



AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
<http://ageconsearch.umn.edu>
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

The Implications of Heterogeneous Habit in Consumer Beverage Purchases on Soda and Sin Taxes

Wenying Li

University of Georgia
wenying.li25@uga.edu

Jeffrey H. Dorfman*

University of Georgia
Jdorfman@uga.edu

Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2018 AAEA Annual Meeting, Washington, D.C., August 5-7, 2018

Generous financial support from USDA's Food Assistance and Nutrition Research Program is gratefully appreciated. The views expressed here are those of the authors and cannot be attributed to the Economic Research Service or the U.S. Department of Agriculture.

Copyright 2012 by Wenying Li and Jeffrey H. Dorfman. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.

* Corresponding Author

Abstract

In this article, we study the heterogeneity of habit strength in households' demand for regular carbonated sweetened beverages (CSBs) and beer in the United States. A demand model that nests a smooth transition function is used to describe habit-based consumption patterns, revealing heterogeneous strengths of habits among households. We find that more habitual consumers, those with a strong preference for a particular product, are not as sensitive to price or expenditure as the aggregate population. This finding is further supported by simulations of the potential effects of soda and beer taxes. In contrast to previous results, we find the aggregate response to soda and beer taxes is smaller than when the influence of habit is assumed to be homogeneous.

Key Words: Heterogeneity, Habit Formation, Sin Tax, Soda Tax, Smooth Transition

1. Introduction

There are numerous studies that analyze consumer responses and welfare effects due to government policies related to products with habit effects (cf., Härkänen, Kotakorpi, Pietinen, Pirttilä, Reinivuo, and Suoniemi 2014; Goryakin, Monsivais, and Suhrcke 2017; Lin, Dong, Carlson, and Rahkovsky 2017). This type of research is specifically targeted at unhealthy and habit-forming products, such as sugary beverages, junk food, alcohol, and tobacco, etc. (Andreyeva, Long and Brownell.2010; Pacula and Rosalie 1998; Zhen et al. 2011; Zhen, Brissette and Ruff 2014, Zheng et al. 2017). The models employed to study such policies consider price and income as the main determinant of consumption. A general question is whether increasing the cost would, in fact, decrease the consumption of unhealthy products and break consumers' original habits. To answer such questions, a common practice is to estimate an econometric model for consumer demand under habit formation. Then, the associated economic impact under different tax or subsidy policies is simulated with the estimated model to assess such policies.

Over decades, demand models have evolved to better describe people's behavior as well as to be consistent with economic theory. Models have been greatly improved by considering nonlinear income effect, endogeneity, dynamics, and censoring, etc. But one strict econometric assumption, homogeneity, has barely been relaxed. By assuming all consumers react equally to changes, such models might yield biased estimates of even aggregate responses if heterogeneous responses are not

symmetrically distributed. Moreover, real-life experience tells us there exists extreme preference over specific goods, such as tobacco, alcohol, and sweetened beverages, which severely undermines the assumption of homogeneous responses.

This paper takes an innovative approach to investigate the demand for regular carbonated sweetened beverages (CSBs)² and beer under habit formation.

Specifically, our research seeks to determine the extent to which heterogeneous habits characterize the household's heterogeneous responses to price or income changes.

Using a smooth transition autoregressive, or STAR, model to represent a continuous range of habit strengths, this paper extends earlier research into public food policies by considering individual heterogeneity. Our main result is that households with more habit-based consumption are more insensitive to price or income changes. Because such households consume more than average households, when heterogeneity is considered the aggregate declines in demand for both soda and beer in response to tax increases are found to be smaller than under an assumption of homogeneity. This suggests food policies should be evaluated and designed with consideration for consumers' heterogeneous habits and sensitivity to changes in price or income.

² Carbonated sweetened beverages (CSBs) is one of the four categories included in Sugary-sweetened beverages (SSBs), which is the common target of soda tax policies. The other three categories are regular non-diet fruit juices, non-diet sports and energy drinks, and all other SSBs. Among the four categories of SSBs, regular CSBs is the most prevalent SSB type across all years for all age groups except children (for whom fruit drinks were the most prevalent in 1999 and 2005) (Han and Powell 2013). We choose only CSBs as our research subject since it is the most representative group and analyzing the effect of soda tax on the full categories of SSBs would generally involve estimation of a system of demand equations.

Exploring the role of heterogeneity in explaining household demand is important especially from marketing and policy perspectives. For example, consumers, whose demands are in the tails of the distribution, are the most (least) price sensitive or have the weakest (strongest) preference for a particular product. Because those consumers who buy the largest quantities of the products studied are the least responsive to the policy, taxes on habit-prone products are less effective than better targeted policies.

In this paper, we make three major contributions to the empirical literature on demand analysis and habit formation. First and foremost, this study contributes to the existing literature by relaxing the homogeneity assumption. The proposed model allows continually varying household price/income elasticities as habit differs in strength across households. The model can be easily extended to include other exogenous variables representing household heterogeneity and can also be applied to more sophisticated demand systems. Second, habit formation is generally explained as a repeated behavior pattern. The underlying hypothesis is that current consumption of one product is substantially affected by consumption of the same product in the previous period. Lagged purchases are usually included in demand models to demonstrate habits. An issue of this approach is that lagged response variables could suppress the explanatory power of other explanatory variables. The lagged purchase often acquires a large statistically significant coefficient, which may bias downward the coefficients of other explanatory variables. This can be solved by including a smooth transition function of past purchases in the demand model, as we do here.

Third, we introduce variance as a co-measurement of habit. Habitual consumption behavior refers to situations where the demand for a bundle of goods of a consumer reveals very few differences across periods. Those loyal or even addicted consumers show different economic behavior than “normal” consumers and are more important in policy analysis due to their higher levels of consumption. Incorporating variation in transition variables helps better measure customers’ habitual behavior and allows us to better characterize individual policy responses, leading to better estimates of the aggregate response.

The outline of the paper is as follows. We lay out our research design in Section 2, followed by the empirical demonstration in Section 3 that applies the heterogeneous habit model to both regular CSBs and beer in the United States, finding strong evidence for heterogeneity in both price and income elasticities across households. Finally, some policy implications and conclusions are provided.

2. Empirical Strategy

Numerous studies have incorporated habit formation in demand models. It is well recognized among economists that demand in one period may depend on demand decisions in other periods (Becker and Murphy 1988; Boyer 1983; Lluich 1974). The literature has provided evidence of habit formation in not only addictive goods such as tobacco and alcohol but also non-addictive consumer goods (Arnade, Gopinath, and Pick 2008; Fuhrer 2000; Heien and Durham 1991; Hendel and Nevo 2007; Holt

and Goodwin 1997). Particularly relevant here, Zhen et al. (2011) found the presence of habit in demand for nine categories of non-alcoholic beverages. Milk consumption has a particularly strong habit effect. Habit formation in drinking behavior was also shown by Moore and Cook (1995) and Williams (2005).

This paper extends such models by combining a variant of the Smooth Transition Autoregressive (STAR) model with simple demand functions to model habit that is heterogeneous across households. In the time series literature, Smooth Transition Autoregressive (STAR) modeling has been developed by Teräsvirta (1994) to model nonlinearity and structural change. The STAR model and its variants have also been used to detect potential structural shifts and market changes by Holt and Craig (2006), and Holt and Balagtas (2009) and to study regional markets that periodically link and unlink by Goodwin, Holt and Prestemon (2011), and Hood and Dorfman (2015). In this study, to estimate the impact of food tax policies on consumption, we use the STAR approach to model continuous habit regimes, thus introducing heterogeneity to habit effects in demand studies.

In the last decade, economists have increased their modeling of heterogeneity by such methods as latent class models and clustering analysis. These approaches can work well, but they reduce the modeling of heterogeneity down to a set of discrete values or groups. In contrast, we essentially create an infinite number of latent classes to represent the range of possible strengths of habit in beverage demand by using a demand model that nests a smooth transition function. Each household is treated

differently based on the value of an index variable that summarizes the role of habit in their household beverage purchasing decisions.

The empirical model developed here is based on a myopic model of habit formation. Specifically, the underlying assumption is that individuals maximize their utility, which depends on both current and past consumption of the habitual product. Two structural demand models are combined using a Smooth Transition Autoregressive (STAR) model to represent the effect of heterogeneous habit persistence on household purchases. This takes the form:

$$(1) \ln Q_{ijt} = f(\ln P_{jt}, \theta_1) (1 - G(\gamma, s_{ijt}, c_{jt})) + f(\ln P_{jt}, \theta_2) G(\gamma, s_{ijt}, c_{jt})$$

where $\ln Q_{ijt}$ is the natural logarithm of demand for product j at time t of household i , G is a smooth transition function, and $\ln P_{jt}$ is the natural logarithm of a Törnqvist panel price index price of product j at time t .

In equation (1), $f(\ln P_{jt}, \theta_1)$ and $f(\ln P_{jt}, \theta_2)$ are demand functions in two extreme regimes. Regime 1 represents the households who do not consume product i based on habit at all, implemented through parameters θ_1 , whereas, Regime 2 represents households who have a strong habit of consuming product i or are even addicted to it, expressed through parameters θ_2 . Most consumers behave consistent with some state in between the two extremes, with an infinite number of such regimes lying on that continuum and their location on the continuum expressed by the value of G . If consumers overall display little heterogeneity in the strength of their habits they will show similar responses to price or income changes; that is, the parameter vectors

θ_1 and θ_2 will be similar. In this case, estimation results will be similar to those of a standard regression without a transition function. The transition function $G(\gamma, s_{ijt}, c_{jt})$ is a continuous and smooth function of s_{ijt} and c_{jt} . The habit indicator s_{ijt} is defined here as:

$$(2) \quad s_{ijt} = \frac{(\sum_{d=1}^8 Q_{ijt-d})}{v_{ij}}$$

where Q_{ijt} is the consumption of product j in quarter t for household i . v_{ij} is the standard deviation of $(Q_{ijt-1}, Q_{ijt-2}, \dots, Q_{ijt-8})$. Accordingly, habitual behavior is indexed by the sum of quarterly consumptions in the last two years over the standard deviation of those eight lagged values. Both quantity and variation are incorporated to depict past consumption behavior because habit as we envision it in consumer demand consists of two dimensions: purchase level and purchase stability. If a household consistently purchases the same product, we still regard these families as habitual, even if the amounts purchased are small. In this formulation, their standard deviation v_{ij} would be small, resulting in a large s_{ijt} . Consequently, the higher the value s_{ijt} , the more habitual a household is. A common practice in previous literature was to use only the sum of purchases in past periods to measure habit. By introducing the standard deviation, we believe our index will better capture what is typically meant by habit.

The transition function G assumes values from 0 to 1, indexing the strength of each household's habitual behavior in beverage consumption. A number of candidates have been proposed for the transition function G (Goodwin, Holt and Prestemon,

2011). The most commonly used specification of G is the exponential form, denoted the ESTAR model. (e.g., Fan and Wei 2006; Kilian and Taylor 2003; Taylor, Peel and Sarno. 2001). The ESTAR model expresses the transition function as

$$(3) \quad G(s_t, \gamma, c) = 1 - \exp[-\gamma(s_t - c)^2]$$

where c is the location parameter and $\gamma > 0$ is the speed-of-adjustment parameter.

The transition model employed here is modified from Hood and Dorfman (2015):

$$(4) \quad G(\gamma, s_{ijt}, c_{jt}) = 1 - \exp\left\{-\gamma \left[\Phi\left(\frac{s_{ijt} - c_{jt}}{\sigma_{jt}}\right)\right]\right\}$$

where c_{jt} is the mean value of s_{ijt} across households, and σ_{jt} is the standard deviation of s_{ijt} . $s_{ijt} - c_{jt}$ is normalized by σ_{jt} to make the speed-of-adjustment parameter γ unit free, and $\Phi(\cdot)$ is the cumulative density function (cdf) of the standard normal distribution. The cdf of the standard normal distribution has flatter tails when the value goes to extremes, is almost linear for values within 2 standard deviations about zero, and satisfies the positivity requirement that keeps the transition function bounded between 0 and 1. This property gives the model higher flexibility and a better ability to represent heterogeneity of across households.

The demand equation for regular CSBs applied here to demonstrate the importance of including heterogeneity into the habit strength of common demand models is specified as:

$$(5) \quad \ln Q_{ijt} = \alpha + \beta_1 \ln P_{jt} + \beta_2 \ln Y_{it} + \sum_{k=1}^3 \beta_{3k} D_{kt} + \beta_4 CHD_{it} + U_{it}$$

where $\ln Q_{ijt}$ is the natural logarithm of household i 's demand for product j at time t .

$\ln P_{jt}$ is the Törnqvist panel price index of product j at time t , and $\ln Y_{i,t}$ is the natural logarithm of expenditure of household i at time t . To control the effect of children and seasonality, we include children and quarter-specific (D_{kt}) indicator variables in this demand model. $CHD_{i,t}$ is the indicator whether household i has at least one child ($CHD_{i,t} = 1$). The demand equation for beer is defined in a similar fashion, except that the variable $CHD_{i,t}$ is not included since the number of children should not be a key variable in explaining the demand for beer.

3. Data

Our primary source of data is the Nielsen Homescan household panel for the years 2008 to 2015. More than 100,000 households across the U.S. record information on shopping trips and purchased items using an optical scanner on a weekly basis over a period of at least a year. Every recorded transaction contains information including the Universal Product Code (UPC), quantity, price paid, size, single or multipack, and brand. The Nielsen Homescan data is available to academic researchers through a partnership between Nielsen and USDA-Economic Research Service (ERS). The biggest advantage of the Homescan panel data set is that the sample is nationally representative. The participating households reside in fifty-two Nielsen markets and nine remaining areas in the United States. Household survey weights provided by Nielsen can be used to create national estimates of household purchases. Further, the Homescan dataset includes almost all U.S. retailers including mass merchants such as

Walmart.

To analyze demand responsiveness for CSBs and beer, we apply the following screens to ensure the data used consists only of households who consistently recorded their purchasing sometime between 2008 and 2015. Households who fail to satisfy any of the following criteria are excluded from the dataset:

- (i) Each household must be on the panel for at least nine quarters since we track household habits based on two years of purchasing history,
- (ii) Each household must have at least one shopping trip per quarter. A quarter is considered long enough to identify that the household has stopped recording its purchases.
- (iii) The consumption of regular CSBs or beer by the household must be positive for at least one quarter because the target population in our study is CSBs or beer consumers.

We also deleted observations with abnormally large or small prices. Specifically, we deleted transactions in which unit price for a specific product was more than five times or less than one-fifth of the sample mean price. Table 1 summarizes the number of households, average units purchased, average volume purchased, and average expenditures of our final data set.

To reduce the unit value bias (Deaton 1988; Cox, T. L., and Wohlgenant, M. K. 1986), we created a quarterly superlative Törnqvist price index for product j for each state. The Törnqvist price index is defined as

$$(6) p_T^{0k} = \exp\{0.5 \sum_{v \in 0k} (s_v^0 + s_v^k) \ln(p_v^k / p_v^0)\}$$

p_v^k is the price of product v in entity k ; p_v^0 and q_v^0 are the base price and quantity of product v , respectively; and v_{0k} demotes the common set of items sold in both base 0 and entity k . s_v^0 and s_v^k are budget shares of product v in base 0 and entity k .

4. Empirical Results

This section presents demand estimation for regular CSBs and beer, respectively, with both homogeneous and heterogeneous habit, followed by a simulation of demand change when soda and beer taxes are imposed.

4.1 Carbonated Sweetened Beverages

First, the linear demand model in equation (5) is estimated for regular CSBs. As shown in Table 2, the coefficient on $\ln P_{jt}$, β_1 , is estimated to be negative, at -1.085, and statistically significant, indicating that a one percent increase in prices would result in a 1.085% decrease in quantity consumed.

Next, the regime-switching model with heterogeneous habit is estimated. The fourth column of Table 2 presents the STAR model results, which are further illustrated in Figure 1. In Figure 1, the x-axis represents the value of G , which is bounded between 0 (no habit at all) and 1 (addiction). Based on our estimation, the value of G ranges from 0.11 to 0.81. The solid line shows the absolute value of

household's own-price elasticity decreases from 1.612 to 0.437 as a household's habit level increases from 0.11 to 0.81. Intuitively, the more habit driven a household is, the less price sensitive they are. Also, note that the coefficient on $\ln P_{jt}$ becomes insignificant under extremely strong habit (see Table 2), indicating that $\ln P_{jt}$ no longer has much impact on such people's demand. Thus, for the more habitual consumers, sin tax style policies are not as effective as for those who are not habitual in consumption. The dotted line represents the expenditure elasticity of each household under different habits. The expenditure elasticity increases from 0.235 to 0.353 as a household's habit level increase from 0.11 to 0.81. These findings are in line with expected behavior. Habitual consumers would allocate more spending on goods they are most habituated to as their total expenditure increases. Additionally, model selection criteria (AIC and BIC) are smaller when the STAR model is applied, providing evidence in favor of the heterogeneous habit model for these data.

To understand the influence of a soda tax on consumption, we simulate a scenario where a half-cent per ounce tax is levied on regular CSBs. We assume that the tax is fully passed through to retail prices. Applying the parameters of the homogeneous habit model, the estimated decrease in purchases of each household is illustrated in Figure 2, where blue bars and orange bars indicate demand drop under homogeneous and heterogeneous habit assumptions, respectively. With a model of homogeneous habit, the percentage change is the same across households given equal price elasticities. Consequently, the absolute decrease in purchases of habitual households is

larger than for non-habitual households when facing the same percentage increase in prices. Based on the reactions simulated for each household with homogeneous habit, the half-cent per ounce soda tax would result in an aggregate 14.83% decrease in household CSBs.

From the results of the heterogeneous habit model, the own-price elasticity ranges from -1.612 to -0.437. As the orange bar in Figure 2 indicates, the net decrease in purchases of habitual households is not much larger than that of non-habitual households because the households with the largest purchases tend to be more price inelastic. Based on this simulation, a half-cent per ounce soda tax would result in an 11.48% decrease in overall consumption. Thus, the demand response to a soda tax when heterogeneous habit is allowed for in the model is considerably less than under the standard, homogeneous habit model. In fact, when individual heterogeneity is ignored, the overall decrease in household regular CSBs demand would be overestimated by 3.35 percentage points.

4.2 Beer

To further demonstrate the importance of allowing heterogeneity in habit, we perform a second simulation, this time applied to beer purchasing behavior. Similar results will suggest that the specific product chosen has not biased our results. Intuitively, beer is a more habit-forming product than regular CSBs. As before, first a constant habit regression for beer demand is conducted using the following model:

$$(7) \ln Q_{it} = \alpha + \beta_1 \ln P_{jt} + \beta_2 \ln Y_{it} + \sum_{k=1}^3 \beta_{3kt} D_{kt} + U_{it}$$

We used the same model as for regular CSBs except for dropping the indicator variable for at least one child in the household. The coefficient on $\ln P_{jt}$ is estimated to be -1.139 and statistically significant, indicating that a one percent increase in prices would result in a 1.139% decrease in average consumption of beer. Linear regression results are presented in the fifth column of Table 2.

Next we estimate our heterogeneous habit STAR model for beer. Column 6 in Table 2 presents the nonlinear regression results, and Figure 4 shows the relationship between habit, price elasticity, and income elasticity. Similar to Figure 1, the x-axis measures the level of habit, which ranges from 0.57 to 0.98, suggesting that even the least habitual consumer in the dataset has a medium level of habit in purchasing beer. The absolute own-price elasticity decreases from 1.282 to 0.118 and the expenditure elasticity increases from 0.286 to 0.351 as a household's habit level increases. Additionally, model selection statistics (AIC and BIC) are again smaller when the STAR model is applied, indicating that incorporating heterogeneous habit is the preferred model specification.

The federal excise tax on beer is \$18 per 31-gallon barrel or 5 cents per 12 oz. can (0.42 cents per ounce). We again simulated a scenario of an additional half-cent per ounce tax being implemented. Based on the result of the linear regression, with its price elasticity of -1.139, the tax would result in a 7.00% decrease in overall beer sales. The decrease in purchases among consumers with different habits when habit is modeled as constant is illustrated by the blue bar in Figure 4. Under our

heterogeneous habit model, a half-cent per ounce beer tax would result in only a 3.53% decrease in overall sales of beer. The reduced purchases among consumers at different habit levels when heterogeneous habit is modeled are illustrated by the orange bar in Figure 4. The figure makes clear that beer is a more habitual product, and the more habitual a household is, the less sensitive to price changes they are. Like the results from regular CSBs, the net decrease from more habitual households is quite similar to less habitual households. If individual heterogeneity is ignored, the overall decrease in household beer demand would be overestimated by 3.47 percentage points. In other words, with the stronger habit of beer demand across the spectrum, incorporating heterogeneous habit leads to estimates of responsiveness to a beer tax only half that suggested by the uniform habit model.

5. Conclusions and Policy Implications

Previous food demand research typically has found an own-price elasticity of -1.05 to -1.1 for the category of regular CSBs (Ergtold J, Akobundu, and Peterson, 2004; Heien and Wessells, 1990; Pittman and Falwell, 2005). An estimated own-price elasticity of -1.2 was applied by Yale University's Rudd Center to calculate the tax revenues generated by a soda tax (Rudd Center, 2010). More recently, Zhen et al (2013) estimated that the price elasticity of regular CSBs as -1.035 based on the Nielsen Homescan Dataset (also used here). With previous published estimates of price elasticities, the percentage drop in aggregated purchase of regular CSBs due to a

half-cent per ounce soda tax is between the interval of 14.35% to 16.40% given our calculated CSBs prices, which contains our simulated results (14.83%) in the homogeneous habit model. Compared with estimates and simulation from the heterogeneous habit model, such elasticities and simulated drop in purchase would significantly overestimate the effect of soda tax on CSBs purchases.

In this article, we proposed an innovative procedure to investigate the demand for regular CSBs and beer under heterogeneous habit formation. To demonstrate how important this model generalization is for policy analysis, we reported an analysis of the potential effects of a half-cent per ounce soda tax and a half-cent per ounce beer tax. Our results shed light on the importance of incorporating individual heterogeneity when conducting research on public food policies. Habitual consumers have the strongest preference for a particular product and are less price sensitive than those with weaker habit effects. Because those with stronger habit effects have more inelastic demands and consume larger average quantities, ignoring the heterogeneity of habit leads to an aggregation bias that could lead to faulty policy analyses.

The STAR model of habit introduced here reveals heterogeneous consumption patterns for regular CSBs and beer, leading to different responses to public policy among people. If individual heterogeneity is ignored, the overall effect of soda tax and beer tax would be overestimated by 3.35 and 3.47 percentage points respectively. This implies sin and food taxes will be less successful at discouraging consumption than predicted by constant-habit demand models. Our analysis also suggests food

policies should be designed with consideration of heterogeneity in consumers' habits and their varying sensitivity to price and income changes. A combination of price adjustment and other targeted policies could improve policy efficiency.

5 References

Andreyeva, Tatiana, Michael W. Long, and Kelly D. Brownell. "The Impact of Food Prices on Consumption: A Systematic Review of Research on the Price Elasticity of Demand for Food." *American Journal of Public Health* 100, no. 2 (2010): 216-222.

Arnade, Carlos, Munisamy Gopinath, and Daniel Pick. "Brand Inertia in US Household Cheese Consumption." *American Journal of Agricultural Economics* 90, no. 3 (2008): 813-826.

Becker, Gary S. and Kevin M. Murphy. "A Theory of Rational Addiction." *Journal of Political Economy* 96, no. 4 (1988): 675-700.

Bergtold, Jason, Ebere Akobundu, and Everett B. Peterson. "The FAST Method: Estimating Unconditional Demand Elasticities for Processed Foods in the Presence of Fixed Effects." *Journal of Agricultural and Resource Economics* (2004): 276-295.

Boyer, Marcel. "Rational Demand and Expenditures Patterns Under Habit Formation." *Journal of Economic Theory* 31, no. 1 (1983): 27-53.

Caro, Juan Carlos, Shu Wen Ng, Lindsey Smith Taillie, and Barry M. Popkin. "Designing a Tax to Discourage Unhealthy Food and Beverage Purchases: The Case of Chile." *Food Policy* 71, (2017): 86-100.

Cornelsen, Laura and Richard D. Smith. "Soda taxes—Four Questions Economists Need to Address." *Food Policy* 74, (2018): 138-142.

Cox, Thomas L. and Michael K. Wohlgenant. "Prices and Quality Effects in Cross-Sectional Demand Analysis." *American Journal of Agricultural Economics* 68, no. 4 (1986): 908-919.

Deaton, Angus. "Quality, Quantity, and Spatial Variation of Price." *The American*

Economic Review (1988): 418-430.

Fan, Kai-Wei, Sha Liu, and Prasun Sinha. "Scalable Data Aggregation for Dynamic Events in Sensor Networks." ACM, 2006.

Fuhrer, Jeffrey C. "Habit Formation in Consumption and its Implications for Monetary-Policy Models." *American Economic Review* 90, no. 3 (2000): 367-390.

Goodwin, Barry K., Matthew T. Holt, and Jeffrey P. Prestemon. "North American Oriented Strand Board Markets, Arbitrage Activity, and Market Price Dynamics: A Smooth Transition Approach." *American Journal of Agricultural Economics* 93, no. 4 (2011): 993-1014.

Goryakin, Yevgeniy, Pablo Monsivais, and Marc Suhrcke. "Soft Drink Prices, Sales, Body Mass Index and Diabetes: Evidence from a Panel of Low-, Middle-and High-Income Countries." *Food Policy* 73, (2017): 88-94.

Han, Euna and Lisa M. Powell. "Consumption Patterns of Sugar-Sweetened Beverages in the United States." *Journal of the Academy of Nutrition and Dietetics* 113, no. 1 (2013): 43-53.

Härkänen, Tommi, Kaisa Kotakorpi, Pirjo Pietinen, Jukka Pirttilä, Heli Reinivuo, and Ilpo Suoniemi. "The Welfare Effects of Health-Based Food Tax Policy." *Food Policy* 49, (2014): 196-206.

Heien, Dale and Cathy Durham. "A Test of the Habit Formation Hypothesis using Household Data." *The Review of Economics and Statistics* (1991): 189-199.

Heien, Dale and Cathy Roheim Wesseils. "Demand Systems Estimation with Microdata: A Censored Regression Approach." *Journal of Business & Economic Statistics* 8, no. 3 (1990): 365-371.

Hendel, Igal and Aviv Nevo. "Measuring the Implications of Sales and Consumer Inventory Behavior." *Econometrica* 74, no. 6 (2006): 1637-1673.

Holt, Matthew T. and Joseph V. Balagtas. "Estimating Structural Change with Smooth Transition Regressions: An Application to Meat Demand." *American Journal of Agricultural Economics* 91, no. 5 (2009): 1424-1431.

Holt, Matthew T. and Lee A. Craig. "Nonlinear Dynamics and Structural Change in the US Hog—corn Cycle: A Time-Varying STAR Approach." *American Journal of Agricultural Economics* 88, no. 1 (2006a): 215-233.

Holt, Matthew T. and Lee A. Craig. "Nonlinear Dynamics and Structural Change in the US Hog—corn Cycle: A Time-Varying STAR Approach." *American Journal of Agricultural Economics* 88, no. 1 (2006b): 215-233.

Holt, Matthew T. and Barry K. Goodwin. "Generalized Habit Formation in an Inverse almost Ideal Demand System: An Application to Meat Expenditures in the US." *Empirical Economics* 22, no. 2 (1997): 293-320.

Hood, Harrison B. and Jeffrey H. Dorfman. "Examining Dynamically Changing Timber Market Linkages." *American Journal of Agricultural Economics* 97, no. 5 (2015): 1451-1463.

Kilian, Lutz and Mark P. Taylor. "Why is it so Difficult to Beat the Random Walk Forecast of Exchange Rates?" *Journal of International Economics* 60, no. 1 (2003): 85-107.

Lin, Biing-Hwan, Diansheng Dong, Andrea Carlson, and Ilya Rahkovsky. "Potential Dietary Outcomes of Changing Relative Prices of Healthy and Less Healthy Foods: The Case of Ready-to-Eat Breakfast Cereals." *Food Policy* 68 (2017): 77-88.

Lluch, Constantino. "Expenditure, Savings and Habit Formation." *International Economic Review* (1974): 786-797.

Moore, Michael J. and Philip J. Cook. "Habit and Heterogeneity in the Youthful Demand for Alcohol " *National Bureau of Economic Research* (1995).

Paarlberg, Robert, Dariush Mozaffarian, and Renata Micha. "Can US Local Soda Taxes Continue to Spread?" *Food Policy* 71, (2017): 1-7.

Pacula, Rosalie Liccardo. "Does Increasing the Beer Tax Reduce Marijuana Consumption?" *Journal of Health Economics* 17, no. 5 (1998): 557-585.

Pittman, Grant Falwell. "Drivers of demand, interrelationships, and nutritional impacts within the nonalcoholic beverage complex." PhD diss., Texas A&M University, 2005.

Pollak, Robert A. and Terence J. Wales. "Estimation of the Linear Expenditure System." *Econometrica: Journal of the Econometric Society* (1969): 611-628.

Rudd Center for Food Policy and Obesity. Revenue calculator for soft drink taxes, 2010, <http://www.yaleruddcenter.org/sodatax.aspx>

Taylor, Mark P., David A. Peel, and Lucio Sarno. "Nonlinear Mean - Reversion in Real Exchange Rates: Toward a Solution to the Purchasing Power Parity Puzzles." *International Economic Review* 42, no. 4 (2001): 1015-1042.

Teräsvirta, Timo. "Specification, Estimation, and Evaluation of Smooth Transition Autoregressive Models." *Journal of the American Statistical Association* 89, no. 425 (1994): 208-218.

Williams, Jenny. "Habit Formation and College Students' Demand for Alcohol." *Health Economics* 14, no. 2 (2005): 119-134.

Zhen, Chen, Eric A. Finkelstein, James M. Nonnemaker, Shawn A. Karns, and Jessica E. Todd. "Predicting the Effects of Sugar-Sweetened Beverage Taxes on Food and Beverage Demand in a Large Demand System." *American Journal of Agricultural Economics* 96, no. 1 (2013): 1-25.

Zhen, Chen, Ian F. Brissette, and Ryan Richard Ruff. "By Ounce Or by Calorie: The Differential Effects of Alternative Sugar-Sweetened Beverage Tax Strategies." *American Journal of Agricultural Economics* 96, no. 4 (2014): 1070-1083.

Zhen, Chen, Michael K. Wohlgenant, Shawn Karns, and Phillip Kaufman. "Habit Formation and Demand for Sugar-Sweetened Beverages." *American Journal of Agricultural Economics* 93, no. 1 (2011): 175-193.

Zheng, Yuqing, Chen Zhen, Daniel Dench, and James M. Nonnemaker. "US Demand for Tobacco Products in a System Framework." *Health Economics* 26, no. 8 (2017): 1067-1086.

Table 1 Homescan Sample Summary Statistics

Year	Regular Carbonated Sweetened Beverages				Beer			
	Household Number	Average Unit Purchased per Household per Quarter	Average Volume Purchased per Household per Quarter (OZ.)	Average Spending on CSBs per Household per Quarter (Dollar)	Household Number	Average Unit Purchased per Household per Quarter	Average Volume Purchased per Household per Quarter (OZ.)	Average Spending on beer per Household per Quarter (Dollar)
2008	9347	26.437	1476.211	55.999	1908	16.638	2163.102	149.407
2009	10399	26.517	1462.552	56.864	2138	17.142	2152.165	155.469
2010	10921	25.825	1457.658	55.625	2488	16.006	2091.338	152.728
2011	10920	25.094	1403.695	55.550	2284	16.686	2118.572	160.043
2012	10921	24.421	1344.837	54.677	2244	16.874	2080.011	159.631
2013	10921	23.342	1256.560	51.435	2378	16.931	1984.459	155.384
2014	10723	22.503	1171.541	49.021	2206	16.525	1887.934	151.307
2015	9980	21.382	1091.633	47.384	2060	15.488	1813.260	147.613

Table 2 Parameter Estimates for Regular CSBs and Beer

Model	Regular Carbonated Sweetened Beverages		Beer		
	Linear Demand Model Coefficient (Stand Error)	STAR Model Coefficient (Stand Error)	Linear Demand Model Coefficient (Stand Error)	STAR Model Coefficient (Stand Error)	
<i>Scheme 1</i>	<i>Intercept</i>	4.361* (0.021)	0.003* (0.001)	4.929* (0.053)	0.002* (0.001)
	<i>Natural log of Price</i>	-1.085* (0.070)	-1.802* (0.167)	-1.139* (0.171)	-2.948* (0.867)
	<i>Natural log of Expenditure</i>	0.345* (0.003)	0.216* (0.006)	0.308* (0.007)	0.192* (0.035)
	<i>1st Quarter</i>	0.028* (0.005)	4.493* (0.014)	-0.028* (0.005)	3.140* (0.260)
	<i>2nd Quarter</i>	0.096* (0.005)	4.588* (0.014)	0.070* (0.014)	3.278* (0.260)
	<i>3rd Quarter</i>	0.035* (0.005)	4.489* (0.014)	0.096* (0.014)	3.367* (0.260)
	<i>Two or more children in the household</i>	0.103* (0.005)	0.068* (0.014)		
	<i>Gamma</i>		1.669* (0.044)		3.790* (0.127)
<i>Scheme 2</i>	<i>Intercept</i>		-9.293* (0.059)	-30.388* (0.099)	
	<i>Natural log of Price</i>		-0.120 (0.189)	-0.047 (0.307)	
	<i>Natural log of Expenditure</i>		0.385* (0.007)	0.354* (0.013)	
	<i>1st Quarter</i>		14.165* (0.049)	35.590* (0.025)	
	<i>2nd Quarter</i>		14.209* (0.049)	35.677* (0.026)	
	<i>3rd Quarter</i>		14.189* (0.049)	35.679* (0.026)	
<i>Two or more children in the household</i>		0.068* (0.011)			
<i>N</i>	10921	10921	1613	1613	
<i>SSE</i>	175087	156408	59019	50360	
<i>MSE</i>	16.03	14.32	36.59	31.22	
<i>Number of Parameters</i>	7	15	6	13	
<i>AIC</i>	13173.71	12654.64	2533.70	2436.55	
<i>BIC</i>	13187.98	12685.21	2540.94	2452.25	

Note: Asterisk (*) denotes statistically significant at the 5% level

Figure 1 Habit, Price Elasticity and Expenditure Elasticity for Regular CSBs

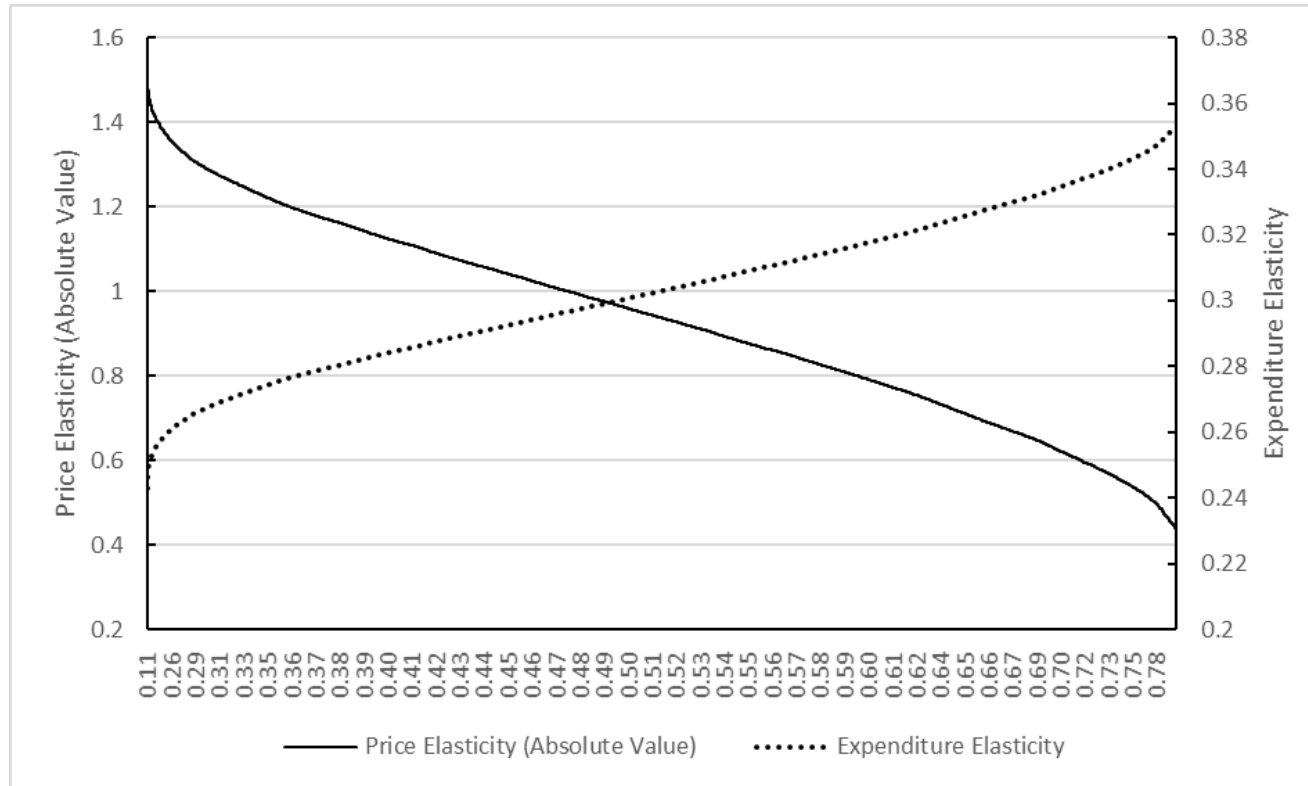


Figure 2 Decrease in demand of regular CSBs due to soda tax under both heterogeneous and homogeneous habit assumptions

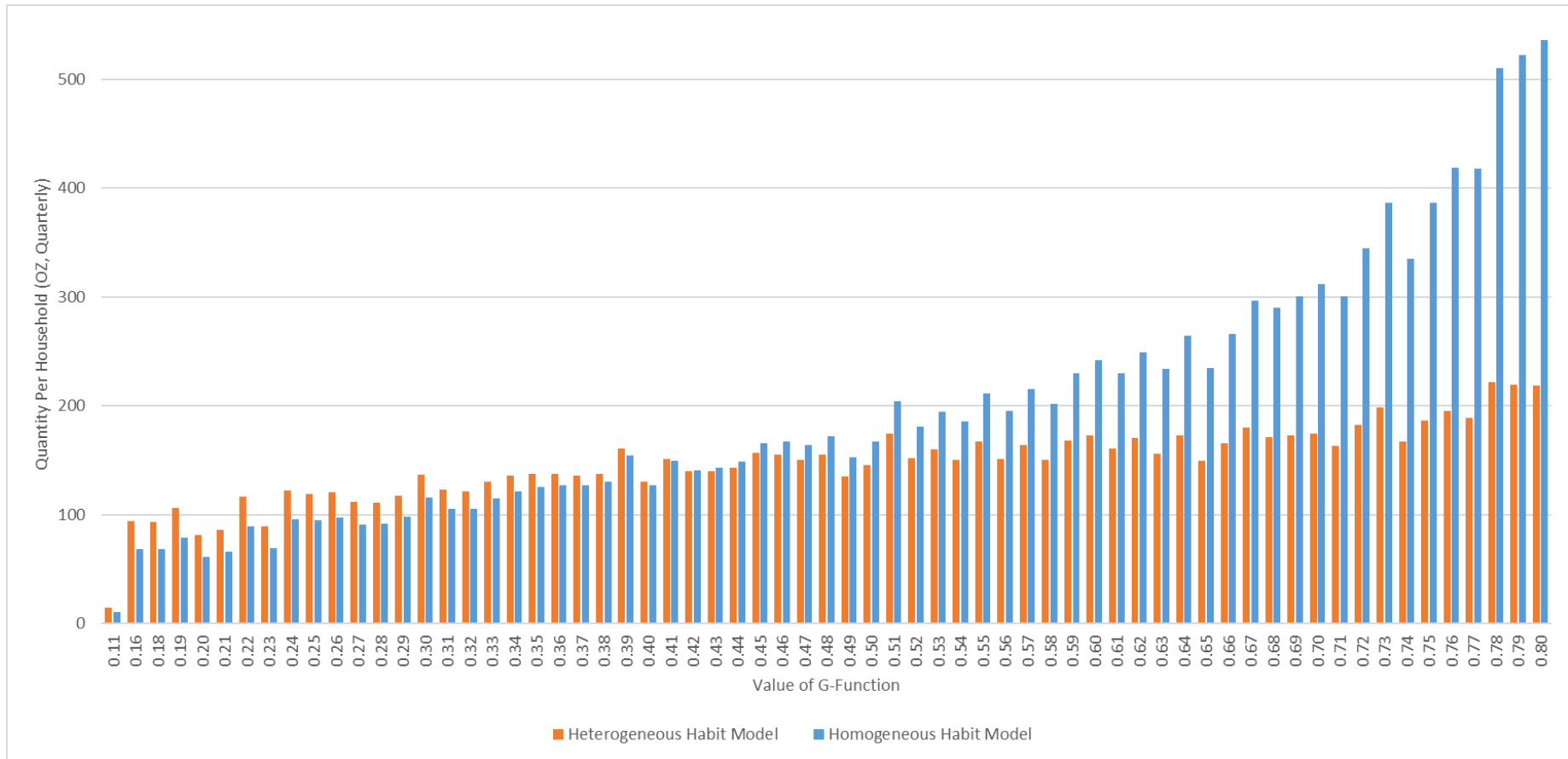


Figure 3 Habit, Price Elasticity and Expenditure Elasticity for Beer

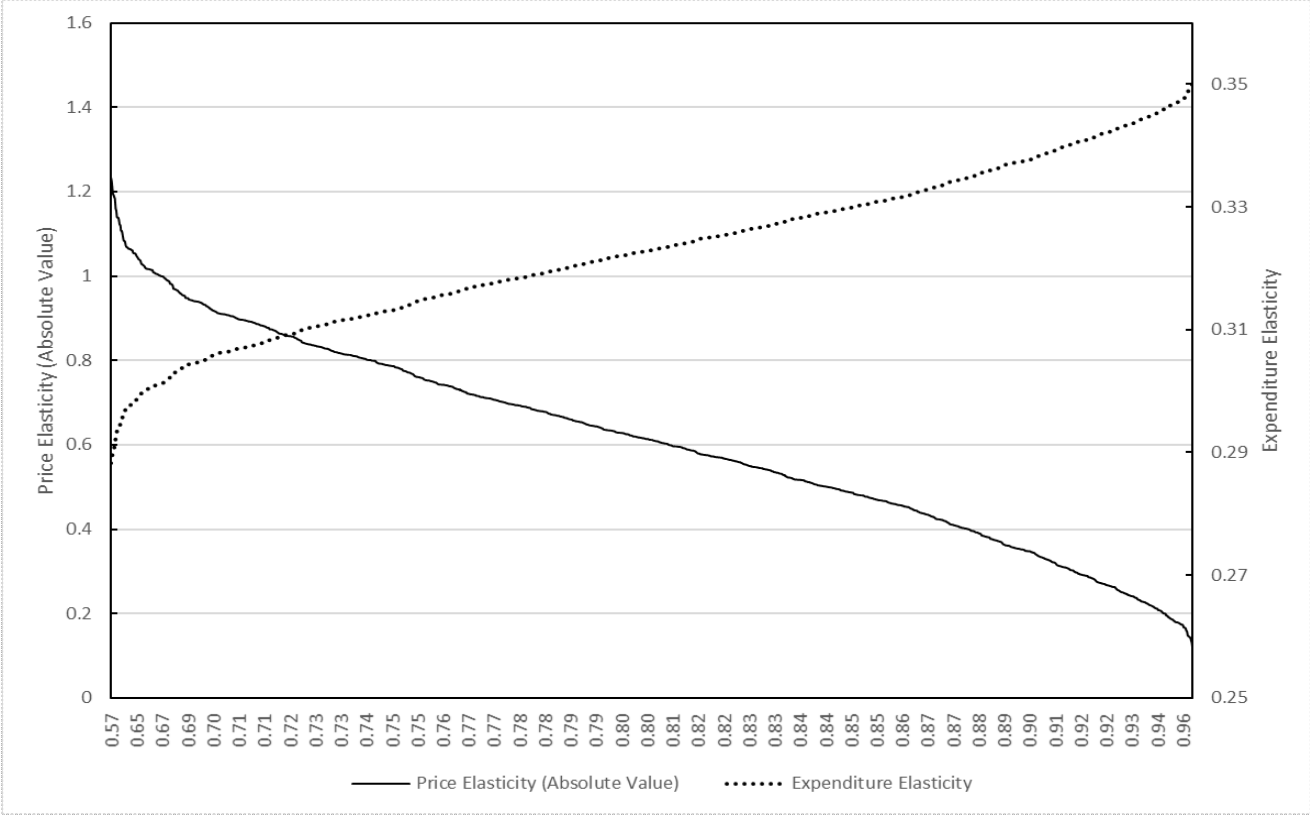


Figure 4 Decrease in demand of beer due to beer tax under both heterogeneous and homogeneous habit assumptions

