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Taxing mechanisms on salty foods: investigation of effectiveness through price elasticity and cross price elasticity of demand

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Abstract

Background Salt consumption control strategies can help to decrease hypertension and related cardiovascular diseases. Taxation mechanisms help to reduce the utilization of harmful commodities like salts. This study aims to analyze the impact of taxing salty foods on salt intake in Iran by examining the price elasticity of demand (PED) and cross-price elasticity of demand (XED) for salty foods.

Methods This study used 38,328 household-level data from the 2019 Iranian Household Income and Expenditures Survey. This PED and XED for salty foods were calculated, and changes in household salt consumption due to salt taxation were estimated using a mathematical simulation method.

Results The findings revealed that the PEDs for noodles and pilaffs (−4.89) and bread (−2.03) are higher than that for other commodities. Noodles and salt (−4.55) and breads and salt (−1.61) exhibited the highest XED. Following 20% taxation, total salt intake is projected to increase by approximately 125 g per month.

Conclusion Taxing mechanisms are ineffective in reducing the consumption of salty foods. Instead of reducing salt intake, households tend to shift to lower-quality, cheaper salty foods after the tax are implemented. However, these mechanisms can be used for increasing the government revenue.

Keywords Salty foods, Tax effectiveness, Price elasticity of demand, Cross price elasticity of demand, Hypertension, Cardiovascular disease

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Introduction

Hypertension, a 'silent killer,' remains a global public health crisis, significantly contributing to cardiovascular diseases (CVD) and premature mortality [1]. As the target 3.4 of sustainable development goals, non-communicable diseases-related mortality must be decreased one third through prevention and treatment [2].

Salt intake decrease can significantly help the policy makers for this concern. One in three adults suffers from hypertension, and many are unaware of their disease, especially in low- and middle-income countries [3]. The role of salt intake on hypertension is an undeniable fact for the health professions [4].Public health system can effectively control hypertension by identifying salt intake control programs specially in the countries where the salt intake is high [5, 6]. These interventions varied from supply side salt controlling interventions like controlling the salt standards in producing foods to demand side programs like health promotion and education plans and increasing the price of salty foods [7].

Studies in Iran have showed that male and female Iranians consume an average of nine and seven grams of salt daily, respectively, with variation in intake across different provinces [8–11]. Iranians consume about twice the recommended daily amount of salt [10]. A significant portion of this intake comes from traditional Iranian foods, such as cheese, bread, and yogurt-based drink, Dough [12, 13]. Strategies to control salt consumption can effectively reduce this intake and, in turn, lower the prevalence of hypertension and CVDs [14]. These strategies can include revising the salt content standards for salty foods like bread, cheese, and Dough, banning advertisements for salty foods, and educating the public on reducing salt consumption. Additionally, policymakers can implement policies to manage the consumption of harmful goods through demand-side controls, such as rationing, taxing high-salt foods, and social marketing campaigns. These interventions are crucial in managing salt intake and its associated health risks [8, 15]. A recent Meta-Analysis showed that average salt intake of Iranians is 9.674 g daily [16]. Due to high salt intake, CVDs are a major health issue in Iran, causing 3911.25 disability-adjusted life years (DALYs) per 100,000 people in 2018. In this year, 196.3 out of every 100,000 Iranians died due to cardiovascular issues [17]. High blood pressure, largely driven by increased salt consumption, is one of the leading risk factors for mortality and DALY in Iran [10, 18].

Earmarked taxation, where tax revenues are designated for specific purposes, has a long history, particularly with taxes on tobacco and alcohol. Similarly, many countries have implemented specific tax laws targeting salt consumption to support public health initiatives [19–22]. In the past decade, several studies demonstrated that increasing taxes on harmful items can effectively reduce their consumption [23]. A recent systematic review specifically found that taxing high-salt foods leads to a decrease in their use [5]. All these studies have analyzed the impact of taxation on consumption patterns and food choices.

Tax-oriented policies, known as earmarked taxes, are implemented to control consumption and improve public health. By increasing the price of harmful commodities, these taxes leverage a fundamental principle of microeconomics: as the price of a product rises, demand typically decreases [22, 24, 25]. Accordingly, raising taxes on harmful commodities can reduce their consumption patterns towards substitutes. However, tax-oriented policies are only effective if the price elasticity of the commodity is sufficiently high, ensuring that the demand decreases enough to mitigate the harmful effects.

Calculating price elasticity of demand (PED) and cross-price elasticity of demand (XED) is an effective method for predicting changes in demand and consumption patterns in response to price adjustment [26]. PED measures how the demand for a commodity change in response to price changes, while XED assesses how the demand for one good shifts in response to price changes in a substitute or complementary good. For example, if the price of beef increases, consumers may reduce their beef purchases and instead buy other meats that have not seen a price increase. However, the price responsiveness of different commodities varies [26, 27]. For instance, a price change in emergency medical services may have a much smaller impact on demand than a price change in cosmetic surgery because the PED and XED for these services differ [28–30]. Taxing mechanisms and price increasing interventions might have welfare implications on consumers and the policy makers must notice to the welfare loss in such interventions [31, 32]. Many studies have calculated the effects of salty foods price interventions on salt consumptions. The Salty foods have many substitutes, so when the price of one salty food increases, people can easily switch to alternatives. Some studies have focused on the price elasticity of demand. However, there is a lack of evidence on the effects of salty foods price interventions on salt consumption through PED and XED. The main aim of this study was to analyze the impact of taxing salty foods on salt intake in Iran. For this issue, this study examined the PED and XED for salty foods using the 2019 Iranian Household Income and Expenditures Survey (HIES).

Methods

Study design

This cross-sectional study consisted of two main steps. First, we used data from the 2019 HEIS of Iran to calculate the PED for salt and salty foods in both quality and quantity. We also estimated the PED and XED for salty foods. Second, we conducted a simulation to analyze the effects of various sales taxes on salt consumption.

Data sources and study variables

The HEIS contained data on income and expenditures for 38,328 Iranian households. The Iranian Statistical Centre (ISC), which administers the survey, collects this data annually, with the most recent collection occurring in the month prior the study. The ISC employs a multistage random sampling method, conducting detailed face-to-face interviews with selected households.

We identified the code for salty foods and extracted them from the database using Microsoft access. The salty foods included seventeen different categories: various types of traditional and non-traditional bread, biscuit, cakes, canned foods, hamburgers, steaks, traditional salty fishes, oysters and caviar, Dough, different type of cheeses, curds, almonds, pistachio, hazelnuts, snack chips and salty snacks, salt, different types of pastes, dried fruits, and restaurant food services. First, since the foods were recorded in different units (some in kilograms and others in grams), we standardized all food quantities to 100 g. Second, we gathered data on the salt content of each food from the Iranian Standard Organization (ISO) and calculated the salt content for each food [33]. Additionally, we extracted household-level socioeconomic information, such as household income, the number of males in the household, household size, place of living, and residency, from the database.

Price elasticity demand measurement

We employed the Deaton method to calculate PED and XED [23, 34]. The Deaton method calculates PED and XED through a regression model as follow:

$$W_{c,i} = a_0 + b_1 x_i + \varphi_0 z_i + \vartheta_0 \ln\left(v_{c,i}\right) + \varepsilon_{0,i} \tag{1}$$

where $W_{c,i}$ is the share of the budget for group c, x_i represents the total household income, and z_i is other confounding variables like household size and the number of males in each household, as previously discussed. $v_{c,i}$ is the unit value, which can be calculated as:$v_c = \frac{E_c}{Q_c}$, where E_c is the expenditures share of group c and Q_c represents the aggregate quantity for group c, specifically the quantity of salt intake in the household. It can be calculated as: $Q_c = g_c q_c$, where g_c is the standard amount of salt per 100 g of food, and q_c is as food intake per 100 g. PED and XED with symmetry restriction and quality correction were calculated in this study. PED and XED have values between $-\infty$ to $+\infty$, with values between -1 and $+1$ indicating low price elasticity of demand. To estimate PED and XED, we used the amount of salt in each food as a quantity indicator, allowing for a more accurate analysis of the effects of the tax on salt intake.

To validate the results of Deaton method, several robustness tactics was used in the study. First, we reanalyzed the results using bootstrap standard errors (with 1000 bootstrap). (Online Appendix 1) Second, we checked the results by adding different analysis for calculation of PED and XED.

Taxing mechanisms assumptions in the study

Several taxing policies can be used for checking the effects of tax mechanisms on salt intake. For example, tiered taxes can be levied for different salt used in the commodities. Or some exemptions can be made for those commodities which has the main source of calory for the poor (like breads). In this study we only focused on sin taxes which are earmarked for the health system. First, we calculate the salt unit value for each commodity. For example, if a bread had 1 dollar's price and had 4 g salt, we calculate the price of salt intake by dividing the bread price to the salts added in it (unit value of salt = 0.25 dollars). Then we make different percentages of tax (from 0 to 100%) on the price of commodity. We test the tiered tax by dividing the commodities in to two groups of high salty foods (Cheese, Dough, Sausage, Chips and Salt) and low salty foods (Breads, Pasta, Noodles, Biscuits, curds, nuts, pastes, Sauce, juice, Fast foods, Traditional foods and Breakfasts). We added 50% tax to high salty foods and 25% tax to low salty groups and reanalyzed the results.

Mathematical simulation approach

We used a mathematical approach to calculate the effects of salt taxing on salt intake. This method provides a robust way to simulate the impact of public policy on outcomes [26]. To ensure comparability and accurately assess salt intake post-taxation, we calculated the standard amount of salt for each food group. Instead of using the quantity of food in the model, we used the amount of salt, denoted as q. Assume that the price of one gram of salt in commodity c is p_c, and that the government imposes a percentage tax on salty food, which increases the price of the commodity from its original price, p_1, to the new price after taxation, p_2. The new price can be written as:

$$p_2 = p_1 + \theta p_1, \tag{2}$$

where θ is the tax percentage. Depending on the price elasticity, a tax increase may lead to either an increase or decrease in the quantity of consumed and corresponding salt intake. Assume that $dq_2 = q_2 - q_2$, representing the change in quantity of salt intake. The change in salt intake quantity is related to the PED as follows:

$$\varepsilon = \frac{dq}{dp}.\frac{p}{q}, dq_2 = \varepsilon.dp_2.\frac{q_2}{p_2} \tag{3}$$

Where ε represents PED and dp_2 denotes the changes in the price of the good between two times (θp_1).

$$dq_2 = \varepsilon.\theta p_1.\frac{q_2}{p_2} \tag{4}$$

In addition, the quantity of salt intake for the commodity q is related to the price and consumption of substitute goods. Therefore, the XED of other commodities may affect the quantity of q. The XED (ε_y) can be negative for substitute goods or positive for complementary goods. The XED can be expressed as:

$$\varepsilon_y = \frac{dq}{dp_y}\frac{p_y}{q}, dq_2 = \varepsilon_y.dp_{y_2}.\frac{q_2}{p_{y_2}} \tag{5}$$

In this study, we focus exclusively on salty foods as substitutes and complements to the commodities, considering other foods as negligible. Therefore, we can rewrite the above formula to account for all substitutes and complements of each salty food:

$$\sum_{n=1}^{k}(dq_2)_n = \sum_{n=1}^{k}(\varepsilon_y.dp_{y_2}.\frac{q_2}{p_{y_2}})_n \tag{6}$$

Thus, we express the total salt intake (dQ) for each salty food as:

$$dQ = \varepsilon.\theta p_1.\frac{q_2}{p_2} + \sum_{n=1}^{k}(\varepsilon_y.dp_{y_2}.\frac{q_2}{p_{y_2}})_n \tag{7}$$

We analyzed the results using different taxing percentages and compared the resulting changes in salt consumption. STATA SE v14.1 (DASP package) was used for estimating PED and XED, while Excel software was used for mathematical simulations. The Ethics Committee of Guilan University of Medical Sciences approved this study (Ethics Code: IR.GUMS.REC.1399.585).

Results

The descriptive analysis of the households revealed that the average household size was 3.55 (±1.48). On average, each household consisted of 1.79 (±1.05) males, 0.28 (±0.52) children under the age of five, 0.26 (±0.55) individuals aged over 65, 0.88 (±0.90) illiterate members, 0.32 (±0.82) members with a university degree, and 1.07 (±0.81) individuals with paid employment. Table 1 provides a detailed summary of the household characteristics in the HEIS dataset.

Table 2 presents the PED and XED for various salty foods, along with their respective standard errors. As shown in the table, noodles and pilaf had the highest PED among all salty foods at −4.89 (0.64), followed by bread with a PED of −2.03 (0.12). This meant that by increase 1% in the price of noodles and pilaf, the salt intake will decrease 4.89%. and by increase 1% in the price of bread the salt intake will decrease 2.03%. Conversely, Dough had the lowest PED at −0.40 (0.40). Additionally, the highest XED was observed between salt and noodles/pilaf at −4.55 (0.08). Negative XEDs indicates that by one percentage increase in the price of one good, the salt intake in the interacted good will decrease. So, these two goods are complementary goods. Conversely, positive XEDs shows that by one percentage increase in the price of a good, the salt intake in the interacted good will increase and these two goods are substitute goods. This meant that by increase 1% in the price of noodles and pilaf, the salt use will decrease 4.55%. (Noodles and salts are Complementary goods).

Figure 1 illustrates the changes in salt intake related to PED, XED, and total salt as the tax percentage changes. As shown in the figure, there is no change in salt intake when no tax is applied, and the salt intake related to PED decreases as the tax percentage increases. However, the salt intake related to XED rises with increasing tax percentages. The changes in salt intake due to XED are more significant than those due to PED, leading to an overall increase in total salt intake. This suggests that total salt intake (dQ) increases as tax percentages rise.

Table 3 presents the quantities related to PED for different types of salty foods. Based on the price elasticity of demand and the amount of salt in each food, taxation has a significant impact on the salt intake of certain foods, such as bread, pasta, noodles and pilaf, sauces, and fast foods. However, it has little to no effect on the intake of foods like salt, chips, nuts, and curds.

Table 1 Household characteristics in the 2019 HEIS

Variable	Mean	SD	Min	Max
The average number of males in each household	1.79	1.05	0	9
Age average of household	36.14	17.27	0	98
The average number of children < 5	0.28	0.52	0	5
The average number of elderlies > 65	0.26	0.55	0	4
The average number of illiterate people in each household	0.88	0.90	0	13
The average number of people with a university degree in each household	0.32	0.82	0	18
The average number of people who have a job in each household	1.07	0.81	0	9
The average household size	3.55	1.48	0	16

Table 2 Price Elasticity of Demand (PED) and Cross Price Elasticity of Demand (XED) for various salty foods

	Bread	pasta	Noodles and pilaf	Biscuits	Sausage	Dough	Cheese	Curd	Nuts
Bread	**−2.03 (0.11)**	0.00 (0.11)	−0.57 (0.38)	0.15 (0.07)	0.10 (0.3)	−0.11 (0.57)	0.09 (0.07)	0.00 (1.44)	0.00 (0.08)
Pasta	0.00 (0.72)	**−1.00 (0.72)**	0.00 (0.10)	0.00 (0.08)	0.00 (0.17)	0.00 (0.25)	0.00 (0.12)	0.00 (0.56)	0.00 (0.11)
Noodles and Pilaf	−3.01 (0.07)	0.00 (0.07)	**−4.89 (0.64)**	−0.21 (0.10)	−0.57 (0.07)	−0.73 (0.33)	−1.83 (0.06)	0.00(0.09)	0.00 (0.05)
Biscuits	0.55 (0.07)	0.00 (0.07)	−0.15 (0.13)	**−1.57 (0.05)**	−0.01 (0.05)	0.15 (0.10)	0.18 (0.12)	0.00(0.09)	0.00 (0.03)
Sausage	0.34 (0.17)	0.00 (0.17)	−0.39 (0.1)	−0.01 (0.06)	**1.14 (0.81)**	0.51 (0.50)	0.37 (0.16)	0.00 (0.56)	0.00 (0.13)
Dough	−0.71 (0.13)	0.00 (0.13)	−0.91 (0.26)	0.27 (0.06)	0.96 (0.27)	**−0.40 (0.40)**	0.13 (1.9)	0.00 (0.77)	0.00 (0.11)
Cheese	0.33 (0.07)	0.00 (0.07)	−1.26 (0.17)	0.18 (0.06)	0.38 (0.12)	0.07 (0.28)	**2.37 (0.46)**	0.00 (0.65)	0.00 (0.09)
Curd	0.01 (0.39)	0.00 (0.39)	0.00 (0.09)	0.01 (0.07)	0.01 (0.39)	0.00 (1.01)	0.00 (0.09)	**1.00 (4.21)**	0.00 (0.09)
Nuts	−0.01 (0.1)	0.00 (0.1)	0.00 (0.07)	0.00 (0.03)	0.00 (0.12)	0.00 (0.21)	0.00 (0.17)	0.00(0.12)	**−1.00 (0.61)**
Chips, Cheetos	2.37 (0.18)	0.00 (0.18)	1.87 (0.19)	0.36 (0.05)	0.52 (0.08)	1.60 (0.23)	−1.34 (0.21)	0.00 (0.1)	0.00 (0.16)
Salt	−1.61 (0.07)	0.00 (0.07)	−4.55 (0.08)	0.86 (0.03)	1.03 (0.18)	−1.32 (0.29)	2.75 (0.22)	0.00 (0.89)	0.00 (0.04)
Pastes	0.00 (0.09)	0.00 (0.09)	0.00 (0.19)	0.00 (0.03)	0.00 (0.09)	0.00 (0.16)	0.00 (0.02)	0.00 (0.07)	0.00 (0.00)
Sauce	0.01 (0.00)	0.00 (0.00)	0.00 (0.06)	0.01 (0.01)	0.01 (0.01)	0.00 (0.00)	0.00 (0.00)	0.00 (0.02)	0.00 (0.00)
Juices	0.00 (0.00)	0.00 (0.00)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.07)	0.00 (0.13)	0.00 (0.00)	0.00 (0.00)
Fast foods	−0.03 (0.07)	0 (0.07)	0.00 (0.06)	0 .00 (0.04)	0.00 (0.32)	0.00 (0.39)	−0.01 (0.21)	0.00 (0.40)	0.00 (0.14)
Traditional restaurant foods	0.25 (0.29)	0.00 (0.29)	−0.03 (0.27)	0.18 (0.09)	0.29 (0.16)	0.21 (0.36)	0.43 (0.09)	0.00 (1.07)	0.00 (0.09)
Breakfast restaurant foods	−1.52 (0.15)	0.00 (0.15)	0.19 (0.16)	−0.5 (0.04)	−0.13 (0.11)	−0.41 (0.23)	−0.02 (0.23)	0.00 (0.37)	0.00 (0.12)

	Chips, Cheetos	Salt	Pastes	sauce	Juices	Fast foods	Traditional Restaurant foods	Breakfast restaurant foods
Bread	0.31 (0.32)	−0.07 (1.8)	0.00 (0.10)	0.00 (0.05)	0.00 (0.02)	0.00 (0.20)	0.21 (0.12)	−0.39 (0.20)
Pasta	0.00 (0.39)	0.00 (0.46)	0.00 (0.07)	0.00 (0.00)	0.00 (0.00)	0.00 (0.05)	0.04 (0.12)	0 (0.16)
Noodles and Pilaf	1.27 (0.28)	−0.99 (0.36)	0.00 (0.09)	0.00 (0.15)	0.00 (0.01)	0.00 (0.03)	0.06 (0.08)	0.27 (0.12)
Biscuits	0.17 (0.11)	0.13 (0.22)	0.00 (0.02)	0.00 (0.03)	0.00 (0.02)	0.00 (0.03)	0.5 (0.04)	−0.49 (0.04)
Sausage	0.24 (0.18)	0.15 (1.22)	0.00 (0.07)	0.00 (0.02)	0.00 (0.02)	0.00 (0.26)	0.74 (0.07)	−0.12 (0.12)
Dough	1.37 0(0.27)	−0.36 (1.06)	0.00 (0.06)	0.00 (0.01)	0.00 (0.08)	0.00 (0.17)	1.02 (0.08)	−0.7 (0.13)
Cheese	−0.63 (0.36)	0.41 (1.38)	0.00 (0.16)	0.00 (0.08)	0.00 (0.00)	0.00 (0.1)	1.11 (0.08)	−0.02 (0.09)
Curd	0.00 (0.15)	0.00 (4.24)	0.00 (0.03)	0.00 (0.06)	0.00 (0.00)	0.00 (0.23)	0.05 (0.3)	0.00 (0.28)
Nuts	0.00 (0.35)	0.00 (0.28)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.11)	0.03 (0.04)	0.00 (0.12)
Chips, Cheetos	**0.91 (0.6)**	0.21 (0.61)	0.00 (0.18)	0.00 (0.02)	0.00 (0.02)	0.00 (0.05)	0.27 (0.06)	0.3 (0.14)
Salt	0.66 (0.19)	**−1.19 (1.83)**	0.00 (0.08)	0.00 (0.00)	0.00 (0.03)	0.00 (0.11)	6.02 (0.07)	−0.6 (0.11)
Pastes	0.00 (0.55)	0.00 (0.77)	**−0.98 (0.47)**	0.00 (0.36)	0.00 (0.1)	0.00 (0.06)	0.04 (0.03)	0.00 (0.15)
Sauce	0.00 (0.02)	0.00 (0.00)	0.00 (0.07)	**−1.00 (0.26)**	0.00 (0.00)	0.00 (0.02)	0.05 (0.01)	0.01 (0)
Juices	0.00 (0.02)	0.00 (0.09)	0.00 (0.04)	0.00 (0.00)	**-1.00 (0.13)**	0.00 (0.04)	0.04 (0.02)	0.00 (0.01)
Fast foods	0.00 (0.15)	0.00 (0.93)	0.00 (0.05)	0.00 (0.07)	0.00 (0.1)	**−1.00 (0.24)**	0.02 (0.05)	−0.01 (0.1)
Traditional restaurant foods	0.05 (0.34)	0.35 (1.22)	0.00 (0.06)	0.00 (0.08)	0.00 (0.08)	0.00 (0.1)	**1.00 (0.16)**	−0.24 (0.14)
Breakfast restaurant foods	0.15 (0.29)	−0.09 (0.68)	0.00 (0.1)	0.00 (0.01)	0.00 (0.02)	0.00 (0.08)	0.61 (0.05)	**0.41 (0.12)**

Bold font indicates PED, while regular font represents XED. Standard errors are provided in parentheses.

Table 4 presents the salt intake related to XED across different food types at various tax percentages. The table shows that the salt intake for each item related to XED varies. For example, the salt intake from bread and noodles decreases after taxation on the prices of other salty foods. However, there is a significant increase in salt consumption from items like chips and Cheetos. Specifically, a 20% tax on other salty foods would result in an additional 242.42 g of total salt consumption per month, with 126.33 g of that coming from chips and Cheetos.

Figure 2 illustrates the share of each food in total salt intake after a 20% tax. The results indicate that following

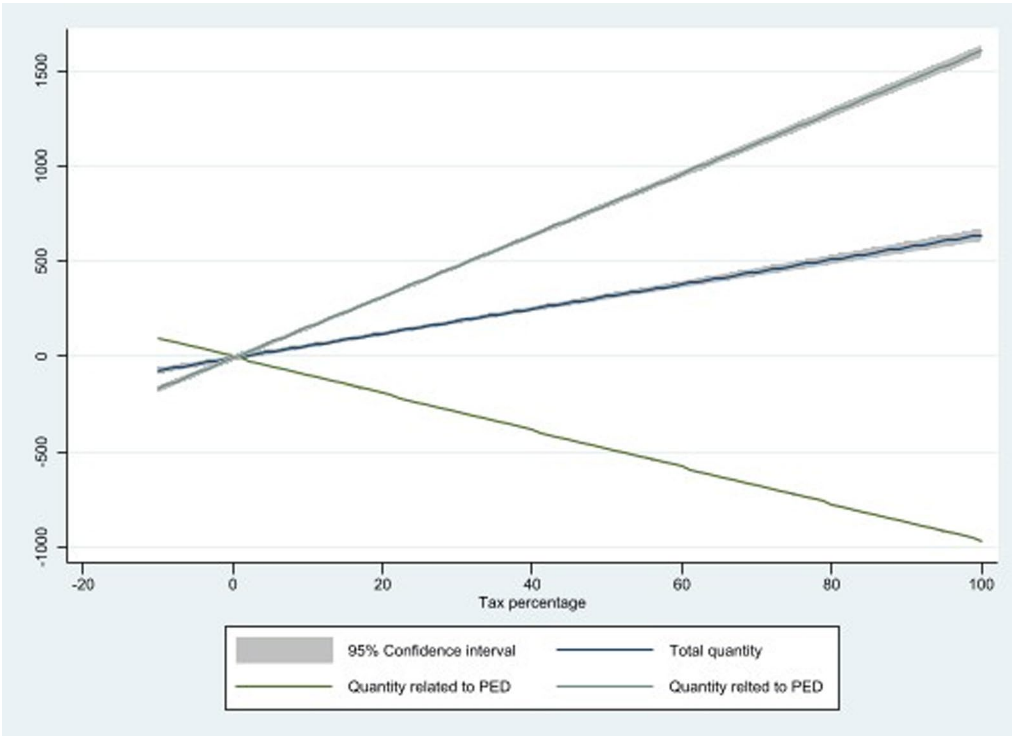

Fig. 1 The changes in salt intake related to PED, XED, and total salt intake by changes in different tax percentage and confidence intervals. The horizontal axis shows tax percentages and the vertical axis shows changes in salt intake. As shown in the figure, a 40% tax on salty foods will decrease salt intake near 400 g monthly (from the view of PED), while it increases the salt intake more than 500 g for the substitution and complementary goods (from the view of XED). The total salt intake will increase near 100 g in 40% tax

Table 3 The salt intake related to PED based on the type of food under different tax percentage

Tax percentage	Bread	Pasta	Noodles and Pilaf	Biscuits	Sausage	Dough	Cheese	Curd	Nuts
2	− 13.66	− 0.47	− 5.66	− 0.09	0.38	0.48	0.10	0.00	0.00
5	− 34.15	− 1.17	− 14.16	− 0.22	0.95	1.20	0.23	0.00	0.00
10	− 68.30	− 2.35	− 28.31	− 0.43	1.91	2.40	0.45	0.00	0.00
20	− 136.59	− 4.69	− 56.63	− 0.87	3.81	4.80	0.82	0.00	0.00
50	− 341.49	− 11.73	− 141.57	− 2.17	9.54	12.00	1.64	0.00	0.00
100	− 682.98	− 23.46	− 283.13	− 4.35	19.07	24.00	2.46	0.00	0.00

Tax percentage	Chips, Cheetos	Salt	Pastes	sauce	Juices	Fast foods	Traditional Restaurant foods	Breakfast restaurant foods
2	0.00	0.00	− 0.31	− 0.10	0.00	− 0.14	0.14	0.05
5	0.00	0.00	− 0.77	− 0.26	0.00	− 0.36	0.36	0.13
10	0.00	0.00	− 1.53	− 0.52	0.00	− 0.72	0.71	0.25
20	0.00	0.00	− 3.06	− 1.04	0.00	− 1.45	1.42	0.50
50	0.00	0.00	− 7.65	− 2.60	0.00	− 3.62	3.56	1.25
100	0.00	0.00	− 15.30	− 5.19	0.00	− 7.23	7.11	2.51

The first column shows the tax percentages and the first row shows the salty food type. As shown in the table, a 2% tax on bread will decrease salt intake 13.66 g monthly (from the view of PED). A 10% tax on noodles and pilaffs will decrease salt intake 28.31 g monthly.

Table 4 The salt intake related to XED based on the type of food under different tax percentages

Tax percentage	Bread	Pasta	Noodles and Pilaf	Biscuits	Sausage	Dough	Cheese	Curd	Nuts
2	−0.63	0.00	−6.72	0.07	2.51	0.01	0.03	0.00	0.00
5	−1.57	0.00	−16.79	0.18	3.76	0.02	0.08	0.00	0.00
10	−3.14	0.00	−33.58	0.36	5.84	0.04	0.16	0.00	0.00
20	−6.29	0.00	−67.16	0.72	10.00	0.08	0.32	0.00	0.00
50	−15.71	0.00	−167.90	1.80	22.50	0.21	0.79	0.00	0.00
100	−31.43	0.00	−335.80	3.60	43.33	0.42	1.58	0.00	0.00

Tax percentage	Chips, Cheetos	Salt	Pastes	sauce	Juices	Fast foods	Traditional Restaurant foods	Breakfast restaurant foods
2	12.64	24.24	0.00	0.00	0.00	0.00	1.53	−1.76
5	31.61	60.60	0.00	0.00	0.00	0.00	3.83	−1.99
10	63.22	121.20	0.00	0.00	0.00	0.00	7.66	−2.38
20	126.43	242.40	0.00	0.00	0.00	0.00	15.31	−3.16
50	316.08	606.00	0.00	0.00	0.00	0.00	38.29	−5.51
100	632.16	1212.00	0.00	0.00	0.00	0.00	76.57	−9.41

The first column shows the tax percentages and the first row shows the salty food type. As shown in the table, a 2% tax on bread will decrease salt intake in it 0.63 g monthly (from the view of XED). A 20% tax on sausages will increase salt intake 5.84 g monthly.

taxation, people tend to shift from foods such as bread and noodles to other salty options, like chips and salt.

Sensitivity analysis

We reanalyzed the results adding a tired tax for salty foods. For this purpose, we added two different tax percentages for the food. The results showed that the total salt intake increased 157.06 g, the salt intake due to PED decreased 230.653 g and salt intake due to XED increased 387.71 g. In addition, we analyzed the standard errors of XEDs and PEDs using 1000 bootstrap resampling. (Online Appendix 1-Table 5). In addition, we reanalyzed the results using almost ideal demand system (AIDS) estimator, assuming that the price elasticities are uncompensated and the goods are asymmetric and heterogeny. Findings showed a higher increase in salt intake in all tax percentages in comparison to DUVM estimator. PEDs and XEDs and the salt intake in different tax percentages are added in the online Appendix 2 (Table 6 and Table 7).

Discussion

This study analyzed the potential impact of a key public health policy—sin taxation—on the consumption of unhealthy goods, specifically salty foods. We first calculated the PED and XED, which are critical factors in assessing the effectiveness of a taxation policy. Taxation raises the price of unhealthy goods, leading to a reduction in their consumption due to the supply–demand equilibrium. However, the extent of this reduction depends largely on the PED. Goods with higher PEDs are more sensitive to price changes, making taxation more effective for commodities with high price elasticity. In this study, we calculated the PEDs for various salty foods. Since these foods come in different forms and their measurement units vary, we analyzed changes in consumption and taxation strategies by using the weight of salt as a standardized measure, instead of relying on the specific unit of each commodity. This approach allowed for more comparable taxation effects across different types of salty foods.

The findings of this study showed that the PED of salty foods varied widely, ranging from approximately −4.9 to 2.4. The PED for salt was zero, while for bread—a significant source of salt in Iran—it was −2.03. A study conducted in the United States calculated the PED for cheese at around −0.44 [35]. A randomized experiment in New Zealand demonstrated that people shifted toward healthier diets following the implementation of salt taxes [36]. Similarly, a study in Chile found that taxing salty foods could reduce the population's sodium intake. The results indicated that the price elasticity for salty snacks was −1.95, and an 18% tax could decrease sodium intake by 20 mg per month [37]. In the USA, the estimates of potential weight loss from different tax rates on salty snacks under different price elasticities show that a 10% price increase from a national excise tax reduces body weight between 0.1 and 0.5 kg per year, although generates about $1 billion tax revenue [25]. All of these countries have several diet and economic differences with Iran. In all of these countries bread is one of the main sources of calorie, however, he salts use in bread is different in these countries and salt use in bread in Iran

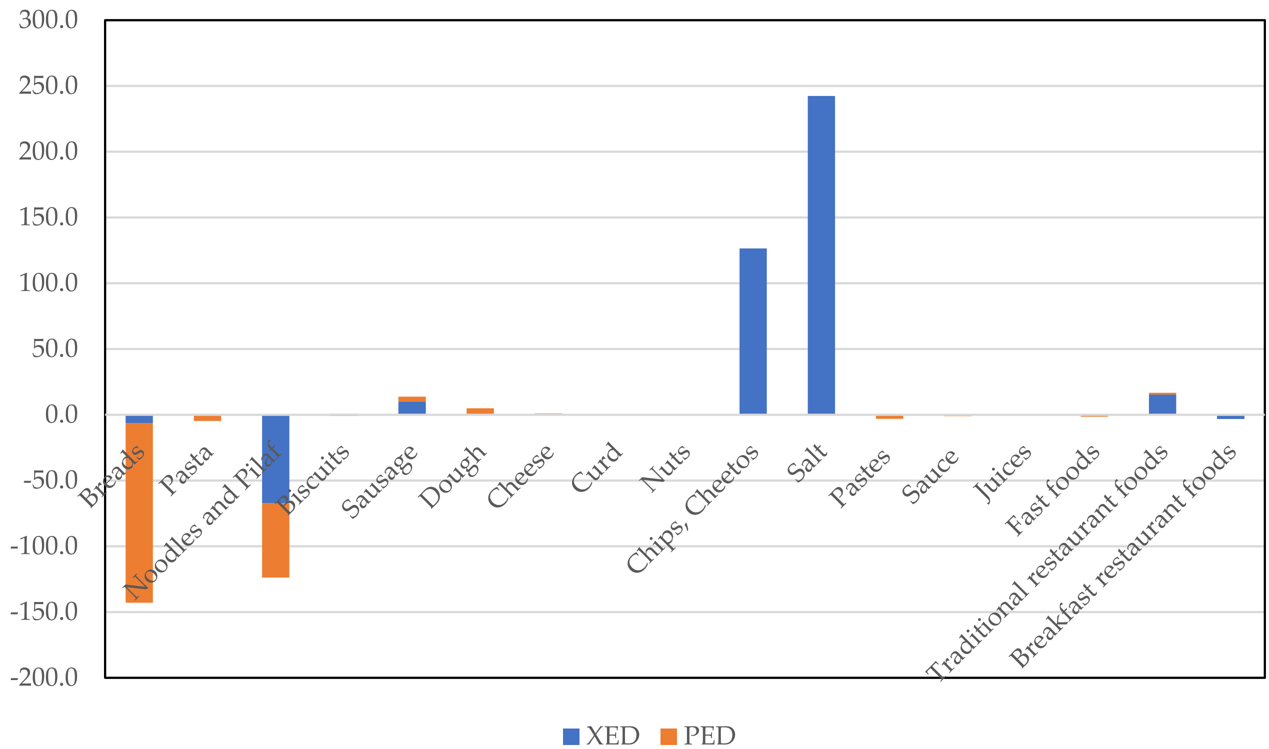

Fig. 2 Share of each food in salt intake after a 20% tax. The horizontal axis shows changes in salt intake and the vertical axis shows the salty foods. As shown in the figure, a 20% tax on salty foods will decrease salt intake in breads and noodles for both PED and XED. It highly increase the salt intake for cheeps and Cheetos and packed salt for XED which compensates the benefits of decreasing salt intake in breads and noodles

is one of the highest in the World. Near 80% of Iranian household use more than 5 g of salt daily [38, 39]. Due to low level use of salt in bread in other countries, taxing mechanisms do not affect the bread price highly, but it highly effects bread price in Iran and might have negative impacts on bread and carbohydrates intake of the country specially for the poor.

Our study showed that taxing interventions for salty foods did not decrease salt intake. A survey conducted in the USA concluded that taxation on salty foods would not have a reducing effect on the consumption of such foods, and price changes do not appear to induce significant changes in consumers' salty foods choices. Thus, a tax could raise earmarked revenues [40]. Furthermore, a systematic review on the effectiveness and feasibility of taxing salt and foods concluded that, while there is some evidence supporting the potential effectiveness of salt taxation, food taxes can lead to unintended consequences, such as reduced consumption of healthy foods, or increased consumption of unhealthy, untaxed substitutes [5]. A study in the United States analyzed price elasticity of Soda and salty snacks and discussed that increase in the price of these foods might increase utilization of other unhealthy foods [41]. A possible explanation for this is that as salt intake decreases from certain foods, the population shifts to consuming lower-quality salty alternatives. For instance, our simulation showed that while the demand for noodles, bread, and pasta decreased, there was a significant increase in salt demand. This suggests that the population may not alter their overall salt intake behavior but instead opt for cheaper, lower-quality salty foods. Additionally, as highlighted in the literature review, alongside broad-based tax policies aimed at improving diets, implementing carefully designed subsidies on healthy foods may create a synergistic effect, encouraging a shift in dietary behavior from unhealthy to healthier options [35]. In this context, experimental research demonstrates that lowering the price of healthier foods, while raising the price of less healthy alternatives, shifts consumer purchases toward more nutritious food options [42–45]. Another study showed that combining taxes on unhealthy foods with subsidies for healthy foods was effective in promoting healthier choices [5]. These findings are critical for policymakers, challenging the notion that taxation alone is effective in changing the population's behavior. Taxing all foods based on their salt content is likely to have a greater impact than targeting specific high-salt products, given the widespread presence of salt throughout the food supply chain. Moreover, the studies investigating the effectiveness of fiscal policies on salt intake did not adopt a holistic approach and failed to incorporate the cross-price elasticities (XED) between commodities, which may have influenced the results. In our study, we found that the price elasticity of demand (PED) for most foods was negative. This suggests that relying solely on the PED to evaluate the effectiveness of policies on salt intake could lead to a decrease in utilization.

Despite the ineffectiveness of sin-taxes on decreasing salt intake, these types of taxes can increase the tax revenue. They are a major source of the government budget of improving health of population [46, 47]. As the salt intake increased through higher taxes rates, this policy is effective in increasing the government budget. This policy can be effective for the health system if the additional tax revenue prioritized for health promotion and controlling the side effects of harmful commodities [48, 49].

Policymakers must consider both PED and XED when designing tax interventions on foods to ensure a shift in dietary behavior from unhealthy to healthy choices. Another important implication is that XED may be more critical than PED. Health policymakers should focus their tax interventions on foods with lower XED and higher absolute PED to maximize impact. Meanwhile, a study conducted in the USA indicated that taxing soft drinks and snacks at higher rates than other foods has minimal effects on consumption, suggesting that such taxes are primarily designed to generate revenue rather than influence consumer behavior [50]. XED can be either negative or positive, depending on the type of commodity. For commodities without substitutes, XED is close to zero. Additionally, if a good has complements, XED will be positive, and taxing it will reduce the consumption of the complementary good. The effects of tired taxes on more salty foods are another issue which must be noticed. Notably, for many key salty foods, we did not find any studies that estimated price elasticities, including cross-price elasticities, to predict within-category shifts between healthier and less healthy alternatives.

Study limitations and strength

This study is one of the first to measure both PED and XED for salt and salty foods, along with the effects of taxation. However, the study also had some limitations. First, there is a relationship between PED and XED for a wide range of salty foods that have complementary or substitute relationships. The study did not examine shifts within categories between healthier and less healthy alternatives. Therefore, further research is needed to explore how variations in tax rates affect the consumption of salty foods within categories that exhibit complementary or substitution relationships. Second, while our study addresses some economic questions regarding the PED and XED of salty foods and the impact of taxation on consumption, it does not answer all concerns. For instance, it remains uncertain whether taxing the entire range of high-salt foods will significantly improve dietary quality. Third, there are some interactions between XEDs and salty foods. To avoid complexity, they were deleted from salt intake estimations. Third some items like traditional restaurant foods and Breakfast restaurant foods might have a high heterogeneity. We were not able to break down these foods to more humogen groups due to the lack of data.

Conclusion

The results of this study answer the effectiveness of interventions which can help the societies to achieve one of the Sustainable Development Goals (SDGs) about decreasing noncommunicable diseases. Health promotion policies that impose taxes to reduce the consumption of unhealthy products are not always effective for salty foods. Policymakers should target these strategies at foods that do not have low-quality or harmful substitutes. Both price PED and XED are crucial for the potential outcome of such policies. Tax interventions on salt can affect utilization of some essential foods like bread specially for the poor. Policies can focus on subsidies healthier substitute foods, work on health promotion tactics to reduce salt intake in the population. For future studies it is suggested to focus on the impacts of salt taxation on salt intake and related welfare loss and comparing it to earmarked revenues, health promotion financing and cardiovascular diseases. Furthermore, analyzing the XED between salty and non-salty foods could offer a more comprehensive understanding of substitution effects of taxation in salty foods.

Supplementary Information

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Additional file 1.

Additional file 2.

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Author contributions

EHR participated in designing the study, analyzing and interpreting data. MH participated in writing and revising the manuscript. VY participated in writing the manuscript. AR critically revised the manuscript several times and had several intellectual comments on the drafted manuscript. MR gathered the data, AH helped on analyzing the results. All authors reviewed the manuscript.

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Availability of data and material
The data used in the study are available upon request from the corresponding author.

Code availability
Not applicable.

Declarations

Ethics approval
This study was approved by the Ethics Committee of Guilan University of Medical Sciences (IR.GUMS.REC.1399.585).

Consent to participate
Not applicable.

Consent for publication
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References

1. Sawicka K, Szczyrek M, Jastrzebska I, Prasal M, Zwolak A, Daniluk J. Hypertension–the silent killer. Journal of Pre-Clinical and Clinical Research. 2011;5(2).
2. Fund S. Sustainable development goals. Available at this link: https://www.un.org/sustainabledevelopment/. 2015.
3. Organization WH, Group ISoHW. World health organization (WHO)/international society of hypertension (ISH) statement on management of hypertension. J Hypertens. 2003;21(11):1983–92.
4. Mente A, O'Donnell M, Rangarajan S, Dagenais G, Lear S, McQueen M, et al. Associations of urinary sodium excretion with cardiovascular events in individuals with and without hypertension: a pooled analysis of data from four studies. Lancet. 2016;388(10043):465–75.
5. Dodd R, Santos JA, Tan M, Campbell NRC, Ni Mhurchu C, Cobb L, et al. Effectiveness and feasibility of taxing salt and foods high in sodium: a systematic review of the evidence. Adv Nutr. 2020;11(6):1616–30.
6. Silva-Santos T, Moreira P, Rodrigues M, Padrão P, Pinho O, Norton P, et al. Interventions that successfully reduced adults salt intake-a systematic review. Nutrients. 2021;14(1).
7. Ide N, Ajenikoko A, Steele L, Cohn J, C JC, Frieden TR, et al. Priority actions to advance population sodium reduction. Nutrients. 2020; 12(9)
8. Layeghiasl M, Malekzadeh J, Shams M, Maleki M. Using social marketing to reduce salt intake in Iran. Front Public Health. 2020;8:207.
9. Khoram K, Asghari-Jafarabadi M, Ebrahimi-Mamagani M, Shokrvash B, Hariri-Akbari M. The Magnitude of Salt Intake Behaviors and Its Predictors among Saqez Urban Population of Kurdistan District in Iran: A Cross-Sectional Study. International Journal of Hypertension. 2022.
10. Gholami A, Baradaran HR, Khatibzadeh S, Sheidaei A, Parsaeian M, Farzadfar F. National and subnational cardiovascular diseases mortality attributable to salt consumption in Iran by sex and age from 1990 to 2016. Archives of Iranian medicine. 2018.
11. Azadnajafabad S, Ebrahimi N, Mohammadi E, Ghasemi E, Moghaddam SS, Aminorroaya A, et al. Disparities and spatial variations of high salt intake in Iran: a subnational study of districts based on the small area estimation method. Public Health Nutr. 2021;24(18):6281–91.
12. Jafari M, Mohammadi M, Ghazizadeh H, Nakhaee N. Feasibility and outcome of reducing salt in bread: a community trial in Southern Iran. Glob J Health Sci. 2016;8(12):163.
13. Lynch E, Dal Bello F, Sheehan E, Cashman K, Arendt E. Fundamental studies on the reduction of salt on dough and bread characteristics. Food Res Int. 2009;42(7):885–91.
14. Ha SK. Dietary salt intake and hypertension. Electrol Blood Pressure: E & BP. 2014;12(1):7.
15. Rafieifar S, Pouraram H, Djazayery A, Siassi F, Abdollahi Z, Dorosty AR, et al. Strategies and Opportunities Ahead to Reduce Salt Intake. Archives of Iranian Medicine (AIM). 2016;19(10).
16. Pourkhajoei S, Yazdi-Feyzabadi V, Amiresmaeili M, Nakhaee N, Goudarzi R. Mean population salt intake in Iran: a systematic review and meta-analysis. Health Sci Rep. 2022;5(6):e855.
17. Roth GA, Mensah GA, Johnson CO, Addolorato G, Ammirati E, Baddour LM, et al. Global burden of cardiovascular diseases and risk factors, 1990–2019: update from the GBD 2019 study. J Am Coll Cardiol. 2020;76(25):2982–3021.
18. Sarrafzadegan N, Mohammmadifard N. Cardiovascular disease in Iran in the last 40 years: prevalence, mortality, morbidity, challenges and strategies for cardiovascular prevention. Arch Iran Med. 2019;22(4):204–10.
19. Organization WH. Assessment of the impact of a public health product tax. Final report, Budapest. 2015.
20. Trieu K, Neal B, Hawkes C, Dunford E, Campbell N, Rodriguez-Fernandez R, et al. Salt reduction initiatives around the world–a systematic review of progress towards the global target. PLoS ONE. 2015;10(7):e0130247.
21. Taillie LS, Rivera JA, Popkin BM, Batis C. Do high vs. low purchasers respond differently to a nonessential energy-dense food tax? Two-year evaluation of Mexicos 8% nonessential food tax. Preventive Med. 2017;105:S37–42.
22. Bank W. Using taxation to address noncommunicable diseases: lessons from Tonga: World Bank; 2019.
23. Homaie Rad E, Pulok MH, Rezaei S, Reihanian A. Quality and quantity of price elasticity of cigarette in Iran. Int J Health Plann Manage. 2021;36(1):60–70.
24. Akanonu PC, Ishaku J, Onyekwena C. The economics of tobacco control in Nigeria: modelling the fiscal and health effects of a tobacco excise tax change. 2019.
25. Kuchler F, Tegene A, Harris JM. Taxing snack foods: what to expect for diet and tax revenues. United States Department of Agriculture, Economic Research Service; 2004.
26. Borges D, Nascimento MCV. COVID-19 ICU demand forecasting: A two-stage Prophet-LSTM approach. Appl Soft Comput. 2022;125:109181.
27. Duarte F. Price elasticity of expenditure across health care services. J Health Econ. 2012;31(6):824–41.
28. Alsarraf R, Alsarraf NW, Larrabee J, Wayne F, Johnson J, Calvin M. Cosmetic surgery procedures as luxury goods: measuring price and demand in facial plastic surgery. Arch Facial Plast Surg. 2002;4(2):105–10.
29. Ramos P, Almeida A. The impact of an increase in user costs on the demand for emergency services: the case of Portuguese hospitals. Health Econ. 2016;25(11):1372–88.
30. Ellis RP, Martins B, Zhu W. Health care demand elasticities by type of service. J Health Econ. 2017;55:232–43.
31. Forgenie D, Hutchinson SD, Muhammad A. Welfare implications of rising imported food costs in the Caribbean. J Agricult Food Res. 2024;18:101489.
32. Khoiriyah N, Forgenie D, Iriany A, Apriliawan H. Assessing the welfare effects of rising prices of animal-derived sources of food on urban households in Indonesia. Economics and Business Quarterly Reviews. 2023;6(1)
33. Organization IS. Standards of Salt in Foods. In: Organization IS, editor. Tehran 2020.
34. Deaton A. Quality, quantity, and spatial variation of price. Am Econ Rev. 1988;78:418–30.
35. Andreyeva T, Long MW, Brownell KD. The impact of food prices on consumption: a systematic review of research on the price elasticity of demand for food. Am J Public Health. 2010;100(2):216–22.
36. Waterlander WE, Jiang Y, Nghiem N, Eyles H, Wilson N, Cleghorn C, et al. The effect of food price changes on consumer purchases: a randomised experiment. Lancet Public Health. 2019;4(8):e394–405.
37. Caro JC, Ng SW, Taillie LS, Popkin BM. Designing a tax to discourage unhealthy food and beverage purchases: the case of Chile. Food Policy. 2017;71:86–100.

38. Loloei S, Pouraram H, Majdzadeh R, Takian A, Goshtaei M, Djazayery A. Policy analysis of salt reduction in bread in Iran. AIMS Public Health. 2019;6(4):534–45.
39. Esmaeili M, Kamali Z, Abdollahi M, Houshiarrad A, Soleimani M, Nematollahi S, et al. The status of sodium intake and excretion and the primary dietary sources of sodium in Iranian adults, a comprehensive pilot study. Cardiovasc Endocrinol Metab. 2025;14(1):e00322.
40. Kuchler F, Tegene A, Harris JM. Taxing snack foods: manipulating diet quality or financing information programs? Rev Agric Econ. 2005;27(1):4–20.
41. Xian L. Price Elasticities of Demand for Soda and Salty Snacks: University of Georgia; 2020.
42. Epstein LH, Dearing KK, Paluch RA, Roemmich JN, Cho D. Price and maternal obesity influence purchasing of low- and high-energy-dense foods. Am J Clin Nutr. 2007;86(4):914–22.
43. Horgen KB, Brownell KD. Comparison of price change and health message interventions in promoting healthy food choices. Health Psychol. 2002;21(5):505–12.
44. Herman DR, Harrison GG, Afifi AA, Jenks E. Effect of a targeted subsidy on intake of fruits and vegetables among low-income women in the Special Supplemental Nutrition Program for Women, Infants, and Children. Am J Public Health. 2008;98(1):98–105.
45. French SA. Pricing effects on food choices. J Nutr. 2003;133(3):841s-s843.
46. Miracolo A, Sophiea M, Mills M, Kanavos P. Sin taxes and their effect on consumption, revenue generation and health improvement: a systematic literature review in Latin America. Health Policy Plan. 2021;36(5):790–810.
47. Allcott H, Lockwood BB, Taubinsky D. Regressive sin taxes, with an application to the optimal soda tax*. Q J Econ. 2019;134(3):1557–626.
48. Javadinasab H, Masoudi Asl I, Vosoogh-Moghaddam A, Najafi B. Comparing selected countries using sin tax policy in sustainable health financing: implications for developing countries. Int J Health Plann Manage. 2020;35(1):68–78.
49. Gruber J. Taxing Sin to Modify Behavior and Raise Revenue. National Institute for Health Care Management Foundation, avril. 2010.
50. Chriqui JF, Eidson SS, Bates H, Kowalczyk S, Chaloupka FJ. State sales tax rates for soft drinks and snacks sold through grocery stores and vending machines, 2007. J Public Health Policy. 2008;29(2):226–49.

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