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Sugar-based beverage taxes and beverage prices: Evidence from South Africa's Health Promotion Levy

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ABSTRACT

A growing number of jurisdictions are introducing taxes on sugar-sweetened beverages (SSBs) in efforts to reduce sugar intake, obesity, and associated metabolic conditions. A key dimension of the impact of such taxes is how they induce changes in the prices of the taxed beverages and their un-taxed substitutes. At present these taxes have typically been based solely on volume. More recently, however, due to the potential to target the source of SSBs' health harms and to incentivize product reformulation, SSB taxes are being levied based on sugar content. In April of 2018 South Africa implemented such a tax, the Health Promotion Levy (HPL), at a rate of 0.021 ZAR (approximately 0.15 US cents) for each gram of sugar over an initial threshold of 4 g/100 ml. Drawing on a dataset of price observations (N = 71, 677) collected in South Africa between January 2013 and March 2019, we study changes in beverage prices following the introduction of the HPL. We find null price increases among un-taxed beverages and find significant price increases for carbonates, the largest taxed product category. However, within carbonates we find similar increases in price for low- and high-sugar brands, despite the underlying difference in tax liability. In addition, while we find evidence of product reformulation, we find significant price increases among the brands that reduced their sugar content. While the findings are broadly consistent with the price changes of volume-based SSB taxes, future considerations of price effects of sugar-based SSB taxes need to account for the opportunity for intra-firm heterogeneity in price response among large multi-product firms.

1. Introduction

In response to rising prevalence of obesity and its comorbidities, a number of jurisdictions have introduced or are in the process of introducing taxes on obesogenic foods and beverages and in particular on sugar-sweetened beverages (SSBs). SSBs are non-alcoholic beverages containing added sugar, with common examples including carbonated sodas, juice drinks, and sports and energy drinks (Hu, 2013). Excessive consumption of SSBs is strongly associated with weight-gain, type 2 diabetes mellitus, and other metabolic conditions (Feeley et al., 2013; Malik et al., 2013; Malik et al., 2006; Te Morenga et al., 2013; Te Morenga et al., 2014; Vorster et al., 2014).

One key rationale for such taxes is Pigouvian in nature. Pooled or publicly financed healthcare provision results in consumers externalising the costs of the treatment of the diseases associated with their consumption of SSBs (Brownell et al., 2009). However, is the source of this externality cost the SSB product in its whole, or is it its constituent ingredients? SSBs' association with obesity is driven by their high sugar content and its liquid form, often not compensated for via equivalent reduction in calories from other foods, which is rapidly absorbed by the liver (DellaValle et al., 2005; DiMeglio and Mattes, 2000; Mourao et al., 2007).

As recommended by the World Health Organization, some countries have introduced taxes that differentially tax soft drinks based on how much sugar they contain (WHO, 2016). Chile and the United Kingdom tax beverages at different rates relative to several discrete sugar content thresholds (Caro et al., 2018; gov.uk, 2016; Nakamura et al., 2018). By taxing ingredients rather than whole products, one introduces an incentive for producers to reformulate products to reduce the concentration of the taxed ingredient (Blecher, 2015). Such a mechanism

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does not exist for uniform per volume taxes such as the one peso per litre tax on drinks containing added sugar implemented by Mexico in 2014, where SSBs of differing sugar contents are taxed at equivalent rates (Colchero et al., 2016). The notion of ingredient-based taxation is common in the treatment of alcoholic beverages where taxes are often levied relative to absolute alcohol content, while cigarette products are more appropriate to uniform taxation due to the uniformity of the harms (Blecher, 2015).

Price is a critical tool that governs the ultimate behavioural and public health impacts of excise taxes. From a public health standpoint, the extent to which a tax might induce reductions in consumption of the unhealthy taxed products is determined, in conjunction with how price elastic demand is, by the extent to which prices respond to the tax. There is a significant literature examining the impact of volume-based taxes. These studies find significant or entire pass through of taxes particularly in low- and middle-income settings. For instance, Colchero et al. (2015) and Gogger (2015) find Mexico's one peso per litre tax was on average entirely passed through to consumer prices, with some heterogeneity across product size and geography. Evidence from local soda taxes implemented by cities in the United States suggests some variation in pass through across cities (Cawley et al., 2018a, 2018b; Cawley and Frisvold, 2017; Falbe et al., 2015; Silver et al., 2017). However, due to their heretofore limited implementation there is at present no published evidence on the price effects of sugar-based SSB taxes.

Conventional economic theory suggests that profit maximizing firms will increase their products' prices with the magnitude of this price change being mediated by the price elasticity of consumers' demand (Hines, 2008). However, in the face of an ingredient-based tax, producers face an additional decision which is whether or not to reformulate their products to reduce the levels of the taxed-ingredient and the associated tax liability. Further, reformulation involves costs, some fixed but others variable and determined by the extent that firms are price-takers and do not hold significant monopsony power in the market for sugar (or sugar substitutes). Firms may also respond by refocusing advertising efforts (Blecher, 2015). All of these mechanisms interact with firms being multi-product firms. There is thus not much known *ex-ante* about how firms (and particularly their products' pricing) respond to sugar-based SSB taxes.

South Africa presents an opportunity to study the effects of such sugar-based SSB tax policies. Facing an increasingly severe burden of disease attributable to excess sugar and SSB consumption, South Africa implemented a tax on SSBs on April 1, 2018. This new tax instrument titled the Health Promotion Levy (HPL) was introduced through the passage of the 2017/18 Rates and Monetary Amounts Bill (Stacey et al., 2017; National Treasury, 2016, National Treasury, 2018). The tax is levied at 0.021 ZAR (approximately 0.15 US cents) for each gram of sugar over a threshold of 4 g per 100 ml on non-alcoholic drinks subject to the tax (National Treasury, 2018).

Do sugar-based taxes result in price increases? If so, is the pass-through complete? Does the incentive for product reformulation interact with firms' pricing responses? We seek to address these gaps by providing evidence on South Africa's implementation of the Health Promotion Levy. Drawing on price data collected for compilation of Statistics South Africa's Consumer Price Index and exploiting the discrete introduction of South Africa's HPL on the sugar content of SSBs, we estimate the change in prices of taxed and untaxed products following the introduction of this sugar-based tax. We proceed with a description of the HPL, our data and econometric approach, a presentation of our results, and close with a discussion and conclusion.

1.1. South Africa's Health Promotion Levy

A generic call for a tax on SSBs was first made in 2012 by South Africa's National Department of Health in their National Strategy for Prevention and Control of NCDs, 2013–2017, and then again in 2015 in their National Strategy for Prevention and Control of Obesity, 2015–2020. In February 2016, the National Treasury formally announced its intentions to implement a tax on SSBs as of the next fiscal year, April 2017, and subsequently released a policy paper outlining the nature of proposed tax (National Treasury, 2016). Following what was a protracted legislative process, including extensive public consultations, the policy was only signed into law in December 2017. This process saw implementation delayed a year, with the HPL going into effect in April 2018.

The intention, outlined in the National Treasury policy paper, was to tax SSBs to reduce harms arising from excessive sugar content and to levy the tax in such a way so as to create an explicit incentive for producers to reduce the sugar-content of their taxable products (National Treasury, 2016). While other settings, such as the United Kingdom, opted for a tiered tax with rates increasing in discrete steps with increasing sugar content, the National Treasury proposed a tax linear in sugar content, with the rate set at 0.0228 ZAR/gram of sugar. This original proposal, which would have produced a burden of 20% of the price of the most popular soft drink brand was opposed by the beverage industry. A revised proposal was adopted which exempted the first 4 g of sugar per 100 ml from taxation, and taxed each gram over the 4 g threshold at 0.021 ZAR (depicted in Fig. 1). This compromise significantly reduced the burden of the HPL to 10–11% of the price of the most popular soft drink brand.

The formal delineation of which products are subject to the HPL is done via the World Customs Organization's Harmonized System designations (See Supplementary Table 1). Practically, beverages subject to the HPL include carbonates (sugar-sweetened and artificially-sweetened), concentrates, fruit nectars, sports and energy drinks, and ready-to-drink teas with their respective tax liabilities being determined by their sugar content. Beverages not subject to the HPL include non-flavoured bottled waters and 100% fruit juices. In the context of the South African drinks market, as displayed in Fig. 2, sales of carbonates dwarf sales of other beverage types, and consequently the impact of the HPL on these products is of particular consequence. Beverage manufacturers, and importers of beverages, are legally responsible for payment of the HPL to the South African Revenue Service, with tax liability determined by tests of sugar content undertaken by accredited laboratories. Small manufacturers, defined to be those using less than 500 kg of sugar in a year, are exempt from paying the HPL.

While not formally earmarked, some of the revenue raised from the HPL will be "soft-earmarked" for health promotion activities across government. As of December 2018, revenue raised had exceeded forecasts and reached approximately 2 billion ZAR. This is about 0.15% of South Africa's total tax revenue for the 2018/19 fiscal year.

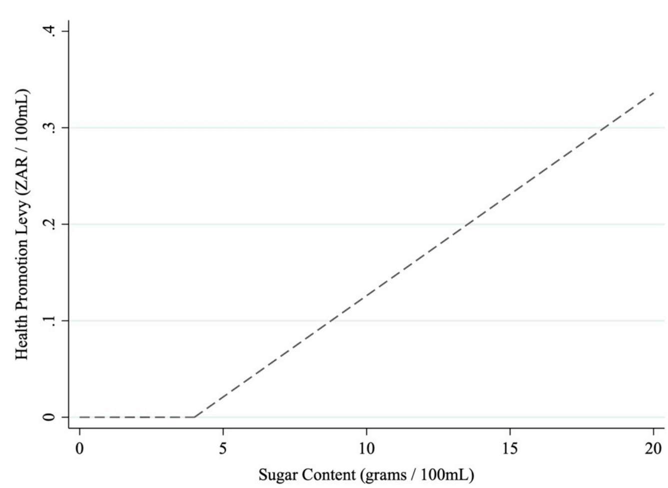
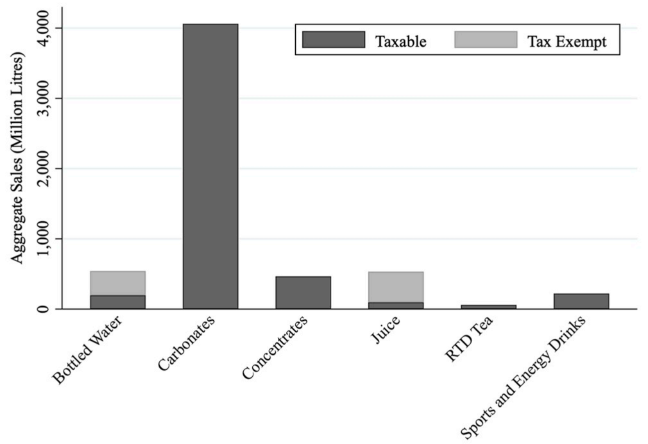


Fig. 1. Health promotion levy rate by sugar content.



Notes: Data from Euromonitor Passport database. Bottled water includes still water (tax exempt), carbonated water (tax exempt), and flavoured water (taxable). Juice includes juice drinks (taxable), nectars (taxable), and 100% juices (tax exempt).

Fig. 2. Aggregate sales of beverages in South Africa, 2017.

2. Methods

2.1. Empirical strategy

2.1.1. Overview

We take three econometric approaches to studying the effect of the introduction of South Africa's HPL on prices. The first is a simple pre-post analysis, which identifies changes in average price across various taxed and un-taxed product categories following the introduction of the HPL. A second approach seeks to estimate the pass-through, price change relative to tax liability, among taxed products. And the third and final approach studies differential price change among brands that were reformulated to reduce their sugar content as compared to those that did not. As the study did not constitute human subjects research, ethical approval was not required.

2.1.2. Price change

To estimate general changes of price following the introduction of the HPL, we estimate regressions of the following form:

$$Price_{ibpmy} = \alpha_1 Post_{my} + \alpha_2' Vol_{ibpmy} + \beta_b + \gamma_p + \delta_m + \varepsilon_y + \psi_{ibpmy} \tag{1}$$

where i indexes product, b indexes brand, p indexes province, m indexes month, y indexes year. $Post_{my}$ is an indicator variable identifying time periods post the introduction of the HPL in April 1, 2018, Vol_{ibpmy} is a vector of container volume category indicators, β_b is a brand fixed effect, γ_p is a province fixed-effect, δ_m is a month fixed-effect, ε_y is a year fixed effect, and ψ_{ibpmy} is an idiosyncratic error term. We estimate this separately for categories of taxed (carbonates and non-carbonates) and tax-exempt beverage products (bottled water and 100% fruit juice).

A potential threat to this estimation strategy is that contemporaneous to the introduction of the HPL was a one percentage point increase of South Africa's value-added tax (VAT) from 14% to 15%. Although a minor change in VAT which impacted both taxed and un-taxed beverages alike, it arguably could confound our estimate of the impact of the change in price arising from the HPL. To address this concern, for our outcome price measure, $Price_{ibpmy}$, we construct a measure of price exclusive of VAT for each of our observations. We construct the pre-VAT price as follows. First, we assume:

$$RetailPrice_{ibpmy} = Price_{ibpmy} \times (1 + VAT) \tag{2}$$

Where $RetailPrice_{ibpmy}$ is the retail price we observe in the data of observation i of brand b in province p in month m and year y, and $Price_{ibpmy}$ is the underlying pre-VAT or VAT-exclusive price for that observation. We then transform our price measure to exclude VAT as follows:

$$Price_{ibpmy} = \begin{cases} \frac{RetailPrice_{ibpmy}}{1.14} & \textit{if before April } 2018 \\ \frac{RetailPrice_{ibpmy}}{1.15} & \textit{if after April } 2018. \end{cases} \tag{3}$$

In addition, we adjust this measure for inflation and for container volumes by expressing prices in per litre terms. Consequently, our final outcome measure is the real VAT-exclusive price of each product in 2016 ZAR per litre.

2.1.3. PPPass through

In instances with uniform specific taxes, such as Mexico's one peso per litre SSB tax, price change regressions similar to those above would provide a measure of the extent to which the HPL was passed through to retail prices. However, in instances with variable taxes, such as the HPL, these regressions provide a measure of the extent to which prices changed on average but do not provide a measure of the extent to which taxes were proportionately passed through relative to their tax liability. Consequently, in addition to estimating the average changes in price arising with the introduction of the HPL, for products for which we observe significant changes in price, we also estimate the extent to which the levy is passed through. We estimate regressions of the following form:

$$Price_{ibpmy} = \alpha_1 Levy_{bmy} + \alpha_2' Vol_{ibpmy} + \beta_b + \gamma_p + \delta_m + \varepsilon_y + \psi_{ibpmy} \tag{4}$$

Where $Levy_{bmy}$ is the HPL rate per litre on product i of brand b in month m and year y. $Levy_{bmy}$ takes the value zero for periods prior to the introduction of the HPL in April of 2018. For later periods, $Levy_{bmy}$, is calculated based on brand sugar content, $Sugar_b$, as follows:

$$Levy_{bmy} = \begin{cases} 0 & \textit{if } Sugar_b < \frac{4g}{100mL} \\ (Sugar_b - 4) \times 0.021 \times 10 & \textit{if } Sugar_b \geq \frac{4g}{100mL} \end{cases} \tag{5}$$

The underlying mathematical relationship is depicted in Fig. 1. The parameter of interest in regression (4) is α_1, and should be interpreted as the proportion of the HPL due on each product that was passed through to retail prices. A value of $\alpha_1 = 1$ would imply an equivalent change in price for a given change in HPL.

For the purposes of assessing pass through, an estimate of HPL liability in the period after the HPL was enacted is required. While brands could have reduced their sugar content in anticipation of the introduction of the HPL, sugar content in the pre-HPL period is irrelevant as the liability is zero for all products in this period regardless of sugar content. Consequently, the measure of sugar content we use for estimating tax liability is only for the post-HPL period.

2.1.4. Reformulation and price change

The design of the HPL may have incentivized reformulation to reduce sugar content, which in turn could have impacted price-response for the reformulated products. We construct a binary measure of reformulation taking the value one if a brand's sugar content fell with the introduction of the HPL. We study how price and reformulation interact by fitting equation (1) for: (i) carbonates for which sugar content decreased, (ii) carbonates for which sugar content was not reduced, and (iii) for carbonates for who sugar content was reduced to below 4 g/100 mL (i.e. below the initial exemption and so would have a zero tax-liability). In addition, we conduct brand-specific analyses for certain exemplar brands that were and weren't reformulated.

3. Data

The primary data utilized in this study are retail prices for non-alcoholic beverages collected by Statistics South Africa's Consumer Price Index (CPI) unit. These prices are collected by in-store observation in urban areas across South Africa on a monthly basis (StatsSA, 2017). Products sampled are intended to be the most popular item for each product type and unit size in each store. This is operationalized by enumerators recording the prices of the products occupying the most significant shelf space for each product type and unit size (StatsSA, 2017). This data provides information on product type (coded according to the Classification of Individual Consumption according to Purpose system), brand, package size, month of observation, as well as the region and province where data collection took place. The time period covered by the data is from January 2013 through March 2019, twelve months post the introduction of the HPL in April 2018. We adjust prices for inflation deflating all to December 2016 price levels, and standardize across volumes by expressing our price measure in per litre terms. As we do not have information on the stores in which prices were collected, we treat each month's wave of data as a repeated cross-section.

A limitation of this data is that beyond the price observations, only few other product characteristics are reported. To address this, we match the Statistics South Africa data to the Euromonitor Passport database at the brand-level (Euromonitor International, 2018). This provides a richer hierarchy of information on beverage type and subtype. We supplement the price data with data on the sugar content. Data on sugar content post the introduction of the HPL was collected through in-store observation for the brands' in the post-HPL period data. Data on sugar content prior to the introduction of the HPL was compiled from a 2012 Coca-Cola Company publication on the nutritional composition of their South African product range, and from the Euromonitor Passport database for the sugar content of other companies' brands covering the period 2015 to 2017 (Euromonitor International, 2018; The Coca-Cola Company, 2012).

We exclude concentrates from our analysis. Tax liability for concentrates is determined relative to diluted or reconstituted volume. In our data we do not observe reconstitution factors and so we are unable to construct a price per diluted litre.

4. Results

Table 1 presents summary statistics across beverage categories for the full analytical sample. The mean retail price per litre is lowest among bottled water and highest among juice beverages. Mean sugar content is 9.441 g/100 mL among high sugar carbonates ($Sugar_b \geq 4$ g/100 mL) and only 2.990 g/100 mL among low sugar carbonates ($Sugar_b < 4$ g/100 ml), which include both entirely artificially sweetened beverages as well as lower sugar content beverages.

Table 2 presents estimates of the pre-post regression analysis. Panel A presents the regression estimates across all container sizes, while Panel B through Panel E presents results of the analysis separately by container size. Among the tax exempt beverage categories, bottled water and 100% fruit juice, we observe no change in prices following the introduction of the HPL. The exception is 100% Juices in containers over 1.2 L for which we find a statistically significant reduction in price. For taxable beverage categories, we conduct our analysis across carbonates and non-carbonates. We find on average a 1.006 ZAR increase in price per litre on all carbonated beverages post the introduction of the HPL. For non-carbonates we do not find a statistically significant change in price. We find the largest price increase is for the smallest container carbonates, with the price increases for larger containers being significantly smaller and similar in magnitude to one another.

We further stratify carbonates into low ($Sugar_b < 4$ g/100 ml) and high sugar ($Sugar_b \geq 4$ g/100 mL) products. Low sugar carbonates, are not exempt from the HPL, but have a zero effective liability. We find comparable magnitude increases in price across container sizes for low and high sugar carbonates, despite the levy due on low sugar carbonates being effectively zero. For the smallest container category, the price increase on low sugar carbonates is substantially higher than that of the high sugar carbonates.

We plot trends in retail price before and after the introduction of the HPL in Fig. 3. There is a notable and discrete price increase for carbonates contemporaneous to the introduction of the HPL, while for the other beverage categories there are not apparent changes in price as the HPL was introduced. It is noteworthy that the observed price increase occurs immediately following implementation of the HPL, rather than a more gradual change. There is a small rise in prices three months prior to the introduction of the tax, potentially indicative of a pre-emptive price increase, and a larger price increase at the beginning of 2019.

For the second component of our analysis, we examine the extent to which the HPL was passed through (the magnitudes of price increases relative to tax liability). We restrict our sample to those carbonates which would have a positive and non-zero tax liability in the post period (i.e. those that would experience a change in effective tax liability with the introduction of the HPL). Table 3 presents our findings for these carbonates. The overall passthrough was approximately 68%. Analogous to the price changes observed in Table 2, we observe a larger pass through point estimate for smaller containers of approximately 100% for larger container the pass through varies between 51 and 56% for larger (≥400 mL) high sugar carbonates.

The final part of our analysis documents the relationship between reformulation and price change. We present in Fig. 4 a scatter plot of brands' sugar contents before and after the introduction of the HPL. Brands that were not reformulated lie on the line of equality through the origin, brands that were reformulated lie below the line of equality. As can be seen there has been significant reformulation. Panel A of Table 4 shows that the price increases were comparable for brands that were reformulated and those that were not reformulated. Moreover, for brands that were reformulated to fall below 4 g/100 mL (column (3), Panel A) there were similarly large price increases despite the zero tax liability. When we examine particular brands (Panel B of Table 4), rather than pooled categories, we see a similar pattern. Brands 2 and 3, both brands whose sugar content was significantly reduced, see price increases comparable to that of Brand 1 whose sugar content did not change. Notably, while these exemplar brands all adopted differing strategic responses to the HPL, they are all owned and operated by a single company.

5. Discussion

The ultimate reductions in disease risk which excise taxes are intended to achieve are determined by how market actors respond to the incentive structure that these policies impose. In the case of SSB taxes, many of the existing policies currently implemented, have been taxes levied per volume. There has, however, been some implementation of sugar-based taxes, with the rationale that these target the source of SSB's health harms. The dimensions of how industry respond to an excise tax, increase with the complexity of the design adopted. In this study, we examine price responses to South Africa's per gram sugar-based HPL.

Prior studies of SSB and other excise taxes find price increases in the face of their introduction or increase. For instance, in the South African setting, Linegar and van Walbeek (2018) find increases in tobacco excise result in price increases, and Russell and van Walbeek (2016) find increases in beer excise are similarly passed through to retail prices. In aggregate, the results of our study of the HPL are consistent with these and other previous studies. We find null increases in price among tax-exempt products, and statistically significant increases in the prices of carbonates which are subject to the HPL. From a public health viewpoint, the findings are indicative of an increase in the cost of consumption of the largest selling SSB by volume, namely carbonates, and

Table 1
Descriptive statistics.

	(1)	(2)	(3)	(4)	(5)	(6)
	Tax Exempt		Taxable			
	Bottled Water	100% Fruit Juice	Carbonates (All)	Carbonates (Low Sugar)	Carbonates (High Sugar)	Non-Carbonates
Price (Mean)						
Price per Litre (2016 ZAR/Litre)	10.216 (0.027)	18.474 (0.057)	16.107 (0.035)	15.782 (0.069)	16.223 (0.041)	27.328 (0.157)
Tax per Litre (2016 ZAR/Litre)			0.794 (0.007)	0.000 (0.000)	1.050 (0.004)	0.508 (0.011)
Sugar (Mean)						
Sugar content (g/100mL)			7.868 (0.040)	2.990 (0.028)	9.441 (0.022)	6.570 (0.061)
Container (Share)						
< 400 mL	0.000 (0.000)	0.047 (0.002)	0.412 (0.002)	0.416 (0.005)	0.41 (0.003)	0.213 (0.004)
> 400 mL & < 800 mL	0.789 (0.004)	0.091 (0.003)	0.188 (0.002)	0.193 (0.004)	0.186 (0.002)	0.459 (0.005)
> 800 mL & < 1.2 L	0.018 (0.001)	0.727 (0.004)	0.062 (0.001)	0.027 (0.002)	0.075 (0.001)	0.200 (0.004)
> 1.2 L	0.193 (0.004)	0.136 (0.003)	0.339 (0.002)	0.365 (0.005)	0.329 (0.003)	0.127 (0.003)
Brands (Number)						
Brands	15	16	27	13	14	28
Province (Share)						
Eastern Cape	0.103 (0.003)	0.136 (0.003)	0.103 (0.001)	0.093 (0.003)	0.107 (0.002)	0.070 (0.003)
Free State	0.129 (0.003)	0.117 (0.003)	0.085 (0.001)	0.108 (0.003)	0.077 (0.002)	0.058 (0.002)
Gauteng	0.210 (0.004)	0.203 (0.004)	0.283 (0.002)	0.278 (0.004)	0.284 (0.003)	0.244 (0.004)
KwaZulu-Natal	0.110 (0.003)	0.111 (0.003)	0.162 (0.002)	0.147 (0.003)	0.167 (0.002)	0.136 (0.003)
Limpopo	0.068 (0.003)	0.066 (0.002)	0.056 (0.001)	0.041 (0.002)	0.061 (0.001)	0.033 (0.002)
Mpumalanga	0.113 (0.003)	0.106 (0.003)	0.087 (0.001)	0.077 (0.003)	0.091 (0.002)	0.127 (0.003)
North-West	0.113 (0.003)	0.077 (0.003)	0.084 (0.001)	0.068 (0.002)	0.090 (0.002)	0.086 (0.003)
Northern Cape	0.062 (0.002)	0.058 (0.002)	0.052 (0.001)	0.081 (0.003)	0.041 (0.001)	0.057 (0.002)
Western Cape	0.092 (0.003)	0.128 (0.003)	0.087 (0.001)	0.108 (0.003)	0.080 (0.002)	0.189 (0.004)
Observations	9,712	10,399	41,879	10,997	30,882	9,677

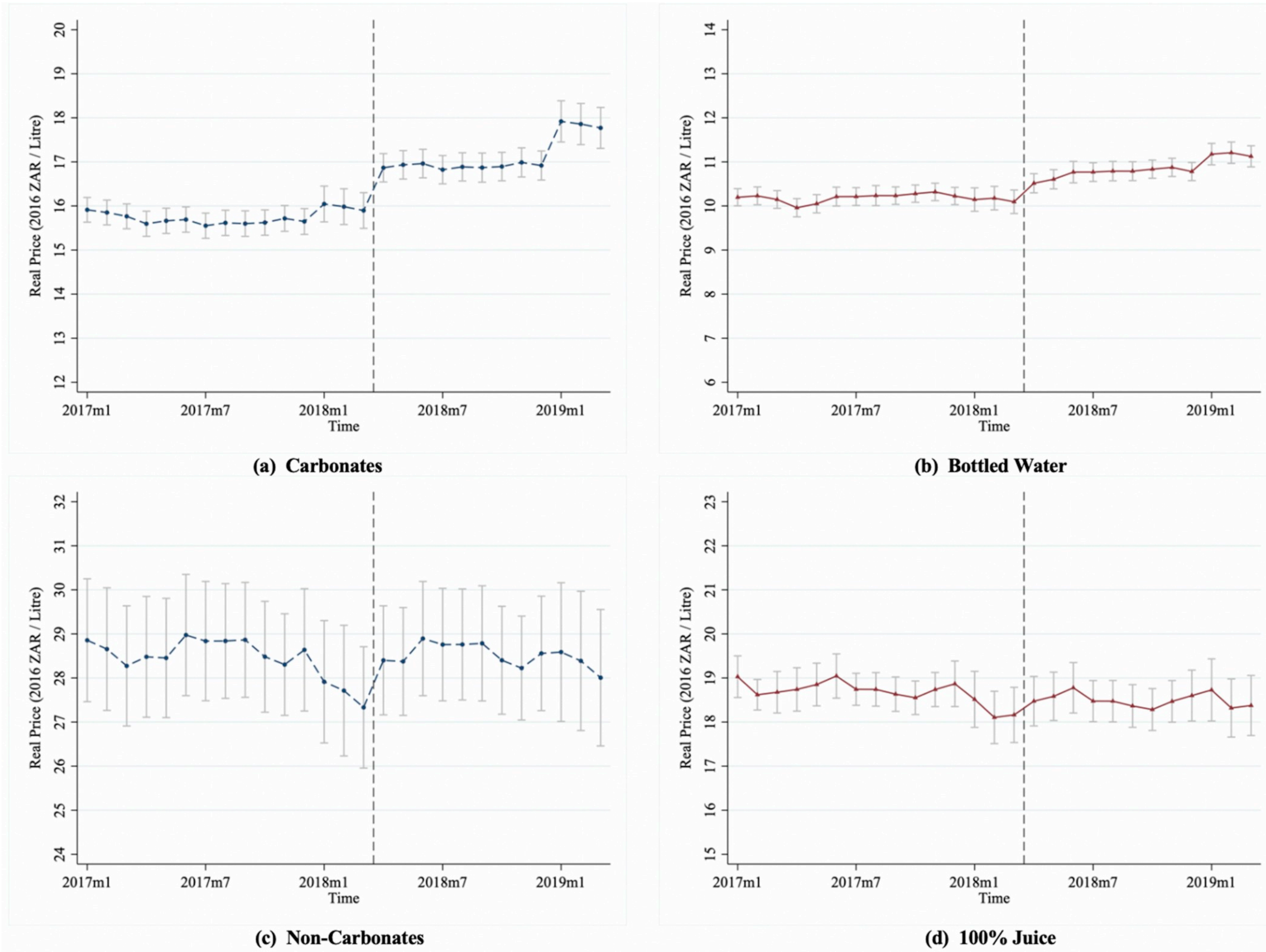
Notes: Standard errors in parenthesis. Price data from Statistics South Africa. Bottled water beverage category excludes flavoured bottled waters. Carbonates (low sugar) are carbonates with sugar content less than 4 g/100 mL. Carbonates (high sugar) are carbonates with sugar content equal to or greater than 4 g/100 mL. Non-Carbonates are sports and energy drinks, ready-to-drink teas, nectars, and flavoured bottled waters.

an increase in the price of carbonates relative to un-taxed beverages. Our estimate of pass through for carbonates is nearly 70%, with 100% pass through on small containers, and 50% pass through on larger containers. This differential pass through by container size is consistent with findings from studies of SSB taxes elsewhere and with studies of alcohol taxes in South Africa (Colchero et al., 2015; Russell and van Walbeek, 2016). An explanation worthy of further research rests with the potential greater price sensitivity of consumers who seek out the economies of scale offered by larger containers. If this is the case, lower pass through rates for larger containers would not necessarily imply

Table 2
Price change.

	(1)	(2)	(3)	(4)	(5)	(6)
	Tax Exempt		Taxable			
	Bottled Water	100% Juice	Carbonates (All)	Carbonates (Low Sugar)	Carbonates (High Sugar)	Non-Carbonates
Panel A: All container volumes						
Post	−0.114 (0.0941)	0.218 (0.352)	1.006*** (0.0740)	1.119*** (0.101)	0.950*** (0.0747)	−0.0992 (0.467)
Observations	9,712	10,399	41,879	10,997	30,882	9,677
R-squared	0.732	0.372	0.902	0.918	0.898	0.754
Panel B: Volume < 400 mL						
Post		0.818 (0.590)	1.588*** (0.131)	1.974*** (0.149)	1.450*** (0.138)	0.769 (1.763)
Observations		485	17,239	4570	12,669	2,062
R-squared		0.988	0.455	0.492	0.457	0.444
Panel C: Volume ≥400 mL & <800 mL						
Post	−0.178 (0.110)	−0.235 (0.280)	0.522*** (0.121)	0.488*** (0.183)	0.533*** (0.128)	−0.317 (0.238)
Observations	7,658	942	7,859	2,121	5,738	4,444
R-squared	0.525	0.779	0.620	0.801	0.413	0.903
Panel D: Volume ≥800 mL & <1.2 L						
Post	0.140 (0.246)	0.285 (0.387)	0.626*** (0.0749)	0.991*** (0.214)	0.606*** (0.0758)	−0.209 (0.247)
Observations	175	7,555	2,598	293	2,305	1,940
R-squared	0.770	0.266	0.708	0.802	0.708	0.926
Panel E: Volume ≥1.2 L						
Post	−0.159 (0.114)	−0.956*** (0.250)	0.624*** (0.0641)	0.371** (0.146)	0.626*** (0.0667)	1.001* (0.527)
Observations	1,878	1,413	14,182	4,013	10,169	1,228
R-squared	0.639	0.750	0.373	0.274	0.605	0.583

Notes: Outcome measure across specifications is price per litre in 2016 ZAR. Price data from Statistics South Africa. Bottled water beverage category excludes flavoured bottled waters. Carbonates (low sugar) are carbonates with sugar content less than 4 g/100 mL. Carbonates (high sugar) are carbonates with sugar content equal to or greater than 4 g/100 mL. Non-carbonates are sports and energy drinks, ready-to-drink teas, nectars, and flavoured bottled waters. Panel A includes container size controls. All specifications include brand, province, month, and year fixed effects. Robust standard errors clustered at the province-company-month level in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1.



Notes: Data from Statistics South Africa. Regression-predicted mean real price by month. 95% confidence intervals indicated by light gray bars. Vertical dashed line indicates introduction of the Health Promotion Levy. Taxed products indicated by navy dashed line.

Fig. 3. Mean retail price before and after introduction of the health promotion levy across beverage categories.

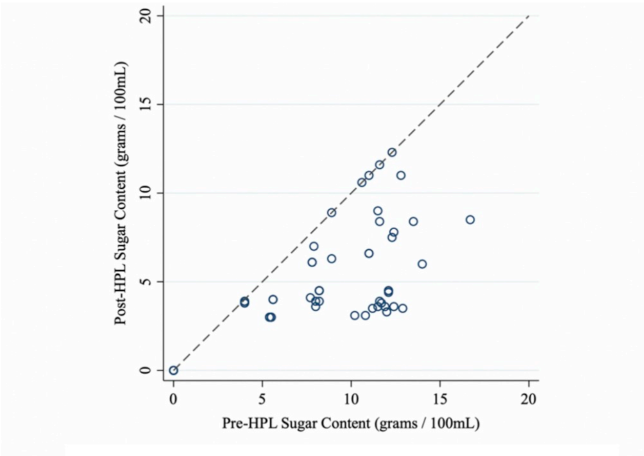
Table 3
Tax pass through.

	(1)	(2)	(3)	(4)	(5)
	Carbonates	Carbonates	Carbonates	Carbonates	Carbonates
	(High Sugar)	(High Sugar, Volume <400 mL)	(High Sugar, Volume ≥400 mL & <800 mL)	(High Sugar, Volume ≥800 mL & <1.2 L)	(High Sugar, Volume ≥1.2 L)
Tax per Litre (2016 ZAR/ litre)	0.676*** (0.0594)	1.005*** (0.109)	0.509*** (0.0953)	0.564*** (0.0569)	0.511*** (0.0641)
Observations	30,882	12,669	5738	2305	10,169
R-squared	0.898	0.455	0.414	0.714	0.605

Notes: Outcome measure across specifications is price per litre in 2016 ZAR. Price data from Statistics South Africa. Sample restricted to carbonates with sugar content equal to or greater than 4 g/100 mL in the post-HPL period. All specifications include brand, province, month, and year fixed effects. Robust standard errors clustered at the province-company-month level in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1.

smaller effects on consumption, as consumption would fall by larger amounts for a given price change.

If we go beyond aggregate patterns between products subject to the levy and not, and examine heterogeneity in price behaviour by sugar content and HPL liability, we uncover some counter-intuitive regularities. We find price increases among low sugar carbonates, beverages which are technically subject to the HPL but are taxed at an effective rate of zero ZAR per litre, are positive and of similar magnitude to those of high sugar carbonates. This suggests that although the HPL increased the relative price between carbonates and un-taxed products, the HPL was not effective in increasing the relative price between higher sugar and lower sugar varieties within the carbonate segment. While the HPL may incentivize substitution from high sugar carbonates to bottled water (or other untaxed products), it has not created an incentive to substitute to low sugar or diet carbonates. The ultimate public health impacts of these price changes will be borne out by overall substitutions



Notes: Pre-HPL sugar content data are from Euromonitor Passport Database, and Coca-Cola (2012). The dashed line through the origin is a line of equality, indicating equivalent sugar content before and after introduction of the HPL. Points falling below that line indicate brands for which the sugar content was reduced.

Fig. 4. Brands' sugar content pre- and post-introduction of the HPL.

and changes in purchasing patterns which warrant further study.

The notion that a tax that is increasing in sugar content will necessarily produce greater price increases among higher sugar products makes intuitive sense. However, it is a product of a simplified partial equilibrium theoretical construct. Reality, however, is complex and includes simultaneous existence of highly heterogenous products, multiproduct firms, and heterogeneous consumers with differential demand across a variety of beverages. Conditional on demand price elasticities, it is possible our counter-intuitive findings of increased prices on lower sugar carbonates could be evidence of an intra-firm strategy to compensate for profits lost on higher sugar and therefore higher tax products by increasing margins on lower sugar products (particularly if demand for these products is less price sensitive).

Related to this is the behaviour we observe in our analysis of joint pricing-reformulation response to the HPL. Comparing sugar content across brands before and after the introduction of the HPL, we find significant evidence of reformulation. When we examine how pricing and reformulation interact, we find that brands that reformulated (including those reformulated to contain less than 4 g of sugar per 100 mL) did so alongside initiating an increase in prices, despite the reduction in tax liability. If reformulation is costly, this may arise as there is a short term need to increase prices and so whether this phenomenon persists should be examined.

That the per gram tax design was able to generate some very large reductions in sugar content has some implications for tax design. Tiered tax designs create large marginal incentives for reformulation around the thresholds of their tiers, while a per gram tax such as the HPL has much smaller but constant incentive for marginal reformulation regardless of baseline sugar level. Nevertheless, the HPL coincided with some instances of very large sugar reduction. As can be seen in Fig. 4, many brands with over 10 g of sugar per 100 mL reformulated to well below 5 g of sugar per 100 ml. Thus, it appears the locally large reformulation incentives of tiered tax designs may not be necessary to motivate meaningful product change.

Our study is necessarily subject to some limitations. A pervasive issue in the study of the effects of the introduction of national SSB tax policies is the absence of a viable counterfactual. Conventional policy evaluation methods such as differences-in-differences require an untreated population which nationally-implemented policies do not allow for. It could be possible to construct counterfactuals from populations in neighbouring or unaffected countries, however this would require data collected in a consistent manner across countries. Further, while it is true that there are taxed and un-taxed classes of beverages, it is not the beverages themselves that are subject to the intervention. The subjects of the intervention are the entities manufacturing or importing the beverages, who typically would produce a range of taxed and untaxed beverages, and thus untaxed beverage prices could be subject to some spill-over effects.

6. Conclusion

With growing interest in the use of tax and fiscal policy to reduce the harms associated with SSB consumption, there has been some general guidance issued to levy taxes on SSBs with higher tax rates on higher sugar content products relative to those of lower sugar products (WHO, 2016). However, due to the novelty of such sugar-based SSB tax policies, there is limited actual experience from which best practices on how to design and implement such taxes could be based. Our study provides evidence on industry responses to a linear tax (with an initial tax free threshold) as implemented in South Africa. We find some price responses consistent with the volumetric tax literature, however we find some unexpected responses, namely through price increases among low sugar (zero tax) carbonatescarbonates similar to those of high sugar carbonates carbona, as well as price increases for reformulated products similar to those of products that were not reformulated. These results suggest that at least in the South African context, the beverage industry's pricing response to the introduction of the HPL has encompassed their whole portfolio of taxed and un-taxed products. As evidence on the effects of tax designs adopted elsewhere come in, our understanding of the differential effects of alternative designs will grow as will the evidence base for effective SSB excise policy.

Table 4
Price change and reformulation.

	(1)	(2)	(3)
Panel A: All Brands	Not Reformulated	Reformulated	Reformulated to Less Than 4 g/100 mL
Post	0.919*** (0.0755)	1.080*** (0.0877)	1.158*** (0.0910)
Observations	17,800	21,473	8663
R-squared	0.879	0.928	0.931
Panel B: Exemplar Brands	Brand 1 (Not Reformulated)	Brand 2 (Reformulated)	Brand 3 (Reformulated to Less Than 4 g/100 mL)
Post	0.941*** (0.0815)	0.899*** (0.0821)	1.224*** (0.114)
R-squared	0.901	0.968	0.896

Notes: Outcome measure across specifications is price per litre in 2016 ZAR. Price data from Statistics South Africa. Sample restricted to carbonates. We omit sample size for brand-specific analyses to prevent brand identification. All specifications include brand, province, month, and year fixed effects. Robust standard errors clustered at the province-company-month level in parentheses. ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Declaration of interests

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2019.112465.

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