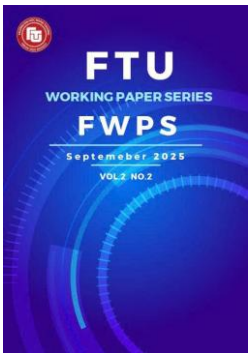

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PHÂN TÍCH TÁC ĐỘNG CỦA THUẾ TIÊU THỤ ĐẶC BIỆT ĐỐI VỚI ĐỒ UỐNG CÓ ĐƯỜNG LÊN TỶ LỆ BÉO PHÌ: ÁP DỤNG MÔ HÌNH TRUNG GIAN

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Tóm tắt

Béo phì đã trở thành một vấn đề sức khỏe toàn cầu nghiêm trọng, với hơn 650 triệu người bị ảnh hưởng trên toàn thế giới. Các loại đồ uống chứa nhiều đường bổ sung và ít giá trị dinh dưỡng, được công nhậN là một trong những nguyên nhân chính gây ra béo phì. Để đối phó với tình trạng này, nhiều quốc gia đã áp dụng thuế tiêu thụ đặc biệt đối với đồ uống có đường nhằm giảm tiêu thụ và giải quyết gánh nặng liên quan đến béo phì. Nghiên cứu này phân tích dữ liệu từ 32 trong số 117 quốc gia đã áp dụng loại thuế này trong giai đoạn từ năm 2013 đến 2023, sử dụng mô hình trung gian bằng phần mềm JASP để phân tích mối quan hệ giữa việc áp dụng thuế lên mức độ tiêu thụ giảm và tỷ lệ béo phì quốc gia. Nghiên cứu phát hiện ra một hiệu ứng trung gian cạnh tranh: mặc dù thuế gián tiếp làm giảm béo phì thông qua việc giảm tiêu thụ, nhưng tổng ảnh hưởng đến tỷ lệ béo phì vẫn mang tính dương. Kết quả nghiên cứu này mang lại những giá trị quan trọng cho các nhà hoạch định chính sách tài khóa về hiệu quả của việc đánh thuế tiêu thụ đặc biệt lên đồ uống có đường trong việc giải quyết vấn đề béo phì.

Từ khoá: mô hình trung gian, tỷ lệ béo phì, thuế tiêu thụ đặc biệt

THE IMPACTS OF EXCISE TAXES ON SUGAR-SWEETENED BEVERAGES ON OBESITY RATE: A MEDIATION MODEL

Abstract

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Obesity has emerged as a critical global health issue, with more than 650 million individuals affected worldwide. Sugar-sweetened beverages, high in added sugars and low in nutritional value, are widely recognized as a key driver of obesity. In response, many countries have introduced excise taxes on these products to curb consumption and address obesity-related issues. This study analyzes data from 32 out of 117 countries that implemented such taxes between 2013 and 2023, using Hayes mediation model to examine the relationship between excise taxation, consumption, and national obesity levels. This study identifies a competitive mediation effect: while the tax reduces obesity indirectly through lowered consumption, the total effect on obesity remains positive, suggesting potential counterintuitive outcomes. This finding offers significant insights to fiscal policy makers into the effectiveness of sugar-sweetened beverages taxation in addressing obesity.

Keywords: excise tax, mediation model, obesity, sugar-sweetened beverages

1. Introduction

Obesity has now emerged as one of the world's most serious public health issues. The World Health Organization (WHO) reports that over 650 million persons worldwide suffer from obesity, which has nearly tripled since 1975 (WHO, 2020), raising healthcare expenses significantly, which has a negative impact on people's lives and the economies of entire countries (Ng et al., 2014).

The consumption of sugar-sweetened beverages (SSBs) is considered to be one of the major contributing factors to the global obesity epidemic. These beverages contribute to excessive calorie consumption and unhealthy eating habits since they are heavy in added sugars and have little to no nutritional value. According to studies, consuming too many sugar-sweetened beverages (SSBs) is closely linked to a higher risk of obesity and related illnesses (Malik et al., 2013). As a result, governments throughout the world have started looking into different ways to reduce the use of these unhealthy drinks, and one of the most popular approaches is the imposition of excise taxes on these products (Sánchez-Romero et al., 2016).

Numerous studies affirm that SSBs taxes can significantly increase price and shift consumer behavior toward healthier alternatives (Briggs, 2013; Alvarado et al., 2019). However, while price-based interventions can lower intake, the direct causal link between taxation and obesity reduction remains an open empirical question.

Therefore, by analyzing panel data from 32 countries that implemented such taxes between 2013 and 2023 and employing a modern mediation analysis, specifically Hayes' PROCESS Model 4, this study evaluates not only whether excise taxes affect obesity rates, but also how this effect may be transmitted through changes in SSBs consumption. The results may contribute to practical policy discussions of policy makers on how fiscal interventions can serve as effective public health strategies.

2. Literature review and definitions

2.1. Literature review

2.1.1. Effects of Taxation on Obesity Rates

While it is well-established that taxing sugar-sweetened beverages (SSBs) and other unhealthy food products can reduce their consumption (Lee et al., 2019), a critical question remains as to whether these behavioral changes translate into measurable improvements in population-level weight outcomes and obesity rates.

Most existing evidence comes from simulation models, which project potential long-term health gains based on assumed reductions in caloric intake. For instance, in Brazil, a 20–30% tax on SSBs is estimated to reduce obesity prevalence by up to 9.1% over a decade, preventing 3.8 million cases (Pereda et al., 2024). Similar projections in the U.S. suggest that such taxes could prevent over 230,000 obesity cases and tens of thousands of diabetes cases (Basu et al., 2017).

However, these models rely heavily on consumption data and do not directly observe changes in obesity outcomes. Empirical post-tax evaluations, such as the study in Philadelphia showing slight BMI reductions (Petimar, 2024), offer more cautious optimism. Yet, these findings remain limited in scope and duration. While such studies suggest a link between fiscal policy and public health improvements, they do not provide conclusive evidence of a direct causal effect of taxation on individual or population-level obesity.

2.1.2. Mediation Model - Hayes' PROCESS Model 4

Mediation analysis is a statistical approach used to examine the mechanism through which an independent variable (X) influences a dependent variable (Y) via a third variable, known as a mediator (M). Hayes' PROCESS Model 4 posits that an independent variable affects a mediator (path a), which in turn affects the dependent variable (path b), while also allowing for the estimation of a direct effect of the independent variable on the outcome (path c′). The indirect effect, calculated as the product of paths a and b, represents the portion of the effect of X on Y that occurs through M (Hayes, 2013; Hayes, 2018).

One of the core methodological advancements of the PROCESS approach is its use of bootstrapping techniques to assess the significance of indirect effects. Traditional approaches to mediation, such as the causal steps method proposed by Baron and Kenny (1986), rely on assumptions that may not always hold, particularly regarding the normality of sampling distributions. In contrast, bootstrapping does not assume normality and provides confidence intervals that are more accurate and reliable, especially in smaller samples or in data that deviate from normality (Preacher and Hayes, 2004; Preacher and Hayes, 2008).

In health behavior research, mediation models have been widely applied to reveal mechanisms of interventions. Tobacco control offers classic examples: prevention programs for youth are designed to change intermediate targets like attitudes and norms, which in turn reduce smoking. MacKinnon et al. (2002) note that tobacco programs often work "through attitudes, social norms,

beliefs about consequences, and accessibility". In other words, an anti-smoking campaign (X) reduces smoking (Y) primarily by shifting social norms or perceived harm (M). Alcohol intervention research likewise focuses on mediators: commonly include increased coping skills or self-efficacy. For instance, reviews of cognitive-behavioral therapy (CBT) trials often find that improvements in coping strategies predict reductions in heavy drinking (Finney, 2018). Thus, one conceptual chain is that therapy (X) strengthens coping skills (M), which then lowers alcohol use (Y). Dietary and obesity interventions have increasingly used mediation analysis as well. Lockwood et al. describe cases where an intervention "successfully reduced portion size, and portion size was related to body weight," even if exercise did not change. Here portion size mediates the effect of the diet program on weight loss: the program (X) led to smaller meal sizes (M), which in turn lowered body weight (Y).

Building on this tradition, this study apply mediation models to sugar-sweetened beverage (SSBs) taxation and obesity outcomes. The logic is straightforward: a tax on SSBs (X) discourages consumption (M), and lower consumption should then lead to lower obesity (Y). Previously, Liu et al. (2021) examined children in China and found that sugar-sweetened carbonated beverage consumption mediated the effect of dietary knowledge on obesity: higher dietary knowledge (X) led to lower SSBs intake (M), which then reduced the incidence of overweight and obesity (Y). This example highlights how mediation analysis can reveal the chain connecting fiscal policy to health by confirming that consumption changes carry the effect of SSBs taxes to lower obesity, researchers can better understand and predict the indirect impacts of excise taxes on public health.

2.2. Definitions

2.2.1. Excise Taxes on Sugar-Sweetened Beverages

Sugar-sweetened beverages (SSBs) are defined as non-alcoholic drinks that contain added caloric sweeteners, such as sucrose, high-fructose corn syrup, or fruit juice concentrates. These include carbonated soft drinks, energy drinks, sweetened teas, sports drinks, and certain fruit beverages (WHO, 2016). Excessive consumption of SSBs is strongly linked to weight gain, obesity, type 2 diabetes, and other diet-related non-communicable diseases (Malik et al., 2010).

Excise taxes on sugar-sweetened beverages (SSBs) are government-imposed levies these types of drinks, aimed at reducing consumption and addressing public health concerns like obesity and diabetes (Tax Foundation, n.d.). These taxes, either specific (per volume or sugar content) or ad valorem (percentage of price), raise prices to discourage intake (Thow et al., 2018).

2.2.2. Obesity rate

Obesity is commonly defined as excessive or abnormal fat accumulation that presents a risk to health. It is typically measured using the Body Mass Index (BMI), with a BMI of 30 or above classified as obese (WHO, 2021).

One of the key theoretical models is the Energy Balance Model, which states that obesity results when energy intake (calories consumed) consistently exceeds energy expenditure (calories burned) (Hill et al., 2003). From this perspective, sugar-sweetened beverages (SSBs) contribute

significantly to excess caloric intake due to their low satiety and high sugar content (Malik et al., 2010).

Another relevant theory is the Social Determinants of Health Framework, which emphasizes that obesity is not solely a product of individual choices but also shaped by social, economic, and environmental conditions. Factors such as urbanization, food environments, education, and income levels have been shown to correlate with obesity prevalence across countries (Swinburn et al., 2011).

2.3. Hypothesis development

Excise taxes on sugar-sweetened beverages (SSBs) should reduce consumption by raising prices and deterring purchases. Economic theory predicts that SSBs - which have high price-elasticity - will see lower demand when their price rises (Fernandez & Raine, 2019). This can be shown in the Berkeley's one-cent-per-ounce soda tax produced a 21% drop in SSBs consumption in the taxed city, compared to a 4% increase in nearby untaxed cities (Falbe et al., 2016). Similarly, Oakland's excise tax was associated with a sustained around 26.8% reduction in SSBs purchases over 2.5 years (White et al., 2023). Such declines in consumption following taxation are consistent across settings and models, confirming the causal rationale that higher SSBs prices curb intake.

Hypothesis 1: Excise tax has a negative effect on SSBs consumption.

Reducing SSBs consumption should in turn lower obesity by cutting excess calories. A systematic review found that each additional daily serving of SSBs was associated with measurable BMI increases, and randomized trials showed that removing SSBs from the diet slowed BMI gain in children (Malik et al., 2013). Because liquid calories from SSBs tend to be additive and not fully compensated by eating less, cutting them from the diet should reduce total energy intake and weight over time (Fernandez & Raine, 2019). Models of public health interventions reinforce this: one simulation estimated that a 50% rise in SSBs prices (implying large drops in consumption) could significantly shrink obesity prevalence - potentially averting millions of premature deaths over decades (da Silva et al., 2024).

Hypothesis 2: SSBs consumption has a negative effect on Obesity rate.

Taxation may also impact obesity through channels beyond consumption changes alone. For instance, SSBs taxes often motivate industry reformulation, public awareness, and funding for health programs. After Britain implemented its tiered sugar tax on sodas, manufacturers cut sugar content sharply: one report found the levy led to reformulations that removed the equivalent of 45 million kg of sugar per year from soft drinks (Scarborough et al., 2020). This large reduction in sugar supply would lower calorie intake. A recent model combining sales data and health outcomes predicts that the UK tax's sugar reduction will prevent roughly 64,100 cases of child or adolescent overweight or obesity over 10 years (Cobiac et al., 2024).

Hypothesis 3: Excise tax has a negative effect on Obesity rate.

3. Methodology

3.1. Research Methodology

This study uses JASP software to adopt a mediation model to examine the direct and indirect relationship between excise tax on sugar-sweetened beverages (SSBs) and obesity rates among adults, with SSBs consumption per capita serving as a mediating variable. To assess the statistical significance of the indirect effect, the analysis employed bootstrapping with 5,000 resamples. This non-parametric approach generated bias-corrected 95% confidence intervals (CIs) for the indirect path estimates (Hayes, 2018).

Afterwards, to test Model fit, several standard fit indices are used including the Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and Standardized Root Mean Square Residual (SRMR). Conventional thresholds were applied in determining adequacy of fit, with values such as RMSEA < 0.06 and CFI > 0.95 indicating a well-fitting model. Finally, to ensure the robustness of the mediation model, residual diagnostics were examined through the residual covariance matrices, both raw and standardized.

Proposed model and data

Direct effect:

$$obs = \gamma_0 + \gamma_1 tSSBs + \gamma_2 inac + \gamma_3 pgdp + \gamma_4 popu + \gamma_5 edu + \gamma_6 hexp + \gamma_7 urb + \gamma_8 hu + \gamma_9 hgdp + \in$$

Indirect effect:

Step 1: Effect of excise tax on consumption

$$cons = \alpha_0 + \alpha_1 tSSBs + \alpha_2 inac + \alpha_3 pgdp + \alpha_4 popu + \alpha_5 edu + \alpha_6 hexp + \alpha_7 urb + \alpha_8 hu + \alpha_9 hgdp + \in_1$$

Step 2: Effect of consumption on obesity rate

$$obs = \beta_0 + \beta_1 tSSBs + \beta_2 cons + \beta_3 inac + \beta_4 pgdp + \beta_5 popu + \beta_6 edu + \beta_7 hexp + \beta_8 urb + \beta_9 hu + \beta_{10} hgdp + \in_2$$

Total effect:

$$\text{Total effect} = \text{Direct effect} + \text{Indirect effect} = \gamma_1 + (\alpha_1 \times \beta_1)$$

In which:

Type	Variables	Definition	Unit	Source
Dependent variable	tSSBs	Imposition of excise tax on sugar-sweetened beverages	0 (no tax applied) or 1 (tax applied)	WorldBank

Type	Variables	Definition	Unit	Source
Independent variable	obs	Obesity rate (percentage of adult population classified as obese)	Percentage (%)	WorldBank
Mediating variable	cons	Consumption of sugar-sweetened beverages	Liters per capita/year	Euromonitor
Control variables	inac	Physical inactivity (percentage of adults population NOT meeting WHO recommended physical activity levels)	Percentage (%)	WHO
	pgdp	Gross Domestic Product per capita	Dollar ($)	WorldBank
	popu	Population from 15 to 29 years old	individuals	WorldBank
	edu	Government expenditure on education	Percentage (%) of GDP	WorldBank
	hexp	Public health expenditure	Percentage (%) of GDP	WorldBank
	urb	Percentage of population living in urban areas	Percentage (%)	WorldBank
	hu	An interaction variable, measuring the effect of health expenditure on obesity across urbanization levels (computed by hexp * urb)	No unit	Author's calculation based on collected data
	hgdp	An interaction variable, representing the effect of combined economic and health expenditure on obesity rate.	No unit	Author's calculation based on collected data

The authors assembled a country-level panel dataset covering the period 2013-2023. Global health agencies report that over 100 countries have such taxes (OECD, 2021; WHO, 2022). From this universe, we selected countries that met two strict criteria: (a) the country introduced excise tax on SSBs during 2013-2023, and (b) all key variables are available annually throughout a 11-year-period. Many countries were excluded because of missing consumption surveys or sporadic health data, or because the tax was too new (post-2023) to analyze. Moreover, only countries with a legally enacted national excise on SSBs (not just subnational or voluntary measures) were considered. This ensures comparability of the policy measure. After applying these filters, the final sample comprised 32 countries with the sample size is 32 * 11 = 352 observations.

In detail, there are 10 countries in Asia, 9 countries in Africa, 7 countries in the Americas, 5 European countries and a country named Vanuatu in Oceania. In terms of income level, 6 countries are now considered low-income countries, 7 countries with lower-middle income level, 14 countries with upper-middle income level, and 5 among 32 countries are high-income countries. As we can see, the diversity of countries is quite large, meaning the research covers a great variety of countries, with a relatively-balanced selection of countries, both geographically and income-wise.

In addition to the main variables, the study incorporates several control variables to enhance the robustness and comprehensiveness of the analysis, as long as account for potential confounders and minimize omitted variable bias, thereby improving the reliability of the regression estimates.

4. Empirical results analysis

4.1. Empirical results

Table 1. Path coefficients (Direct effect)

Independent Variable	Dependent Variable	Estimate	Std. Error	z-value	p
cons	obs	0.075	0.015	4.934	< 0.001
tSSBs	obs	4.458	0.974	4.576	< 0.001
tSSBs	cons	-8.273	2.885	-2.868	0.004

Source: Extraction from Author's calculation

The Path Coefficients Table offers critical insight into the direct relationships between variables within the structural equation model (SEM). The direct effect of the excise tax on SSBs consumption is significantly negative (Estimate = -8.273, p = 0.004), confirming that higher taxation levels are effective in reducing the intake of SSBs. Besides, the direct effect of consumption on obesity is positive and statistically significant (Estimate = 0.075> 0, p < 0.001),

confirming that reducing consumption is theoretically and empirically associated with lowering obesity prevalence.

Table 2. Indirect effect

Independent Variable	Mediating Variable	Dependent Variable	Estimate	Std. Error	z-value	p
tSSBs	cons	obs	-0.617	0.256	-2.407	0.016

Source: Extraction from Author's calculation

The indirect effects table reveals the nuanced pathways through which variables influence obesity via the mediator - sugar-sweetened beverage consumption (cons). Notably, the excise tax on SSBs (tSSBs) exerts a significant negative indirect effect on obesity (Estimate = -0.617, p = 0.016). This suggests that, although the direct effect of tSSBs on obesity is positive, the indirect path through reduced SSBs consumption counteracts this by lowering obesity rates by approximately 0.617 units whenever tax is adopted on these products.

Table 3. Total effect

Independent Variable	Dependent Variable	Estimate	Std. Error	z-value	p
tSSBs	obs	3.841	0.955	4.023	< 0.001

Source: Extraction from Author's calculation

The total effects table combines both direct and indirect pathways, providing a clear picture of overall influence on obesity outcomes (Total effect = Direct effect + Indirect effect).

The excise tax on sugar-sweetened beverages (tSSBs) exerts a significant and substantial **positive total effect** on obesity (Estimate = 3.841, $p < 0.001$). This means that when both the direct impact and the indirect, consumption-mediated pathway are accounted for, the net effect of increasing the tax still leads to higher obesity rates.

This counterintuitive result underscores the complexity of policy interventions: while the tax effectively reduces SSBs consumption (as seen in indirect effects), its direct relationship with obesity remains positive, possibly reflecting broader systemic or behavioral compensations that offset its intended benefits.

4.2. Model testing

Table 4. Model fit

Model fit indicators	Results
AIC	5832.657
BIC	5921.521

Model fit indicators	Results
Observations	352
Total n Parameters	23
Free n Parameters	23
X^2	2.501 * 10^(-12)
df	0.000

Source: Extraction from Author's calculation

The model fit summary presents an AIC of 5832.66 and a BIC of 5921.52 — both of which are only meaningful when comparing several models, with lower values generally indicating a better fit (Burnham & Anderson, 2004). With 352 observations and 23 freely estimated parameters, the model produces a chi-square (χ^2) value close to zero and a p-value of 0.000, suggesting it fits significantly better than a null model where no relationships exist. However, because the chi-square test is highly sensitive to sample size and the model has zero degrees of freedom, this near-perfect fit should be approached with caution.

Overall, while these statistics suggest the model performs well, a complete and confident evaluation still requires looking at other key fit indicators like RMSEA and CFI to ensure the results are truly robust and reliable. In the next part, the result of tests related to the RMSEA and CFI results will be provided.

Table 5. Fit indices

Comparative Fit Index (CFI)	1.000
Tucker-Lewis Index (TLI)	1.000
Bentler-Bonett Non-normed Fit Index (NNFI)	1.000
Bentler-Bonett Normed Fit Index (NFI)	1.000
Parsimony Normed Fit Index (PNFI)	0.000
Bollen's Relative Fit Index (RFI)	1.000
Bollen's Incremental Fit Index (IFI)	1.000

Relative Noncentrality Index (RNI)	1.000
Root mean square error of approximation (RMSEA)	0.000
RMSEA 90% CI lower bound	0.000
RMSEA 90% CI upper bound	0.000
RMSEA p-value	
Standardized root mean square residual	4.482 * 10^(-15)
Hoelter's critical N (alpha = 0.05)	1.000
Hoelter's critical N (alpha = 0.01)	1.000
Goodness of fit index (GFI)	1.000
McDonald fit index (MFI)	1.000
Expected cross validation index (ECVI)	0.131
Log-likelihood	-2893.329
Number of free parameters	23.000
Akaike (AIC)	5832.657
Bayesian (BIC)	5921.521
Sample-size adjusted Bayesian (SSABIC)	5848.556

Source: Extraction from Author's calculation

The evaluation of the model's fit, using a broad set of established indices, reveals an exceptionally strong and flawless alignment between the model and the data. Key indicators such as the Comparative Fit Index (CFI = 1.000), Tucker-Lewis Index (TLI = 1.000), Normed Fit Index (NFI = 1.000), Non-Normed Fit Index (NNFI = 1.000), Incremental Fit Index (IFI = 1.000), and Relative Noncentrality Index (RNI = 1.000) all surpass the widely accepted benchmark of 0.95, signaling outstanding model performance (Hu & Bentler, 1999). While these ideal scores look

appealing on paper, they are rarely encountered in real-world research and may hint at potential overfitting or a fully saturated model where every possible parameter has been estimated.

Turning to the Root Mean Square Error of Approximation (RMSEA), the result is strikingly low at 0.000, with a 90% confidence interval tightly fixed between 0.000 and 0.000. According to Browne and Cudeck (Browne & Cudeck, 1992), RMSEA values below 0.05 suggest a very close fit, values between 0.05–0.08 are seen as acceptable, and anything above 0.10 raises concerns. Here, an RMSEA of zero theoretically signals a perfect match, but such perfection is rarely seen and might call for extra caution.

Table 6. Standardized residuals covariance matrix

	cons	**obs**	**tSSBs**	**pgdp**	**hexp**	**edu**	**urb**	**popu**	**hgdp**	**inac**	**hu**
cons	-2.592e-11										
obs	2.274e-12	-3.126e-12									
tSSBs	-7.327e-15	1.421e-14	0.000e+00								
pgdp	1.506e-12	-2.274e-13	0.000e+00	0.000e+00							
hexp	9.237e-13	1.386e-13	0.000e+00	0.000e+00	0.000e+00						
edu	-3.695e-13	-2.132e-14	0.000e+00	0.000e+00	0.000e+00	0.000e+00					
urb	-3.865e-13	-1.990e-12	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00				

	cons	obs	tSSBs	pgdp	hexp	edu	urb	popu	hgdp	inac	hu
popu	-1.501e-13	5.524e-13	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00			
hgdp	8.185e-13	2.558e-12	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		
inac	2.842e-12	8.527e-10	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	
hu	6.253e-13	-7.638e-14	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00

Source: Extraction from Author's calculation

The standardized residuals covariance matrix serves as a detailed check on how well the model has captured the relationships between variables. Essentially, this matrix shows the leftover covariances — the differences between what the model predicts and what the data actually show — after everything has been standardized. In a well-fitting model, these residuals should be close to zero, signaling that the model has done an excellent job explaining the connections between variables.

Looking at the current matrix, we see that nearly all the residual values are either exactly zero or extremely small (e.g., in the range of 10^{-12} or smaller). According to standard guidelines, any residual exceeding ±1.96 (for 95% confidence) or ±2.58 (for 99% confidence) would be worth concern (Kline, 2016), as it might point to a local misfit or a part of the model that's failing to capture something meaningful. Fortunately, this matrix shows no such warning indicators, which suggests that the model is well-calibrated across all variable pairs.

This strengthens the reliability of the findings, reinforcing that the reported effects are genuinely present in the data, not just statistical quirks. In short, this near-perfect residual profile gives us confidence that the pathways reflect meaningful, well-supported relationships, making the model a strong foundation for practical insights and future policy recommendations.

5. Discussions and implications

5.1. Results discussions

Hypothesis 1: Excise tax has a negative effect on SSBs consumption.

Based on the regression results, the imposition of excise tax on sugar-sweetened beverages (tSSBs) significantly reduces consumption (cons) with $\beta = -8.273$, $p = 0.004$, strongly supporting Hypothesis 1. This finding aligns with global evidence showing that taxes on sugary beverages effectively reduce demand by raising retail prices and internalizing the external costs of unhealthy consumption (Wright et al., 2017; Eykelenboom et al., 2019). The economic theory behind this is grounded in the price elasticity of demand; studies suggest that for every 10% increase in price, consumption drops by 6-12% (Powell et al., 2013). This approach has been validated in countries like Mexico, where a 10% tax led to a 12% reduction in SSBs purchases in the first year (Colchero et al., 2016).

Hypothesis 2: SSBs consumption has a negative effect on Obesity rate.

The model demonstrates a strong positive association between consumption and obesity ($\beta = 0.075$, $p < 0.001$), supporting Hypothesis 2. This confirms a well-established relationship in public health research: excessive intake of sugar-sweetened beverages contributes to increased body mass index (BMI) and obesity prevalence (Malik et al., 2010; Hu, 2013). Farhadnejad et al. (2019) found that reducing SSBs intake by just one serving per day resulted in a measurable reduction in obesity risk over time, reinforcing the argument that targeting SSBs is an effective obesity prevention strategy.

The positive association between SSBs consumption and obesity is further explained by research examining the mechanisms by which sugary drinks affect body weight. SSBs are calorie-dense but do not induce a feeling of fullness, leading to increased total calorie intake and, ultimately, weight gain (Micha et al., 2017).

Hypothesis 3: Excise tax has a negative effect on Obesity rate.

While an indirect path exists with $\beta = -0.617$, $p = 0.016$ proving that taxation reduces consumption (as confirmed in Hypothesis 1), and consumption increases obesity (as confirmed in Hypothesis 2), the direct effect with $\beta = 4.458$, $p < 0.001$ makes total effect ($\beta = 3.841$, $p < 0.001$) of tSSBs on obesity is positive and significant, failing to support Hypothesis 3.

On the one hand, the indirect pathway provides strong support for the hypothesis. The model reveals that the SSBs tax has a significant negative indirect effect on obesity through reduced consumption. This confirms that taxation leads to a decline in SSBs consumption, which in turn contributes to lower obesity rates. This finding is consistent with previous empirical studies indicating that price increases through taxation can discourage consumption of high-calorie sugary beverages, thereby reducing calorie intake and subsequent weight gain (Powell & Chaloupka, 2009; Teng et al., 2019).

However, the total effect result implies that regions implementing the SSBs tax tend to have higher obesity rates, which appears to contradict the theoretical assumption that taxation helps reduce obesity. This total effect reflects the net result of two opposing influences: (1) a positive direct effect, where obesity rises even after controlling for SSBs consumption, and (2) a negative indirect effect via reduced consumption, where taxation successfully lowers SSBs consumption,

which in turn reduces obesity. As the direct effect outweighs the indirect one, the total effect remains positive. This pattern is classified by Hayes (2018) and Zhao, Lynch, & Chen (2010) as ***competitive mediation***, wherein both direct and indirect effects are statistically significant but work in opposite directions.

This finding runs counter to the theoretical expectation that taxing sugar-sweetened beverages would reduce obesity at the population level. Although there is consistent empirical support for the effectiveness of SSBs taxes in reducing consumption (Colchero et al., 2016; Silver et al., 2017), evidence on their effectiveness in lowering obesity prevalence remains mixed. Some studies, such as Falbe et al. (2016), observed reductions in SSBs intake following taxation but found no significant changes in obesity within the early years of implementation. Others, like Veerman et al. (2016), used simulation models and found that meaningful reductions in obesity are only likely under high tax rates or when combined with broader interventions. The positive total effect found in this analysis may reflect such limitations. It is also possible that consumers engage in substitution behaviors, replacing taxed beverages with untaxed but similarly caloric drinks or foods (Zhen et al., 2014; Cornelsen & Carreido, 2015), thereby negating the caloric reduction intended by the tax.

This conclusion aligns with previous research that found SSBs taxes reduce consumption but may not immediately reduce obesity due to the complex nature of obesity (Brownell et al., 2009; Colchero et al., 2016). A tax might reduce consumption of sugary drinks, but without comprehensive public health strategies that target diet, physical activity, and education, its effects on obesity may be limited.

5.2. Implications

From a policy perspective, this result does not necessarily imply that sugar-sweetened beverage (SSB) taxes are ineffective, but rather highlights the limitations of relying solely on fiscal instruments to address complex and multifactorial public health issues such as obesity. Obesity is influenced by a range of interrelated determinants, including socioeconomic status, cultural norms, food environments, physical activity levels, and health literacy, which cannot be fully resolved through pricing strategies alone (Brownell et al., 2009; WHO, 2022). While the tax mechanism can successfully discourage consumption, as shown by the significant negative indirect effect found in this study, it is clear that taxation, in isolation, may not be sufficient to produce measurable reductions in obesity prevalence.

First, to amplify the effects of SSB taxation, governments should adopt complementary regulatory measures such as mandatory front-of-pack nutrition labeling, reformulation targets, and marketing restrictions for high-sugar products. These tools improve consumers' ability to make healthier choices and incentivize industry reformulation (WHO, 2022; Taillie et al., 2020). Mandatory labeling systems like Nutri-Score or warning labels have proven effective in Latin America and Europe in reducing purchases of unhealthy products (Khandpur et al., 2018).

Second, fiscal policies should not only penalize unhealthy consumption but also promote access to healthier options. Subsidizing fruits, vegetables, and potable water particularly in low-

income or rural communities can increase consumption of nutritious foods and reduce the likelihood of caloric compensation (Mozaffarian et al., 2018). For example, combining taxes with subsidies has been shown to produce greater net reductions in energy intake than taxation alone (Niebylski et al., 2015).

Last, public understanding of the health risks associated with sugary beverages remains limited in many populations. Sustained mass media campaigns and school-based programs can increase awareness and reduce social acceptability of excessive sugar intake, thus reinforcing the behavioral impact of the tax (Cecchini et al., 2010; Backholer et al., 2021). Evidence suggests that pairing taxes with strong communication strategies enhances public support and compliance (Donaldson et al., 2015).

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