This is a repository copy of Soft drink prices, sales, body mass index and diabetes: Evidence from a panel of low-, middle- and high-income countries.

White Rose Research Online URL for this paper:
http://eprints.whiterose.ac.uk/132892/

Version: Published Version

Article:
Goryakin, Yevgeniy, Monsivais, Pablo and Suhrcke, Marc orcid.org/0000-0001-7263-8626 (2017) Soft drink prices, sales, body mass index and diabetes: Evidence from a panel of low-, middle- and high-income countries. Food Policy. pp. 88-94. ISSN 0306-9192

https://doi.org/10.1016/j.foodpol.2017.09.002

Reuse
This article is distributed under the terms of the Creative Commons Attribution (CC BY) licence. This licence allows you to distribute, remix, tweak, and build upon the work, even commercially, as long as you credit the authors for the original work. More information and the full terms of the licence here:
https://creativecommons.org/licenses/

Takedown
If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing eprints@whiterose.ac.uk including the URL of the record and the reason for the withdrawal request.
Soft drink prices, sales, body mass index and diabetes: Evidence from a panel of low-, middle- and high-income countries

Yevgeniy Goryakin, Pablo Monsivais, Marc Suhrcke

Article Info

ARTICLE INFO

Keywords:
Soft drink prices
Diabetes
Body mass index
Fiscal policies

ABSTRACT

We take advantage of four different cross-country datasets containing data on 78 countries for the period 1999–2014, in order to assess the relationship of carbonated soft drinks’ sales, as well as their prices, with body mass index (BMI), overweight, obesity and diabetes. Using an ecological study design and multivariate regression longitudinal estimation approaches, we find that carbonated soft drink sales were significantly positively related to BMI, overweight and obesity – but only in the low and lower-middle income countries. This finding was robust to a number of sensitivity and falsification checks. In this sub-sample, an increase in per capita soft drink sales by 1 litre per year was related to an increase of BMI by about 0.009 kg/m² (p < 0.1). This is a small effect, implying that halving annual consumption per capita in this group of countries would result in a drop of BMI by only about 0.03 kg/m². Although soft drink prices were negatively related to weight-related outcomes in the sample of higher middle income and high income countries, this finding was not robust to falsification checks. The results thus suggest that sales restrictions to steer consumers away from soft drinks could indeed have a beneficial health effects in poorer countries, although the effect magnitude appears to be very small. However, given potential limitations of using ecological research design, results from individual level studies would be required to further ascertain the role of soft drink sales and prices in obesity and diabetes.

1. Introduction

Consumption of soft drinks, and in particular of sugar-sweetened beverages (SSBs), has been singled out as a global public health concern (Vartanian et al., 2007), in light of their contribution to total dietary sugar intake, high glycemic index and purported role in excess energy intake (Vartanian et al., 2007). Soft drinks consumption has been growing globally (Popkin, 2010); as (Moodie et al., 2013) have shown, the average annual growth rate of per capita soft drink consumption between 1997 and 2009 was 5.2% in low and middle income countries, and 2.4% in high income countries.

Converging lines of evidence indicate that SSBs are associated with greater adiposity and weight gain. Three systematic reviews (Malik et al., 2013, 2006; Vartanian et al., 2007), as well as another review article (Hu, 2013) concluded there was evidence of a positive association between individual-level soft drink intake and body weight or the odds of overweight and obesity. Interestingly, larger effect sizes were observed in experimental than in observational studies, suggesting a potential attenuation bias in non-experimental studies. Likewise, estimates were found to be larger in non-industry-sponsored studies. More recent trials provided yet stronger causal evidence, indicating that replacement of SSBs with non-caloric beverages reduced weight gain and fat accumulation in normal-weight children (de Ruyter et al., 2012).

Consumption of SSBs may also increase the risk of type-2 diabetes. For example, ecological studies have suggested correlations between increasing consumption of soft drinks and rates of diabetes (Basu et al., 2013; Greenwood et al., 2014; Gross et al., 2004; Schulze et al., 2004). In their meta-analysis of 11 studies, Malik et al. (2010) estimated that people in the highest quintile of SSB consumption have an about 26% greater risk of diabetes compared to people in the lowest one. Nevertheless, it should be emphasized that the difference in these consumption thresholds is very large, with people in the first group having 1–2 servings of SSBs a day, and those in the latter having none or one serving a month. Finally, in another recent systematic review, one extra serving per day of SSB was found to be related to an about 18% greater risk of diabetes, with nearly nine percent of USA type-2 diabetes cases...
attributable to SSBs (Imamura et al., 2015).

From the policy point of view, it is important to know how overweight/obesity and diabetes are related to consumption and prices of soft drinks and juices. For the association to hold there should be a correlation not only between consumption of these drinks and overweight/diabetes, but also between prices and consumption. While a recent meta-analysis estimated a rather large combined own price elasticity of SSBs (Cabrera Escober et al., 2013) of around –1.3, this finding was based mostly on studies from high income countries (8 out of 10). Moreover, the study with the largest elasticity (–4.45) included in the meta-analysis was actually restricted to children and adolescents only. Yet, if there was any negative effect of prices on average BMI, it was not possible to conclude this from the studies reviewed: in 2 out of 5 the association was positive, while in the remaining 3 the association appeared to be small. Nevertheless, the association between prices and overweight/obesity was in the expected negative direction in 8 studies reviewed, although it appears it was significant in only two of them. Similarly, Schroeter et al. (2008) concluded that even in the US, only modest changes in population weight will result from increasing soft drinks taxation, because their consumption represents only 7% of total energy intake. In a recent modelling study for the UK, Briggs et al. (2013) also estimated a rather small effect, implying that an increase in the tax on SSD by 20% would lead to a 1.3% reduction in the proportion of people who are overweight.

In sum, the existing evidence on the effect of soft drink consumption on BMI/overweight/diabetes, as well as on the effect of prices on BMI/overweight/diabetes, is incomplete with most evidence coming from higher-income countries. The evidence base would benefit from more research based on longitudinal and/or individual-level data (Basu et al., 2013). In this paper, we compose and utilize a large, cross-country longitudinal dataset, attempting to find out how the soft drinks sales per capita, as well as their prices, are related to average BMI, overweight, obesity and diabetes prevalence in a sample of 78 low, middle and high income countries.

2. Methods

2.1. Data

2.1.1. Outcome variables

The outcome data in our paper is taken from several sources. First, the data on average, age-standardized country-level BMI levels, overweight, obesity and diabetes prevalence are from the NCD Risk Factor Collaboration (NCD-RisC) project, available annually between 1999-2014. The data have been estimated on the basis of a large number of surveys, articles and epidemiological studies (Danaei et al., 2011a, 2011b; Finucane et al., 2011a).

2.1.2. Key independent variables

The data on carbonated soft drink sales and prices is from the Euromonitor, Passport Global Market Information Database (2014 edition). The data contains information on carbonated soft drink sales and prices from 78 countries worldwide, spanning the period from 1999 to 2014. We obtained carbonated soft drink prices (in US$ per litre, historic constant 2013 prices) by dividing the total off-trade value of carbonated soft drinks by the off-trade volume of these beverages (in million litres). To facilitate inter-country comparisons, we divided these prices by the price level index (PLI) produced by the World Bank. PLI is a ratio of purchasing power parities to corresponding exchange rates, and it is often used to compare prices between different countries.

capita sales of carbonated soft drinks were derived by dividing the off-trade volume of these drinks by the population of each country. To reduce potential for reverse causality, the main independent covariates of interest (prices as well as sales of soft drinks) were lagged by one year in all models.

2.1.3. Control variables

When estimating the association between carbonated soft drink sales and weight-related outcomes, it is important to keep in mind that soft drink production is highly globalized, with more than half of it being controlled by large international corporations, such as Coca-Cola and PepsiCo (Moodie et al., 2013). Therefore, we control for the degree of globalization as measured by the KOF Globalization index (Dreher, 2006b), which was shown in previous research to also contribute to overweight and obesity (Goryakin et al., 2015; Vogli et al., 2014). The index is based on the conceptualisation by Keohane and Nye (2000) who proposed three distinct dimensions of globalization: (1) economic: long distance flows of goods, capital and services as well as information and perceptions that accompany market exchanges, (2) political: the diffusion of government policies internationally, and (3) social: the spread of ideas, information, images, and people. For all dimensions, this index was created using comprehensive data collected annually since 1970. In our main analysis we use the overall KOF globalization index. The KOF globalization index, including its three subcomponents, has been obtained from the KOF project website http://globalization.kof.ethz.ch, and is described in detail in (Dreher, 2006a).

We also included several control variables from the World Bank Development Indicators. Specifically, as soft drink sales were also found to increase with national per capita income (Basu et al., 2013), and as income is a determinant of health (Grossman, 2000), we also control for the logarithm of GDP per capita in all our models (in constant, 2005 US dollars). We also control for other potential correlates of soft drink sales and BMI – the proportion of the population living in urban areas, proportion of the population aged 15–64, and the proportion of women in the population, using data from the World Bank indicators. As soft drink and fast food consumption can go hand in hand, the latter may confound the association of the former with overweight/diabetes. Although we do not have a reliable measure for fast food sales, we expect that controlling for globalization and urbanization – both potentially important determinants of fast food consumption (Mendez and Popkin, 2004) – would tend to alleviate this concern. In addition, as both soft drink prices and BMI/obesity may follow a time trend, we also control for time dummies.

Finally, using year-specific thresholds applied to GDP per capita, current US$ (Atlas method) from the World Bank, we split countries into two groups: low and lower middle income countries (which we abbreviate, for convenience, as LMICs) vs upper middle and high income countries (UHICs). As the income classification does vary over the observation period for some countries, we used the 2013 year-specific income group definition, and applied it to each country over the whole period. Using this classification, the data included 63 LMICs and 15 UHICs (see Annex).

2.2. Analysis

We estimate our associations of interest using ordinary least squares (OLS) multivariate regressions models as a baseline specification. As described below, we further take advantage of the longitudinal nature of the data by controlling for time effects, as well as for country-level fixed effects.

When estimating the associations between soft drink prices and BMI/weight/diabetes, it is important to control for cross-country differentials in the local price levels. We deal with this by using standardized, US$-denominated prices in all countries, adjusted by the PLI. Furthermore, any potential association between the variables of interest may be confounded by heterogeneity, both time-varying and time-
invariant. We deal with the latter by controlling for country fixed effects (CFE), which may proxy for the potential determinants of both weight/diabetes and price levels, which do not change over time. Conditional on the assumption that the residual error term is uncorrelated with the soft drink sales/prices after controlling for CFE and other variables of interest, the CFE estimator is unbiased. However, using CFE comes at a cost of a less precise estimation than under the alternative random effects assumption (Cameron and Trivedi, 2005). Nevertheless, as the random effects assumption is more restrictive than the fixed effects one, we prefer to be more conservative in our estimation approach, and consistently control for CFE across all specifications (besides the baseline OLS estimates). Formally, we aim to estimate parameters in the following equation:

\[ Y_{ij} = \alpha + \beta_j X_{it-1} + Z_{it} \beta_2 + \alpha_i + \epsilon_{ij} \]  

(1)

where \( Y_{ij} \) is one of the four outcome variables \( j \) associated with country \( i \) at time \( t \); \( X_{it-1} \) captures lagged soft drink sales per capita, or CFE-adjusted price; \( Z_{it} \) is the vector of control variables as described above, with the associated parameter vector \( \beta_2 \); \( \alpha_i \) are country fixed effects, possibly correlated with \( X \) and \( Z \), and \( \epsilon_{ij} \) is an error term.

Another complication is that health behaviours may cluster. For example, lack of physical exercise (Hill et al., 2003), soft drink and fast food sales can correlate with each other (Malik et al., 2006). Again we assume that controlling for country and time effects, as well as for globalization and urbanization (both of which are potentially important drivers of these health behaviours and of health in general (Goryakin et al., 2015; Goryakin and Suhrcke, 2014)), should help alleviate this concern. However, we cannot rule out that some important variables may be omitted. To deal with this issue, we will perform a simple falsification check, based on the assumption that bottled water sales per capita, as well as the price of the bottled water, should be unrelated to any of our outcome variables. If this is not the case, then there can be some confounding mechanism common to both soft drink and bottled water equations. For example, propensity to exercise, to consume fast food, or some socioeconomic dimension that we are unable to control for, may be correlated with both soft drink and bottled water sales. Any potential correlation that we find between bottled water sales/prices and our outcome variables of interest may reflect this residual confounding, which might also apply in the case of the soft drink sales/prices equations.

3. Results

3.1. Descriptive statistics

Table 1 presents basic descriptive statistics, showing that between 1999 and 2014, the average PLI-adjusted price of soft drinks has been decreasing for the countries in this study. Compatible with this trend, soft drink sales per capita has been on the increase around the world, which is in line with previous evidence (Basu et al., 2013). These trends have been accompanied by a small but steady increase in mean BMI, as well as by much more marked increase in average overweight, obesity and diabetes prevalence in our global sample of countries.

Figs. 1 and 2 below provide a first glimpse of the bivariate relationships between the main variables of interest, using locally weighted scatterplot smoothing (‘lowess’) graphs.

Fig. 1 indicates that, as expected, PLI-adjusted soft drink prices are quite strongly negatively related to soft drink sales. Fig. 2 similarly suggests that soft drink prices are strongly negatively related to mean overweight and obesity prevalence. Likewise, there is a clear positive relationship, if at a decreasing rate, between soft drink sales per capita and average overweight and obesity prevalence. However, the relationship is not pronounced when diabetes is used as the outcome variable.

This simple preliminary analysis seems to support prior expectations regarding the direction of the relationship between the main variables of interest. However, as it might be driven by omitted covariates and time trends, we consider these issues further in the next section.

3.2. Regression analysis

3.2.1. Do higher soft drink prices reduce soft drink sales?

We start by estimating the elasticity of soft drink sales with respect to their relative prices. In Table 2 (and in all tables that follow), we only present the main parameters of interest. For example, in column 1, the parameter of \(-0.209\) was obtained from regressing log soft drink sales on log relative prices for soft drinks (lagged by 1 year), controlling for the percentage living in urban areas, the percentage aged 15–64 years, the proportion of females (all out of the total population), log GDP per capita, a measure of the country’s degree of globalization, regional dummies and time effects.

As was the case in Fig. 1, the bivariate association in the preferred CFE model is negative. The relationship appears to be much more pronounced in the sample of the UHIC countries, where each 1% increase in the PLI-adjusted price of soft drinks is related to about 0.3% fall in soft drink sales per capita.
we estimate di

5

0.022

15

20

150

100

0.085

200

0.116

60

0.044

0.098

50

40

80

10

0.059

Source: NCD Risk Factor Collaboration dataset. All models control for % living in urban areas, % aged 15-64, proportion of females in total population, log GDP per capita, total globalization index, regional dummies, country and time effects. Soft drink sales per capita are lagged 1 year. *The alternative controls set is: % living in urban areas, % aged 15-64, proportion of females in total population, log GDP per capita, economic, social and political globalization; food supply, kcal/capita/day; fat supply, g/capita/day; protein supply, g/capita/day; regional dummies, country and time effects. Standard errors are clustered on a country level.

** * p < 0.05, ** p < 0.01

Source: NCD Risk Factor Collaboration dataset. All models control for % living in urban areas, % aged 15-64, proportion of females in total population, log GDP per capita, total globalization index, regional dummies, time effects. Soft drink sales per capita are lagged 1 year. UHICs: high income and upper middle income countries; LMICs: low and lower middle income countries. All models control for % living in urban areas,% aged 15-64, proportion of females in total population, log GDP per capita, economic, social and political globalization; food supply, kcal/capita/day; fat supply, g/capita/day; protein supply, g/capita/day; regional dummies, country and time effects. Standard errors are clustered on a country level.

** * p < 0.05, ** p < 0.01

Source: Euromonitor (2014), and Global Burden of Metabolic Risk Factors of Chronic Diseases data (downloaded in 2015). Note: each dot represents one country in one year.

Table 2

| Country            | PLI-adjusted price, soft drinks | All countries | LMICs | UHICs |
|--------------------|---------------------------------|---------------|-------|-------|
|                    | (1) (2) (3) (4)                 |               |       |       |
| PLI-adjusted price | -0.209** -0.087* -0.321*** -0.066 |               |       |       |
| Soft drinks        | (0.132) (0.046) (0.055) (0.055) |               |       |       |
| Country fixed effects | No Yes Yes Yes |               |       |       |
| Observations       | 1162 1162 225 937               |               |       |       |
| R-squared          | 0.766 0.515 0.709 0.505         |               |       |       |

Outcome variables and relative prices are in log form. All models control for % living in urban areas,% aged between 15 and 64; proportion of females in total population, log GDP per capita, total globalization index, regional dummies, time effects. Relative price is lagged 1 year. UHICs: high income and upper middle income countries; LMICs: low, lower middle and middle income countries. Standard errors are clustered on a country level.

### 3.2.2. Do higher soft drink sales increase mean BMI, as well as overweight and obesity prevalence?

Our baseline estimates suggest that when all countries are pooled together, each litre increase in per capita sales of soft drinks is associated with a 0.02 unit increase in BMI in the OLS specification (Table 3).

Likewise, the same increase in sales implies a significant increase in the risk of obesity by 0.10 percentage points (p.p.), and of overweight by 0.116 p.p. Nevertheless, these findings are not robust to controlling for country fixed effects in the longitudinal dataset, as all parameters turn insignificant.

Next, in Table 4 we estimate differential associations between soft

Table 4

| Country            | (1) (2) (3) | (1) (2) (3) | (1) (2) (3) |
|--------------------|------------|------------|------------|
|                    | BMI | Overweight% | Obese% | BMI | Overweight% | Obese% | BMI | Overweight% | Obese% |
| Soft drink sales, per capita | 0.099** | 0.022** | 0.059*** | (0.002) | (0.012) | (0.018) | Soft drink sales, per capita | 0.099** | 0.022** | 0.059*** | (0.002) | (0.012) | (0.018) |
| Observations       | 225 | 225 | 225 | Observations | 176 | 176 | 176 |
| R-squared          | 0.966 | 0.978 | 0.904 | R-squared | 0.978 | 0.982 | 0.918 |
| Bottled water sales, per capita | 0.001 | 0.018 | 0.014 | Bottled water sales, per capita | 0.001 | 0.018 | 0.014 |
| Observations       | 225 | 225 | 225 | Observations | 937 | 937 | 937 |
| R-squared          | 0.958 | 0.979 | 0.888 | R-squared | 0.906 | 0.963 | 0.928 |

Source: NCD Risk Factor Collaboration dataset. UHICs: high income and upper middle income countries; LMICs: low and lower middle income countries. All models control for % living in urban areas,% aged 15-64, proportion of females in total population, log GDP per capita, total globalization index, regional dummies, country and time effects. Soft drink sales per capita are lagged 1 year. **The alternative controls set is: % living in urban areas,% aged 15-64, proportion of females in total population, log GDP per capita, economic, social and political globalization; food supply, kcal/capita/day; fat supply, g/capita/day; protein supply, g/capita/day; regional dummies, country and time effects. Standard errors are clustered on a country level.

** * p < 0.05, ** p < 0.01, *** p < 0.01
drink sales and weight outcomes among low and lower-middle income countries vs upper-middle and high income countries, in all cases controlling for country fixed effects. The association is now positive and statistically significant in the LMICs subsample, and it is also robust to the use of the alternative control set. Specifically, in that set, we control for the separate components of the globalization index, as well as for three additional variables from the Food and Agricultural Organisation (FAO) proxying for the energy availability in a given country – food, protein and fat supply per capita. The falsification check also confirms that bottled water sales per capita are unrelated to any of our weight-related outcome variables of interest. Finally, the association is insignificant in the UHICs subsample.

Next, we find that soft drink sales are unrelated to diabetes prevalence in all specifications (Table 5).

In Table 6, the association between relative prices and all four outcomes of interest is shown. First, consider the top part of the table. As expected, BMI and overweight are negatively related to increases in the PLI-adjusted price of soft drinks, both in the pooled sample and in the sample of UHICs. Thus, in the overall sample, each one point increase in the price of soft drinks is related to decreases in BMI by about 0.03 units, and in the risk of overweight by 0.17 p.p. This association becomes much more pronounced in the sample of UHICs, including for obesity and diabetes.

Next, we test the robustness of these findings by using a different definition for the relative soft drink prices. First, we divide the soft drink price per litre by the bottled water price per litre, in each country. This price metric is useful for assessing how relatively less expensive the alternative of consuming non-sugary drinks is compared to soda. In accordance with basic microeconomic theory, we assume that the more expensive the soft drinks are relative to bottled water, the less likely people will be to choose the former. One might reasonably object that local characteristics such as the availability of fresh, potable water may drive the pricing of bottled water (as well as whether people choose to drink tap water instead). We account for this by allowing for country-specific fixed effects. Again, our results suggest that price is strongly negatively related to weight-related outcomes in the sample of UHICs, implying that for each doubling of the price of soft drinks relative to bottled water, there is a drop of overweight and obesity prevalence by about 0.3 p.p.

Finally, we adjust soft drink prices by the prices of wheat per ton. The magnitude of the parameters is not directly comparable with the PLI-adjusted price of soft drinks, both in the pooled sample and in the sample of UHICs. However, in the sample of UHICs, the price of soft drinks per litre is related to decreases in BMI by about 0.06 p.p. and in the risk of overweight by 0.26 p.p.

We found that in the sample containing all countries, soft drink sales were positively related to BMI, obesity and diabetes in the baseline OLS models, which was also consistent with findings from several recent systematic reviews (Imamura et al., 2015; Pereira, 2006; Vartanian et al., 2007). Nevertheless, this relationship was rendered insignificant after controlling for country fixed effects, implying that unobserved time-invariant heterogeneity accounts for a significant part of the positive association observed in the OLS models. It is unclear a priori why controlling for CFE makes such a large difference, but it might be the case that some local preferences for sugary or generally unhealthy foods may introduce positive bias if this relationship is estimated by OLS. This was not the case in the LMICs sample, as the association between per capita soft drink sales and all three weight-related outcomes continued to remain significant even after controlling for country fixed effects, as well as after running several robustness and falsification checks.

Nevertheless, even in the LMICs sample, the magnitude of this association was modest, with each litre increase in soft drink sales per capita per year leading only to a 0.009 unit increase in BMI in the more robust CFE model (Table 4). This translates to a 0.26 greater BMI for one standard deviation drop in soft drink sales, which would explain about 16% of one standard deviation of the BMI distribution. Another way to look at it is that annual soft drink sales range from 0.9 to 70 litres per capita in the LMICs. Reducing sales from the highest to the lowest level in that group of countries could potentially lead to a reduction of BMI by about 0.62 kg/m², or by about 3%. More informatively, however, would be to consider the effect of changes in the annual soft drink consumption in LMICs, which is about 6 litres per capita. A very ambitious goal of halving this level would be predicted to lead to only about a 0.03 kg/m² reduction in BMI, a 0.06 p.p. reduction in overweight, and a 0.18 p.p. reduction in obesity prevalence.

Another ecological study which used similar data yet with a

---

4 http://www.fao.org/faostat/en/
5 The data is from FAOSTAT: http://www.fao.org/faostat/en/#data

---

Table 5

|               | (1) OLS | (2) CFE | (3) LMICs | (4) UHCs |
|---------------|---------|---------|-----------|----------|
| Soft drink sales, per capita | 0.009   | 0.002   | 0.012     | 0.002    |
| Country fixed effects | (0.006) | (0.004) | (0.017)   | (0.004)  |
| Observations   | 1162    | 1162    | 225       | 937      |
| R-squared      | 0.702   | 0.737   | 0.786     | 0.782    |

Notes: Risk Factor Collaboration dataset. UHICs: high income and upper middle income countries; LMICs: low and lower middle countries. All models control for% living in urban areas,% aged 15-64, proportion of females in total population, log GDP per capita, total globalization index, regional dummies, country and time effects. Soft drink sales per capita are lagged 1 year. Standard errors are clustered on a country level.

*** p < 0.01, ** p < 0.05, * p < 0.1

---

4. Policy implications

To date, the evidence on the impact of soft drink sales on overweight/obesity has been dominated by studies from North America which may have little applicability to other contexts (Gibson, 2008). The present paper adds to the evidence base by helping fill several gaps in the existing literature. For example, there is a dearth of studies using more advanced methods of controlling for unobserved heterogeneity (e.g. via country fixed effect estimation), or which consider additional metabolic disorder-related outcomes, such as diabetes. There are also very few studies which consider the association between prices of soft drinks and these outcome variables, in particular for low and middle income countries.

We found that in the sample containing all countries, soft drink sales were positively related to BMI, obesity and diabetes in the baseline OLS models, which was also consistent with findings from several recent systematic reviews (Imamura et al., 2015; Pereira, 2006; Vartanian et al., 2007). Nevertheless, this relationship was rendered insignificant after controlling for country fixed effects, implying that unobserved time-invariant heterogeneity accounts for a significant part of the positive association observed in the OLS models. It is unclear a priori why controlling for CFE makes such a large difference, but it might be the case that some local preferences for sugary or generally unhealthy foods may introduce positive bias if this relationship is estimated by OLS. This was not the case in the LMICs sample, as the association between per capita soft drink sales and all three weight-related outcomes continued to remain significant even after controlling for country fixed effects, as well as after running several robustness and falsification checks.

Nevertheless, even in the LMICs sample, the magnitude of this association was modest, with each litre increase in soft drink sales per capita per year leading only to a 0.009 unit increase in BMI in the more robust CFE model (Table 4). This translates to a 0.26 greater BMI for one standard deviation drop in soft drink sales, which would explain about 16% of one standard deviation of the BMI distribution. Another way to look at it is that annual soft drink sales range from 0.9 to 70 litres per capita in the LMICs. Reducing sales from the highest to the lowest level in that group of countries could potentially lead to a reduction of BMI by about 0.62 kg/m², or by about 3%. More informatively, however, would be to consider the effect of changes in the annual soft drink consumption in LMICs, which is about 6 litres per capita. A very ambitious goal of halving this level would be predicted to lead to only about a 0.03 kg/m² reduction in BMI, a 0.06 p.p. reduction in overweight, and a 0.18 p.p. reduction in obesity prevalence.

Another ecological study which used similar data yet with a
different focus (De Vogli et al., 2014) found that soft drink sales per capita were mediating the relationship between fast food sales and age-standardized BMI, although the parameter on soft drink sales per capita were mediating the relationship between fast food sales and age-averaged BMI – aged 15–64, proportion of females in total population, log GDP per capita, total globalization index, regional dummies, country and time effects. Soft drink sales per capita are lagged 1 year. Standard errors are clustered on a country level. PLI: price level index.

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| SD price, PLI- adjusted | -0.025 | -0.166 | -0.041 | -0.074 | 0.004 | 0.079 | 0.167 | 0.016 | -0.033 | -0.251 |
| R-squared | 0.915 | 0.964 | 0.903 | 0.742 | 0.958 | 0.978 | 0.889 | 0.783 | 0.909 | 0.965 |
| RM-squared | 0.995 | 0.993 | 0.993 | 0.993 | 0.993 | 0.993 | 0.993 | 0.993 | 0.993 | 0.993 |
| Observations | 1162 | 1162 | 1162 | 1162 | 225 | 225 | 225 | 225 | 937 | 937 |
| Water price | (0.013) | (0.07) | (0.081) | (0.053) | (0.020) | (0.106) | (0.135) | (0.112) | (0.016) | (0.095) |
| R-squared | 0.912 | 0.963 | 0.907 | 0.737 | 0.960 | 0.979 | 0.888 | 0.790 | 0.908 | 0.964 |
| SD relative to bottled price | 0.004 | 0.003 | 0.004 | 0.003 | 0.038 | 0.043 | 0.026 | 0.032 | 0.034 | 0.034 |
| Observations | 870 | 870 | 870 | 870 | 114 | 114 | 114 | 114 | 756 | 756 |
| R-squared | 0.92 | 0.965 | 0.937 | 0.764 | 0.964 | 0.983 | 0.932 | 0.918 | 0.919 | 0.966 |
| Bottled water price, PLI- adjusted | -0.046 | -0.303 | -0.256 | -0.15 | -0.043 | 0.027 | 0.028 | -0.054 | -0.04 | -0.311 |
| Observations | 1162 | 1162 | 1162 | 1162 | 225 | 225 | 225 | 225 | 937 | 937 |
| R-squared | 0.917 | 0.965 | 0.907 | 0.750 | 0.960 | 0.979 | 0.885 | 0.784 | 0.910 | 0.966 |

Notes: Risk Factor Collaboration dataset. UHICs: high income and upper middle income countries; LMICs: low and lower middle countries. All models control for % living in urban areas, % aged 15–64, proportion of females in total population, log GDP per capita, total globalizatation index, regional dummies, country and time effects. Soft drink sales per capita are lagged 1 year. Standard errors are clustered on a country level. PLI: price level index.
period for which data was available. Finally, even though we have an equal split between LMICs and HICs, the relatively small number of countries in each group and overall (78) implies that our results may not be fully representative for all countries in the world.

5. Conclusion

Overall, although we did find some evidence that soft drink sales are a statistically significant predictor of BMI and obesity, at least in the sample of low and lower middle income countries, the magnitude of this effect was small. However, this does not imply that soft drink sales and prices are an insignificant driver of obesity, but it does highlight the potential limitations of using ecological research design when studying this association. Therefore, results from individual level studies will be required to further ascertain the role of prices and of soft drink sales in obesity and diabetes.

Acknowledgements

We thank seminar participants at IHEA 2015 in Milan and at the London School of Hygiene & Tropical Medicine for valuable comments received. The work of PM on this paper was funded by the Centre for Diet and Activity Research (CEDAR), a UK Clinical Research Collaboration (UKCRC) Public Health Research Centre of Excellence. Funding from the British Heart Foundation, Cancer Research UK, Economic and Social Research Council, Medical Research Council, the National Institute for Health Research [grant number ES/G007462/1], and the Wellcome Trust [grant number 087636/2/08/Z], under the auspices of the UK Clinical Research Collaboration, is gratefully acknowledged.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.foodpol.2017.09.002.

References

Azad, M.B., Abou-Setta, A.M., Chauhan, R.F., Rabbani, R., Lys, J., Copstein, L., Mann, A., 2013. Evidence that a tax on sugar sweetened beverages reduces the obesity rate: a meta-analysis. BMC Public Health 13, 1.
Cameron, A.C., Trivedi, P.K., 2005. Microeconometrics: Methods and Applications. Cambridge University Press.
Cecchini, M., Warn, L., 2011. Impact of food labelling systems on food choices and eating behaviours: a systematic review and meta-analysis of randomized controlled trials and prospective cohort studies. Can. Med. Assoc. J. 189, E929-E939.
Casswell, S., Group, L.N.A., 2013. Proof points: the effectiveness of food and beverage taxes and subsidies for improving public health: a systematic review of prices, and body weight outcomes. Obes. Rev. 14, 110-128.

-period for which data was available. Finally, even though we have an equal split between LMICs and HICs, the relatively small number of countries in each group and overall (78) implies that our results may not be fully representative for all countries in the world.

5. Conclusion

Overall, although we did find some evidence that soft drink sales are a statistically significant predictor of BMI and obesity, at least in the sample of low and lower middle income countries, the magnitude of this effect was small. However, this does not imply that soft drink sales and prices are an insignificant driver of obesity, but it does highlight the potential limitations of using ecological research design when studying this association. Therefore, results from individual level studies will be required to further ascertain the role of prices and of soft drink sales in obesity and diabetes.

Acknowledgements

We thank seminar participants at IHEA 2015 in Milan and at the London School of Hygiene & Tropical Medicine for valuable comments received. The work of PM on this paper was funded by the Centre for Diet and Activity Research (CEDAR), a UK Clinical Research Collaboration (UKCRC) Public Health Research Centre of Excellence. Funding from the British Heart Foundation, Cancer Research UK, Economic and Social Research Council, Medical Research Council, the National Institute for Health Research [grant number ES/G007462/1], and the Wellcome Trust [grant number 087636/2/08/Z], under the auspices of the UK Clinical Research Collaboration, is gratefully acknowledged.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.foodpol.2017.09.002.

References

Azad, M.B., Abou-Setta, A.M., Chauhan, R.F., Rabbani, R., Lys, J., Copstein, L., Mann, A., 2013. Evidence that a tax on sugar sweetened beverages reduces the obesity rate: a meta-analysis. BMC Public Health 13, 1.
Cameron, A.C., Trivedi, P.K., 2005. Microeconometrics: Methods and Applications. Cambridge University Press.
Cecchini, M., Warn, L., 2011. Impact of food labelling systems on food choices and eating behaviours: a systematic review and meta-analysis of randomized controlled trials and prospective cohort studies. Can. Med. Assoc. J. 189, E929-E939.
Casswell, S., Group, L.N.A., 2013. Proof points: the effectiveness of food and beverage taxes and subsidies for improving public health: a systematic review of prices, and body weight outcomes. Obes. Rev. 14, 110-128.

-period for which data was available. Finally, even though we have an equal split between LMICs and HICs, the relatively small number of countries in each group and overall (78) implies that our results may not be fully representative for all countries in the world.

5. Conclusion

Overall, although we did find some evidence that soft drink sales are a statistically significant predictor of BMI and obesity, at least in the sample of low and lower middle income countries, the magnitude of this effect was small. However, this does not imply that soft drink sales and prices are an insignificant driver of obesity, but it does highlight the potential limitations of using ecological research design when studying this association. Therefore, results from individual level studies will be required to further ascertain the role of prices and of soft drink sales in obesity and diabetes.

Acknowledgements

We thank seminar participants at IHEA 2015 in Milan and at the London School of Hygiene & Tropical Medicine for valuable comments received. The work of PM on this paper was funded by the Centre for Diet and Activity Research (CEDAR), a UK Clinical Research Collaboration (UKCRC) Public Health Research Centre of Excellence. Funding from the British Heart Foundation, Cancer Research UK, Economic and Social Research Council, Medical Research Council, the National Institute for Health Research [grant number ES/G007462/1], and the Wellcome Trust [grant number 087636/2/08/Z], under the auspices of the UK Clinical Research Collaboration, is gratefully acknowledged.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.foodpol.2017.09.002.

References

Azad, M.B., Abou-Setta, A.M., Chauhan, R.F., Rabbani, R., Lys, J., Copstein, L., Mann, A., 2013. Evidence that a tax on sugar sweetened beverages reduces the obesity rate: a meta-analysis. BMC Public Health 13, 1.
Cameron, A.C., Trivedi, P.K., 2005. Microeconometrics: Methods and Applications. Cambridge University Press.
Cecchini, M., Warn, L., 2011. Impact of food labelling systems on food choices and eating behaviours: a systematic review and meta-analysis of randomized controlled trials and prospective cohort studies. Can. Med. Assoc. J. 189, E929-E939.
Casswell, S., Group, L.N.A., 2013. Proof points: the effectiveness of food and beverage taxes and subsidies for improving public health: a systematic review of prices, and body weight outcomes. Obes. Rev. 14, 110-128.