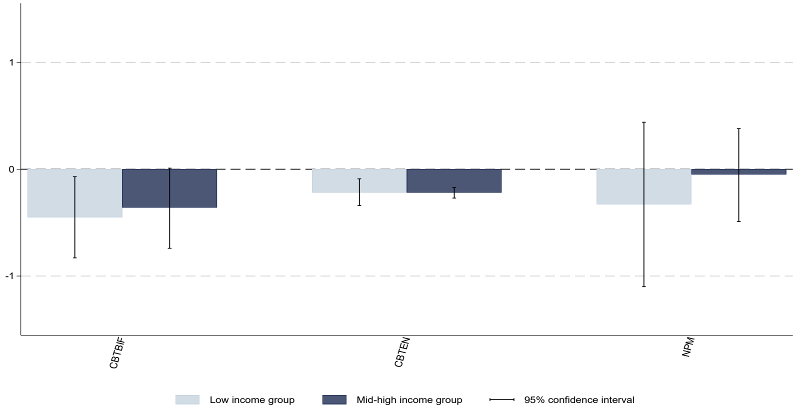
- 3) **NPM scenario**, two-tiered VAT based on PAHO NPM (1% below the PAHO NPM thresholds; 13% above)

NPM Composition scenarios

# Results: Nutrient availability, inc group



# Results: HH total expenditure



# DISCUSSION

# Discussion

- Baseline nutrient availability is comparable to findings in the Costa Rican literature *(Fisberg et al, Nut, 2018; Rosello-Araya et al, Nut, 2022)*
- **UP foods and SSBs as proportion of total calories purchased (18.4%)** similar to Brazil *(Levy et al, RSP, 2022)*
- Elasticity estimates are **in line with estimates** in other Latin American countries and middle-income countries *(Dal et al, FiN, 2022; Alfonzo & Peterson, AE, 2006; Caro et al, PLOS One, 2017; Green et al, BMJ, 2013)*
- **Demand for UP foods is price-inelastic (-0.74 sweet, -0.81 savoury)** as found in Brazil by *Pereda et al (FP, 2024)*
- **Low-income HH tend to be more price sensitive**, as in *Green et al (BMJ, 2013)*. Except for animal meat and fish, consistent with other studies *(Akbay et al, ERAE, 2007; Caro et al, FP, 2017)*

# Discussion

- CBTBIF associated with ↑ household purchases of calories (+0.7%), sugar (+0.4%), and saturated fat (+1.2%)
- Counterfactual PAHO NPM scenario associated with the largest ↓ in calories (-0.2%), sodium (-1.0%), and saturated fat (-0.6%)
- **Higher benefits for lower-income HH**
- **No negative impact on HH exp**, even minor decreases

⇒ **CBTBIF may slightly worsen nutrient intake** from the baseline CBT, driven by the increased number of discounted UP savoury food items

Composition scenarios

⇒ **CBTEN/PAHO NPM may instead improve nutrient intake**, but not substantially enough to bring average daily adult sodium and sugar availability below WHO-recommended levels

# Robustness checks

- ANOVA test, Ho: no spatially varying unit values $\Rightarrow$ rejected for all groups ($p < 0.01$)
- Relevance of disposable income IV (F-stat $= 235$, $p < 0.01$)
- QUAIDS restrictions satisfied: Positivity of prices $\hat{p}_i^c > 0$, Monotonicity $w_i^* \geq 0$, Adding-up $\sum_i w_i = 1$ (imposed only first step), and Negativity $\varepsilon_{ii}^c \leq 0$ Comp. elasticities
- Not accounting for censoring and endogeneity biases elasticities downwards (i.e., more price-elastic)
- Food aggregation by processing may not provide an optimal representation of purchasing behaviour. Results robust to UN COICOP COICOP
- Results robust to various tax passthrough assumptions *(Andreyeva et al, JAMA, 2022; Benzarti et al, NBER, 2024)*

# Limitations

- Concerns may remain about the exogeneity to local demand of the factors driving the spatial variation of prices
- Demand parameters derived from spatial price variations are suboptimal representations of consumer responses to tax-induced price changes
- Symmetry and homogeneity conditions are not necessarily expected to be satisfied empirically *(Keuzenkamp & Barten, JE, 1995)*
- Exclusion criteria for disp. income IV may only be valid if labour supply weakly separable from consumption *(Attanasio & Lechene, JPE, 2014)*
- Limited sample size for further disaggregation of income and food groups
- Longitudinal consumer panel data would allow the use of event-study methods to assess the *ex-post* impact of the policy
- Industry behaviours are not accounted for (e.g., reformulation) and symmetry assumption in response to own-price changes *(Bondi et al, JEBO, 2020)*.
- Analysis limited to calories, sodium, sugar, and fat, while overall dietary quality is not analysed and off-trade sector not accounted for

# Policy implications

Magnitude:

- CBTEN/PAHO NPM associated with nutritional improvements, but limited impacts on total calories purchased, in line with observational evidence of the taxation of HFSS foods *(Pineda et al, FP, 2024)*
- Evidence from sales data in Mexico suggests compensatory shifts in energy intake *(Aguilar et al, JHE, 2021)*

Fiscal instrument:

- Excise taxes are considered the preferred fiscal instrument to target well-defined unhealthy commodities (e.g., tobacco, alcohol, SSBs)
- However, HFSS foods represent a larger tax base, which may raise equity concerns
- 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

# Policy implications

Recent EU COUNCIL DIRECTIVE 2022/542: "giving more flexibility to design VAT systems according to national policy priorities".

Amendment 27 to the EU Farm2Fork strategy: the EU parliament "supports 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."

# Policy implications

- The impact of such an approach on VAT revenue generation efficiency should be assessed
- Taxing foods based on their nutritional content at product-level may require a strong tax administration capacity and lead to non-negligible compliance costs
- Costa Rica: demand for UP foods and SSBs is price inelastic $\Rightarrow$ potential limitation for differentiated VAT rates to promote healthier diets
- Additional excise tax on HFSS foods may further disincentivize consumption
- Other complementary policies could be considered (e.g., front-of-pack labelling schemes, marketing restrictions)

# CONCLUSION

# Conclusions

- Increasing number of countries 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)
- Opportunity to use fiscal policies more broadly to impact the relative price of foods and beverages based on their nutritional impact
- Adopted **CBTBIF may not fulfil this potential**
- **CBTBIF includes many UP savoury foods** and is expected to lead to increased 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 HH
- Further investigation is needed to **assess administration complexity, distributional welfare, and tax revenue impacts**

# Thank you!

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# APPENDIX

# APPENDIX - PAHO's nutrient profile model

| **Sodium** | **Free sugars** | **Other sweeteners** | **Total fat** | **Saturated fat** | **Trans fat** |
|---|---|---|---|---|---|
| $\geq$ 1 mg of sodium per 1 kcal | $\geq$ 10% of total energy from free sugars | Any amount of other sweeteners | $\geq$ 30% of total energy from total fat | $\geq$ 10% of total energy from saturated fat | $\geq$ 1% of total energy from trans fat |

Source: *Pan American Health Organization (2016)*. Notes: mg: milligrams.

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# APPENDIX - Excise tax

Excise tax on non-alcoholic beverages (**not accounting for sugar content**, rates as of March 2019)

- Carbonated soft drinks: CRC 19.15 ($0.03) per L, representing approximately 12.8% of the retail price for regular pakaged soft drinks.
- Other liq bev (incl. bottled waters): CRC 14.21 ($0.02) per L, representing approximately 11.0% of the retail price for bottled water.

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# APPENDIX - Policy timeline

**Law 6826, 8 November 1982**
Created the VAT and the CBT with a 0% VAT rate.

**Law 9635, 3 December 2018**
Reformed the CBT to be subject to a 1% VAT rate and mandated the Ministry of Finance and the Ministry of Economy, Industry and Commerce to set the list of items based on the latest ENIGH data and the purchasing patterns of the 20% poorest households.

**Executive Decree 41615, 13 March 2019**
The Ministry of Finance and the Ministry of Economy, Industry and Commerce updated the CBT items list based on ENIGH 2012-2013 data.

**Law 9914, 19 November 2020**
Created the CBTBIF, replacing the CBT, mandating that the list of items be (1) selected by the Ministry of Finance and the Ministry of Economy, Industry and Commerce based on the latest ENIGH data and the purchasing patterns of the 30% poorest households and (2) be revised by the Ministry of Health to additionally account for nutritional aspects. The process also includes a mandatory public consultation period.

**March 2021**
The Ministry of Health and FAO proposed the CBTEN defined based on several nutritional, cultural, and economic criteria including processing levels, the content of key nutrients and vitamins, traditional Costa Rican foods, costs, and consumption patterns.

**Executive Decree 43693, 14 September 2022**
The Ministry of Finance, the Ministry of Economy, Industry and Commerce, and the Ministry of Health published the methods and criteria used to select CBTBIF items.*

**27 September 2022**
The Ministry of Finance, the Ministry of Economy, Industry and Commerce, and the Ministry of Health launched a 10-day public consultation on a proposed list of items to be included in the CBTBIF.

**Executive Decree 43790, 9 November 2022**
The Ministry of Finance, the Ministry of Economy, Industry and Commerce, and the Ministry of Health defined the final list of items included in the CBTBIF following Law 9914 and ENIGH 2018-2019 data.

**1 February 2023**
The CBTBIF entered into effect.

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# APPENDIX - Criteria CBTBIF

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**Criteria for inclusion in the CBTBIF (Executive Decree 43693 H-MEIC-S):**

Items are included in the CBTBIF if they fulfil the following two requirements (excluding ready-to-eat items):

1. At least 6.25% of the national total expenditure on the item is spent by the 30% poorest households
2. At least 2% of households within the 30% poorest households declare consuming the item

If an item only fulfils criterion 1), it is up to the Ministry of Health to decide on its inclusion in the CBTBIF, based on nutritional aspects.
The Ministry of Health can also propose to exclude an item fulfilling both criteria 1) and 2) if it deems the item not suitable for daily consumption from a nutritional perspective.

$\Rightarrow$ The final list of CBTBIF items needs to be agreed upon by the Ministry of Finance, the Ministry of Economy, Industry and Commerce, and the Ministry of Health.

# APPENDIX - CBT vs. CBTEN vs. CBTBIF

| ENIGH item code | Item description | CBT | CBTEN | CBTBIF |
|---|---|---|---|---|
| **UN COICOP 1.1.1: Cereal and cereal products** | | | | |
| 0005 | Baguette bread with cheese, sesame, etc | X | | X |
| 0006 | Baguette bread or italian bread | X | X | X |
| 0007 | White bread, french bread | | | X |
| 0010 | White bread, square | | | X |
| 0013 | Whole bread, bakery | | | X |
| 0014 | Whole wheat square bread (packaged) | | X | X |
| 0021 | Pita or Arabic bread | | | X |
| 0029 | Other savory breads | | | X |
| 0030 | Sweet bread roll | X | | X |
| 0031 | Sweet bread bonnet or homemade bread | X | X | X |
| 0032 | Bread with fruits | | X | |
| 0041 | Corn tortilla package | X | X | X |
| 0042 | Whole flour tortilla | | | X |
| 0052 | Biscuits, salty sticks of flour or cheese | | | X |
| 0086 | Sweet donuts, with icing | X | | |
| 0107 | Whole wheat sweet biscuits (extra fibre) | | X | |
| 0108 | Sweet biscuits without filling | | | X |
| 0110 | Crackers | | | X |

...

# APPENDIX - CBT vs. CBTEN vs. CBTBIF

| UN COICOP 1.1.9: Ready-made food and other food products (including condiments) | | | | |
|---|---|---|---|---|
| 0234 | Nutritious formula | | X | |
| 0235 | Milk formula, powdered | X | X | |
| 0552 | Mayonnaise, regular | | | X |
| 0554 | Mayonnaise, light | | X | X |
| 0741 | Chamomile, fresh | | X | X |
| 0745 | Oregano, fresh | | | X |
| 0748 | Parsley, fresh | X | X | X |
| 0758 | Thyme, fresh | | X | X |
| 0939 | Sodium bicarbonate | X | X | X |
| 0940 | Cinnamon | X | X | X |
| 0944 | Clove | | | X |
| 0946 | Cumin | X | X | X |
| 0948 | Broth or consommé cubes | X | | |
| 0961 | Ginger | | | X |
| 0963 | Yeast | X | X | X |
| 0970 | Black pepper | | X | X |
| 0972 | Baking powders | X | X | |
| 0975 | Salt, fine or coarse | X | X | X |
| 0980 | Vanilla | | X | |
| 0996 | Mustard | | | X |
| 0997 | Tomato pastes | | | X |
| 1006 | Ketchup | | | X |

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# APPENDIX - ENIGH 2018 descriptive stat

| | ENIGH 2018-2019 | | | | | |
|---|---|---|---|---|---|---|
| | Low-income (N=2453) | | Mid-high income (N=4592) | | Total sample (N=7045) | |
| | mean | sd | mean | sd | mean | sd |
| Area (rural = 1) | 0.45 | 0.01 | 0.22 | 0.01 | 0.29 | 0.00 |
| Size | 3.80 | 0.05 | 3.00 | 0.03 | 3.24 | 0.03 |
| Head sex (female = 1) | 0.40 | 0.01 | 0.38 | 0.01 | 0.38 | 0.01 |
| Head age (years) | 49.99 | 0.40 | 51.39 | 0.35 | 50.97 | 0.29 |
| Head completed primary school | 0.67 | 0.02 | 0.86 | 0.01 | 0.81 | 0.01 |
| Employed adults (all employed = 1) | 0.41 | 0.01 | 0.64 | 0.01 | 0.57 | 0.01 |
| Total monthly expenditure (CRC, 2018) | 113,941.17 | 2,464.23 | 148,661.03 | 2,479.00 | 138,243.33 | 2,084.56 |

*Source: Prepared by the authors using the study data. CRC: Costa Rican Colón (USD 1 = CRC 587, in 2019).*

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# APPENDIX - Food groups description

| Food group | Description | NOVA |
|---|---|---|
| Cereals | Breads, rice, flour, pasta, oat and other cereals, starches, tortillas | 1, 2, 3 |
| Dairy | Cheese, butter, cream | 2, 3 |
| Animal meat | Fish and seafood, beef, pork, poultry, animal fat, eggs, other types of meat | 1, 2, 3 |
| F&V | Fruit, vegetables, tubercules, legumes, nuts and seeds | 1, 3 |
| UP sweet foods | Sweets, pastries, breakfast cereals, biscuits, sweet dairy, ice creams, chocolates, cakes and sweet pies, cheese, food supplements | 4 |
| UP savoury foods | Cold cuts and sausages, ready-meals, salty snacks, sauces, meat and fish, condiments, breads, tortillas, salty pastries, margarine | 4 |
| Other foods | Condiments, oils, sugar, honey, salt, vinegar, other culinary ingredients | 1, 2, 3 |
| SSBs | Sugar-sweetened soft drinks, juices, nectars, energy and sports drinks | 4 |
| Non-SSBs | Coffee, tea, water, diet soft drinks | 1, 4 |
| Milk | Unsweetened milk | 1 |

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# APPENDIX - NOVA details

As described by *Martinez-Steele et al (Nature F, 2023)*:

- **Unprocessed or minimally processed foods**: Obtained from plants or animals and do not undergo any alteration or minimally processed (drying, fermentation, freezing, etc.)
- **Processed culinary ingredients**: Extracted from natural foods, use oils, fats, salt, and sugars in small amounts for seasoning/cooking and to create culinary preparations.
- **Processed foods**: Industrially-produced with salt, sugar, oil or other substances in significant quantities. Recognized as versions of the original foods. Most have 2 or 3 ingredients.
- **Ultra-processed foods**: Industrially-produced mostly from substances extracted from foods (e.g., hydrogenated fats) or synthesized in laboratories from food substrates or other organic sources (e.g., additives).

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# APPENDIX - Baseline av nut availability by AEU per day, 2018 - low-income

| | Energy (kcal) | Sodium (mg) | Sugar (g) | Sat fat (g) | Total fat (g) |
|---|---|---|---|---|---|
| Cereals | 761.7 | 196.8 | 3.3 | 1.4 | 7.2 |
| Dairy | 39.4 | 86.7 | 0.4 | 1.8 | 3.4 |
| Animal meat | 129.2 | 98.8 | 0.1 | 2.6 | 8.1 |
| F&V | 217.8 | 32.5 | 9.4 | 0.5 | 1.5 |
| UP sweet foods | 92.3 | 68.7 | 9.1 | 1.1 | 3.1 |
| UP savory foods | 142.1 | 544.5 | 1.9 | 2.4 | 9.4 |
| Other foods | 573.1 | 3,086.6 | 67.9 | 6.1 | 34.1 |
| SSBs | 35.7 | 4.4 | 8.4 | 0.0 | 0.0 |
| Non-SSBs | 1.0 | 2.1 | 0.0 | 0.0 | 0.0 |
| Milk | 52.2 | 52.5 | 5.6 | 1.1 | 1.8 |
| **Total** | **2,044.6** | **4,173.7** | **106.1** | **17.1** | **68.6** |
| **Total (% energy)** | **.** | **.** | **20.8** | **7.5** | **30.2** |

# APPENDIX - Baseline av nut availability by AEU per day, 2018 - mid-high-income

| | Energy (kcal) | Sodium (mg) | Sugar (g) | Sat fat (g) | Total fat (g) |
|---|---|---|---|---|---|
| Cereals | 701.8 | 218.7 | 3.2 | 1.3 | 6.7 |
| Dairy | 67.1 | 146.7 | 0.6 | 3.2 | 5.7 |
| Animal meat | 195.8 | 146.4 | 0.2 | 3.9 | 11.8 |
| F&V | 296.3 | 67.0 | 18.1 | 1.1 | 3.3 |
| UP sweet foods | 161.2 | 129.0 | 16.2 | 1.9 | 5.4 |
| UP savory foods | 243.3 | 809.4 | 3.5 | 3.6 | 15.0 |
| Other foods | 488.4 | 3,160.1 | 57.4 | 5.0 | 29.1 |
| SSBs | 58.9 | 7.6 | 13.8 | 0.0 | 0.0 |
| Non-SSBs | 2.0 | 3.1 | 0.2 | 0.0 | 0.0 |
| Milk | 64.1 | 64.2 | 6.9 | 1.3 | 2.1 |
| **Total** | **2,279.0** | **4,752.2** | **120.0** | **21.3** | **79.3** |
| **Total (% energy)** | **.** | **.** | **21.1** | **8.4** | **31.3** |

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# APPENDIX - Survey items & quant by sc

| | Baseline - CBT | | CBTBIF | | CBTEN | | NPM | |
|---|---|---|---|---|---|---|---|---|
| | # items | share q (%) | # items | share q (%) | # items | share q (%) | # items | share q (%) |
| Cereals | 11 | 98.2 | 21 | 99.8 | 10 | 96.1 | 24 | 87.5 |
| Dairy | 4 | 34.1 | 5 | 82.6 | 9 | 87.3 | 5 | 6.3 |
| Animal meat | 19 | 72.6 | 31 | 88.3 | 25 | 80.2 | 77 | 92.2 |
| F&V | 34 | 62.8 | 82 | 86.6 | 85 | 96.2 | 168 | 97.6 |
| UP sweet foods | 16 | 39.3 | 9 | 9.7 | 10 | 12.1 | 4 | 0.5 |
| UP savory foods | 15 | 40.8 | 26 | 67.7 | 7 | 16.0 | 8 | 6.1 |
| Other foods | 16 | 93.2 | 22 | 94.5 | 15 | 88.6 | 53 | 99.0 |
| SSBs | 2 | 15.9 | 1 | 0.1 | 1 | 0.1 | 2 | 0.1 |
| Non-SSBs | 1 | 87.2 | 4 | 88.6 | 2 | 88.1 | 10 | 96.2 |
| Milk | 6 | 92.7 | 9 | 100.0 | 7 | 99.2 | 9 | 100.0 |
| **Total** | **124** | **69.4** | **210** | **63.2** | **171** | **63.8** | **360** | **59.9** |

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# APPENDIX - Exp / Compensated

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| Food Group | Expenditure Elasticity | Compensated Own-Price Elast |
|---|---|---|
| Cereals | 1.034*** | −0.388* |
| | (0.119) | (0.207) |
| Dairy | 1.031*** | −0.673*** |
| | (0.132) | (0.166) |
| Animal meat | 1.300*** | −0.436*** |
| | (0.151) | (0.116) |
| F&V | 1.177*** | −0.586*** |
| | (0.067) | (0.167) |
| UP sweet foods | 1.029*** | −0.579*** |
| | (0.078) | (0.102) |
| UP savory foods | 1.176*** | −0.698*** |
| | (0.086) | (0.082) |
| Other foods | 1.301*** | −0.911*** |
| | (0.143) | (0.075) |
| SSBs | 0.965*** | −0.508*** |
| | (0.107) | (0.084) |
| Non-SSBs | 1.151*** | −0.757*** |
| | (0.093) | (0.069) |
| Milk | 0.993*** | −0.543*** |
| | (0.030) | (0.043) |

# APPENDIX - COICOP

| Change in quantity | Change in price | | | | | | | | Change total exp |
|---|---|---|---|---|---|---|---|---|---|
| | Cereals | Animal meat | Dairy | Oils & fat | F&V | Sugar & conf | Other food | Non-alc bev | |
| Cereals | −0.642** | −0.005 | 0.035 | 0.054 | 0.008 | −0.018 | −0.014 | 0.001 | 1.053*** |
| | (0.295) | (0.094) | (0.142) | (0.063) | (0.085) | (0.035) | (0.107) | (0.076) | (0.258) |
| Animal meat | −0.110 | −0.840*** | −0.079 | −0.016 | −0.149** | −0.107* | −0.101 | −0.051 | 1.425*** |
| | (0.098) | (0.107) | (0.123) | (0.044) | (0.065) | (0.062) | (0.083) | (0.097) | (0.287) |
| Dairy | 0.075 | −0.008 | −0.705*** | −0.013 | 0.025 | 0.053 | −0.010 | 0.018 | 1.032*** |
| | (0.153) | (0.068) | (0.061) | (0.045) | (0.055) | (0.044) | (0.093) | (0.041) | (0.071) |
| Oils & fat | −0.263 | −0.173 | −0.224 | −0.670** | −0.096 | −0.193** | −0.189 | −0.150 | 1.505** |
| | (0.511) | (0.190) | (0.269) | (0.296) | (0.131) | (0.083) | (0.490) | (0.202) | (0.675) |
| F&V | −0.016 | 0.018 | −0.008 | −0.021 | −0.886*** | 0.029 | −0.034 | −0.050 | 1.191*** |
| | (0.093) | (0.088) | (0.061) | (0.026) | (0.063) | (0.034) | (0.041) | (0.057) | (0.053) |
| Sugar & conf | −0.122 | −0.176 | 0.002 | −0.080** | 0.058 | −0.921*** | −0.032 | −0.020 | 1.180*** |
| | (0.077) | (0.136) | (0.039) | (0.036) | (0.093) | (0.131) | (0.075) | (0.083) | (0.128) |
| Other food | −0.036 | −0.029 | −0.039 | −0.034 | −0.027 | −0.001 | −0.872*** | −0.009 | 1.085*** |
| | (0.192) | (0.124) | (0.056) | (0.109) | (0.062) | (0.041) | (0.094) | (0.123) | (0.167) |
| Non-alc bev | 0.003 | 0.067** | 0.025 | −0.014 | 0.012 | 0.015 | 0.007 | −0.801*** | 1.004*** |
| | (0.091) | (0.034) | (0.077) | (0.037) | (0.053) | (0.025) | (0.071) | (0.099) | (0.091) |

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# APPENDIX - Derivation of AIDS model (1)

Price Invariant Generalized Logarithmic (PIGLOG) expenditure (cost) function *(Muellbauer, Econometrica, 1976)*:

$$\log c(u, \mathbf{p}) = (1 - u) \log \{a(\mathbf{p})\} + u \log \{b(\mathbf{p})\}$$

*Deaton & Muellbauer (AER, 1980)* show that the following choice has the required flexible form and can satisfy the necessary restrictions:

$$\log a(\mathbf{p}) = \alpha_0 + \sum_k \alpha_k \log p_k + \frac{1}{2} \sum_k \sum_j \gamma_{kj}^* \log p_k \log p_j$$

$$\log b(\mathbf{p}) = \log a(\mathbf{p}) + \beta_0 \prod_k p_k^{\beta_k}$$

# APPENDIX - Derivation of AIDS model (2)

$$\log c\left(u, \mathbf{p}\right) = \alpha_0 + \sum_k \alpha_k \log p_k + \frac{1}{2}\sum_k \sum_j \gamma^*_{kj} \log p_k \log p_j + u\beta_0 \prod_k p_k^{\beta_k}$$

Given its form, its indifference curves are convex and the Shephard's lemma applies. Therefore, the cost minimizing point for a given good $i$ with price $p_i$ is unique and $q_i = \frac{\partial c(u,\mathbf{p})}{\partial p_i}$.
And, we obtain: $\frac{\partial \log c(u,\mathbf{p})}{\partial \log p_i} = \frac{p_i q_i}{c(u,\mathbf{p})} = w_i$.

$$\frac{\partial \log c\left(u, \mathbf{p}\right)}{\partial \log p_i} = w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i u \beta_0 \prod_k p_k^{\beta_k}$$

# APPENDIX - Derivation of AIDS model (3)

Given that for a utility-maximizing consumer, cost is actually total expenditure, i.e., $c(u, \mathbf{p}) = x$:

$$\frac{1}{\beta_0 \prod_k p_k^{\beta_k}} \left[ \log x - \alpha_0 - \sum_k \alpha_k \log p_k - \frac{1}{2} \sum_k \sum_j \gamma_{kj} \log p_k \log p_j \right] = u(x, \mathbf{p})$$

$$w_i = \alpha_i + \sum_j \gamma_{ij} \log p_j + \beta_i (\log x - \log P)$$

$$\log P = \alpha_0 + \sum_k \alpha_k \log p_k + \frac{1}{2} \sum_k \sum_j \gamma_{kj} \log p_k \log p_j$$

Following *Pollak & Wales (Econometrica, 1981)*'s translating approach: $\alpha_i = \alpha_0 + \sum_{k \in K} \rho_{ik} z_k$.

# APPENDIX - Derivation of AIDS model (4)

We have by definition: $\begin{cases} w_i = p_i q_i / x \\ e_i = \partial \ln q_i / \partial \ln x \\ \varepsilon_{ij}^u = \partial \ln q_i / \partial \ln p_j \\ \varepsilon_{ij}^c = \varepsilon_{ij}^u + e_i w_j \quad \text{(Slutsky's equation)} \end{cases}$

$$e_i = 1 + \frac{\partial \ln w_i}{\partial \ln x} = 1 + \frac{\partial w_i}{\partial \ln x} / w_i = 1 + \frac{\beta_i}{w_i}$$

$$\varepsilon_{ij}^u = -\delta_{ij} + \frac{\partial \ln w_i}{\partial \ln p_j} = -\delta_{ij} + \frac{\partial w_i}{\partial \ln p_j} / w_i = -\delta_{ij} + \frac{\gamma_{ij} - \beta_i \alpha_j - \beta_i \sum_i \gamma_{ij} \ln p_i}{w_i}$$

with $\delta_{ij}$ the Kronecker delta, equal to one if $i = j$ and zero if $i \neq j$.

# APPENDIX - Derivation of QUAIDS elast

Similarly for QUAIDS:

$$e_i = 1 + \frac{1}{w_i}\left(\beta_i + \frac{2\lambda_i}{\prod_k p_k^{\beta_k}} \ln\left[\frac{x}{P}\right]\right)$$

$$\varepsilon_{ij}^u = -\delta_{ij} + \frac{1}{w_i}\left[\gamma_{ij} - \left(\beta_i + \frac{2\lambda_i}{\prod_k \; p_k^{\beta_k}} \ln\left[\frac{x}{P}\right]\right)\left(\alpha_j + \sum_k \gamma_{jk} \ln p_k\right) - \frac{\lambda_i \beta_j}{\prod_k p_k^{\beta_k}}\left[\ln\left[\frac{x}{P}\right]\right]^2\right]$$

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# APPENDIX - Two-step censored model

Fist step: Probit equations

$$d_{ih} = \mathbb{1}_{d^*_{ih}>0} = \mathbf{r}'_h\theta_i + \vartheta_{ih} = \sum_{j=1}^{I} \tau_j \ln \hat{p}_j + \pi_i lnx + \sum_{k\in K} \theta_k z_k + \vartheta_{ih}$$

Second step: Using first step estimates to calculate $\Phi\left(\mathbf{r}'_h\hat{\theta}_i\right)$ and $\phi\left(\mathbf{r}'_h\hat{\theta}_i\right)$

$$w^*_{ih} = \Phi\left(\mathbf{r}'_h\hat{\theta}_i\right) w_{ih} + \zeta_i\phi\left(\mathbf{r}'_h\hat{\theta}_i\right) + \epsilon_{ih}$$

where $[\vartheta_i, \epsilon_i]'$ are assumed bivariate normal with $(\vartheta_i, \epsilon_i) = \zeta_i$.

# APPENDIX - Main model elasticities

Given *Shonkwiler & Yen (AJAE, 1999)*'s two-step censoring approach result (similar to Tobit II), *Boysen (SAJE, 2016)* derives the following final expressions, conditional on positive demand from the first step (probit):

$$e_i = 1 + \frac{1}{w_i^*}\left[\Phi_i\left(\beta_i + \frac{2\lambda_i}{\prod_k \; p_k^{\beta_k}} \ln\left[\frac{x}{P}\right]\right) + \tau_j \phi_i \left(w_i - \zeta_i d_i^*\right)\right]$$

$$\varepsilon_{ij}^u = -\delta_{ij} + \frac{1}{w_i^*}\left[\Phi_i\left(\gamma_{ij} - \left(\beta_i + \frac{2\lambda_i}{\prod_k \; p_k^{\beta_k}} \ln\left[\frac{x}{P}\right]\right)\left(\alpha_j + \sum_k \gamma_{jk} \ln p_k\right)\right.\right.$$
$$\left.\left. - \frac{\lambda_i \beta_j}{\prod_k p_k^{\beta_k}}\left[\ln\left[\frac{x}{P}\right]\right]^2 + \tau_j \phi_i \left(w_i - \zeta_i d_i^*\right)\right]$$

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