EAI Endorsed Transactions
on Pervasive Health and Technology
Research Article EAI.EU

Dynamics of prices and consumption of unhealthy foods as a monitoring tool of the strategy against obesity in Mexico

José-Antonio Lozano-Díez[1] , Román Rodríguez-Aguilar[2,*]

[1] Universidad Panamericana, Augusto Rodin 498, Mexico, Mexico City 03920, Mexico
[2,*] Escuela de Ciencias Económicas y Empresariales, Universidad Panamericana, Augusto Rodin 498, México, Mexico City 03920, Mexico

Abstract

INTRODUCTION: Mexico faces an epidemic of overweight and obesity, in 2018 75% of adults were overweight or obese. This condition as a risk factor generates a significant financial impact in the Health Sector. In response, the National Strategy for Prevention and Control of Overweight, Obesity, and Diabetes was implemented in 2013, which included as one of its pillars the implementation of fiscal policies. As part of fiscal policy, taxes were established on sugary drinks and foods with high-calorie content. Seven years after the implementation of the Strategy to control the epidemic of overweight and obesity, there have been some results. However, it is necessary to continue working and especially monitoring the performance of the different actions implemented.
OBJECTIVES: Propose an analytical intelligence model for monitoring the fiscal policies implemented to control overweight and obesity in Mexico.
METHODS: The proposed analytical intelligence model considers three methodological bases, a) price index of healthy and unhealthy foods through Principal Component Analysis, b) volatility measurement of both baskets through a GARCH model and c) monitoring of consumption patterns through household income and expenditure surveys.
RESULTS: The main results identified a price differential between the baskets of products healthy and unhealthy, especially at the beginning of the fiscal policy. Healthy products have higher price volatility than unhealthy products and according to consumption patterns, on average Mexican households spend 30% of their food expenditure on unhealthy products.
CONCLUSION: To strengthen fiscal actions to control overweight and obesity, it is recommended to have monitoring systems for the dynamic design and implementation of public policies. Although taxes have reduced in some grade the consumption of unhealthy products, it is necessary to promote the affordability of healthy products, helping to improve the diet of Mexican households.

Keywords: tax policy, overweight and obesity, GARCH models, Analytical intelligence, Mexico.

Received on 28 October 2019, accepted on 12 November 2019, published on 13 November 2019

doi: 10.4108/eai.5-5-2020.164218

1. Introduction

Mexico ranks second in obesity in the world, the latest measurement in 2018 shows that the percentage of adults 20 years and over with overweight and obesity is 75.2% (39.1% with overweight and 36.1% with obesity). In response to this obesity epidemic in Mexico, various actions have been taken to attack the problem. The impact of obesity epidemic not only affects health spending also impacts productivity loss. In 2013, the strategy against overweight and obesity was implemented, which contemplated various actions, from market mechanisms, prevention, and education, as well as clinical treatment schemes.

* Corresponding author. Email: rrodrigueza@up.edu.mx

One of the main strategies was the implementation of special taxes on high-calorie foods and sugary drinks. In this regard, various studies have been carried out on the effectiveness of these measures. As part of these fiscal measures, an update of the tax rate applicable to these products was envisioned according to the observed response of consumers. To date the tax rates have not been updated, however, it is interesting to study the performance over time of the consumption of these products as well as the dynamics of their prices.

The consumption of individuals is determined by their tastes and preferences, in addition to their disposable income. That is why it is necessary to know the price dynamics between the product segments considered healthy and unhealthy, to identify possible lines of action to strengthen the strategy against overweight and obesity in Mexico. The present work proposes the monitoring system of the price dynamics through estimation of a price index for healthy and unhealthy food based on the information available in the National Consumer Price Index. The results show that there is a differentiated dynamic in the prices of healthy and unhealthy baskets, where the products considered as healthy present greater volatility in their prices.

Additionally, the consumption patterns of both baskets are studied with the information available in the National Household Income and Expenditure Survey (ENIGH by Spanish acronym), to examine the proportion that each basket considered represents of total food consumption of household. The data clearly shows that the dynamics of consumption is related to household net available income, as well as their preferences for healthy foods, in addition to their consumption patterns inside and outside the home. It is important to make a public policy successful, have continuous monitoring and evaluation, to adapt the strategies based on the observed results. The proposed work seeks to be a mechanism for monitoring prices and consumption patterns of households, which helps to improve the national strategy against overweight and obesity.

The work is structured as follows, in the first section, the background of the problem in Mexico is presented as well as the main actions considered within the “National Strategy for Prevention and Control of Overweight, Obesity, and Diabetes”. In the second section, the applied methodological framework is presented. The estimation of price index by basket, the estimation of volatility and the analysis strategy of household microdata are explained. The third section presents the results of the study and the last section presents the conclusions and recommendations.

2. Background

Mexico is undergoing an epidemiological transition, the effects of which are present in the burden of morbidity and mortality. This transition is defined by economic and social factors, lifestyles and situations as lack of physical activity, inadequate diet, drug use, as well as other problematic [1]. According to information from the Ministry of Health of Mexico, the current levels of overweight and obesity in the Mexican population represent a threatens the sustainability of the health system. Due the association of this condition with the non-communicable diseases and high costs for their care. The World Health Organization (WHO) defines overweight and obesity as an abnormal or excessive accumulation of fat, the most common indicator that used to identify excess weight is the body mass index (BMI) and classifies as overweight when BMI is equal to or greater than 25 and obesity when it is equal to or greater than 30 [2].

According to the 2012 National Health and Nutrition Survey (ENSANUT by its acronym in Spanish), among men over 20 years of age, 42.6% are overweight and 26.8% obese; while in women, these figures correspond to 35.5% and 37.5%, respectively. On the other hand, in the population school (5-11 years) the prevalence of overweight is 19.8% and that of obesity is 14.6% [3].

The non-communicable diseases with the highest prevalence and incidence are diabetes mellitus, ischemic heart disease, and malignant tumors. Based on ENSANUT 2012, diabetes mellitus affected 9.2% of the country's population, presenting an increase of 2.2 points percentage concerning that registered in 2006. The relationship between economy and health shows that a 20-year increase in life expectancy of the population translates into an additional 1.4% increase of the Gross Domestic Product (GDP), so it should be considered that the increase in prevalence and disease burden caused by obesity or diabetes can limit such growth. According to the Organization for Cooperation and Economic Development (OECD), an overweight person spends 25% more on health services, earns 18% less than the rest of the healthy population and presents higher work absenteeism.

In 2012 Mexico ranked second in the prevalence of obesity in the OECD, preceded by the United States of America. This problem becoming a matter of priority for most member countries od OECD since half of its population is overweight and one in six people suffer from obesity [4] (Figure 1).

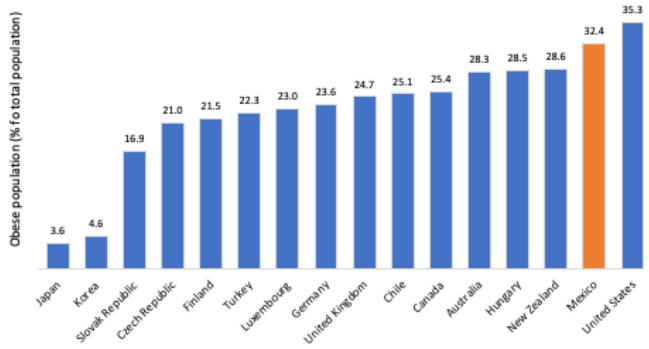

Figure 1. Obesity among adults in OECD countries (2012 or last year available).

The official estimation of the impact of direct and indirect costs, represented by the epidemic of overweight and obesity in Mexico, was realized by the Ministry of Health. The direct costs are related to the financial impact to the public sector for the medical care of patients linked to overweight and obesity, and the indirect impact is related to indirect costs for premature death and lost earnings due to absenteeism and disability of groups of diseases attributable to overweight and obesity. The estimated direct impact on the health sector in 2008 was equivalent to 33% of total public spending on medical care, which was equivalent to 0.3% of GDP. Additionally, the indirect impact was equivalent to 0.2% of the GDP of said period [5].

In 2015 an update of the estimates was carried out, for it was considered as the period of analysis and projection 1999-2023, in addition to five groups of diseases that include 35 pathologies and 269 keys of the International Statistical Classification of Diseases and Problems related to Health (ICD-10). The results show that in 2014 the direct cost of medical care was estimated at MXN151.94 million, equivalent to 34% of spending on medical care and 0.9% of GDP of that year. On the other hand, the indirect cost was estimated at MXN 71.669 million, equivalent to 0.4% of the 2014 GDP. Without any intervention through the prevention and control of overweight and obese patients, and their respective comorbidities, it is estimated that by 2023 the expected amount of the direct cost will increase by 17% and the indirect cost by 15%, equivalent to MXN184,982 and MXN 87,452 million, respectively [6].

Given the complexity of the problem due to its effects related to a greater financial burden in the health sector as well as productivity losses due to premature death, it was necessary to establish a "National Strategy for Prevention and Control of Overweight, Obesity, and Diabetes" in Mexico. This strategy was based on the previous strategy called the National Agreement for Food Health (ANSA for its Spanish acronym). The strategy was implemented in 2013 and contemplated the best international practices on the subject. The strategy was defined on three pillars [3] (Figure 2).

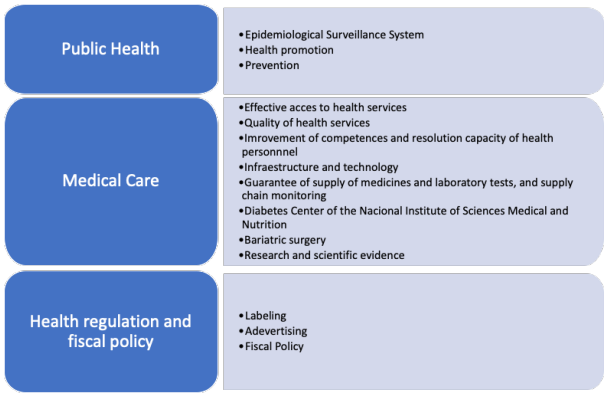

Figure 2. Pillars of the National Strategy.

In each pillar, their corresponding objectives and goals for the implementation of the strategy were defined (Table 1) [3].

Table 1. Objectives and goals of the Strategy

Pillar	Objective	Goal
Public Health	Implement proactive schemes for the prevention and timely detection of cases.	Achieve coverage of diabetes mellitus detection in 33% of the population aged 20 years and over, annually.
	Increase the number of patients with type 2 diabetes mellitus in control with glycated hemoglobin (HbA1c).	Achieve coverage of patients in follow-up with glycated hemoglobin (Hb A1c).
	Increase the number of patients with controlled diabetes mellitus type 2 glycated hemoglobin	Achieve by 2018 33% of patients with type 2 diabetes controlled with glycated hemoglobin (Hb A1c) below 7%
	Promote healthy lifestyles through the mass media with messages that emphasize diagnosis, correct nutrition, and physical activation.	Perform at least one educational communication dissemination campaign in the mass media annually.
Medical Care	Strengthen the updating of health personnel of the first level of care in the adequate management of the overweight, obese and diabetes patient.	Achieve a terminal efficiency of over 80% in updating non-communicable disease care for selected health personnel from first-level care units.
	Increase the number of units in the first level of	Achieve 90% of first-level care units with a timely

	care, with the supervision of the state authority, with a timely and sufficient supply of drugs for the control of diabetes.	and sufficient supply of medicines and supplies for the control of diabetes.
	Identify and validate useful genomic markers to establish preventive and therapeutic measures for obesity and type 2 diabetes.	Reduce the prevalence of obesity and its metabolic complications through the design of strategies based on genomic evidence.
Health Regulation	Improve nutritional information on foods and beverages to guide consumers on healthy options.	Achieve 100% of the foods and beverages that contain nutritional information on their front labeling.
	Regulate the advertising of drinks and food directed at children.	Reduce the advertising of drinks and food at specific times in mass media aimed at children.

These actions were complementary to what has already been done in the Ministry of Health through the specific action programs and the sectoral programs. Once the strategy was implemented, with the participation of civil society, the private sector, and higher education institutions. A system of indicators was defined to monitor the results of the Strategy. This System of Indicators arises from the need to concentrate relevant information to monitor progress in the factors that influence overweight and obesity in the population, as well as their associated diseases. The design of the methodology was in charge of the Mexican Institute for Competitiveness A.C. (IMCO for its Spanish acronym). Furthermore, the opinion of three civil society organizations was consulted regularly: "Contrapeso", "Fundación Mídete" and "Mexicanos Activos". The Indicator System was created to become one of the tools for analysis of the Mexican Observatory of Noncommunicable Diseases (OMENT for its Spanish acronym), responsibility from the Autonomous University of Nuevo León (UANL). The indicators proposed for this monitoring system are presented in Table 2 [7].

Table 2. Reference indicators of Strategy for controlling overweight and obesity

Indicator	Description	Base Line (2012)	2016*
Overweight prevalence	% of the total population	30.29	27.71
Obesity prevalence	% of the total population	23.50	21.64
Prevalence of type 2 diabetes mellitus	% of the population aged 10 years and over	9.17	9.44
Prevalence of high blood pressure	% of population aged 20 years or older	15.92	15.29
Type 2 diabetes mellitus mortality	Deaths per 100,000 inhabitants.	70.79	79.93
Hypertensive disease mortality	Deaths per 100,000 inhabitants.	16.02	19.22

Source: [7], * 2016 or last data available.

In the same way, the private initiative, the academy, and civil society have participated in this initiative for the control of overweight and obesity in Mexico. Likewise, various recommendations have been formulated for the control of overweight and obesity in Mexico, such as the regulation of food sold in schools, the installation of public drinking fountains as well as strategies for promoting physical activity. In recent years, the debate on the relevance of the strategy implemented in Mexico has been reactivated. In this regard, various studies have documented the effects of the various policies implemented, emphasizing fiscal policies.

[8] evaluated the effect of the special tax applied to sugary drinks, through the estimation of the price elasticity of demand for sugar-sweetened beverages and soft drinks in Mexico. Identifying the price elasticity of demand for -1.06 for soft drinks and -1.16 for sugar-sweetened beverages. This means that a 10% price increase was associated with a decrease in the quantity consumed of soft drinks by 10.6% and 11.6% for sugar-sweetened beverages. Therefore, the fact of implementing a fiscal policy could generate a potential decrease in these products. In the effect of implementing the sweetened beverages, soft drink tax is evaluated. Identifying the effect of the transfer of the tax to final consumer prices in urban areas at the household level. Through a pre-post quasi-experimental approach using a fixed-effects model. The results show that the implemented tax was transferred directly to the consumers of these products, as well as over shifting for carbonated drinks sweetened beverages, this effect was focused to a greater extent on small packages and had a heterogeneous performance by region of the country. Nationwide, when applying the tax, the prices of sweetened beverages increased about one peso per litter (CI, 0.95 to 1.12). Price changes for carbonated sweetened beverages are between 0.96 and 1.20 and between 0.53 to 0.74 pesos per litter for non-carbonated sweetened beverages [9].

[10] carried out in 2016 an observational study of purchases of non-alcoholic beverages in Mexico, to identify the effect on consumption derived from the implementation of the tax on sugary beverages through a

model of differences in differences with fixed effects at the household level. The main findings identify decreases in the quantities of beverages to which the special tax applies and an increase in beverages that do not apply a tax, a substitution effect is observed. The average volume of taxed beverages purchased monthly was 6% lower in 2014 compared with expected purchases without special tax. The reduction was greatest among households of low socioeconomic status averaging 9.1%. A substitution effect of sugary drinks with tax for non-tax drinks is identified, especially related to the increase in sales of bottled water by 4%. Identifying as a main result an increase in the consumption of bottled water and a decrease in the consumption of sugary drinks.

The segment of non-alcoholic beverages with high sugar content was of great interest to several authors, for example [11] investigated the impact of the tax on soft drinks and other sugary drinks, identifying increases above the special tax in the first month of its implementation, also increasing the price of diet sodas. [12] shows the effect of the tax on sugary drinks and products with high caloric density through a longitudinal study of 8,000 households, including information on 46,000 products for the period 2013-2014. Their main findings were the direct transfer of the tax to the price of sugary drinks and in the case of products with a high caloric density of 8%, it translated into an average 4% increase in the price of calories consumed at home. Regarding consumption, a decrease of 6.5-7% was identified for sugary drinks and in total calories consumed in the home, it is estimated that consumption decreased by 1%. Regarding the body mass index of the head of the household, no evidence of a decrease attributable to fiscal policy was found.

Regarding the effect of taxes on foods with high-calories content, there is little literature that addresses the subject for Mexico. Internationally authors such as [13] study the effect of a tax on food with high caloric content implemented in Denmark among 2011 and 2013, generating a decrease between 10 and 20% depending on the type of product. [14] documents for Hungary a tax on foods with high caloric content, sugar or caffeine, identifying a 3.4% decrease in the purchase volume of these foods. In the case of Mexico, [15] analyses the effect of the tax in Mexico for the first year of its application for a panel household database on food with and without tax, identifying a decrease of 25 grams per capita per month for 2014, for groups with the lowest socioeconomic level identified a decrease of up to 10.2% in the purchase of food with tax.

[16] focuses on the study of a group of products with high-calories content, among which snacks. The article analyses the performance of snack prices in the face of the tax increase and its possible impact on consumption. This tax applies to foods with high caloric content and is 8% for foods with more than 275 kilocalories per 100 grams. A panel data model and an interrupted time series model were performed. Elasticity scenarios and tax rates were considered to evaluate the possible decrease in the consumption of these products. The results show that taxes were transferred directly to the consumer in the snack segment. For the 2014-2016 period the tax generated a moderate decrease in consumption, according to the scenarios presented, a higher tax rate would generate greater decreases in consumption, since while the more elastic the product demands are, the greater the effectiveness of a tax will be. Concluding that to achieve the consumption reduction goals it is necessary to adjust the tax dynamically.

Authors like [17] focus on the study of fiscal policy on consumer welfare, taking into account their socioeconomic level. Identifying a loss of real income derived from the increase in taxes on these products, with a greater impact on lower income levels. Other authors focused precisely on estimating price elasticities of demand for the products to tax is applied, mostly identifying that they are elastic normal goods so that a sufficiently high tax should discourage their consumption products. However, in the case of fiscal policies, it is necessary to take into account the collection balance as well as the progressivity of the tax, it has been documented that in the case of taxes on sugary drinks and products with high caloric content, these are regressive taxes. That is, they have a greater impact on the lower-income population [18].

The differential effect of the tax on the population due to income inequality has been emphasized by [19]. Proposes an index of caloric prices comparing the purchasing power parity of the products considered as part of a healthy versus unhealthy diet. In the same way [20] have documented the gap between the prices of healthy and unhealthy food, identifying a greater growth in the prices of healthy products. This leads us to think about the extent to which fiscal policies influence consumer preferences, generating an effect of substituting unhealthy products for healthy products, and the extent to which the adjustment of consumer baskets is affected by an income effect derived from the increase in the prices of both product segments. In the case of the healthy ones due to their seasonality and inherent volatility and the case of the unhealthy ones due to the established taxes [21]. Other authors recommend the monitoring and updating of fiscal policies dynamically because once the tax is implemented, the consumer is likely to adapt their preferences to the new context and the tax loses effectiveness over time.

Very few studies show results in health and result in a decrease in overweight and obesity in the population. Until now, what has been conclusively shown is that an increase in the prices of unhealthy products and sugary drinks generates a decrease in their consumption. However, there are dual substitution effects, both for healthy products and for other types of unhealthy products that can hardly be taxed, such as informal trade and bulk sales [22, 23].

Seven years after the implementation of the Strategy, some progress has been observed concerning the baseline, but it has not been possible to significantly reduce the incidence and prevalence of overweight and obesity in the Mexican population. So, the debate now focuses on how far fiscal policy can discourage unhealthy consumption and to what extent it has the opposite effect by replacing the consumption of expensive calories by cheaper calories. There are other associated factors such as the use of time, work dynamics, as well as education for consumer decision-making. However, product prices and household disposable income prevail as determining variables [24].

In the following sections it is proposed the monitoring system of the prices of healthy and unhealthy products through a special price index for each product, as well as the measurement of the volatility of both groups of products and consumption patterns. It will allow evaluating the margin of adjustment in taxes for unhealthy products as well as the definition of additional strategies that allow the adoption of healthier eating styles in the population.

3. Materials and methods

This section briefly describes the methodologies used to estimate price indices, volatility, and consumption patterns for baskets of healthy and unhealthy products. This section briefly describes the methodologies used to estimate price indices, volatility, and consumption patterns for baskets of healthy and unhealthy products.

3.1. Laspeyres Index

The information available in the National Consumer Price Index (INPC for its Spanish acronym) will be used. There is a group of products that are part of the basket that makes up the index, among these products according to [25] was classified between products with high calorie-containing products as unhealthy and healthy products (Appendix A). The information available for all the products that are part of the sample covers the period 1969-2020. However, the sample considered was the period 2002-2020 because for that period there was information on the vast majority of the products included in the index. The index estimation is based on the Laspeyres index according to the Tax Code of the Federation of Mexico [26].

$$PL^{0:t} = \frac{\sum_{i=1}^{n} p_i^t q_i^0}{\sum_{i=1}^{n} p_i^0 q_i^0} = \sum_{i=1}^{n} \left(\frac{p_i^t}{p_i^0}\right) * \left(\frac{p_i^0 q_i^0}{\sum_{i=1}^{n} p_i^0 q_i^0}\right) = \sum_{i=1}^{n} \left(\frac{p_i^t}{p_i^o}\right) w_i^0 \quad (1)$$

Where:

$PL^{0:t}$ = Laspeyres price index in the period t concerning reference period 0.
p_i^t = Price of product i at time t.
p_i^0 = Product price i in the period of reference 0.
q_i^0 = Quantity of the product in the reference period 0.
w_i^0 = Share of expenditure (expenditure weight) of product i in period 0, that is $\frac{p_i^0 q_i^0}{\sum_{i=1}^{n} p_i^0 q_i^0}$.

For a price index to be considered as Laspeyres it is necessary the period of reference of the Index, reference period of prices (the basis of price comparison) and period benchmarks of the weights have the same reference period, which for the present change of base corresponds to the second half of July 2018. Also, the index must be representative taking into account the goods and services most consumed by households, and data must be comparable over time.

The INPC contains biweekly and monthly information on prices for 299 generic products collected in 55 cities, compiling a total of 318,000 monthly quotes. Likewise, the National Household Income and Expenditure Survey is used to establish the index weights based on the proportion of disposable income dedicated to each item of household expenditure. The information available to date has the second half of July 2018 as the base period. The index is representative at the national level and by city, and the available data is comparable for the entire existing period.

The analysis proposed for this work starts from the classification of the products that are part of the INPC basket by the object of expenditure, at their most aggregated level the 299 generic products are grouped into eight groups.

- Food, drinks, and tobacco.
- Clothing, footwear, and accessories.
- Living place.
- Furniture, appliances and household accessories.
- Health and personal care.
- Transport.
- Education and recreation.
- Other services.

It is important to maintain the structure in the classification of foods with high caloric content and healthy foods because said classification of the food group will be maintained for the analysis of volatility and household consumption patterns in both sets of products this analysis will be carried out based on ENIGH 2018.

3.2. Principal Components Analysis

For the generation of the index, the Principal Components Analysis (PCA) method will be applied, a method that allows summarizing the information of a set of n variables in a set k of smaller dimension, where $k < n$. This method will allow integrating the individual indices of each generic product of the group considered in the subset of foods with high-calorie content and healthy foods. The objective is to

build through PCA and index for each subset of products, it should be noted that the estimation method of the main components will be based on the variance and covariance matrix, which will allow working with the original units of the index.

Each principal component(Z_i) is obtained by a linear combination of the original variables. They can be understood as new variables obtained by combining the original variables in a certain way. The first main component of a group of variables $(X_1, X_2, \ldots, X_p)$ is the normalized linear combination of these variables that has the greatest variance. Obtaining the main components is shown in equation 2 [27, 28].

$$Z_1 = \phi_{11}X_1 + \phi_{21}X_2 + \cdots + \phi_{p1}X_p \quad (2)$$

That the linear combination is normalized implies that:

$$\sum_{j=1}^{p} \phi_{j1}^2 = 1 \quad (3)$$

The terms $\phi_{11}, \ldots, \phi_{1p}$ are loadings and are what define the component, ϕ_{11} is the loading of variable X_1 of the first main component. Loadings can be interpreted as the importance that each variable has in each component and, therefore, help to know what type of information each component collects.

3.3. Generalized Autoregressive Conditional Heteroscedasticity Model GARCH (p, q)

Once the indices have been prepared for each subset of food products, the volatility of inflation associated with these indices will be estimated. This to identify differences in the price variation of each subset of products. Volatility will be estimated using a Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model, which will allow price volatility to be estimated in a context where the variance is not constant over time. Assuming an autoregressive moving average model (ARMA) for the error variance. The model is a generalized autoregressive conditional heteroskedasticity (GARCH). The GARCH (p, q) model specification is as follows [29, 30].

$$y_t = x_t' b + \varepsilon_t \quad (4)$$

$$\varepsilon_t | \psi_t \sim N(0, \sigma_t^2) \quad (5)$$

$$\sigma_t^2 = \omega + \alpha \sum_{p=1}^{p} \varepsilon_{t-p}^2 + \beta \sum_{q=1}^{q} \sigma_{t-q}^2 \quad (6)$$

The GARCH model (p, q) where p is the order of the GARCH terms σ^2 and q is the order of the ARCH terms. These types of models allow calculating the two-way weighted historical volatility, taking into account recent and historical observations, as well as being autoregressive and the future variance depends on the historical variance.

As a last stage of the analysis, the consumption patterns of the examined food products are compared based on the ENIGH, the consumption patterns of the last measurement of the ENIGH 2018. The objective is to identify the proportions of income dedicated to the consumption of baskets of products with high-calorie content and healthy products, as well as the influence in this decision of the level of disposable income and the performance of the prices of both baskets.

3.4. Monitoring Analytical Intelligence Model

Taking into consideration the methodological tools previously described, it is proposed to build an analytical intelligence model to monitor the performance of the fiscal policy implemented to control overweight and obesity in Mexico. The proposed price indices will allow measuring the monthly or biweekly inflation of the products considered healthy and unhealthy. Similarly, the estimation of the volatility of both baskets will allow projecting these prices in the short and medium-term. And consumption patterns will allow evaluating how households make up their food baskets based on the information available in the market, prices and their respective income (Figure 3).

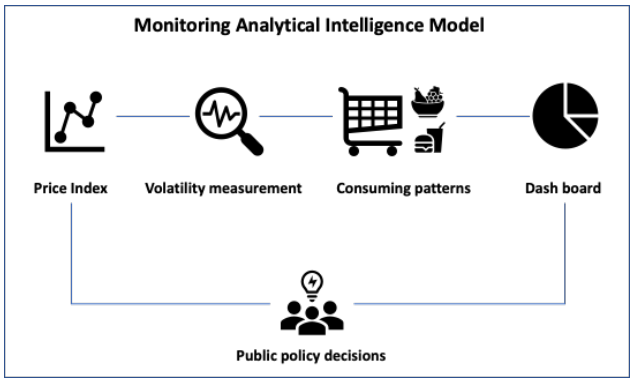

Figure 3. Analytical Intelligence Model.

In the case of household income and expenditure surveys, it is necessary to have information more regularly, at least annually, since these surveys are currently carried out every two years. It is important to have precise consumption information that could be collected through smart devices and be registered voluntarily by consumers instead of waiting to carry out a survey.

This proposal is the first step towards integrating analytical intelligence systems in the health sector for public policy decision-making.

4. Results

4.1. Estimation of Prices Index

For the estimation of the indices, the foods and non-alcoholic beverages considered in the INPC were classified into two groups, those with high caloric content and those considered healthy, this classification was made based on [25] (Appendix A).

The segment of foods considered healthy includes 47 generic products or groups of products. The PCA application was made to the variance-covariance matrix to maintain the original units. The variance proportion explained by the first component is 93%, in this case, the objective is to build an index by product group, so it was decided to keep only the first three main components which accumulate 96.5% of the total variance (Figure 4).

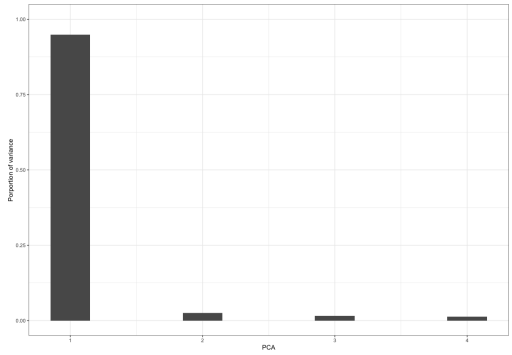

Figure 4. Variance explained by the first components.

The set of products considered presents a significant contribution to the variance and on average all products represents the same importance (Figure 5).

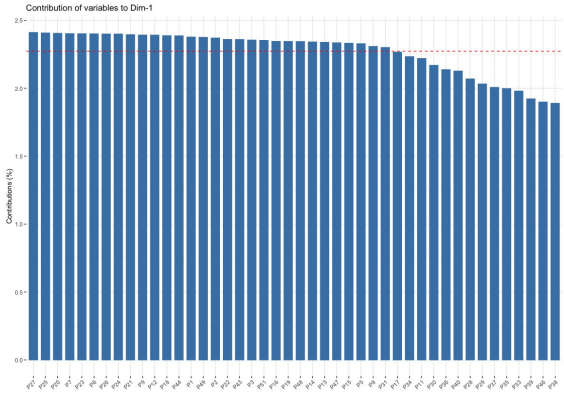

Figure 5. Contribution of variables to PC1.

The index generated for the basket of products considered healthy maintains the same INPC structure, expressing the results in the original units allows calculating inflation using a simple growth rate. Figure 6 shows the estimated healthy products index and its respective probability density.

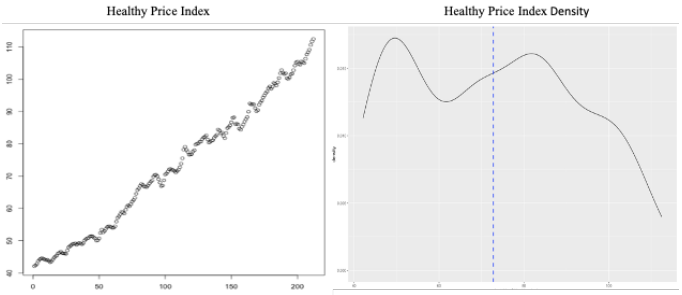

Figure 6. Healthy Price Index

The set of foods considered unhealthy contains 27 products or groups of products. Based on the indices of these generic food groups, the unhealthy food price index was constructed applying principal components analysis. In this case, the first component explains 98.8% of the total variability, if we keep the first three components, 99.6% of the total variability is explained (Figure 7).

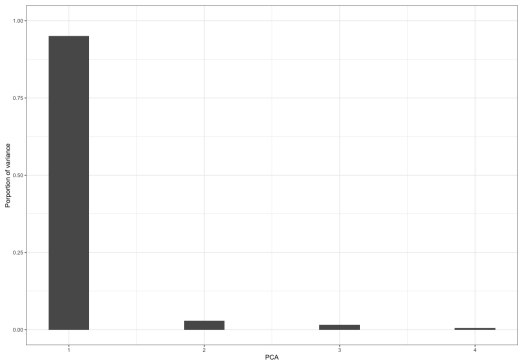

Figure 7. Variance explained by the first components.

The first component contains information on all the products considered. When considering components two and three, the information not explained by component one is included (Figure 8).

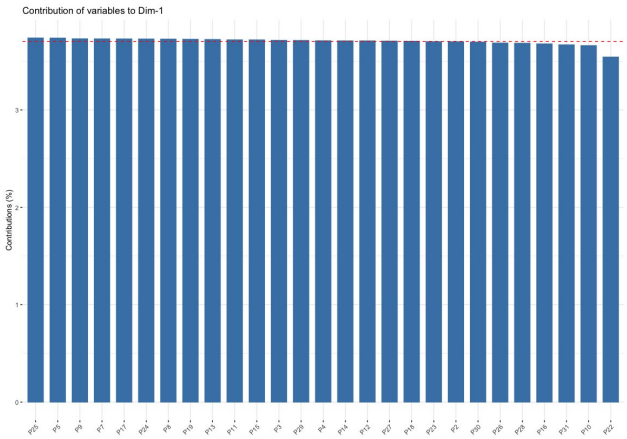

Figure 8. Contribution of variables to PC1.

The index is expressed in the original units, so it is possible to calculate inflation of this basket of products. Figure 9 shows the estimated index for the group of products considered as unhealthy and the probability density.

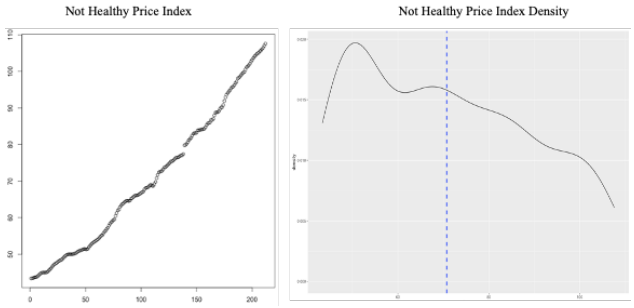

Figure 9. Not Healthy Price Index

The generated indices show a high percentage of total variance explained, they consider the total of products for each category with their respective weights. When comparing the densities of both indices, it is observed that the unhealthy food prices index presents a higher average value in its density, this effect will be studying calculating the inflation of both product baskets based on the estimated index.

4.2. Inflation and volatility of healthy and unhealthy baskets

Based on the estimated index's, the monthly and annual inflation of both product baskets is estimated. When comparing annual inflation, it is observed that there are periods where the gap in the growth of the prices of the basket of healthy and unhealthy products widens (Figure 10).

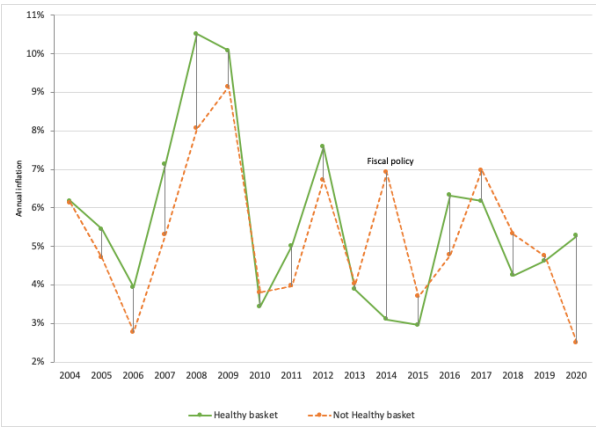

Figure 10. Annual inflation (%) for both baskets

Annual inflation for both baskets shows that on average the prices of the basket of health products have grown more than the prices of the basket of unhealthy products. In the last three years, a decreasing trend has been observed in the prices of the unhealthy basket, and in the case of healthy products, these have inverse behavior with an increase in prices. The annual inflation calculated for both baskets in the period 2003-2020 shows for the case of unhealthy products inflation of 139% and in the case of healthy products inflation of 153% in this period. Inflation observed in 2019 was 4.62% for healthy products and 4.75% for unhealthy ones.

The monthly inflation calculated shows that the basket of healthy products presents a greater variability in the monthly prices. On the other hand, the prices of unhealthy products are more stable over time, the average monthly inflation rate observed in 2019 corresponds to 0.47% and 0.43% for healthy and unhealthy products, respectively (Figure 11).

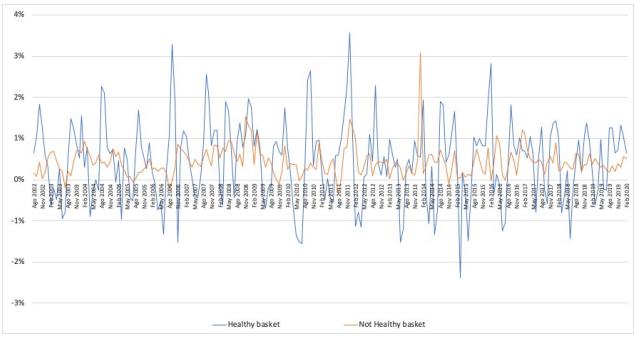

Figure 11. Monthly inflation (%) for both baskets.

To better understand the variability in the observed inflation of both baskets, a GARCH model was estimated which will allow us to estimate the observed volatility. The estimated GARCH model corresponds to a GARCH model (1,1), with parameters $p = 1$ and $q = 1$. The data used correspond to the monthly inflation calculated for the period 2002-2020, this inflation corresponds to the logarithmic returns of the indices calculated for each group of products. The objective is to identify the periods of high and low volatility to build volatility clusters. The results of the parameters estimated for the GARCH model (1,1) are shown in Table 3.

Table 3. Parameters of GARCH models: Healthy basket and Not Healthy basket

Healthy basket	Estimate	Std.Error	t-value	Pr(>|t|)
Omega	0.000	0.000	1.758	0.041
Alpha1	0.168	0.096	0.000	0.007
Beta1	0.273	0.374	0.888	0.037
Not Healthy basket	**Estimate**	**Std.Error**	**t-value**	**Pr(>|t|)**
Omega	0.000	0.062	8.681	0.000
Alpha1	0.001	0.072	0.746	0.045
Beta1	0.988	0.335	1.439	0.015

The volatility estimated with the GARCH model (1,1) for healthy basket shows the presence of volatility clusters in periods generally related to financial crises or periods of high volatility in the markets that directly affect the prices of healthy foods (Figure 12).

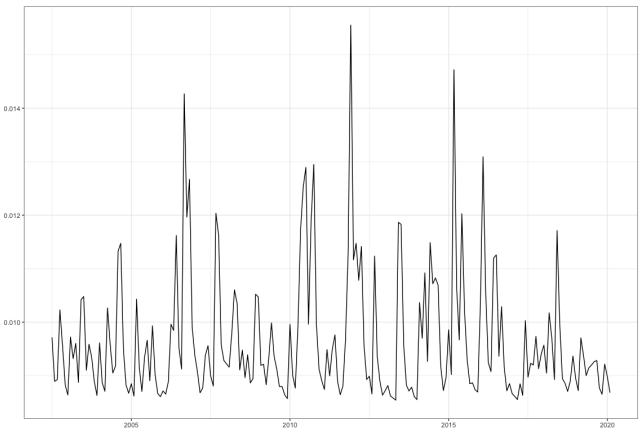

Figure 12. Conditional standard deviation of healthy returns (inflation).

In the case of the conditioned standard deviation for the products considered as unhealthy, it is observed that the series has a more stable price of these products show low variability and volatility clusters are only identified in short periods (Figure 13).

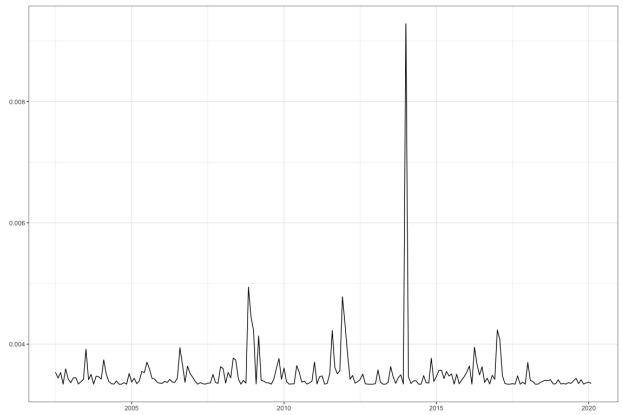

Figure 13. Conditional standard deviation not-healthy returns (inflation).

The estimated values for the volatility of both baskets show differences in price variability, additionally based on the estimated values of the last available period, the expected annualized inflation for both baskets in 2020 was calculated. It is observed that annualized inflation for healthy products it is 6.46% and for the unhealthy 4.72% (Table 4).

Table 4. Volatility and estimated inflation

Basket	Monthly inflation	Sigma	Annualized inflation
Healthy	0.005236	0.008309	6.4673%
Unhealthy	0.004567	0.003473	5.6202%

In general, the prices of unhealthy products are less volatile. It is observed that one of the most significant volatility clusters was presented just in 2014, the first year in which fiscal policy was applied. In the case of the basket of healthy products, this present greater volatility, due to their seasonal nature in most cases.

4.3. Household consumption

Based on the information from the ENIGH, the average expenditure amount for households in both product families was estimated. The same classification used for the estimation of price indices was considered for estimating household spending. Additionally, variables such as the fact that there was a person with chronic diseases in the household, the rural-urban environment, that the head of the family was a woman, education of head household and affiliation with a health institution were considered as control variables.

ENIGH 2018 data shows that on average a household spends MXN 1,999 [95% CI, 1,872-1,891] a month on healthy products and MXN 806 [95% CI, 799-811] on unhealthy products, taking into account an average monthly net expense of MXN 10,415 [95% CI, 9,533-10,418]. This implies that on average in Mexico, households allocate 30% of their expenditure on food within the home to unhealthy foods. Disaggregating this information by income quintile, it is observed that the highest quintile consumes a greater proportion of unhealthy products than the lowest income quintile (Table 5).

Table 5. Distribution of food expenditure household, 2018

	Healthy basket	Not-healthy basket	Food spending/ Net total spending
1stQ	75%	25%	42%
2ndQ	73%	27%	38%
3rdQ	72%	28%	33%
4thQ	70%	30%	28%
5thQ	69%	31%	18%

It is necessary to emphasize that only the consumption of food within the household is considered, as well as the total net expenditure and total net income for the generation of the quintiles. For the analysis of the factors associated with consumption patterns, Analysis of Variance (ANOVA) was proposed to compare the average values of consumption in unhealthy foods based on the presence of individuals with chronic diseases in the household, rural-urban setting, head of women's household, education of head of household and health affiliation (Table 6).

Table 6. ANOVA factors related to consumption of not healthy foods

Source	Partial SS	df	MS	F	Prob>F
Model	1.07E+12	5	2.14E+11	3.30E+05	0.0000
Affiliation	1.4E+07	1	13644467	20.98	0.0000
Female head_h	1.47E+11	1	1.47E+11	2.30E+05	0.0000
Education head_h	3.41E+11	1	3.41E+11	5.20E+05	0.0000
Chronic diseases	9.9E+08	1	9.91E+08	1523.16	0.0000
Rur_urb	3.48E+11	1	3.48E+11	5.30E+05	0.0000

The ANOVA results show that there are differences in the average amounts spent on households according to the control variables considered, these differences show that if the household has any reported health affiliation, it does not imply significant differences in the average amount of spending on unhealthy products this variable is related to the programs implemented in the different institutions on healthy habits for the population. The fact that the head of the household is a woman implies that the average expenditure on unhealthy products is less than those households with a male head of household. The educational level of the head of the household, contrary to what was expected, does not generate less spending on unhealthy products, this is related to the level of household income according to the level of education of the head of the household.

A relevant variable is the presence of a member of the household with chronic diseases, this variable was determined based on the expense related to medications for the treatment of chronic diseases such as diabetes and hypertension, in this case, the fact that there is a member of the household with chronic diseases decrease the average amount of spending on unhealthy products. Finally, the fact that the home is in rural areas reduces the average spending on unhealthy products (Figure14).

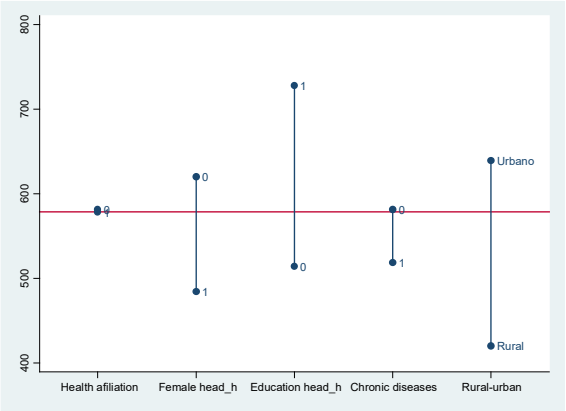

Figure 14. Mean of spending on unhealthy basket by factor, 2018.

Consumption patterns show a lower proportion of spending on unhealthy products, even by income quintile, on average 30% of household food spending is spent on unhealthy products. Household characteristics related to the amount of spending on unhealthy products were identified.

5. Conclusions

The problem of overweight and obesity in Mexico is a public health problem. Its effects on both the demand for health services and the loss of life and productivity are very significant, estimated at around 2% of GDP in 2018. In response to the obesity epidemic in Mexico, the strategy against overweight and obesity was implemented in 2013. This strategy considered various actions, among which the imposition of special taxes on sugary drinks and high-calorie foods stands out.

The results observed to date identify decreases in the consumption of these products, but also the adaptation of the consumer to fiscal measures. For that, it is necessary to monitor and adjust the strategy dynamically, this will allow that taxes do not lose its effectiveness. Among the results identified, it is observed that although there was an increase in the prices of foods with high caloric content and sugary drinks when observing the price dynamics between the two baskets built (healthy and unhealthy), there is a gap in their prices. The indices proposed for monitoring the prices of both baskets show that the dynamics of prices for healthy products have shown higher accumulated inflation in the period 2003-2020 of 153% for healthy products and 139% for unhealthy products.

This performance in prices was confirmed by obtaining the volatility of prices through a GARCH model, where it is observed that in the case of healthy products (due to their own characteristics) volatility clusters are identified so that the monthly volatility estimated for these products was 0.8%. In the case of unhealthy products, there is a low presence of volatility clusters and the estimated monthly volatility was 0.2%. With the data on the price available up to February 2020, the estimated annualized inflation would be 6.46% for healthy products and 4.7% for unhealthy products.

These differences in the prices of both baskets define the pattern of consumption over time. Other studies have documented the decrease in the consumption of products with high caloric content and sugary drinks, the data of the ENIGH 2018 show that the proportion of consumption of unhealthy products within the home remains on average at 30% of food expenditure, regardless of household income level. An interesting fact is that those households with a lower income level have a higher proportion of consumption of healthy products, 75% of the total consumption of food within the home, in contrast to households with a higher income level whose consumption of healthy products it is 69%. Additionally, factors related to a lower amount of spending on unhealthy products were identified, such as the fact that the head of the household is a woman, the presence of chronic diseases in the home, as well as the fact that the household is in the rural environment.

The results identified in this research show the utility of having a price monitoring tool through a tailored index for healthy and unhealthy products. Being able to identify price volatility, in the same way, will serve as a mechanism to monitor the affordability of the basket of healthy products by Mexican households. Although the special tax policy on unhealthy foods implemented in Mexico generated a decrease in the consumption of these products, it is necessary to follow up on this strategy and adjust it if necessary, so that it does not lose its effectiveness. Similarly, it is possible to consider policies based on subsidies for healthy products in those scenarios of high price volatility, to allow them to remain affordable. It is important to note that this paper only analyses the fiscal strategy, but it is necessary to continue working comprehensively through education and prevention, to bring down the obesity epidemic that Mexico suffers. To strengthen fiscal actions to control overweight and obesity, it is recommended to have monitoring systems that allow the dynamic design and implementation of public policies.

Appendix A. Healthy and not healthy products

Healthy products	Not Healthy products
Corn	Snack made with cereals
Corn dough and flours	Sweetbread
Corn tortilla	Cakes and packaged sweet bread
Toasts	Cupcakes and cakes in bulk
White bread	Sweet cookies
Box bread	Lard
Pasta and wheat flour	Processed dried meats and other sausages
Wheat flour	Chorizo
Pasta for soup	Sausages
Wheat flour tortillas	Bacon
Chicken	Butter
Pork meat and offal	Ice cream and ice popsicles
Beef meat and offal	Beef meat and offal
Ham	Instant soups and tomato puree
Fish and shellfish	Packaged juices or nectars
Pasteurized and fresh milk	Packaged soft drinks
Processed milk	Chicken and salt concentrates
Cream and other milk-based products	Mayonnaise and mustard
Other cheeses	Chips
Yellow cheese	Chocolate and confectionery products
Fresh cheese	Liquid and beverage chocolate
Manchego and Chihuahua cheese	Soft drink concentrates
Oaxaca cheese and asadero	Barbecue
Yogurt	Other cooked food
Egg	Pizzas
Edible oils and fats	Roasted chickens
Fresh fruits	
Other fruits	
Papaya	
Pear	
Pineapple	
Bananas	
Watermelon	
Grape	
Fresh vegetables	
Dried vegetables	
Packaged chili peppers	
Processed beans	
Packaged vegetables	
Baby food	
Moles and sauces	
Sugar	
Coffee	
Bottled water	
Other seasonings	
Honey and jams	
Gelatin powder	

Acknowledgments. To the EAI International Conference on Computer Science and Engineering and Health (COMPSE) for the space for the dissemination of knowledge and ideas.

References

[1] Stevens G, Dias RH, Thomas KJA, Rivera JA, Carvalho N, et al. (2008). Characterizing the epidemiological transition in Mexico: National and subnational burden of diseases, injuries, and risk factors. PLoS Med 5(6): e125.

[2] WHO (2011). World situation report of non-communicable diseases 2010. Guidance Summary. Geneva, Switzerland: WHO.

[3] Secretaría de Salud (2013). National Strategy for Prevention and Control of Overweight, Obesity and Diabetes. México: Secretaría de Salud.

[4] OECD (2013), Health at a Glance 2013: OECD Indicators, OECD Publishing.

[5] Gutiérrez-Delgado, C., Guajardo-Barrón, V., Arzoz-Padrés, J. (2009). Modelo para estimar el impacto financiero de la obesidad y el sobrepeso en México. Documento de trabajo 2/2008, Unidad de Análisis Económico, Secretaría de Salud, México.

[6] Sansores-Martinez D. and Gutierrez-Delgado (2015). Impacto Económico del Sobreeso y la Obesidad en México 1999-2023. Nota Técnica UAE-NT-001-2015. Unidad de Análisis Económico, Secretaría de Salud, México.

[7] OMENT. (2015). Sistema de Indicadores para Monitorear los Avances de la Estrategia Nacional para la Prevención y el Control del Sobrepeso, la Obesidad y la Diabetes. Reporte de Resultados. México.

[8] Colchero, M.A. Salgado, J.C. Unar-Munguía, M. Hernández-Ávila, J.A. Rivera-Dommarco, M. (2015). Price elasticity of the demand for sugar sweetened beverages and soft drinks in Mexico, Economics & Human Biology, 19,129-137.

[9] Colchero M.A., Salgado J.C, Unar-Munguía M., Molina M., Ng., Rivera-Dommarco J.A., (2015). Changes in Prices After an Excise Tax to Sweetened Sugar Beverages Was Implemented in Mexico: Evidence from Urban Areas. PLoS ONE, 10(12).

[10] Colchero M. A., Popkin B.M., Rivera J.A., Ng S.W. (2016). Beverage purchases from stores in Mexico under the excise tax on sugar-sweetened beverages: an observational study. BMJ, 352:h6704.

[11] Grogger, J. (2015), "Taxing Soda and the Prices of Sodas and Other Drinks: evidence from Mexico", documento de trabajo del NBER núm. 21197, NBER, Cambridge, Massachusetts.

[12] Aguilar, A., E. Gutiérrez y E. Seira (2015), "Taxing calories in Mexico", documento de trabajo del ITAM-CIE, disponible en: http://cie.itam.mx/sites/default/files/cie/15-04.pdf

[13] Jensen J. D., y S. Smed (2012), "The Danish Tax on Saturated Fat - Short Run Effects on Consumption and Consumer Prices of Fats", documento de trabajo núm. 14 del Departamento de Alimentos y Recursos Económicos, Departamento de Alimentos y Recursos Económicos, Universidad de Copenhague, Dinamarca.

[14] Bíró, A. (2015), "Did the Junk Food Tax Make the Hungarians Eat Healthier?", Food Policy, vol. 54, pp. 107-115.

[15] Batis, C., J. Rivera, B. Popkin y L. Taillie (2016), "First-Year Evaluation of Mexico's Tax on Nonessential Energy-Dense Foods: An Observational Study", PLOS Medicine.

[16] Aguilera Aburto, N., Rodríguez-Aguilar, R., Sansores Martínez, D. N., & Gutiérrez Delgado, C. (2017). Impuestos en botanas. Su impacto en precio y consumo en México. El trimestre económico, 84(336), 773-803.

[17] Romero-Tellaeche J., Caldiño-García E, Minor-Campa E., Romero-Hernández C. (2015). Estudio de los efectos sobre el bienestar de la política de impuestos sobre alimentos y bebidas con alto contenido calórico. Del gasto y la demanda de refrescos de los hogares 2012-2014. Reporte de resultados. Disponible en http://difusion.colmex.mx/images/PDF/refrescos2.pdf

[18] Powell L. M., y F. J. Chaloupka (2009), "Food Prices and Obesity: Evidence and Policy Implications for Taxes and Subsidies", The Milbank Quarterly, vol. 87, núm. 1, pp. 229-257.

[19] Mendoza Velázquez A.(2012) Índice de Paridad Poder de Compra Nutricional: comparación de los precios calóricos entre dietas habituales y saludables. Rev Panam Salud Publica, 31(1)17–24.

[20] Monsivais P, Drewnowski A. (2007). The rising cost of low-energy-density foods. J Am Diet Assoc.107(12):2071–6.

[21] Williams PG, Hull A, Kontos M. (2009). Trends in the affordability of the Illawarra Healthy Food Basket 2000–2007. Nutrition and Dietetics, 66(1):27–32.

[22] Maniadakis, N., Kapaki, V., Damianidi, L., & Kourlaba, G. (2013). A systematic review of the effectiveness of taxes on nonalcoholic beverages and high-in-fat foods as a means to prevent obesity trends. ClinicoEconomics and outcomes research: CEOR, 5, 519–543.

[23] Bonilla-Chacin M. et al. (2016). Learning from the Mexican experience with taxes on sugar-sweetened beverages and energy-dense foods of low nutritional value. Discussion Paper. World Bank Group.

[24] FAO & PAHO/WHO, (2017). Panorama de la Seguridad Alimentaria y Nutricional: Sistemas alimentarios sostenibles para poner fin al hambre y la malnutrición. WHO, Santiago: Chile.

[25] Pérez Lizaur AB, Marván Laborde L. (2005). Manual de dietas normales y terapéuticas. 5.a ed. México: Editorial Prensa Médica.

[26] INEGI- México (2018). Índice Nacional de Precios al Consumidor: documento metodológico: base segunda quincena de julio de 2018/ Instituto Nacional de Estadística y Geografía. México : INEGI.

[27] Pearson, K. (1901). "On Lines and Planes of Closest Fit to Systems of Points in Space". Philosophical Magazine. 2 (11): 559–572

[28] Hotelling, H. (1933). Analysis of a complex of statistical variables into principal components. Journal of Educational Psychology, 24, 417–441, and 498–520

[29] Bollerslev T. (1986), Generalized autoregressive conditional heteroskedasticity, Journal of Econometrics, 31(3), 307-327.

[30] Engle, Robert F. (1982). "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation". Econometrica. 50 (4): 987–100