The 'soda tax' is unlikely to make Mexicans lighter or healthier: New evidence on biases in elasticities of demand for soda

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The 'Soda Tax' is Unlikely to Make Mexicans Lighter or Healthier:

New Evidence on Biases in Elasticities of Demand for Soda

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Abstract

Mexico's 'soda tax' has been predicted to reduce average weight of Mexicans by up to three pounds, based on extant estimates of the own-price elasticity of quantity demand for soda of between −1.0 and −1.3. These elasticity estimates from household survey data are exaggerated by not accounting for how consumers adjust quality demanded as price changes. Some estimates also are biased by correlated measurement error. To illustrate these biases we use budget survey data and soda price data for Mexico to estimate demand models that correct for both errors. The corrected own-price elasticity of quantity demand is between −0.1 and −0.4, implying that the soda tax might cut average weight by just half a pound, which is too little to improve population health.

JEL Codes: D12, I10

Keywords: Demand, Household surveys, Quality, Price, Soda taxes, Mexico

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I. Introduction

Taxes on soft drinks with added sugar have been imposed in more than 20 countries, including France, Mexico, Norway, and the U.K. (Baker et al, 2017). The World Health Organization (WHO) has called on governments to use such fiscal measures to induce a shift towards healthier diets and argues that taxes that lead to at least a 20% increase in the retail price of these sugary drinks will result in proportional reductions in their consumption (WHO 2016). The idea that tax-induced price rises for sugary drinks cause consumption to fall at the same rate, implying an own-price elasticity of quantity demand of −1, is found well beyond the WHO. For example, a revenue calculator for sugary drink taxes in the United States uses an own-price elasticity of −1.2, based on a review by Powell et al (2013).[1] There are many similar elasticity estimates, such as: −0.9 for the United Kingdom (Briggs et al, 2013); −1.3 for New Zealand (Mhurchu et al, 2013); −0.9 for India (Basu et al, 2014); –1.1, –1.2 and –1.5 for Mexico (Colchero et al, 2015; Fuentes and Zamdio, 2014; Bonilla-Chancin et al, 2016); and –1.3 for Peru (Caro et al, 2017).

These elasticities from household survey data suggest a more elastic response to price than found with other data. For example, Arteaga et al (2017) use a monthly time series of industry sales data for soda in Mexico that shows an own-price elasticity of –0.3; just one-quarter as large as for prior studies with household survey data. Dubois et al (2017) use barcode scans by buyers of on-the-go drinks in the UK to estimate product level elasticities (e.g. for a 330ml can of *Coke*) that range from –0.9 to –2.5, but the group-level own-price elasticity for soda is just –0.3.

This paper seeks to explain why estimates of the own-price elasticity of soda demand from household surveys are so large and shows that exaggerated elasticities matter to predicted health effects of soda taxes, using Mexico as an example. Household surveys group diverse products together, as was first noted over sixty years ago, by Prais and Houthakker (1955, p.110):

> "An item of expenditure in a family-budget schedule is to be regarded as the sum of a number of varieties of the commodity each of different quality and sold at a different price."

There are many different brands, package sizes and so forth within survey groups – especially for soda – so a consumer faces two choices: they choose quantity as in the textbook model but they also choose *quality*. If this fact is ignored, quality responses to price get conflated with quantity

[1] See http://www.uconnruddcenter.org/revenue-calculator-for-sugary-drink-taxes for details.

responses, and estimated effects of price on quantity are exaggerated. These quality responses may matter especially in Mexico where the price premium for some soda brands and presentations (type and size of beverage container) gave great scope for consumers to buffer quantity by sliding down the quality ladder as prices rose. For example, prior to the soda tax, *Coke* sold at a 15% price premium over *Pepsi* (based on city-level prices for a 600 ml bottle). The gradient in price per liter due to container size was even steeper, with a 55% premium for buying *Coke* in 355 ml cans rather than in 600 ml bottles and about the same premium for 600 ml bottles over two liter bottles.

Using methods from prior Mexican studies (and widely used elsewhere), we get elasticity estimates of between −1.1 and −1.3. This range applies whether we use data from a single year or pool over 2012, 2014 and 2016. This range of estimates is close to what the prior studies reported, with surveys from 2002 to 2014. These estimates do not identify a price elasticity of quantity demand, and instead mix two separate consumer responses to price changes: adjusting the quantity of what is consumed, and adjusting the *quality* of what is consumed. Both responses are inherent features of household survey data (Deaton, 1990; McKelvey, 2011; Gibson and Kim, 2017) even though quality responses are usually ignored. If we allow for the quality response, the own-price elasticity of quantity demand for soda falls to just −0.1 to −0.4.[2]

We use Mexico to illustrate these biases, due to attention on the peso per liter tax on sugar-sweetened drinks imposed from January, 2014. This attention includes several recent estimates of soda demand that use data other than from household surveys, and these largely corroborate our estimates and cast doubt on the previous elasticity estimates. Also, Mexico is a good case for showing health implications of these elasticity biases. Grogger (2017) used some of the prior elasticity estimates, that ranged from −1.0 to −1.3, to predict soda consumption changes from the tax-induced price rises that he calculated; his conclusion that the soda tax may cut steady state weight of Mexicans by almost three pounds (1.3 kg) and the body-mass index (BMI) by 1.8% gets revised to a weight reduction of less than 300 grams and a fall in average BMI of just 1/200th – too small to have meaningful health benefits – once correct elasticities are used. This lack of impact is in line with some of the U.S. studies summarized in Cawley (2015), who also notes potential biases in elasticity estimates but not due to the unmodeled quality responses studied here.

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[2] Some price elasticity estimates for soda in Mexico are also likely to be biased by a correlated errors problem in double-log demand models, which is a less widespread error, internationally, than is ignoring quality responses.

It may surprise that quality responses to price have such big effects but the bias we show is in line with the few studies that account for these. In the first of these studies, quantity demand elasticities were inflated to an average of 250% of their correct value if quality responses are ignored (McKelvey, 2011).[3] That study had just six broad food groups in a spatially limited setting but a study for 45 food and drink items in Vietnam found an average four-fold exaggeration in the own-price elasticity of quantity demand if the quality response to price variation is ignored (Gibson and Kim, 2016). A study of soft drink demand found a two- to three-fold bias in the quantity demand elasticity in countries with large spatial price variation and little quality variation (Gibson and Romeo, 2017). In contrast, Mexico has large quality variation within soda and only moderate spatial price variation, so the bias is expected to be larger.

In the next section we provide background information on soda in Mexico, reviewing the literature that has estimated elasticities of demand and also highlighting the quality variation which has been ignored in analyses to date. In Section III we discuss biases in elasticity estimates from household survey data, which stem particularly from a failure to distinguish quality responses from quantity responses. Our database that combines price surveys with household surveys is covered in Section IV, while our empirical results are in Section V. The conclusions are in Section VI.

II. Background on Soda in Mexico

The prevalence of obesity in Mexico has risen rapidly. In 2012, 27% of adult males and 38% of females were obese; both rates were up about three percentage points from six years earlier (Bonilla-Chacín et al, 2016). Over 1-in-10 children aged 6-11 are obese. These poor health indicators have been linked to sugar consumption, particularly from soda and other sugary drinks that are calorie-dense but provide few nutrients (Malik et al, 2006). Mexicans are some of the world's biggest soda drinkers, so Mexico's Congress passed budget legislation in October 2013 to impose a one peso per liter tax on sugar-sweetened beverages (SSBs) from 1 January 2014.[4]

The effects of this tax on soft drink prices and demand are studied with various data. All

[3] The framework used by McKelvey (2011) is originally due to Deaton (1990) but Deaton lacked price data and so used a method based on weak separability (Deaton, 1988) that allows indirect estimates of the response of quality to price. If direct estimates of the price elasticity of quality are used, these weak separability restrictions are rejected in both Indonesia (McKelvey, 2011) and in Vietnam (Gibson and Kim, 2016).

[4] The legislation also includes an *ad valorem* 'junk food' tax equivalent to 8% of the value of high-calorie foods of low nutritional value, defined as foods containing 275 kcal or more per 100 grams. This does not apply to soda, since regular soda has less than 50 kcal per 100g.

studies find full pass-through into SSB prices, which rose about 12 percent. The estimated fall in quantity demand ranges from less than four percent (Arteaga et al, 2017) to about seven percent (Colchero et al, 2017). Notably, these demand reductions are inconsistent with the own-price elasticities of −0.9 to −1.6 estimated by the previous studies with household survey data. Debate about the effects of the tax extend to the health domain; Aguilar et al (2016) suggest no effect on total calories and on BMI, while the Grogger (2017) claim of a steady state weight reduction of up to three pounds and a 1.8% fall in the average BMI has already been noted.

The most inelastic response is found by Arteaga et al (2017), who use industry-level soft drink sales from January 2007 to March 2017, from Mexico's monthly manufacturing industry survey (EMIM). These data show that the tax caused a price increase of 12.8% and reduced per capita sales by 3.8%. These results imply an own-price elasticity of quantity demand for the soft drinks group as a whole, at the point of the tax increase, of −0.3. An earlier study that also used the EMIM data, to supplement the main focus on a consumer panel (Aguilar et al, 2016), found a 12% price increase and a 6.9% decrease in demand, implying an own-price elasticity of −0.6.

Three studies use consumer panels for big cities, and results imply own-price elasticities of about −0.5. Aguilar et al (2016) use the Kantar World Panel, with weekly purchases by 9,953 households in 92 cities. For soft drinks, which includes soda, nectars, concentrates and powdered mixes, prices rose 14% due to the tax and quantity demanded fell 6.7%, for an own-price elasticity of −0.5. Colchero et al (2016) use Nielsen homescan data for 6,253 households in 53 cities, from January 2012 to December 2014. The average volume of taxed items sold, made up of carbonated sodas and non-carbonated SSBs, fell by 6% in 2014 compared to the counterfactual volume they estimate. Colchero et al (2017) extend this study to December 2015; declines in average volumes in 2015 exceed those in 2014 (again, relative to their constructed counterfactual) and the pooled effect over the first two years of the tax was a 7.3% reduction, compared to what trends from 2012-13 would predict. The studies using Nielsen data did not calculate price changes, but based on the price rises calculated elsewhere, the volumetric demand changes imply own-price elasticities of −0.5 to −0.6.

The consumer panels lack national evidence, which comes every two years in the Income-Expenditure Household Survey (ENIGH, in Spanish). ENIGH uses daily recording for a week, at household level, and is fielded from August to November. The 2012 survey, fielded prior to the tax, showed a national average of 3.60 liters of soda purchased per capita, per week. The 2014 and 2016 surveys, also fielded from August to November, showed average per capita weekly purchases of 3.35 and 3.36 liters, and so declines relative to 2012 are 6.9% and 6.7%. These figures are for 'cola and flavored soda', and include untaxed diet soda but this has a very small share of the soft drink market in Mexico (Colchero et al, 2017).[5] ENIGH has a larger sample than the consumer panels (e.g. 70,311 households in 2016). Considering just cities, to compare with the consumer panels, the fall in purchased quantity is even less, with demand falling 5.9% from 2012 to 2014. In the largest cities that have a price survey (described below), quantity fell even less, with 2014 (2016) per capita purchases 4.8% (5.4%) below the level in 2012. Since this price survey also shows a tax-induced 12% increase in price, the implied own-price elasticity is around −0.4 to −0.5.

The ENIGH data suggest that the consumer panels slightly overstate the fall in demand, and hardly support a claim by Colchero et al (2016, 2017) that effects of the tax increased over time. This strengthening is not apparent in either the industry-level sales data, with Arteaga et al (2017) finding the tax is best treated as a one-off shock, or in the ENIGH data, which shows that the national demand fall from 2012 to 2016 is about the same as from 2012 to 2014.

2.1 Previous Elasticity Estimates from Mexican Household Surveys

The demand changes from Mexico's soda tax are consistent with own-price elasticities from −0.3 to −0.6 but elasticity estimates from previous Mexican studies using household survey data range from −0.9 to −1.6. As noted above, this apparently elastic response is consistent with what WHO expects and with elasticity estimates from other household surveys around the world. In this sub-section we describe the methods and results of these previous studies of elasticities in Mexico.

Six recent studies using ENIGH data have price elasticities for soda or for soft drinks (Table 1). The reported values are fairly stable across years, with own-price elasticities of quantity demand for soda of −1.5 in both the first (2002) and last (2014) year. The main results for our empirical illustration use the 2014 data, which should be relevant for evaluating bias in the earlier studies, given the temporal stability of the elasticities. The studies in Table 1 all use ENIGH data but do not use the price survey data that we use. Instead, the Table 1 studies rely on unit values (expenditures over quantities), which are commonly (but wrongly) used as proxies for price.

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[5] Appendix 1 has an extract from the ENIGH survey form to show the questions asked and the soft drink groups that are covered. There is no product disaggregation below the level of 'cola and flavoured soda' (group A220).

Studies (a) and (b) in Table 1 use the double-log functional form, so are conditional on positive demand. These two studies use household level unit values as a proxy for the market price of soda. Hence, any error in measuring soda quantities will create a spurious negative correlation between the dependent variable and the 'price' term. These two studies reported own-price elasticities for soda that ranged from −1.1 to −1.3.

The other four studies in Table 1 use budget share models, which allow observations on both purchasers and non-purchasers to be used.[6] Two of these studies, (c) and (d), use unit values, that are either averaged at the cluster level or regression-adjusted, as the proxy for price. The other two studies use the Deaton (1990) method, with cluster dummy variables used in an equation for budget shares and in one for unit values, which this method uses to proxy for quality. The reported demand elasticities range from −1.0 to −1.6, for groups that include soda, juice, and water.

The budget share for a homogeneous good is the product of price and quantity, over total expenditure. But household surveys aggregate over different varieties and brands, each of different quality and selling at a different price so budget shares may vary with adjustments on the quantity margin or on the quality margin. The need to account for quality responses is noted by the Deaton (1990) method used in studies (e) and (f), although results elsewhere show this method understates effects of price on quality and overstates quantity responses to price (McKelvey 2011; Gibson and Kim 2016). The other budget share studies in Table 1 use the wrong framework, for a standardized good for which quality variation is impossible. In this regard they typify many demand studies from around the world that misuse household survey data.

2.2 Evidence on Soda Quality Variation

Quality variation lets consumers buffer quantity as prices rise; for example, by switching brands. The scope for switching is shown in Figure 1, which plots the time series of the real price per liter for *Coke* and *Pepsi* in 600 ml bottles (the most popular container). Prior to the tax, *Coke* was 15% more expensive than *Pepsi*. This brand-related price gap meant that when the tax was imposed in January 2014 someone could switch from *Coke* to *Pepsi* and carry on paying roughly 15 pesos per liter and not cut soda quantity, with all the adjustment on the quality margin. If this brand switching

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[6] To model effects of tax-induced price changes on population health requires averaging over purchasers and non-purchasers. This averaging is like an aggregate demand model, breaking direct links to utility theory (Deaton, 1997 p.304-5) so censored demand approaches to deal with zero budget shares would be misplaced.

is ignored, the constant budget share would wrongly imply a price elasticity of quantity demand of −1. In fact quantities would be unchanged, given that all response was in terms of quality, so calorie intake and bodyweight would also be unchanged.

Another example is that Mexicans could switch to cheaper presentations to cope with the soda tax. Figure 2 shows the size-related price variation within *Coke*, in December, 2016 in a supermarket in Guadalajara where the lead author shops. The ratio of price per liter as one goes down the quality scale from a 235 ml glass bottle of *Coke* to a three-liter plastic bottle varies by a factor of more than three. A consumer willing to forego convenience, by buying larger bottles, could buffer their quantity consumed as prices rise. Any analysis of household survey data that ignores changes in within-group composition (such as from switching brand or container) will wrongly treat any change in spending as evidence of lower quantity consumed.

III. Sources of Bias in Quantity Demand Elasticities from Household Survey Data

Price elasticities of quantity demand estimated from household survey data are subject to several biases, discussed in Deaton (1987; 1989; 1990) and Gibson and Rozelle (2005; 2011). Here we use double-log and budget share models to discuss biases from correlated measurement errors, and from conflating consumer adjustment on the quality margin with adjustment on the quantity margin. Both biases are present in the Mexican studies using household surveys to estimate soda demand elasticities and result in exaggerated estimates of how quantity responds to price.

3.1 Double-log Models

The double-log model is used by studies (a) and (b) in Table 1. But rather than a soda price index, or a representative specification price (a proxy for group-level prices under Hicksian separability), these studies use a household-level unit value. To show the biases introduced, we consider the **"log quantity on log prices"** model for food group *G* that household *i* is surveyed as acquiring:[7]

$$\ln Q_{Gi} = \phi_G + \lambda_G \ln x_i + \eta_G \ln P_G + \rho_G \cdot z_i + \vartheta_{Gi} \tag{1a}$$

which depends on the log of household total expenditure, x_i, on the log of the price index for food group, P_G, on a vector of control variables, like household size, z_i, and on random errors, ϑ_{Gi}. The ENIGH survey (like other surveys) gathers data on groups of related items rather than on specific

[7] We say 'acquiring' not 'consuming' because soda is storable. Acquisition responses to price changes overstate consumption responses if consumers buy when prices are temporarily lower and stockpile to consume later. Wang (2015) finds that ignoring storage may exaggerate the own-price elasticity of quantity demand for soda by 60%.

products. Thus, we think of equation (1a) as representing a commodity-wise aggregate.[8]

The group-level price, P_G lacks an index i since it does not vary household-by-household even though prices will vary over time and space. A consumer may buy a different bundle within the items covered by group G than their neighbor who shops at the same stores and faces the same price structure, giving a difference in the expenditure per unit (the unit value, E_{gi}/Q_{gi}). However, that difference from their neighbor is the outcome of utility-maximizing choices over quantity and quality, rather than being a constraint (prices) that affect those choices. However, if household-specific unit values are used, the **"log quantity on log unit value"** model becomes:

$$\ln Q_{Gi} = \phi_G^* + \lambda_G^* \ln x_i + \eta_G^* \ln\left(\frac{E_{Gi}}{Q_{Gi}}\right) + \rho_G^* \cdot z_i + \vartheta_{Gi}^* \qquad (1b)$$

The (iso-)elasticity of quantity demand with respect to own-price from equation (1b), η_G^* will be larger (that is, more negative) than the true elasticity, η_G. Errors in reported quantity cause a spurious negative bias in the regression coefficient in equation (1b) but not in (1a). If the report is $Q_{Gi} \pm \varepsilon_{Q_{Gi}}$, where $\varepsilon_{Q_{Gi}}$ is a random error, then this error is passed into the residuals of equation (1a). However, for equation (1b) the random error is also in the denominator of the unit value (which can be defined as $\ln v_{Gi} \equiv \ln E_{Gi} - \ln Q_{Gi}$) so a common component is on the left-hand and right-hand side. No matter what the true relationship between price and quantity, the estimated relationship is more negative, by construction, due to this spurious negative correlation.

Random errors in reported quantity are quite likely for soda. The difficulty for people in recalling quantities, compared to recalling expenditures, is shown by many surveys that either do not ask about quantities at all, or ask about them for far fewer items than spending is asked about. Moreover, a lot of soda consumption is likely to take place outside of the purview of the household respondent, since soda is often bought with 'walking around money' by children going to and from school or by other householders at some location other than the homestead.[9] The respondent may

[8] Sufficient conditions for consistent aggregation are the Hicks (Leontief) composite commodity theorem, if prices (quantities) for items in the group move in exact proportion, the generalized composite commodity theory if price deviations for each individual food in the group are independent of income and of all group-level price indexes, or homothetic separability of utility (Shumway and Davis 2001). We assume at least one of these conditions holds, since we lack data on individual items within a food group to do the analysis at a more disaggregate level.

[9] Beverages are the consumption group with the biggest error when relying on one person to report on others in a survey experiment, due to people consuming outside the purview of the survey respondent (Friedman et al (2017).

know roughly how much was spent, say if they give pocket money to children, but not the quantity bought because they do not observe the purchase (and Figures 1 and 2 show that the same spending could result in quite different quantities bought).

The second reason for an exaggerated elasticity in equation (1b) compared to (1a) is that the unit values will tend to vary less over time and space than do prices if consumers react to high prices in local markets by buying lower quality goods. Thus, the same movement in the left-hand side variable (quantity) is attributed to smaller movement in the right-hand side variable (the unit value) than is the case when prices are on the right-hand side. Consequently, $\left|\eta_G^*\right| \geq \left|\eta_G\right|$ and since the elasticity is signed negative the bias due to quality substitution will be to make quantity demand appear as more price elastic than it truly is. This bias still occurs even if some sort of area-level average unit values, or regression-adjusted unit values are used, since households in high-priced areas will slide down the quality ladder as one way to cope with the higher prices, so the average unit value in those areas will be a smaller ratio of the average price than it is in cheaper areas.

3.2 Budget share models

A popular functional form has a dependent variable of w_{Gi}, the share of the budget devoted to food group G by household i. Budget shares are usually modeled as varying with log total expenditure, $\ln x_i$, the log of the price index for foods in group H (where θ_{GG} is for the own-price effect and θ_{GH} is for the cross-price effect), conditioning variables, z_i, and random noise, u:

$$w_{Gi} = \alpha_G^0 + \beta_G^0 \ln x_i + \sum_{H=1}^{N} \theta_{GH} \ln p_H + \gamma_G^0 \cdot z_i + u_{Gi}^0 \quad (2)$$

The budget share numerator is spending on group G, which can be written as the product of average expenditure per unit, v_{Gi} and group quantity, Q_{Gi}. Thus, budget share responses to price will involve both quantity adjustment (a change in Q_{Gi}) and quality adjustment (a change in v_{Gi}). Therefore, and in contrast to much of the applied literature that neglects this point, a second equation is needed to model quality choice (indicated by the unit value for group G, v_{Gi}):

$$\ln v_{Gi} = \alpha_G^1 + \beta_G^1 \ln x_i + \sum_{H=1}^{N} \psi_{GH} \ln p_H + \gamma_G^1 \cdot z_i + u_{Gi}^1 \quad (3)$$

The variables in equation (3) are as defined for equation (2), with superscripts 0 and 1 used to distinguish parameters on the same variables in each equation. Log-differentiating yields:

$$\partial \ln w_G / \partial \ln x = \beta_G^0 / w_G = \varepsilon_G + \beta_G^1 - 1 \quad (4)$$

$$\partial \ln w_G / \partial \ln p_H = \theta_{GH} / w_G = \varepsilon_{GH} + \psi_{GH} \quad (5)$$

where ε_G is the elasticity of quantity demand with respect to total expenditure, β_G^1 is the elasticity of the unit value with respect to total expenditure, ε_{GH} is the elasticity of quantity demand with respect to the price of *H*, which is the parameter of interest for evaluating effects of the soda tax, and ψ_{GH} is the elasticity of the unit value with respect to the price of *H*.

If equation (5) is rearranged, it becomes clear why one needs an equation like (3), for the household's choice of quality amongst the items within group *G*:

$$\varepsilon_{GH} = (\theta_{GH} / w_G) - \psi_{GH}. \quad (6)$$

Equation (6) shows that if one does not know how quality responds to prices, which can be derived from the ψ_{GH} term, one cannot identify the elasticity ε_{GH} that shows how quantity responds to prices. The rate that budget shares vary as prices vary, which θ_{GH} shows, does not by itself identify the quantity response to prices since any quality response also alters spending on group *G*, and thus alters the budget share. However, with data on budget shares, on prices, and on some indicator of quality, such as the unit value, equation (6) can be estimated, with input values from the estimates of equations (2) and (3). This is called the **"unrestricted method"** by McKelvey (2011) because no restriction is put on how the household's choice of quality responds to price variation.

Under the **"standard price method"** that ignores price-induced adjustment on the quality margin, the formula used for the elasticity of quantity with respect to price is:

$$\varepsilon_{GH} = (\theta_{GH} / w_G) - \delta_{GH}, \quad (7)$$

(where δ_{GH} equals 1 if *G*=*H*, and 0 otherwise). Comparing equation (6) and (7) shows that the standard price method, from a budget share regression and no equation (3) to account for quality choice, restricts unit values to move 1:1 with respect to own-prices ($\psi_{GG} = 1$). This is correct only for a standard, undifferentiated, good where adjustment on the quality margin is impossible. If consumers actually respond to higher own-prices by sliding down the quality scale, $\psi_{GG} < 1$ and quantity will be less own-price elastic than what is estimated by the standard price method.

The studies in Table 1 do not use price survey data, and instead estimate a variant of equation (2) with unit values in lieu of prices. Solving equation (3) for ln p_H and substituting the result into equation (2) shows that a budget share equation with unit values rather than with prices has a coefficient of $\psi_{GH}^{-1}\theta_{GH}$ rather than θ_{GH}. Since ψ_{GH} cannot be estimated without prices, the elasticity from equation (7) is unidentified, unless ψ_{GH} is somehow indirectly derived. Typically, it is assumed that $\psi_{GG} = 1$ so that $\psi_{GG}^{-1}\theta_{GG} = \theta_{GG}$; within-group quality substitution is thus ruled out by this **"standard unit value method"**. This method is used by study (c) in Table 1.

A practical issue is that unit values are only available for purchasers, while prices apply to all households. Thus, cluster averages (based on survey enumeration areas, or larger areas) of the unit values are often used so that the budget share equation can be estimated on all observations. Relatedly, the **"Cox and Wohlgenant method"** regresses deviations of unit values from their period *t* and region *r* means on *j* attributes of household *h*, to partition into quality effects due to the attributes and into a residual that is meant to show non-systematic supply factors:

$$v_G^{htr} - \bar{v}_G^{tr} = \sum_j \gamma_{Gj} b_{Gj}^{htr} + e_G^{htr} \tag{8}$$

for $\bar{v}_G^{tr}$ region/period mean unit values, b_{Gj}^{htr} household attributes, and e_G^{htr} residuals. The 'quality-adjusted price' for each purchasing household is then calculated as:

$$p_G^{htr} = \tilde{p}_G = \bar{v}_G^{tr} + \hat{e}_G^{htr} \tag{9}$$

So the region/period mean unit value is augmented with the unexplained component of household-specific deviations from that mean. For non-purchasing households, the 'quality-adjusted price' is based on the mean unit value, $\bar{v}_G^{tr}$. The 'quality-adjusted price' is then used in equation (2) with elasticities calculated according to equation (7). Study (d) in Table 1 uses this method.

However, even if regression adjustments could make unit values like prices; in not varying with household characteristics, in showing supply-side factors like transport costs, and in having data for all households, there will still be a bias. One needs two equations to study responses that can occur on two margins, so irrespective of adjusting unit values, a single equation framework will yield biased elasticities. The standard unit value method, the Cox and Wohlgenant method, and the standard price method all force a two-choice problem into a single equation framework that cannot be expected to identify either the price elasticity of quantity or the price elasticity of quality, and instead will yield some unidentified hybrid of these two types of responses.

The only unit value method to allow consumer's joint choice of quantity and quality (with the right equation (6) elasticity formula) is the **"Deaton method"**. Studies (e) and (f) in Table 1 use this. Deaton (1990) imputed quality responses, so that quantity elasticities can be recovered from observed changes in budget shares, by using weak separability restrictions to derive ψ_{GH} from the income elasticity of quality (that is, from β_G^1 which is observable since household incomes and unit values are observed) and from the price and income elasticities of quantity:

$$\frac{\partial \ln v_{Gc}}{\partial \ln p_{Hc}} = \psi_{GH} = \delta_{GH} + \beta_G^1 \frac{\varepsilon_{GH}}{\varepsilon_G} \tag{10}$$

In order to get the parameters needed for equation (10), Deaton's method estimates variants of equations (2) and (3) that use cluster dummy variables instead of the unavailable prices. The bias from measurement error is accounted for in a between-clusters, errors-in-variables framework.

Despite the pedigree of the method, the limited empirical evidence is that it tends to overstate ψ_{GG} and thus understate within-group quality substitution. Hence, own-price elasticities of quantity demand are exaggerated. For example, a study of 45 food and drink items found that the unrestricted own-price elasticity of quantity demand averaged −0.20 while the Deaton method gave an average value three times as large, of −0.60 (Gibson and Kim 2016).

In Section V we report price elasticities of quantity demand for soda in Mexico that come from each of the methods discussed here. Specifically, by using budget share regressions and unit value equations we derive unrestricted elasticity estimates (based on equation (6)), and these are contrasted with estimates from the standard price method, from the Deaton method, from two variants of the standard unit value method, and from the Cox and Wohlgenant method. For the double-log functional form we compare results with unit values used on the right-hand side (which makes elasticities susceptible to bias from correlated measurement errors and from ignored quality response to price) with results when prices are on the right-hand side.

IV. Data Description

To use the methods highlighted in Section 3 we need data on soda quantity, budget shares, and prices. The prior studies covered in Table 1 have not used price data, ignoring the fact that each month, Mexico's Statistics Institute (INEGI, in Spanish) reports prices of 282 goods and services (101 are foods and beverages) in 46 cities. The surveyed prices are derived from barcode scanning and are from a representative sample that includes supermarkets, department stores, convenience stores, markets, and street vendors, with prices gathered several times during a month. From these surveys, monthly average prices of soda in pesos per liter for various specifications are reported by INEGI, and we average these to obtain a monthly price for soda in each city.[10]

Figure 3 shows where the INEGI price survey is fielded. The cities are spread over Mexico; each state has at least one city surveyed and no municipality has more than one surveyed.[11] In order to illustrate some forms of within-group quality substitution it is helpful to group the cities into those with higher, medium and lower soda prices. Generally, the higher priced cities are either big ones (Mexico City and Monterrey) or close to the US border.[12]

The budget shares, quantities, unit values, and covariates other than prices are from the ENIGH. This cross-sectional, nationally representative survey is fielded by INEGI every two years. For seven days, the householder in charge of expenditures reports household purchases, and also consumption from own-production and gifts, for 254 food, drink, and tobacco products. Each day enumerators visit the respondent to check that information recorded the previous day is correct. The survey also uses mixed period recall for a further 500 goods and services. With these data on the expenditures and quantity of soda purchased, and also otherwise acquired (from gifts and other non-purchases), unit values for purchases, and also for all-acquisitions can be calculated.

The prior studies for Mexico covered in Table 1 mostly use a single cross-section, or give results on a cross-section by cross-section basis. This is also typical of other countries, where identification is mainly from spatial variation in prices. To replicate this approach, we especially use the 2014 ENIGH, whose sample is more than twice as large as the 2012 survey and whose temporal coverage overlaps with one study covered in Table 1. However, our sensitivity results use the 2016 ENIGH or pool the three surveys from 2012 to 2016 and these show very similar results to what we get just using the 2014 data.

We therefore concentrate our data description on the 2014 survey, with summary statistics in Appendix 2. Summary statistics for the other years are available from the authors. We show statistics for the unconditional sample that includes zero purchasers (used in all budget share

[10] The pattern of results across the various methods is robust to using arithmetic, geometric, or harmonic means of the prices. The results reported below are based on arithmetic means for city-level prices.

[11] Municipalities are the administrative level below states, and localities are the next level down.

[12] The city groups in the map use the 2012 and 2014 prices (corresponding to when ENIGH was fielded). The stable patterns are seen in correlations between years (2012, 2014, 2016) in cross-city prices that range from 0.91 to 0.96.

models) and for the conditional sample that purchased soda (used in double-log quantity demand models). We only include households whose municipality of residence matches to the city-level price data from INEGI, which reduces the national-level sample from 19,124 to 12,158 households. The sample further reduces to N=12,087 after trimming outliers (see below) and any observations with missing data. We also report estimates for the urban localities sub-sample that matches even more closely to the locations where INEGI surveys prices (N=9,654 households).

V. Results

Our main analysis uses household-level data to estimate the models highlighted in Section 3. We start, however, with a 'meso-level' analysis of quality responses to soda prices based on city-level averages. Unmodeled quality responses are a key reason for why many reported price elasticities from household surveys are so large, and the city-level data illustrate these responses clearly.

Average soda prices in the most expensive tercile of cities are about one-third higher than in the cheapest tercile of cities. However, average unit values do not vary anywhere near as much over space, being only 8% higher in the most expensive tercile of cities (Table 2, panel A). Thus, the ratio of the average unit value for soda to the average price varies from 0.95 in the cheapest cities to 0.77 in the dearest. Thus, where soda is more expensive, consumers, on average, seem to move down the quality ladder to cope with the higher prices, lowering their average unit values.

This same coping effect is seen in the temporal changes in panel B, that reports how soda prices and unit values changed between 2012 and 2014, with these changes due to the peso per liter soda tax. In real terms, average soda prices in these 46 cities rose 12% between 2012 and 2014; roughly what the manufacturing industry survey and the other data discussed in Section 2 show. The prior studies ignore variation in prices across cities, and so do not note that the rate of price increase in cheap cities (18%) was double that in expensive cities (9%). This is expected with a specific tax. The average unit values for purchased soda rose by only one-half of the rate of increase in prices; the pass-through rate was slightly lower in the cheapest cities (Figure 4). Unit values for all-acquired soda (that includes gifts and other non-market sources) show even less pass through, rising just 5.4% from 2012 to 2014. This incomplete pass through is exactly what would happen if consumers respond to suddenly higher prices (that rose proportionally more in cheap cities) by downgrading the quality of what they drink, as one way to cope with the price increase.

These quality adjustments will lead to overstated estimates of quantity demand responses via two paths. First, if a study uses budget shares, and ignores quality responses (e.g. using the equation (7) elasticity formula for the standard price method), the lower spending due to quality downgrading will be mistakenly treated as less quantity consumed. Second, even if a study has data on quantities, if unit values are used as a proxy for price, as in prior studies for Mexico, the quantity demand response will seem more elastic than it truly is because the quantity change is related to the smaller movement in unit values rather than to the actual (larger) movement in prices. For example, in the ENIGH data the average quantity of soda acquired by households declined 4.6% across these cities from 2012 to 2014. If this is compared with the 5.4% increase in the average unit value (for all-acquisitions), an own-price elasticity of quantity demand of −0.85 is implied. Yet the actual rise in real prices was much larger, at 11.9%, and using that figure gives an elasticity of quantity demand for soda with respect to own-price of just −0.38.

5.1 Household-Level Evidence

Table 3 has estimates of the own-price elasticity of quantity demand for soda from the eight methods highlighted in Section III. To ensure the results are robust to outliers, the estimates use four, successively smaller, samples by trimming observations with prices or unit values more than 5, 4, or 3 standard deviations from the mean. The smallest sample is for households just from urban localities within the municipalities where the INEGI price survey is carried out, since these should best match prices that are obtained from urban retail establishments. The estimates use the ENIGH household survey data and the INEGI price data for 2014, relying on cross-city variation in price and also between-month variation for the August to November period when the ENIGH is fielded.

A total of 40 equations are estimated to get the elasticities reported in Table 3; budget share and unit value equations for the unrestricted method and for the Deaton method, budget share equations for the standard price method, for two standard unit value methods and for the Cox and Wohlgenant method, and double-log models with prices and with unit values. These equations include 22 control variables other than prices or unit values and total expenditures; household size, five age and sex ratios, seven attributes of the household head (for age, gender, education, marital status, and ethnicity), three area characteristics (altitude, latitude and urbanity) and six regional fixed effects.[13] Since this is too much detail to report, the full regression results for each method

[13] We include area characteristics and fixed effects in order to provide a short-run interpretation for the elasticities; such elasticities are more appropriate than long-run price ones for considering price reforms (Deaton, 1997, p.323).

are reported for just one sample (where outlier trimming is at ± 5 SD) in Appendix 3.

When methods based on budget share regressions are used, and quality substitution is ruled out, due to using either the standard price method, the standard unit value method, or the Cox and Wohlgenant method, the own-price elasticity of quantity demand for soda is estimated to be from −1.25 to −1.30, when we use the largest, least-trimmed sample. The elasticities are very stable across the different samples, and even if we restrict attention just to urban localities there is a similar range of estimated elasticities, from −1.21 to −1.25. When the Deaton method is used, which allows for within-group quality substitution in principle but in practice understates quality responses and overstates quantity responses (McKelvey 2011; Gibson and Kim 2016), the results are similar to those from the standard price method and to the other unit value methods, with own-price elasticities that range from −1.15 to −1.18.

Thus, using budget share methods like those used in four of the six prior Mexican studies summarized in Table 1, we get a similar range of elasticities. For example, the mean elasticity in Table 1, for studies with budget shares, is −1.2. Our estimates with similar methods are from −1.2 to −1.3. We also use the standard price method, not used in Mexico but common internationally (e.g Mhurchu et al, 2013), with city-level prices in the budget share equation and this gives results that are similar to when unit values are used. So there should be nothing about our sample or our other procedures that is out of line with these previous studies. Thus, we should have a good basis for illustrating biases since we can recreate similar estimates to what previous studies report.

The bias appears to be very large, and is consistent with the discussion in Section III. When the unrestricted method is used, with a budget share equation and a unit value equation so as to study consumer responses on two margins, and using INEGI price survey data on the right-hand side of both equations, the own-price elasticity of quantity demand for soda is only −0.3. This elasticity estimate is stable across the various samples and is similar to what the city-level averages in Table 2 showed. This elasticity is also consistent with the evidence for Mexico summarized in Section 2 that was not from household surveys. Thus it appears that budget share methods used in prior studies, which mix up consumer responses on the quality margin with those on the quantity margin (or else constrain quality responses to be what weak separability allows, as in the Deaton method), lead to elasticities of quantity demand that are overstated by a factor of up to four.

The double-log quantity demand models show an even larger bias, from correlated errors if soda quantity is mis-reported, and from smaller inter-city variation in unit values than in prices. When log quantity is regressed on log prices, along with all of the control variables, the own-price elasticity is approximately −0.2. This elasticity is conditional on a household purchasing a positive quantity, so it is not necessarily comparable to elasticities from budget share methods that average over purchasers and non-purchasers alike.[14] When the household-specific unit values are used, as in study (a) and (b) in Table 1, the magnitude of the elasticity becomes more than six times larger, and ranges from −1.27 to −1.33. Evidently, household-specific unit values on the right-hand side of a double log demand model induce a very substantial bias in elasticity estimates.

5.2 Sensitivity Analysis: Including Cross-Price Effects

The elasticities in Table 3 are from models where the only price (or unit value) that is controlled for is soda, and other beverages are not considered. Since the Mexican studies in Table 1 also include beverages such as milk, bottled water, and juice, the results in Table 3 may not be a fair basis for assessing biases in the previous literature. Therefore, in Table 4 we report results where we consider budget share models for four beverages: soda, milk, water, and juice, which depend on prices (or unit values) for the same four beverages. Given that results for the various unit value methods in Table 3 were so alike, we only use the standard unit value method based on the all-acquisitions unit values, along with the Deaton method, the standard price method, and the unrestricted method.

The inclusion of the cross-prices in Table 4 makes the own-price elasticity of quantity demand for soda slightly less elastic than in Table 3, for the unrestricted method, the standard price method and the Deaton method. Still, including cross-prices does not change the main finding that commonly used methods overstate the rate of soda quantity responses to own-price. The unrestricted own-price elasticity of demand for soda in Panel A of Table 4 is −0.22, while the estimates from the other three methods are between −1.07 and −1.32. In comparison to models without cross-prices (shown in the first column of Table 3 for the same sample) the degree of bias from using the standard methods is, proportionately, slightly larger with cross-prices included than without. Thus, there is no reason to believe that our evidence on likely bias in the prior elasticity studies for Mexico is

[14] We also used two approaches to deal with households with zero quantities that are not reported in the table; a two-part model, and using the inverse hyperbolic sine (IHS) transformation since the IHS is defined for zero quantities. A probit showed no effect of prices on household's participation in soda acquisition and so the combined elasticity from the two-part model, −0.13 hardly differed from the conditional elasticity from the double log model reported in Table 3. If the IHS transformation is used, the own-price elasticity of quantity demand is −0.19, where this is estimated from the full sample of n=12,087 households.

sensitive to the use of different (or no) sets of cross-prices.

The bias from conflating consumer adjustment on quality and quantity margins is not confined just to elasticity estimates for soda demand. Comparing the own-price elasticities for milk, water, and juice from Panel A with corresponding elasticities in the other three panels of Table 4, overstated quantity responses to own-price are also apparent, albeit not as marked as for soda. For milk, water and juice the unrestricted method gives own-price elasticities that are from 40-50% of the magnitude of what the standard (and Deaton) methods say, while the unrestricted elasticity for soda is only about 20% of what the other methods suggest. Evidently, the greater range of qualities within the soda group gives more scope for adjustment on the quality margin, and therefore more potential for bias when this adjustment is ignored, than is the case for the other beverages.

The cross-price elasticities in Table 4 are not subject to any homogeneity or symmetry constraints, so the data speak most freely about effects of quality substitution. These unconstrained cross-price elasticities suggest that soda demand is affected by the price of bottled water. The reverse effect of soda prices on the demand for water highlights sensitivity to the different methods; the standard price method and the Deaton method show no effect, the standard unit value method shows a positive effect and the unrestricted method shows a negative effect. With the unrestricted method, the effect of soda prices operate through qualities; unit values for bottled water are higher (conditional on bottled water prices) in places where soda prices are higher (giving a positive ψ_{GH} term to subtract from an effect of soda prices on bottled water budget shares that is almost zero). The standard unit value method also differs from the other three methods in its estimates of the effect of milk prices on water demand, and the reverse, and the effect of juice prices on milk and water demand. Thus, there are likely to be more complicated cross-price relationships between the quantity and quality of related items than what is shown by the standard methods.

5.3 Sensitivity Analysis: Results for 2016 and Pooled Results for 2012, 2014 and 2016

Our main results use the ENIGH data for 2014. Using a single year matches what was done previously in Mexico, with four of the six studies in Table 1 using ENIGH data for just one year and the other two reporting year-by-year estimates. Thus, the variation is over space rather than over time and space. Relying on a single ENIGH raises the question of whether results are specific to that year.

In Table 5 we report results for the 2016 ENIGH (and INEGI prices for August to November). This table is directly comparable to Table 3, with the results for 2014, and the findings are the same.

If we use budget share models, like those used previously in Mexico, the own-price elasticity of quantity demand ranges from −1.1 to −1.3. If we use the standard price method – not previously used in Mexico but common elsewhere – the elasticity has the same range. In contrast, the own-price elasticity of quantity demand for soda from the unrestricted method is only from −0.1 to −0.4. The results for the double log models, based on conditional demands, are also very similar in 2016 to what they were in 2014. Hence, the results in Table 5 suggest that there was nothing unusual about 2014, and so the biases we show with the data from that year should hold more broadly.

Finally, we consider results when data from the 2012 survey (which had a much smaller sample) are pooled with those from 2014 and 2016. This pooled dataset spans the introduction of the soda tax, which provides an exogenous source of price variation. Notably, results in Table 6 are very much like those in Tables 3 and 5. The unrestricted method gives own-price elasticities of quantity demand for soda that range from −0.15 to −0.36 while all of the other budget share methods give elasticities between −1.09 and −1.32. If the double log model is used, and the household-specific unit values are used as a proxy for price, elasticities are from −1.30 to −1.32, but if market prices are used in the double-log model the elasticities are just −0.11 to −0.19.

VI. Discussion and Conclusions

Taxes on sugary drinks are being imposed in many countries. Proponents assume that quantity demand for such drinks is highly responsive to own-price so that taxes will help deal with problems like obesity. The price elasticities of demand reported by applied economists over many decades likely contribute to this view. Yet much of this evidence is from household surveys, whose data are not like the textbook demand model because expenditures and budget shares vary with choices that consumers make on the quantity and quality margins.[15] If quality responses are ignored they get bundled in with quantity responses, causing the effect of price on quantity to be exaggerated. This has been known at least since Deaton (1990) but just three published papers have used the unrestricted method that deals with these issues.[16] A further problem with household survey data is that researchers may use household-level unit values as a proxy for price, making elasticities susceptible to correlated measurement error if demand models are in terms of quantities.

[15] The same issue affects scanner data if researchers aggregate UPC-level items into broader categories, as done, for example, by Zhen et al (2011) who formed a "regular carbonated soft drink" group that will have varying qualities.
[16] McKelvey (2011), Gibson and Kim (2013), Gibson and Romeo (2017).

In this paper we show that these biases matter very much for Mexico, where effects of the soda tax are closely studied. The own-price elasticity of quantity demand for soda is overstated by a factor of four when we use standard budget share methods that rule out any possible consumer adjustment on the quality margin. There is a similar overstatement when Deaton's method, which constrains quality responses to be what weak separability allows, is used. A feature of the Mexican literature is the use of double-log models; when these have household-level unit values on the right-hand side the bias is even larger – with a six-fold exaggeration in the own-price elasticity of demand for soda. These biases are stable over time, with our single-year estimates for 2014 and 2016 very similar to what we get when we pool the data from 2012 to 2016. The elasticities that allow for quality responses are consistent with the aggregate changes in soda demand in Mexico shown by various data (summarized in Section 2) while the uncorrected elasticities are not.

Biased elasticities from ignoring consumer quality responses matter to predicted health effects of soda taxes. A rule-of-thumb from Hall et al (2011) is that a 100 kilojoule change in daily dietary energy gives a one kilogram change in steady-state bodyweight. Grogger (2017) uses this rule, and soda quantity changes he predicted by using extant estimates of the own-price elasticity of demand of −1 to −1.3, when claiming the soda tax will cut steady state weight of Mexicans by 0.8 to 1.3 kg, and lower average BMI by up to 1.8%. If these elasticities were correct, tax-induced soda price increases of at least 12% found by all studies using various Mexican data should cause falls in quantity demand of 12-15%. Yet, the estimated fall in soda quantity demand is just 4-7%. This discrepancy is because prior reports of the own-price elasticity of soda demand in Mexico are exaggerated due to a failure by researchers to use household survey data appropriately, through accounting for quality responses to price. The methods used by prior studies in Mexico are widely used internationally, so this bias is likely to occur in other countries as well. Once appropriate methods are used, the own-price elasticity of soda demand falls to about one-fourth the incorrectly estimated value, so using the Hall et al rule-of-thumb, the expected bodyweight reduction due to the soda tax should be just 0.2 to 0.3 kg (about half a pound) and the fall in average BMI will be just 1/200th. These effects are too small for the soda tax to improve population health.

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Figure 1: Brand-Related Quality Premium for Soda
(Based on 2800 city-month price survey observations by INEGI)

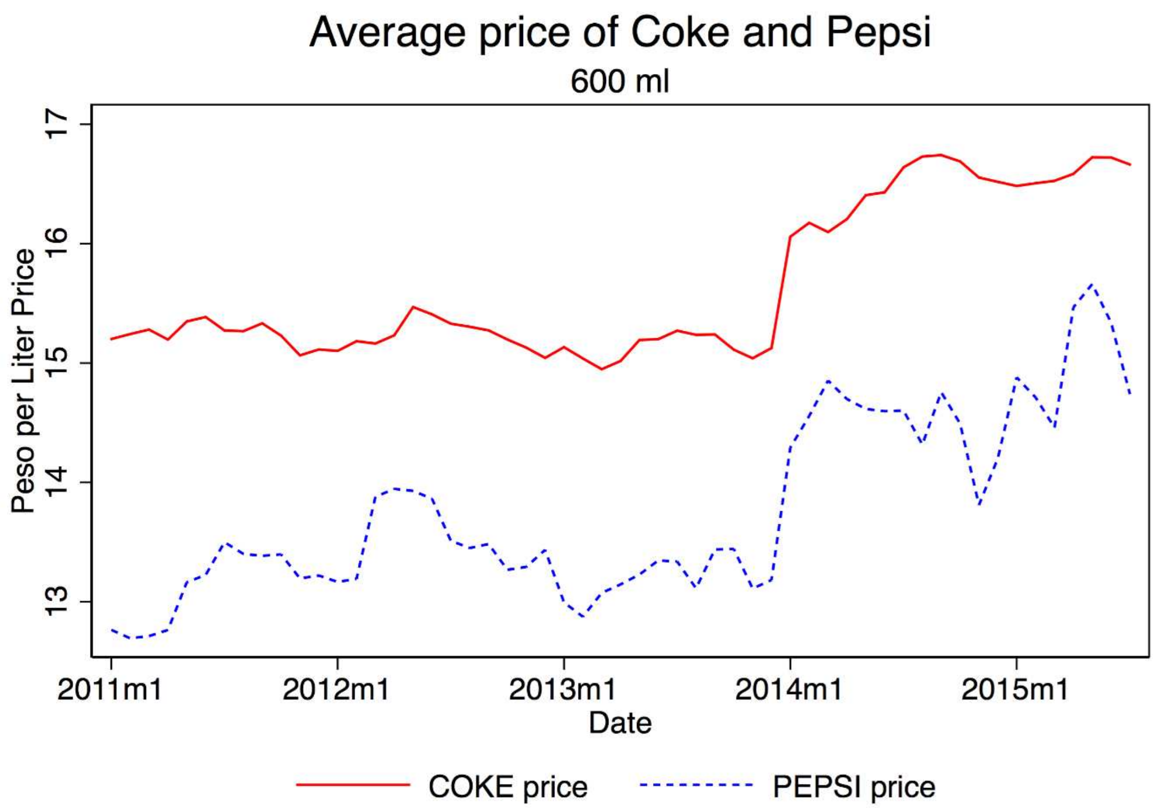

Figure 2: Size-Related Quality Premium for Soda (*Coke* in Different Presentations) Based on Author's Observations from a Supermarket in Guadalajara (December, 2016)

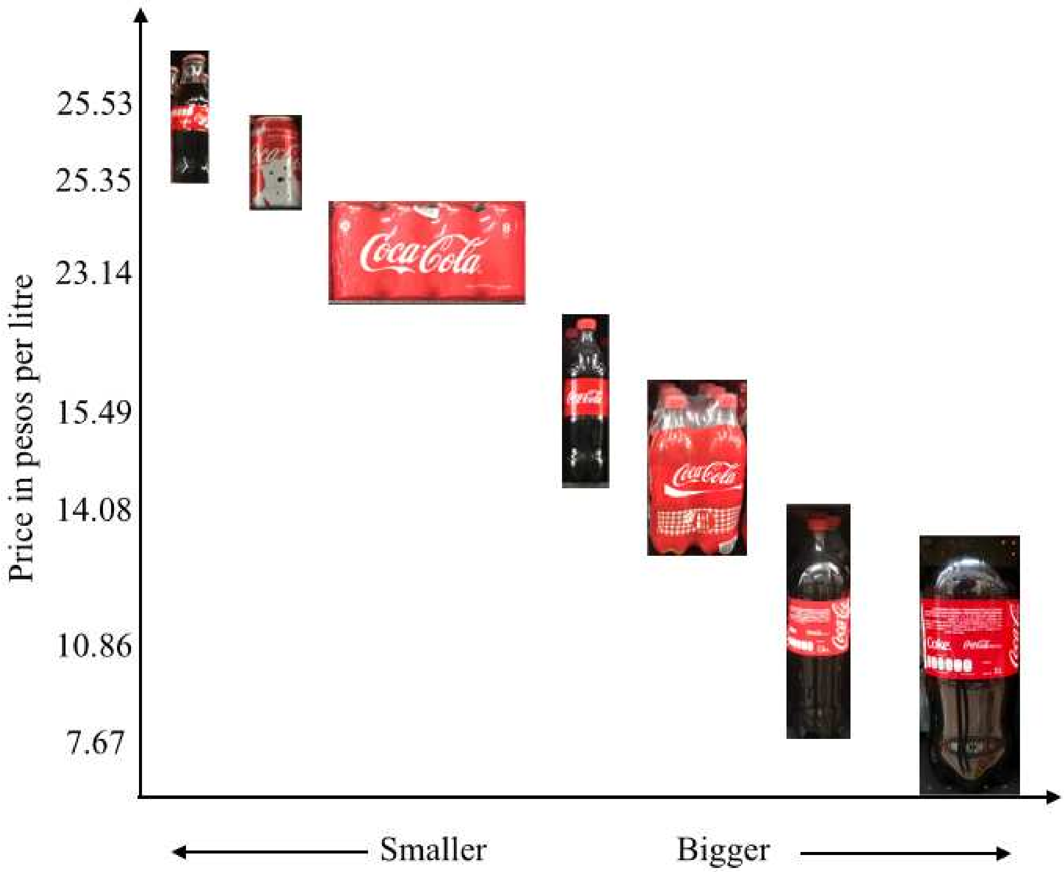

Figure 3: Cities With Monthly Soda Prices, from INEGI Retail Price Survey for Basic Goods

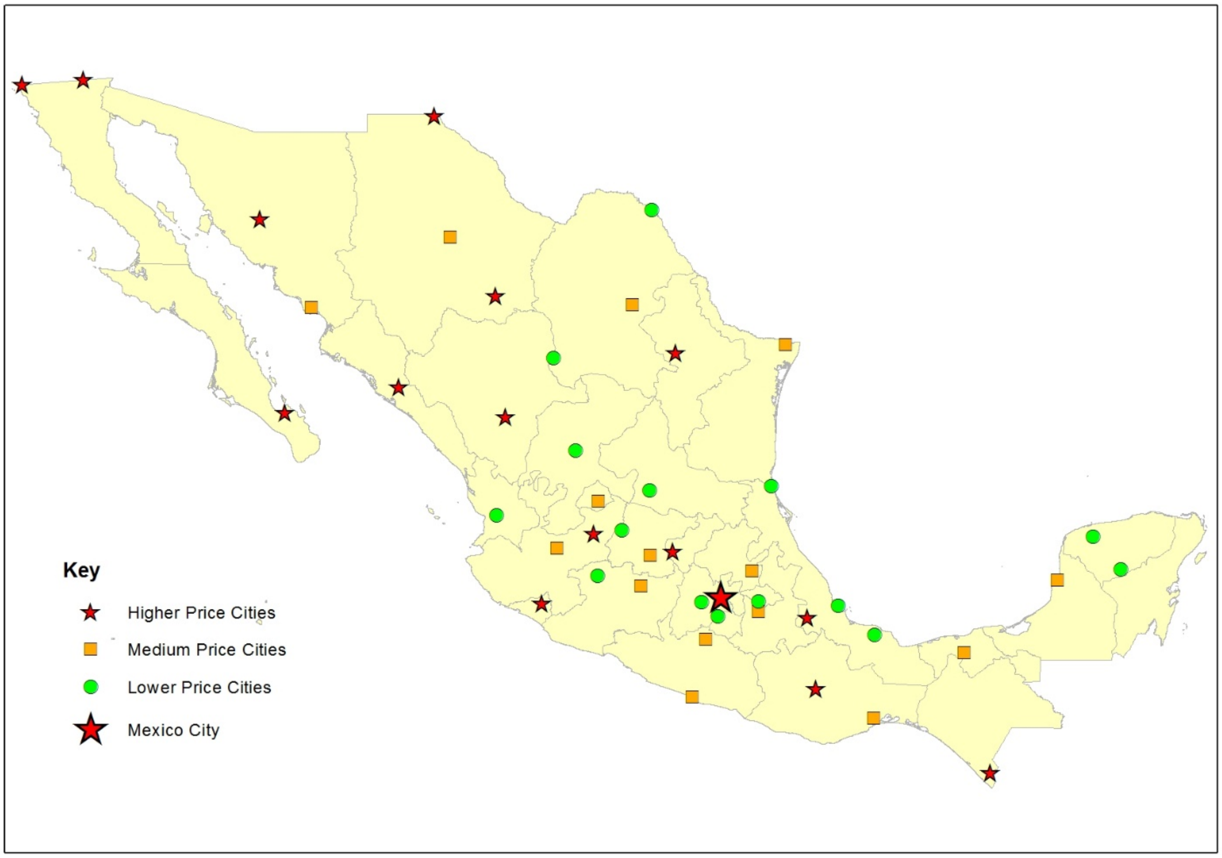

Figure 4: Only Partial Pass-Through Of Higher Soda Prices into Soda Unit Values, Indicating Quality Downgrading

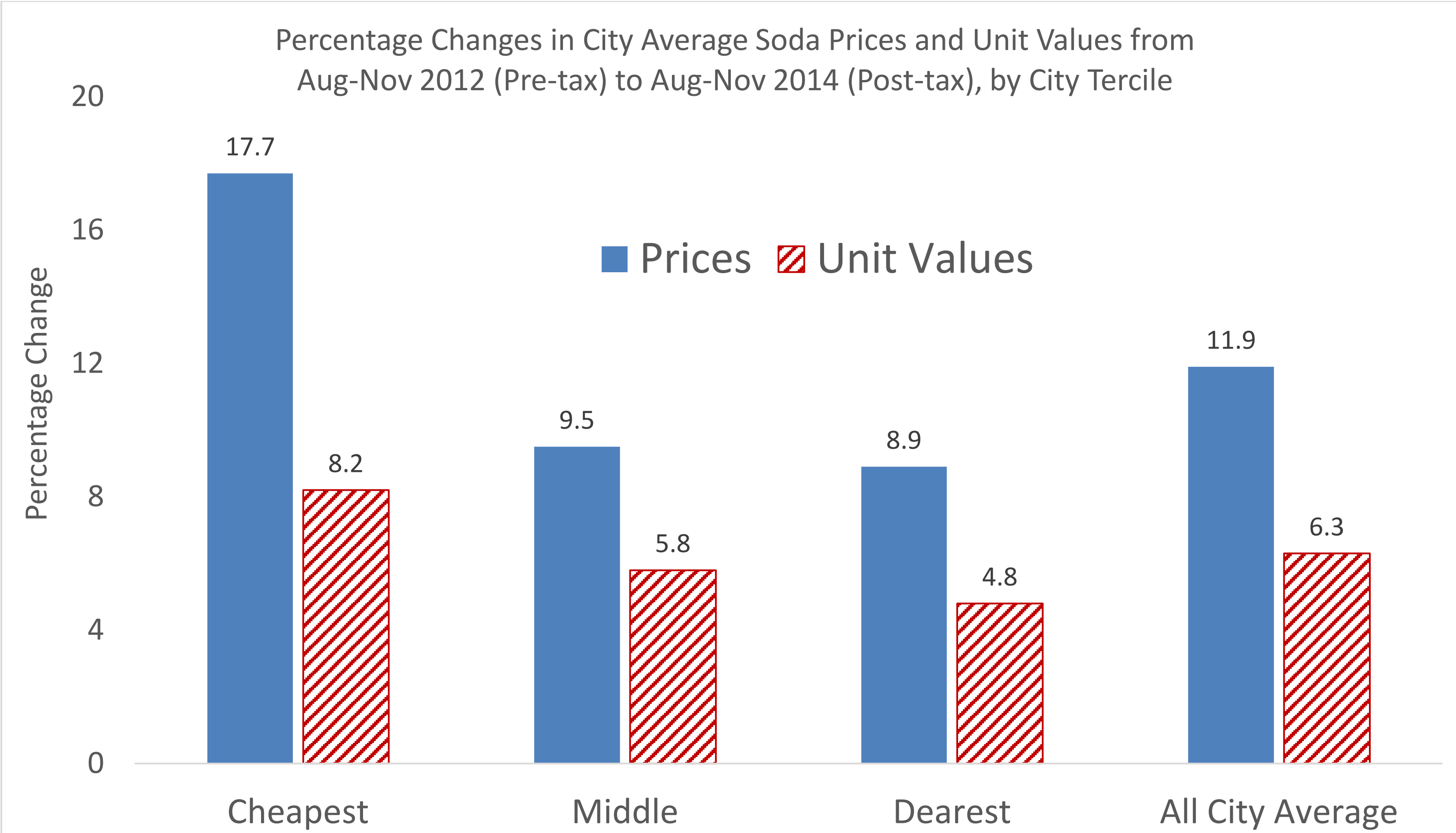

Table 1: Summary of Recent Estimates of The Price Elasticity of Demand for Soda in Mexico

A. Data and Methods

Author(s), year	**Method**	**Price measure**	**Beverages included**	**Foods included**	**Survey**	**Zero expenditure**
(a) Barquera et al., 2008	Double-log model	HH unit value	Soda; sweet drinks; whole milk; juice; bottled water		ENIGH	Included (Two part model)
(b) Fuentes and Zamudio, 2014	Double-log model	HH unit value	Soda; water; juice		ENIGH	Excluded
(c) Colchero et al., 2015	Budget shares (standard unit value method)	Municipality unit value	Soda; other SSB (juices, fruit drinks, flavoured water and energy drinks); bottled water; milk	Candies, snacks, sugar and traditional snacks.	ENIGH	Included
(d) World Bank: Bonilla-Chacin et al., 2016	Budget shares (Cox & Wohlgenant)	Regression-adjusted unit value	Soda; milk; water	Vegetables; fruits; high calorie food	ENIGH	Included
(e) Valero, 2006	Deaton method (budget shares & unit values)	Cluster dummy variables	Soda and juice; water; milk	Tortilla; beef; chicken; eggs; tomato; onion and chili; beans	ENIGH	Included
(f) Urzua, 2008	Deaton method (budget shares & unit values)	Cluster dummy variables	Soda, juice and water; beer; milk	Tortilla; Processed meats (ham, salami etc.); chicken and eggs; medicine	ENIGH	Included

B. Own price elasticities from studies in panel A

	2002	**2006**	**2008**	**2010**	**2012**	**2014**
Soda		-1.1(a), -1.1(c)	-1.1(c), -1. 2(b)	-0.9(c), -1.2(b)	-1.3(b)	-1.5(d)
Soda and juice	-1.4(e) -1.6(e)*					
Soda, juice and water		Rural: -1.0(f), Urban: -1.1(f)				

Notes: * is the quality-corrected elasticity based on the Deaton method. Studies (a), (b), and (e) are used by Grogger (2017) to provide a range of elasticities for converting the estimated price effects of the soda tax into steady state weight and BMI changes.

Table 2: Meso-Level Evidence on Soda Quality Adjustment in Response to Price Differences

	City Terciles Based on Soda Prices			All cities
	Lower	Medium	Higher	
Panel A – Spatial Effects				
Average soda price (peso/ℓ)	10.61	12.06	14.20	12.33
Average unit value for all-acquired soda	10.08	10.28	10.87	10.43
Average unit value for all acquired soda as a fraction of average price	0.95	0.85	0.77	0.89
Panel B – Temporal Changes				
Percentage change in average soda price from Aug-Nov 2012 to Aug-Nov 2014 (a)	17.7%	9.5%	8.9%	11.9%
Percentage change in average unit values for purchased soda (b)	8.2%	5.8%	4.8%	6.3%
Share of price increase reflected in unit value increase (b)÷(a)	0.47	0.61	0.55	0.52
Percentage change in average unit values for all acquired soda (c)	5.8%	5.2%	5.2%	5.4%
Share of price increase reflected in unit value increase (c)÷(a)	0.33	0.55	0.59	0.45
Percentage change in average soda quantity acquired (Aug-Nov, 2012 to Aug-Nov, 2014)	−13.2%	0.2%	1.0%	−4.6%

Notes: The calculations are based on city-month soda price observations calculated from the INEGI price survey and on unit values calculated from the ENIGH survey (where the soda category includes cola and flavoured soft drinks). Price data are merged with ENIGH records based on the city and the month of purchase (5190 ENIGH households match in 2012 and 12,214 households match in 2014). The average soda prices, and the division of cities into terciles is based on the average of the August to November 2012 and August to November 2014 real soda prices (to match the months when the ENIGH household survey is fielded). All monetary values are calculated in real prices (in pesos of August 2014) using the National Consumer Price Index.

Table 3: Estimates of the Own-Price Elasticity of Quantity Demand for Soda in Mexico, 2014

	Price or Unit Value Outliers Trimmed			Only urban households
	± 5 SD	± 4 SD	± 3 SD	
Methods based on budget share regressions				
Unrestricted method	**−0.31**	**−0.30**	**−0.28**	**−0.28**
	(0.12)	**(0.12)**	**(0.10)**	**(0.13)**
Standard price method	−1.25	−1.25	−1.23	−1.22
	(0.13)	(0.13)	(0.14)	(0.15)
Deaton method	−1.18	−1.18	−1.17	−1.15
	(0.11)	(0.11)	(0.09)	(0.12)
Standard unit value method – purchases	−1.28	−1.27	−1.29	−1.22
	(0.06)	(0.06)	(0.06)	(0.06)
Standard unit value method – acquisitions	−1.30	−1.29	−1.29	−1.25
	(0.06)	(0.06)	(0.06)	(0.06)
Cox and Wohlgenant method	−1.26	−1.26	−1.29	−1.21
	(0.06)	(0.06)	(0.06)	(0.07)
Methods based on log quantity regressions				
Log quantity on log prices	**−0.19**	**−0.18**	**−0.17**	**−0.16**
	(0.09)	**(0.09)**	**(0.09)**	**(0.10)**
Log quantity on log unit values	−1.29	−1.29	−1.33	−1.27
	(0.04)	(0.04)	(0.04)	(0.04)
Sample size – budget share methods	12087	12050	11907	9654
Sample size – log quantity methods	7983	7946	7810	6514

Notes: Standard errors in ( ) are clustered by locality and month. In addition to prices or unit values, the regressions used to calculate these elasticities include 23 control variables, for household total expenditure and size, 5 demographic ratios, 7 attributes of the household head (for age, gender, education, ethnicity and marital status), 3 area characteristics (altitude, latitude and urbanity) and 6 regional fixed effects. Full results of the regressions are in Appendix 2.
Methods in **bold** plausibly deal with quality responses to price changes and with correlated measurement error, while methods not in bold do not.

Table 4: Own- and Cross-Price Elasticities of Demand for Beverages in Mexico, 2014

A. Unrestricted Method

Demand for:	Elasticity of quantity demand with respect to the price of: Soda	Milk	Water	Juice
Soda	−0.22	0.03	0.25	0.06
	(0.13)	(0.20)	(0.09)	(0.12)
Milk	−0.05	−0.56	−0.20	−0.29
	(0.12)	(0.18)	(0.08)	(0.10)
Water	−0.63	−1.42	−0.57	−0.65
	(0.18)	(0.29)	(0.14)	(0.18)
Juice	−0.33	0.45	0.05	−0.71
	(0.28)	(0.45)	(0.17)	(0.20)

B. Standard Price Method

Demand for:	Elasticity of quantity demand with respect to the price of: Soda	Milk	Water	Juice
Soda	−1.13	−0.07	0.30	0.07
	(0.15)	(0.24)	(0.10)	(0.13)
Milk	0.04	−1.31	−0.20	−0.20
	(0.14)	(0.21)	(0.09)	(0.09)
Water	0.02	−1.07	−0.85	−0.17
	(0.22)	(0.33)	(0.14)	(0.20)
Juice	−0.33	0.49	0.13	−1.53
	(0.29)	(0.48)	(0.18)	(0.21)

C. Deaton Method

Demand for:	Elasticity of quantity demand with respect to the price of: Soda	Milk	Water	Juice
Soda	−1.07	−0.07	0.28	0.06
	(0.12)	(0.19)	(0.09)	(0.11)
Milk	0.04	−1.25	−0.19	−0.28
	(0.11)	(0.17)	(0.07)	(0.09)
Water	0.02	−0.89	−0.71	−0.14
	(0.14)	(0.22)	(0.11)	(0.14)
Juice	−0.32	0.48	0.12	−1.49
	(0.27)	(0.44)	(0.16)	(0.19)

D. Standard Unit Value Method

Demand for:	Elasticity of quantity demand with respect to the price of: Soda	Milk	Water	Juice
Soda	−1.32	0.15	0.09	−0.02
	(0.06)	(0.04)	(0.02)	(0.04)
Milk	0.01	−0.50	−0.01	−0.01
	(0.06)	(0.06)	(0.02)	(0.04)
Water	0.30	−0.02	−1.16	0.10
	(0.07)	(0.06)	(0.03)	(0.05)
Juice	0.27	0.01	0.12	−1.10
	(0.12)	(0.11)	(0.04)	(0.12)

Notes: See Table 3 for details on the other variables included in the regressions. *N*=12,087. The standard unit value method uses unit values based on all acquisitions. Standard errors in ( ) are clustered by locality and month.

Table 5: Sensitivity Analysis: Estimates of the Own-Price Elasticity of Quantity Demand for Soda in Mexico, 2016

	Price or Unit Value Outliers Trimmed			Only urban households
	± 5 SD	± 4 SD	± 3 SD	
Methods based on budget share regressions				
Unrestricted method	**−0.14**	**−0.14**	**−0.13**	**−0.37**
	(0.05)	**(0.05)**	**(0.05)**	**(0.06)**
Standard price method	−1.10	−1.10	−1.10	−1.33
	(0.06)	(0.06)	(0.07)	(0.07)
Deaton method	−1.07	−1.07	−1.08	−1.29
	(0.05)	(0.05)	(0.05)	(0.06)
Standard unit value method – purchases	−1.24	−1.22	−1.23	−1.24
	(0.03)	(0.03)	(0.04)	(0.04)
Standard unit value method – acquisitions	−1.27	−1.24	−1.24	−1.27
	(0.03)	(0.03)	(0.04)	(0.04)
Cox and Wohlgenant method	−1.31	−1.30	−1.32	−1.29
	(0.03)	(0.03)	(0.04)	(0.04)
Methods based on log quantity regressions				
Log quantity on log prices	**−0.19**	**−0.14**	**−0.13**	**−0.21**
	(0.09)	**(0.05)**	**(0.05)**	**(0.05)**
Log quantity on log unit values	−1.29	−1.31	−1.33	−1.33
	(0.04)	(0.02)	(0.02)	(0.02)
Sample size – budget share methods	42528	42386	42045	30827
Sample size – log quantity methods	28752	28610	28269	20945

Notes: All data except for prices are from ENIGH 2016, fielded from August to November 2016. The price data comes from INEGI surveys and were merged to ENIGH records based on the city of residence and the month (August to November) of purchase. Other notes, see Table 3.

Table 6: Sensitivity Analysis: Estimates of the Own-Price Elasticity of Quantity Demand for Soda in Mexico based on pooled data from ENIGH 2012, 2014 and 2016

	Price or Unit Value Outliers Trimmed			Only urban households
	± 5 SD	± 4 SD	± 3 SD	
Methods based on budget share regressions				
Unrestricted method	**−0.16**	**−0.16**	**−0.15**	**−0.36**
	(0.05)	**(0.05)**	**(0.05)**	**(0.05)**
Standard price method	−1.13	−1.13	−1.12	−1.32
	(0.05)	(0.05)	(0.05)	(0.06)
Deaton method	−1.09	−1.10	−1.09	−1.27
	(0.04)	(0.04)	(0.05)	(0.05)
Standard unit value method – purchases	−1.24	−1.23	−1.24	−1.23
	(0.03)	(0.03)	(0.03)	(0.03)
Standard unit value method – acquisitions	−1.27	−1.25	−1.25	−1.25
	(0.03)	(0.03)	(0.03)	(0.03)
Cox and Wohlgenant method	−1.29	−1.28	−1.31	−1.25
	(0.03)	(0.03)	(0.03)	(0.03)
Methods based on log quantity regressions				
Log quantity on log prices	**−0.12**	**−0.12**	**−0.11**	**−0.19**
	(0.04)	**(0.04)**	**(0.04)**	**(0.04)**
Log quantity on log unit values	−1.31	−1.30	−1.32	−1.30
	(0.02)	(0.02)	(0.02)	(0.02)
Sample size – budget share methods	59768	59578	59058	44617
Sample size – log quantity methods	40243	40053	39540	30282

Notes: See Table 3, except that the sample is from 2012, 2014 and 2016 ENIGH surveys and INEGI price surveys.

Appendix 1: Key Sections from ENIGH Expenditure Survey

Section 1.1 Food, Beverages and Tobacco

Daily Expenditures Consumed at Home

1. Yesterday, did you or another household member spend money on food, beverages to prepare breakfast, lunch or dinner or spend money on pizza, etc or cigarettes, cigars or tobacco or pet food?	1. Yes 2. No ➔*Go to section "Expenditures on food services"*	First Day Date ____________________

Name of item	**Item code**	**Quantity and unit of measurement**	**Place**	**Code of place**	**Expenditure**	**Form of payment**	**Equivalence in KG or Lt**	**Quantity in Gr or Ml**
2. What food, beverages and tobacco did you buy?	*Write the item's code*	3. What quantity did you buy?	4. Where did you buy it?	*Write the code of the place of purchase*	5. How much did you spend?	6. Which of these items did you pay with: 1. Cash 2. Credit card 3. On credit	*If Question 3 was answered in KG or LT, write 1,000.*	*Question 3 times column "Equivalence in Kg or Lt"*
SOFT DRINK GROUPS								
Natural bottled water	A215							
Sparkling water, demineralized water	A216							
Prepared water and natural juices	A217							
Bottled juice and nectar	A218							
Beverage concentrates and powders	A219							
Cola and flavored soda	A220							
Energy drink	A221							
Corn fermented beverages	A222							

The respondent fills out a questionnaire like this every day for seven days. This is the example of day 1 only. Instructions for enumerators in italics.
The table displays the codes of all non-alcoholic beverages other than milk. In the data set, quantity is reported in Kg or LT.

Gifts from other households: Food, beverages, tobacco, food services and public transport

<table>
<tr><td colspan="3">1. Did you or another household member receive as a gift from another household yesterday of food, beverages, cigarettes, cigars, tobacco, pet food, bus tickets or taxi fees?</td><td colspan="2">1. Yes
2. No ➔Go to section "In kind payments"</td></tr>
<tr><td>Name of item or service</td><td>Code</td><td>Quantity</td><td>Estimated value</td><td>Frequency</td></tr>
<tr><td>2. What items or services did you receive?</td><td>Write the item or service code</td><td>What quantity did you receive? (Write it in Kg or Lt , including decimals)</td><td>4. How much would you have paid for the item or service if you have bought it yourself? (quantity in Pesos and cents)</td><td>5. How often do you receive it?
1. Daily
2. Every week
3. Once a month
4. Once a year
5. Only once
6. Other</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
</table>

A similar questionnaire is filled out for in-kind transfers from the government or institutions.

Appendix 2, Table 1: Descriptive Statistics, from ENIGH and INEGI Surveys, Aug-Nov 2014

	Mexico		Urban localities	
	Unconditional	Conditional	Unconditional	Conditional
HH monetary exp. on soda (%)	0.02	0.03	0.02	0.03
	(0.03)	(0.03)	(0.03)	(0.03)
HH monetary exp. on soda (pesos)	139.54	211.27	146.69	217.40
	(174.34)	(175.68)	(178.72)	(178.79)
Price of soda (pesos per liter)	13.30	13.34	13.30	13.33
	(1.66)	(1.65)	(1.67)	(1.65)
Quantity of soda purchased (liters)	14.16	21.45	14.86	22.02
	(19.53)	(20.53)	(20.21)	(21.16)
Unit value of soda purchased (pesos)	10.89	10.89	10.91	10.91
	(3.29)	(3.29)	(3.24)	(3.24)
Quantity of soda acquired (liters)	14.92	22.59	15.53	23.02
	(20.11)	(20.96)	(20.68)	(21.47)
Unit value of soda acquired (pesos)	10.92	10.92	10.95	10.95
	(3.33)	(3.33)	(3.27)	(3.27)
HH monetary expenditure (pesos)	9534.41	9798.70	10288.23	10426.38
	(9967.74)	(9440.45)	(10645.25)	(10020.09)
Household size	3.71	3.81	3.63	3.75
	(1.83)	(1.83)	(1.78)	(1.78)
Share are female children (0 to 11)	0.09	0.09	0.08	0.08
	(0.14)	(0.14)	(0.14)	(0.14)
Share are male children (0 to 11)	0.09	0.09	0.09	0.09
	(0.15)	(0.15)	(0.14)	(0.15)
Share are female adult (12 to 64)	0.37	0.37	0.37	0.37
	(0.24)	(0.22)	(0.24)	(0.23)
Share are male adult (12 to 64)	0.36	0.37	0.36	0.37
	(0.25)	(0.25)	(0.26)	(0.25)
Share are female old (65+)	0.06	0.04	0.06	0.05
	(0.18)	(0.15)	(0.19)	(0.16)
Share are male old (65+)	0.04	0.04	0.04	0.04
	(0.15)	(0.14)	(0.15)	(0.14)
Head age	47.65	46.69	47.96	46.98
	(15.18)	(14.73)	(15.12)	(14.72)
Head female	0.27	0.25	0.28	0.26
	(0.44)	(0.43)	(0.45)	(0.44)
Head education is grades 0 to 8	0.39	0.37	0.34	0.33
	(0.49)	(0.48)	(0.47)	(0.47)
Head education is 9 to 11 grades	0.30	0.32	0.30	0.32
	(0.46)	(0.47)	(0.46)	(0.47)
Head education is grades 12 or more	0.32	0.31	0.36	0.35
	(0.46)	(0.46)	(0.48)	(0.48)
Head is indigenous	0.05	0.05	0.03	0.03
	(0.22)	(0.21)	(0.18)	(0.17)
Head is married/partnered	0.70	0.72	0.68	0.71
	(0.46)	(0.45)	(0.47)	(0.46)
Head is single	0.09	0.08	0.09	0.09
	(0.28)	(0.27)	(0.29)	(0.28)
Head is divorced/widowed	0.22	0.20	0.23	0.21
	(0.41)	(0.40)	(0.42)	(0.41)

HH is in urban locality	0.80	0.82	1.00	1.00
	(0.40)	(0.39)	(0.00)	(0.00)
Observations	12087	7983	9654	6514

Notes: Standard deviations in (). All data except for prices are from ENIGH 2014, fielded from August to November 2014. The price data comes from INEGI surveys and were merged to ENIGH records based on the city of residence and the month (August to November) of purchase.

Appendix 3, Table 1: Regression Results for Four Budget Share Models
(Sample With Trimming of Prices and Unit Values ± 5 Standard Deviations from Means)

	Standard price method	Standard UV method - purchases	Standard UV method - acquisitions	Cox and Wohlgenant method
Log of soda price (INEGI city data)	-0.005			
	(0.003)			
Log of purchase unit values		-0.006		
		(0.001)		
Log of acquisition unit values			-0.006	
			(0.001)	
Log of regression-adjusted unit values				-0.005
				(0.001)
Log of household total expenditure	-0.009	-0.009	-0.009	-0.023
	(0.001)	(0.001)	(0.001)	(0.001)
Log of household size	0.003	0.002	0.002	0.004
	(0.001)	(0.001)	(0.001)	(0.001)
Share of female children (0 to 11)	-0.008	-0.008	-0.008	-0.014
	(0.004)	(0.004)	(0.004)	(0.006)
Share of male children (0 to 11)	-0.004	-0.004	-0.004	-0.015
	(0.004)	(0.004)	(0.004)	(0.006)
Share of female adult (12 to 64)	-0.007	-0.007	-0.007	-0.013
	(0.004)	(0.004)	(0.004)	(0.005)
Share of male adult (12 to 64)	0.004	0.004	0.004	-0.004
	(0.004)	(0.004)	(0.004)	(0.005)
Share of female old (65+)	-0.011	-0.011	-0.011	-0.017
	(0.004)	(0.004)	(0.004)	(0.007)
Household head age	-0.011	-0.011	-0.011	-0.000
	(0.003)	(0.003)	(0.003)	(0.004)
Head is female	-0.002	-0.002	-0.002	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Head education is grades 9 to 11	-0.002	-0.002	-0.002	-0.003
	(0.001)	(0.001)	(0.001)	(0.001)
Head education is grades 12 or more	-0.006	-0.006	-0.006	-0.003
	(0.001)	(0.001)	(0.001)	(0.001)
Head is indigenous	0.001	0.001	0.001	0.003
	(0.002)	(0.002)	(0.002)	(0.002)
Head is married/cohabiting	-0.001	-0.002	-0.002	-0.003
	(0.001)	(0.001)	(0.001)	(0.002)
Head divorced/widowed	0.001	0.000	0.000	-0.001
	(0.001)	(0.001)	(0.001)	(0.002)
Log of municipality altitude	-0.001	-0.001	-0.001	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Log of municipality latitude	0.036	0.035	0.035	0.019
	(0.004)	(0.004)	(0.004)	(0.004)
Urban locality	0.002	0.002	0.002	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Region is Mexico City	-0.001	-0.002	-0.002	-0.008
	(0.001)	(0.001)	(0.001)	(0.002)

Region is North-Central	0.002	0.002	0.002	-0.004
	(0.001)	(0.001)	(0.001)	(0.002)
Region is South-Central	-0.004	-0.004	-0.004	-0.009
	(0.001)	(0.001)	(0.001)	(0.001)
Region is Northern border	-0.007	-0.006	-0.006	-0.005
	(0.002)	(0.002)	(0.002)	(0.002)
Region is Northeast	0.006	0.006	0.006	0.003
	(0.002)	(0.002)	(0.002)	(0.002)
Region is Northwest	-0.005	-0.004	-0.005	-0.005
	(0.002)	(0.002)	(0.002)	(0.002)
Constant	0.019	0.022	0.023	0.189
	(0.014)	(0.013)	(0.013)	(0.017)
R-squared	0.128	0.129	0.130	0.292

Notes: The dependent variable is the budget share for soda. Standard errors in ( ) are clustered by locality and month. *N*=12087 urban and rural households in municipalities with INEGI price surveys. These regressions provide the parameters used to calculate four of the own-price elasticities of quantity demand for soda that are reported in column (1) of Table 3.

Data in the regressions are from the ENIGH survey and INEGI price surveys from August to November, 2014.

Appendix 3, Table 2: Regression Results for Unrestricted and Double Log Models
(Sample With Trimming of Prices and Unit Values ± 5 Standard Deviations from Means)

	Unrestricted method		Double log method	
	Budget share equation	Unit value equation	City-level prices	Household-level unit values
Log of soda price (INEGI city data)	-0.005	0.063	-0.189	
	(0.002)	(0.023)	(0.090)	
Log of purchase unit values				-1.290
				(0.036)
Log of household total expenditure	-0.009	0.030	0.165	0.223
	(0.000)	(0.004)	(0.016)	(0.014)
Log of household size	0.003	-0.088	0.395	0.221
	(0.001)	(0.005)	(0.025)	(0.023)
Share of female children (0 to 11)	-0.008	0.050	-0.360	-0.280
	(0.004)	(0.023)	(0.114)	(0.104)
Share of male children (0 to 11)	-0.004	0.001	-0.240	-0.212
	(0.004)	(0.026)	(0.113)	(0.103)
Share of female adult (12 to 64)	-0.007	-0.009	-0.114	-0.120
	(0.004)	(0.019)	(0.090)	(0.083)
Share of male adult (12 to 64)	0.004	-0.002	0.113	0.102
	(0.004)	(0.015)	(0.080)	(0.074)
Share of female old (65+)	-0.011	-0.004	-0.164	-0.152
	(0.004)	(0.023)	(0.102)	(0.095)
Household head age	-0.011	0.016	-0.097	-0.077
	(0.003)	(0.021)	(0.098)	(0.086)
Head is female	-0.002	0.006	-0.023	-0.019
	(0.001)	(0.006)	(0.032)	(0.029)
Head education is grades 9 to 11	-0.002	-0.012	0.000	-0.025
	(0.001)	(0.006)	(0.024)	(0.022)
Head education is grades 12 or more	-0.006	0.006	-0.156	-0.148
	(0.001)	(0.007)	(0.028)	(0.025)
Head is indigenous	0.001	-0.023	0.056	0.034
	(0.001)	(0.011)	(0.046)	(0.041)
Head is married/cohabiting	-0.001	-0.044	0.107	0.017
	(0.002)	(0.009)	(0.041)	(0.036)
Head divorced/widowed	0.001	-0.032	0.079	0.014
	(0.002)	(0.010)	(0.041)	(0.037)
Log of municipality altitude	-0.001	-0.013	-0.020	-0.034
	(0.000)	(0.002)	(0.007)	(0.006)
Log of municipality latitude	0.036	-0.008	0.770	0.733
	(0.003)	(0.025)	(0.127)	(0.116)
Urban locality	0.002	-0.008	0.073	0.052
	(0.001)	(0.006)	(0.028)	(0.025)
Region is Mexico City	-0.001	-0.095	-0.084	-0.245
	(0.001)	(0.012)	(0.054)	(0.046)
Region is North-Central	0.002	0.048	-0.175	-0.102
	(0.001)	(0.009)	(0.043)	(0.038)
Region is South-Central	-0.004	-0.011	-0.252	-0.263
	(0.001)	(0.009)	(0.043)	(0.038)

Region is Northern border	-0.007	0.112	-0.370	-0.221
	(0.002)	(0.012)	(0.063)	(0.058)
Region is Northeast	0.006	0.088	-0.041	0.076
	(0.001)	(0.012)	(0.056)	(0.051)
Region is Northwest	-0.005	0.097	-0.356	-0.206
	(0.001)	(0.012)	(0.058)	(0.053)
Constant	0.019	2.113	-0.799	1.644
	(0.012)	(0.085)	(0.437)	(0.377)
R-squared	0.128	0.124	0.133	0.304

Notes: The unrestricted method has two dependent variables, the budget share for soda and the unit value for soda. The dependent variable for the double log method is the log quantity of soda acquired. Standard errors in ( ) are clustered by locality and month. *N*=12087 for the unrestricted method and *N*=7983 for the double log models. These regressions provide the parameters used for four of the own-price elasticities of quantity demand for soda that are reported in column (1) of Table 3, with results for the Deaton method derived by imposing restrictions on the coefficients from the unrestricted method. Data in the regressions are from the ENIGH survey and INEGI price surveys from August to November, 2014.