Sin Taxes and Self-Control

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Abstract

"Sin taxes" are high on the political agenda in the global fight against obesity. According to theory, they are welfare improving if consumers with low self-control are at least as price responsive as consumers with high self-control, even in the absence of externalities. In this paper, we investigate if consumers with low and high self-control react differently to sin tax variation. For identification, we exploit two sets of sin tax reforms in Denmark: first, the increase of the soft drink tax in 2012 and its repeal in 2014 and, second, the fat tax introduction in 2011 and its repeal in 2013. We assess the purchase response empirically using a detailed homescan household panel. Our unique dataset comprises a survey measure of self-control linked to the panelists, which we use to divide the sample into consumers with low and high levels of self-control. We find that consumers with low self-control reduce purchases less strongly than consumers with high self-control when taxes go up, but increase purchases to a similar extent when taxes go down. Hence, we document an asymmetry in the responsiveness to increasing and decreasing prices. We find empirical and theoretical support that habit formation shapes the differential response by self-control. The results suggest that price instruments are not an effective tool for targeting self-control problems.

JEL-codes: H20, D12, I18

Keywords: self-control, soft drink tax, fat tax, sin tax, internality

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1 Introduction

The "global obesity epidemic" is a major public health challenge (WHO, 2000) and a leading risk factor for many non-communicable diseases like type 2 diabetes and coronary heart disease (Smith Jr., 2007). Poor diets that contain high levels of sugar and fat are among the main culprits of this phenomenon (Finkelstein *et al.*, 2005). Hence, the World Health Organization advises governments to consider the introduction of so-called "sin taxes" on unhealthy foods, e.g. taxes on sugar sweetened beverages (SSB). A number of countries have already implemented taxes on sugary beverages and other unhealthy foods, e.g. France, Mexico, the United Kingdom, and, until 2014, Denmark.

There are two rationales for sin taxes: externalities and internalities. Externalities mean that sugar consumers do not take the social costs of adverse health behavior into account and the tax is meant to internalize these costs. Internalities in the form of self-control problems imply that people underappreciate the long-term health costs that an unhealthy diet has on themselves. In this paper, we focus on the internality argument since it dominates the public debate about sin taxes on foods.[1] The idea is that a sin tax could help consumers with low self-control to follow their long-run utility by increasing the instantaneous costs. Such a tax can even be welfare-improving if the corrective gains for individuals with low self-control overweigh the distortionary costs for those without self-control problems. However, to ensure that this is the case, individuals with low self-control must reduce their purchases at least as much as those with high self-control (O'Donoghue and Rabin, 2006; Haavio and Kotakorpi, 2011).

In this paper, we investigate empirically the effect of self-control on responsiveness to sin tax changes. For identification, we exploit exogenous variation in two Danish sin taxes: First, we consider the increase of the soft drink tax in 2012 and its complete repeal in 2014. Second, we investigate the fat tax on saturated fat, introduced in 2011 and repealed in 2013. We use a unique panel data set that comprises purchase records of around 1,300 households who stay in the panel for the period of tax changes and who have also answered a well established survey on self-control (Tangney *et al.*, 2004). Using the survey, we stratify the sample into high and low self-control consumers. Consumers with low self-control have larger body mass index and report both the intention to reduce their weight and to improve their eating habits. In our empirical analysis, we estimate the differential effect of tax changes on consumers with low and high self-control.

[1] First, soft drink taxes are often advocated based on the premise that, in particular, children, who are among the heaviest soft drinks consumers, ignore the long-run consequences of high sugar intake (Dubois *et al.*, 2019). Second, the effectiveness of these taxes is usually assessed by the reduction in consumption and not by tax revenue raised (for externality correction this distinction would not be as relevant). For example, on March 13, 2018, the former British finance minister and initiator of the British soft drink tax, George Osborne, tweeted: "In OBR *[Office for Budget Responsibility]* report today is news that our Sugar Tax is even more effective than hoped. Expected receipts halved [...]". (https://twitter.com/George_Osborne/status/973647500551827456, retrieved 09/23/19).

In response to the soft drink tax hike, we find that consumers with low self-control reduce their purchases by only 7 percent and significantly less than those with high self-control who reduce their purchases by 21 percent. In contrast, in response to the soft drink tax repeal, consumers with high and low self-control increase their purchases to a similar extent, between 26 and 28 percent. We find a similar pattern for the introduction and repeal of the fat tax. Here, we look at butter since it experienced substantial tax variation due to its high content of saturated fat. The credibility of our empirical strategy is underscored by parallel pre-tax trends between self-control groups and placebo tests. We demonstrate robustness of the results by performing permutation tests, in which we randomly reshuffle the categorization in high and low self-control, and by varying the sample split.

We assess a range of alternative explanations for the differential response by self-control. We find that the coefficient of self-control remains stable when including measures for education, nutritional knowledge, income, and preferences for unhealthy food. These findings suggest that the differential response is not driven by correlations with one of these variables. Employing the bounding approach of Oster (2019), we find little evidence that selection on unobservables can explain the results. Moreover, the differential response by self-control differs only mildly by distance to the German border, suggesting that border-shopping does not drive the effect.

We provide evidence that habit formation shapes the differential response by self-control. Among panelists who report being addicted to sugar or fat, there is a stronger differential response by self-control to the tax hike but not to the tax repeal. This suggests that, for habituated consumers, it requires self-control to reduce consumption but not to increase consumption. Thus, habit formation can explain the asymmetry in responses to increasing and decreasing prices: If consumers with low self-control are more habituated than those with high self-control, they are less likely to incur the withdrawal costs associated with quitting the consumption of a habituating sin good. In contrast, increasing consumption is not associated with withdrawal costs, such that a differential response to tax cuts is not expected. Ultimately, we show theoretically that such an asymmetry prevails even when the initial habit stock and self-control are independent.

Our study is motivated by the theoretical literature on taxation of behavioral internalities like imperfect self-control. The idea is that a lack of self-control can lead consumers to over-consume goods with long-run costs that are not fully taken into account at the moment of consumption. A sin tax increases the instantaneous and future costs of consumption and reduces over-consumption. Gruber and Köszegi (2001) show that optimal taxes on cigarettes are substantially higher if individuals are addicted due to present-bias. O'Donoghue and Rabin (2006) and Haavio and Kotakorpi (2011) argue that an internality correcting tax can be welfare improving if individuals with low self-control are at least as responsive to a sin tax as those with high self-control. Further, the comprehensive model of Allcott *et al.* (2019), which studies the welfare effects and the distributional implications of sin taxes, takes the correction of internalities into account. However, these papers do not make predictions regarding whether consumers with low self-control actually respond to sin taxes, thus leaving this question to empirical research.

We contribute to the burgeoning empirical literature that assesses targeting properties of sin taxes by estimating heterogeneous tax responsiveness by self-control. Allcott *et al.* (2019) estimate, in their empirical section, the share of soda consumption that is due to a self-reported lack of self-control.[2] They find that bias-induced consumption is decreasing in income, which means that poor consumers can benefit more from the corrective effects of the tax. However, due to their focus on the regressivity of sin taxes, they do not consider if the price elasticity varies with the level of self-control. In contrast, we use actual tax variation and investigate if the tax actually targets consumers with low self-control. The targeting properties of a soft drink tax are also investigated by Dubois *et al.* (2019) in a structural demand model. They estimate price elasticities of different consumer groups and hypothesize that the high soda preference of certain groups (e.g. young people and high sugar consumers) is more likely due to biases. They find that young people are more price responsive, but that high sugar consumers are less price responsive than the average consumer. We complement these findings by employing an established measure of self-control and by exploiting exogenous variation in prices to explicitly test the impact of self-control on price responsiveness.

Furthermore, we contribute to the empirical literature that uses quasi-experimental variation in sin taxes to estimate the impact of taxes on purchases. We are the first to use tax variation to study heterogenous responses by self-control. There is a longstanding literature that uses tax variation in tobacco and alcohol taxes to estimate price elasticities (see the surveys in Chaloupka *et al.* (2012) for tobacco and in Wagenaar *et al.* (2009) for alcohol). With the increasing prevalence of sin taxes on food, there are also more and more evaluations of these kind of policies. Jensen and Smed (2013) and Smed *et al.* (2016) analyze the effects of the fat tax in Denmark in a pre-post design and document a significant drop in average purchases of saturated fat from, for example, butter and margarine. Cawley *et al.* (2019b) survey the empirical literature on soft drink taxes and conclude that average purchases decrease after tax introductions. This is documented for US cities like Berkeley and Philadelphia using geographical control groups (e.g. Cawley *et al.*, 2019a; Rojas and Wang, 2017) and for the tax in Mexico using pre-post designs (Colchero *et al.*, 2016, 2017).[3] In earlier work, we analyze the tax pass-through and average purchase response to the increase 2012 and repeal 2014 of the Danish tax on soft drinks using a pre-post design (Schmacker and Smed, 2020).

[2]They use the Nielsen household panel and classify panelists as low self-control if they respond "Definitely" to the statement "I drink soda pop or other sugar-sweetened beverages more often than I should."

[3]Although a reduction in purchases is not necessarily equivalent with a reduction in (sugar) consumption. Seiler *et al.* (2019) show that many consumers avoid the tax in Philadelphia by shopping in neighboring jurisdictions and Aguilar *et al.* (2019) show that the reduction of calories from soft drinks due to the Mexican tax is offset by an increase of calories from untaxed sugary products.

Where the focus in almost all of these papers is on the average change in purchases, in this paper we use the exogenous variation in prices to test if different levels of self-control imply different degrees of price responsiveness.

Finally, we contribute to the literature on habit formation and responsiveness to taxes by providing empirical and theoretical evidence that tax hikes and cuts can have different effects. The seminal paper by Becker and Murphy (1988) already argues that a permanent change in prices of a habit-forming good may have an initially small effect on consumption that grows over time until a new steady state is reached. Zhen *et al.* (2011) provide empirical evidence for habit formation in demand for sugar sweetened beverages using a demand system model. Colchero *et al.* (2017) evaluate the long-run response to the sugar sweetened beverage tax in Mexico and find that the long-run response is, in fact, stronger than the short-run response. We add a new perspective to this literature and show, both empirically and theoretically, that tax increases have a smaller effect on purchases of habit-forming goods for people with low self-control. However, this effect appears not to be symmetric for tax increases and tax cuts, suggesting that consumers with low self-control find it hard to reduce consumption when prices go up but react to price incentives when prices go down.

The remainder of the paper proceeds as follows. In Section 2, we present the conceptual framework that motivates our empirical analysis. Section 3 describes the institutional setting and the dataset that we are using. Section 4 specifies the empirical strategy. Section 5 presents the results and Section 6 concludes.

2 Conceptual Framework

In this section, we briefly summarize a key result of the sin tax literature that motivates our empirical investigation of heterogenous responses to sin taxes by self-control. O'Donoghue and Rabin (2006) and Haavio and Kotakorpi (2011) show that, in a simple two-good model, the optimal internality-correcting tax depends both on the average internality and on the covariance of the price responsiveness and the internality: The optimal tax is higher if individuals with low self-control respond stronger to price changes than individuals with high self-control and vice versa.[4]

More formally, models in the literature typically assume that preferences can be characterized by a $\beta - \delta$ model of self-control (Laibson, 1997). That means, individuals maximize intertemporal utility:

[4]Following O'Donoghue and Rabin (2006) and Haavio and Kotakorpi (2011), we do not consider externalities of consumption on others but only on the future self, so called internalities.

$$U(u_1, ..., u_T) = u_t + \beta \sum_{\tau=t+1}^{T} \delta^{\tau-t} u_\tau. \quad (1)$$

Each period they receive instantaneous utility u_t and future utility is discounted by time-consistent discount factor δ and a hyperbolic discount factor β. If $\beta < 1$ the agents have a preference for immediate gratification (i.e. low self-control) and if $\beta = 1$ the agents behave time-consistently.

In a two-good model, consumer i decides whether to consume a sin good x_i that provides instantaneous utility $v(x_{it})$, but is associated with long-run costs $c(x_{i,t-1})$, and a numeraire good. Since consumers with low self-control ($\beta < 1$) underweight the future costs of consumption, they overconsume the sin good. A social planner maximizing the long-run utility of all individuals (i.e. setting $\beta = 1$ for everyone), may decide to impose a tax t on the sin good to help consumers with low self-control to consume closer to their long-run utility. The idea is that the tax serves consumers with low self-control as a commitment device by increasing the instantaneous costs of consumption.

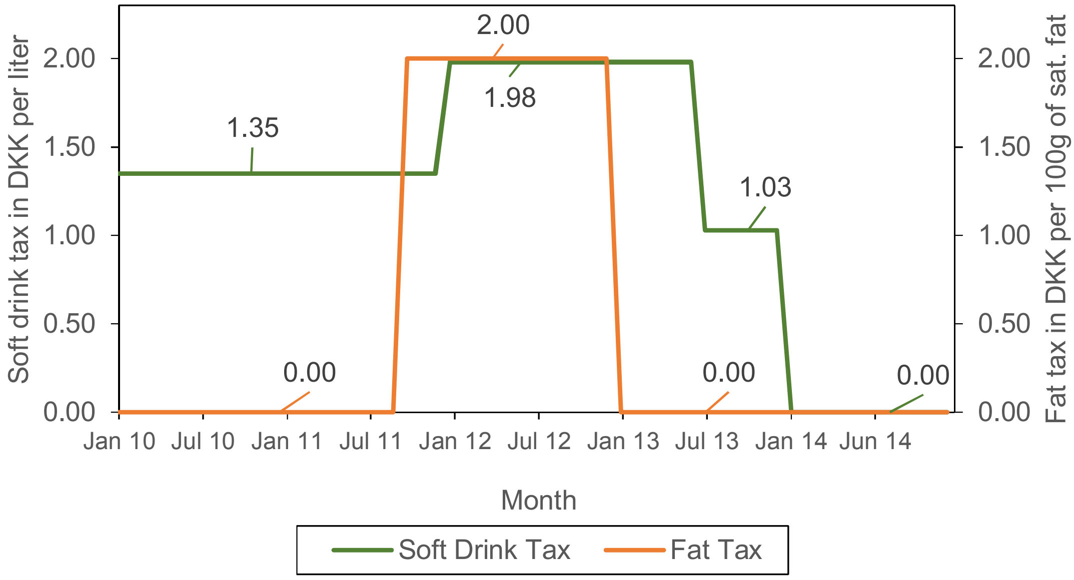
Haavio and Kotakorpi (2011) show that, in this case, the optimal tax is given by

$$t = \frac{1}{N} \sum_i (1 - \beta_i) c'(x_i) + \frac{\mathrm{cov}((1-\beta)c'(x), \frac{\partial x}{\partial t})}{\partial \bar{x} / \partial t}. \quad (2)$$

We provide the derivation of the optimal tax formula in Appendix A. The first term in the optimal tax is the average internality in the population, i.e., the marginal costs that are not accounted for due to a lack of self-control. This first term is corrected by the targeting efficiency of the tax that is represented by the second term. The targeting of the tax is described by the covariance between the internality due to a lack of self-control and the responsiveness of consumption to tax changes (weighted by the average responsiveness of sin good consumption to tax changes). Intuitively, the optimal tax is larger if those with the largest internality reduce their consumption more than those without lack of self-control. In that case, the tax is relatively effective in correcting the internality. However, the tax is smaller if consumers with low self-control respond less to the tax. In that case, the distortionary effect on consumers without self-control problem overweighs the internality-correcting effect.

According to the existing literature, it is an empirical question whether the relationship between self-control and price responsiveness is positive or negative (O'Donoghue and Rabin, 2006). Hence, this is what we aim to investigate empirically using the institutional setting described in the next section.

Figure 1: Soft drink and fat tax variation in Denmark, incl. 25% VAT



Notes: Graph shows soft drink and fat tax variation over time. The denoted taxes include 25% VAT.

3 Data

3.1 Institutional Background

For identification, we exploit variation in two different sin taxes: the soft drink tax and the fat tax. Both were part of the Danish tax reform of 2010. The goal was to reduce income taxes and instead increase taxes on consumption goods that have detrimental effects on public health or the environment (The Danish Ministry of Taxation, 2009). Besides the taxes on soft drinks and fat, taxes on sweets, chocolate, ice cream, and tobacco were increased. Moreover, a tax on the content of sugar in all goods was planned but never realized.

The tax variation is illustrated in Figure 1. The first tax that we study is the tax on sugary soft drinks. It is a volumetric excise tax that is imposed on all soft drinks that contain more than 0.5 grams of sugar per 100 milliliters. The soft drink tax in Denmark has a longstanding tradition. Both its introduction and subsequent tax reforms were mainly motivated by the goal of raising tax revenues (Bergman and Hansen, 2019). However, the increase of the tax in January 2012 from 1.35 DKK to 1.98 DKK per liter (excise tax plus 25% value-added tax) aimed to improve public health. This is also illustrated by the fact that the tax on diet soft drinks remained constant at a lower level. In previous work, we estimate the pass-through of the tax using a regression discontinuity approach and document a price increase of 1.17 DKK (12.5 percent) in reaction to the tax hike (see Figure C.1 in the Appendix) (Schmacker and Smed, 2020). Hence, the tax hike is substantially overshifted, which is consistent with the study of Bergman and Hansen (2019) for earlier soft drink tax increases. In April 2013, the Danish government announced it would repeal the tax on soft drinks in order to secure jobs in the retail sector in the Danish-German border region and to make up for tax revenue losses due to cross border trade. The tax was first decreased to 1.03 DKK (incl. VAT) in July 2013 and completely eliminated in January 2014. In Schmacker and Smed (2020), we estimate a price drop of 2.29 DKK (23.4 percent) in response to the tax repeal, i.e. a bit more than full pass-through (see Figure C.1 in the Appendix).

The second tax variation is the October 2011 introduction and January 2013 repeal of the fat tax. The fat tax was applied to all products that contain more than 2.3g saturated fats per 100g. It amounts to 1.60 DKK per 100g saturated fat plus 25% VAT, i.e. 2.00 DKK per 100g of saturated fats. Vallgårda *et al.* (2015) analyze the political debate around the introduction and repeal of the fat tax. They conclude that a change in the framing from public health arguments to economic arguments (cross-border shopping, administrative burden, and regressive effects on the poor) led from the introduction to the repeal. Since the tax was proportional to the amount of saturated fat, the tax affects product groups very differently. In the analysis, we consider butter since it contains a high amount of saturated fats (approximately 50 percent) and has, therefore, experienced substantial tax variation. In Appendix D.1, we show that the tax introduction is associated with an almost symmetric increase in butter prices by 0.76 DKK per 100g and the repeal with a decrease by 0.61 DKK per 100g.

3.2 Dataset

To investigate the response in purchases due to the tax variation, we use household panel data from GfK Consumertracking Scandinavia for the years 2009 to 2014. Panelists are asked to track all their food purchases on a weekly basis. GfK aims for a representative panel with respect to geography, age, education, and family size. Panelists report quantities and prices paid for grocery purchases that they bring into the home. Moreover, once a year, households fill in a questionnaire on demographic and socioeconomic characteristics. In 2013 and 2015, an additional survey containing a broad range of questions about self-control and dietary habits was sent to panelists. The responses to this questionnaire are matched with the purchase records using the panel identifier.

In the analysis, we only include those households that report at least one purchase of the product in question per year and have responded to the self-control questionnaire. These restrictions leave us with 1,278 panelists for the soft drink tax estimations and 1,324 for the fat tax estimations.

When looking at quantity purchased, we aggregate the purchases to monthly observations to account for potential stockpiling. Hence, in the soft drink estimations, the dependent variable is monthly purchases of taxed soft drinks in centiliter (including colas, lemonades, ice tea, and juices with added sugar). In the fat tax estimations, the dependent variable is monthly purchases of butter in grams. We assign months a zero, in which purchases are observed but none of these purchases belongs to the product category in question (soft drinks or butter). If no grocery purchase is observed in a given month, it is considered a missing observation for that month.

3.3 Measuring self-control

Self-control is measured using the scale developed by Tangney *et al.* (2004), which consists of 36 statements concerning different domains of self-control (see the items in Table B.1). The respondents indicate their approval to each of these statements on a 5-point Likert-scale. Whenever possible, we use the 2013 data and, if the panelist did not fill in the survey in 2013, we impute the missing data with data from 2015. Hence, we assume that self-control is a time-constant trait, which is supported by a high retest-reliability: among the 1,234 panelists, who have answered the self-control scale in both years, the scores from 2013 and 2015 correlate with r=0.783.

In order to reduce the large number of items and to find the latent dimension of self-control that matters for food choices, we perform a principal component factor analysis using all 2,387 panelists who filled in the self-control scale. As suggested in the original study by Tangney *et al.* (2004), we decide to extract five factors. The resulting factor structure is described in Appendix B. Based on the factor loadings and the responses given by the panelists, we compute new variables that measures the level of self-control according to the respective factor. We perform a median split to separate the sample in panelists with high and low self-control. Thereby, we can analyze the association between self-control and the variables of interest without making parametric assumptions about the relationship.

In the analysis, we use the second self-control factor, which can be described as temptation tolerance and is associated with health-related habits. In Table B.2, we see panelists who are in the bottom half of self-control according to this factor have higher body mass index (BMI) and are more likely to be obese. They are more likely to respond that they would like to reduce their weight. Moreover, they agree more often that they should eat less sugar and animal fat. All of these correlations are substantially weaker or non-existent for the other four self-control factors. Taken together, panelists with low self-control are more prone to risky health behavior and are aware of it, but apparently a lack of self-control prevents them from changing their eating habits.

Table B.1 shows the factor loadings of the self-control factors. It can be seen that the selected second self-control factor loads high on the item “I eat healthy foods.” To make sure that the inclusion of this item does not drive the results, we re-run the factor analysis

Table 1: Descriptive statistics

	Overall	Low self-control	High self-control	Unrestricted sample
Equivalized household income in DKK				
<175K	18.7	17.7	19.6	19.3
175K-250K	26.1	28.0	24.4	26.0
250K-325K	18.2	17.5	18.9	17.8
325K-400K	19.6	20.1	19.1	19.5
≥400K	17.4	16.7	18.1	17.4
Age group				
<40	13.0	12.3	13.6	13.7
40-59	48.7	47.4	49.9	47.9
≥60	38.4	40.3	36.5	38.4
Labour market status				
Full time	38.7	42.3	35.3	38.5
Part time	27.2	24.4	29.9	27.7
Not employed	34.1	33.3	34.8	33.9
Education				
No tertiary education	59.4	62.8	56.3	59.4
1-3 years tertiary educ.	15.0	14.3	15.6	14.8
> 3 years tertiary educ.	25.6	22.9	28.1	25.8
Household size	1.921	1.941	1.901	1.909
	(0.985)	(1.041)	(0.928)	(0.988)
Number of child. age 0-6	0.066	0.090	0.044	0.068
	(0.321)	(0.381)	(0.249)	(0.326)
Number of child. age 7-14	0.130	0.147	0.113	0.128
	(0.458)	(0.501)	(0.413)	(0.454)
Number of child. age 15-20	0.100	0.101	0.099	0.099
	(0.367)	(0.365)	(0.370)	(0.365)
Households	1,278	623	655	1,412
Observations (Household-months)	78,137	37,981	40,156	85,400

Notes: Table shows descriptive statistics of the GfK Consumertracking Scandinavia data used in the soft drink tax analysis. Displayed are relative frequencies of values of categorical variables, as well as means and standard deviations (in parentheses) of continuous variables. Household income is equivalized using the OECD scale, i.e. dividing household income by the square root of the household size.

excluding this item. Table B.3 shows that the resulting factor loadings are very similar, suggesting that the results are not driven by the respective item. In Section B.1, we conduct robustness checks using this alternative measure of self-control and find very similar results.

3.4 Descriptive statistics

In Table 1, we show descriptive statistics of the overall sample used in the analysis, as well as descriptives of the sample split by self-control. Moreover, in the last column, we show descriptives for the unrestricted sample, which also includes panelists who report at least one purchase in every sample year but for whom we have no information on self-control.

The demographic characteristics appear quite similar across the different sample restrictions. However, there is an intuitive association between self-control and education, with high self-control respondents having higher education. In the robustness section, we address if the differential response by self-control is affected if we also control for heterogenous responses by education.

4 Empirical strategy

In order to test if the demand response to tax changes differs by self-control, we estimate the within-household variation in soft drink purchases the year before and after the tax changes. Due to our bandwidth of one year, we can keep seasonal variation before and after the tax constant and also can capture changes that occur with a lag due to habit formation.

The empirical model for estimating purchase quantity in month t by consumer i is

$$\text{quantity}_{it} = X'_{it}\alpha = \alpha_0 + \alpha_1 \text{tax}_t + \alpha_2(\text{tax}_t \times \mathbb{1}(\beta_i = \beta^{high})) + \gamma_i + \eta_t + \alpha_4 Z_{it} + \epsilon_{it} \tag{3}$$

where the dependent variable is either the observed quantity, the purchase incidence in a given month (extensive margin), or the log-transformed quantity given a purchase (intensive margin). The variable tax_t is a dummy variable that is one after the tax change and zero before. We interact the tax dummy with indicator functions that specify if consumer i is characterized by low or high levels of self-control as defined in the previous section. Hence, α_2 estimates the differential effect of the tax change on purchase quantity for consumers with high self-control compared to those with low self-control. γ_i denotes household fixed-effects, which are included to control for time-invariant unobserved heterogeneity, and η_t denote quarter fixed effects. Z_{it} is a set of household-specific controls that includes the number of kids in age groups 0-6, 7-14, and 15-20, the household size, income group, and labor market status of the main shopper.[5] In the analysis of the soft-drink tax, Z_{it} also includes the average monthly temperature in Denmark.

The main coefficient of interest is the interaction effect of the tax dummy and the self-control indicator, α_2. In order to identify if the differential responsiveness is due to self-control, we must make the following assumptions. First, we assume that consumers with low and high self-control exhibit parallel trends in consumption. We demonstrate the credibility of this assumptions and show that trends are parallel in the years absent the tax reforms. Second, we assume that differences in price responsiveness are due to self-control and not due to other correlated characteristics, like income and education. Therefore, we investigate if the differential response by self-control remains stable when additionally controlling for differential changes by income, education, nutritional knowledge, and tastes.

[5] We do not control for education since there is little within-household variation over time.

As is often the case with household-level purchase data, the distribution of purchases is characterized by a mass at zero and a right-skewed distribution. To prevent outliers from having an undue influence on the parameter estimates (Manning and Mullahy, 2001), we employ multiple measures. First, we winsorize the reported quantities at the 99 percent level, i.e., the largest 1 percent of reported quantities are set to the quantity at the 99th percentile. Second, we use a two-part model that estimates, first, the likelihood to consume any soft-drinks (extensive margin) and, second, the amount of soft-drinks provided that a positive quantity is observed (intensive margin) (Mullahy, 1998). Consequently, the expected value of the quantity is the product of the predicted purchase probability ($X_{it}'\alpha^{ext.}$) and the conditional (and re-transformed) purchase quantity ($exp(X_{it}'\alpha^{int.})$):

$$E(quantity_{it}|X_{it}) = (X_{it}'\alpha^{ext.}) \cdot exp(X_{it}'\alpha^{int.}) \cdot D \tag{4}$$

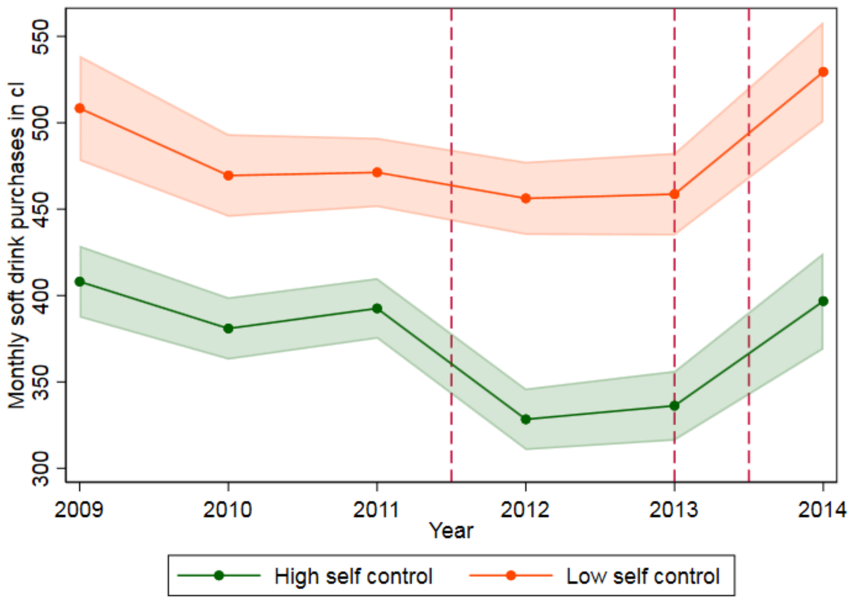
where $D = 1/N \sum \exp(ln(q_{it}) - X_{it}'\beta)$ is the Duan smearing factor that is needed for retransformation since $E(\exp(\epsilon_{it}))$ is not zero (Duan, 1983). We compute the predicted purchase quantity separately for consumers with low and high self-control.

For each tax event, we consider one year before the tax change and one year after the tax change. For the soft drink tax estimations, we omit the months January and December of each year. Otherwise, we might overestimate the effect of the tax hike in January 2012 due to customers stockpiling soft drinks in December 2011 and living off stock in January 2012 (hence, we compare 2/2011-11/2011 to 2/2012-11/2012). In case of the soft drink tax repeal, we compare the year before the first tax cut in July 2013 (10/2012-6/2013, without January and December) to the year after the complete repeal in January 2014 (2/2014-11/2014). For the fat tax, we compare the years before and after the introduction in October 2011 (10/2010-09/2011 versus 10/2011-09/2012) and before and after the repeal in January 2013 (01/2012-12/2012 versus 01/2013-12/2013).

5 Results

In the empirical analysis, we investigate the differential responsiveness by self-control, first, for soft drink tax changes and, second, for fat tax changes. In both cases, we provide graphical evidence on the development of purchases surrounding the tax changes before we present the regression results.

Figure 2: Predicted values of monthly soft drink purchase quantity by self-control



Notes: Graph shows annual predicted values after controlling for household and quarter fixed effects and controls (household size, income, labor market status, number of kids, temperature), using GfK data. The shaded areas represent 95% confidence intervals from standard errors clustered on the household level. The vertical lines indicate the timing of tax changes.

Table 2: Soft drink purchases in response to soft drink tax changes by self-control

	(1) Quantity	(2) Extensive Margin	(3) Intensive Margin	(4) Quantity	(5) Extensive Margin	(6) Intensive Margin
Panel A: Tax Hike						
Tax Hike	-7.128	-0.014	-0.029	-9.622	-0.017*	-0.036
	(16.630)	(0.010)	(0.033)	(16.738)	(0.010)	(0.035)
High self-control × Tax Hike	-60.677***	-0.032**	-0.063	-58.208***	-0.030**	-0.059
	(21.018)	(0.013)	(0.044)	(21.051)	(0.013)	(0.044)
Households	1278	1278	1158	1278	1278	1158
Household Months	22197	22197	9667	22197	22197	9667
Panel B: Tax Repeal						
Tax Repeal	81.143***	0.041***	0.105***	92.683***	0.046***	0.131***
	(17.602)	(0.010)	(0.031)	(18.660)	(0.011)	(0.034)
High self-control × Tax Cut	-5.710	0.001	0.019	-2.741	0.002	0.026
	(24.001)	(0.014)	(0.045)	(23.920)	(0.014)	(0.044)
Households	1278	1278	1164	1278	1278	1164
Household Months	22747	22747	9919	22747	22747	9919
Controls	No	No	No	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Table shows OLS regression results with standard errors clustered on household level, using GfK data. In columns (1) and (4) the dependent variable is monthly quantity in centiliter. In columns (2) and (5) it is purchase incidence in a given month. In columns (3) and (6) it is log-transformed quantity. Controls include household size, income, labor market status, number of kids, temperature, and quarter FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.1 Soft Drink Tax Variation

Figure 2 shows predicted values after controlling for household fixed effects and the control variables specified in Section 4.[6] First, the purchases of consumers with low and high self-control appear to follow parallel trends in the years before the first tax change, thus lending support to our identification strategy. When the tax increased in 2012, soft drink purchases by consumers with low self-control did not change significantly, while we observe a significant drop for consumers with high self-control. The tax was cut in half in July 2013, then completely repealed in January 2014. In response, we observe a marked increase in purchases by both consumer groups.

In order to quantify the purchase response to the tax variation, we show estimation results of the empirical model in Table 2 for the two parameters of interest (α_1 and α_2). The coefficient α_1 is the tax indicator variable, which gives the change in purchases by low self-control consumers (the reference category), and α_2 is the interaction of the tax dummy with the high self-control indicator, which gives the differential change in purchases by high self-

[6]Figure C.2 shows the figure without controlling for household and quarter fixed effects and without demographic controls.

Table 3: Change in soft-drink purchases based on predicted values from two-part model

	Low self-control	High self-control
Panel A: Tax Hike		
Relative change	-0.073*	-0.211***
	(0.039)^b	(0.030)^b
Absolute change	-18.446	-52.394***
	(21.694)^b	(16.647)^b
Panel B: Tax Repeal		
Relative change	0.263***	0.283***
	(0.042)^b	(0.045)^b
Absolute change	56.614***	60.628***
	(21.323)^b	(22.463)^b

Notes: Table shows predicted values from the two-part model as described in Section 4, using GfK data. The predicted values are based on the extensive and intensive margin shown in Table 2. For the absolute change, the unit of measurement is in monthly centiliter. ^{b} Standard errors are bootstrapped with 2,000 replications and clustered on the household level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

control consumers. Panel A shows results for the tax hike and Panel B for the tax repeal. In the first column, we use the absolute quantity as dependent variable, in the second column the purchase incidence (extensive margin), and in the third column the log-transformed quantity given a purchase (intensive margin). In the fourth to sixth column, we add time-varying controls.

The results in Panel A reveal that consumers with high self-control decreased their purchases significantly more than consumers with low self-control in response to the tax hike. Consumers with low self-control have not reduced their purchases significantly as the coefficient of the tax hike dummy tells us. While consumers with high self-control responded more strongly to the tax hike both in terms of purchase probability (extensive margin) and purchase quantity (intensive margin), the differential response is only significant on the extensive margin. In Table 3, we use the estimates from the extensive and intensive margin to calculate predicted values of a two-part model, as described in Equation (4). The results corroborates the findings from the OLS using the untransformed quantity. Consumers with low self-control reduced their purchases by only 7.3 percent. In contrast, the purchases by consumers with high self-control dropped by 21.1 percent. The response is larger both in relative and absolute terms.

In Panel B of Table 2, we conduct the same exercise for the tax repeal. Here, we compare purchases one year after the tax repeal to one year before the first tax cut. The tax repeal dummy shows that consumers with low self-control have increased their purchases of soft-drinks in absolute terms, both on the extensive and intensive margins. Again, the results are not strongly affected by adding time-variant control variables. However, this time we do not observe a differential response by high self-control consumers. In Panel B of Table 3, the predicted values from the two-part model emphasize that the absolute and relative increases in purchases are, in fact, very similar across the consumer groups: While purchases by consumers with low self-control grow by 26.3 percent, consumers with high self-control increase purchases by 28.3 percent.

Our analysis assumes that, absent the tax changes, consumers with low and high levels of self-control would have exhibited the same trends. While we cannot directly test this assumption, we provide credibility for it by running the same estimation for placebo tax changes preceding the actual tax changes. In Table C.1, we complete this exercise for placebo tax changes on January 1, 2010, and January 1, 2011. We observe no differential change in purchases by high self-control consumers, thus lending support to the parallel trend assumption.

Robustness

We provide further robustness checks in the Appendix. In Figure C.4, we show results from a permutation test with 10,000 iterations, in which we randomly reshuffle if consumers are classified as high or low self-control. For the tax hike, only 0.2 percent of coefficients are more negative than the actually estimated interaction coefficient, which corroborates its significance. For the tax repeal, 45.6 percent of randomly reshuffled iterations produce a more negative effect, suggesting that there is no significant difference for the tax cut. While we cluster the standard errors on the consumer level in the main specification, in Table C.2, we follow the suggestion of Bertrand *et al.* (2004) and collapse the months into one pre- and one post-tax change period. The results show that the standard errors are very similar compared to the main specification.

As further robustness tests, we re-estimate our main specification on the subsample of single households. The reason is that there is likely heterogeneity in soft drink preferences within households and the main shopper (whose self-control we elicit) may not be the person demanding to buy the soft-drinks. By restricting to single households, we can be sure that measured self-control coincides with the self-control of the individual who actually buys and consumes the soft drinks. Table C.3 presents the results, which reiterate the previous findings: High self-control individuals reduce their purchases significantly more than low self-control consumers when the tax goes up, and the interaction coefficient is even larger than in the full sample. However, there is no differential change that is significantly different from zero when taxes go down.

Moreover, in Table C.4, we re-run the estimations using a continuous measure of self-control instead of a median sample split. Hence, we make a more restrictive parametric assumption concerning the influence of self-control. For the tax hike, we observe that the higher the level of self-control, the stronger is the reduction in purchases. For the tax repeal, there is not a significant difference between the groups. In Table B.4, we use the alternative measure of self-control that excludes the revealed preference item about healthy food consumption contained in the original scale (cf. Section 3.3). The first column shows that the results are similar to the main specification.

Ultimately, in Figure C.3, we replicate Figure C.2 for the dataset of beverages that are not affected by the tax on sugary soft drinks (including milk, water, fruit juices, diet soft drinks). We observe that there is a similar increase in purchases by both consumers with high and low self-control after the tax hike. The figure suggests that the differential response in purchases of taxed beverages is not due to differential changes in reporting behavior.

5.2 Fat Tax Variation

In the previous section, we show that consumers with low self-control respond less to increasing soft drink taxes than consumers with high self-control. In contrast, when soft drink taxes are cut, there is not a systematically different response. In this section, we check whether this pattern is particular to soft drink tax changes or whether it also emerges for the introduction and repeal of the fat tax.

In the following, we look at butter as it is one of the goods that contains the most saturated fat and is frequently purchased. The analysis of the fat tax complements the soft drink tax analysis in several dimensions. First, unlike the soft drink tax, the magnitude of the fat tax variation is very similar for tax hikes and cuts (see Appendix D.1). Hence, we can exclude that a difference in responsiveness is due to low and high self-control consumers responding differently to larger and smaller tax variation. Second, by looking at butter, we can exclude that the differential responsiveness is explained by low and high self-control consumers having different preferences for sugar.

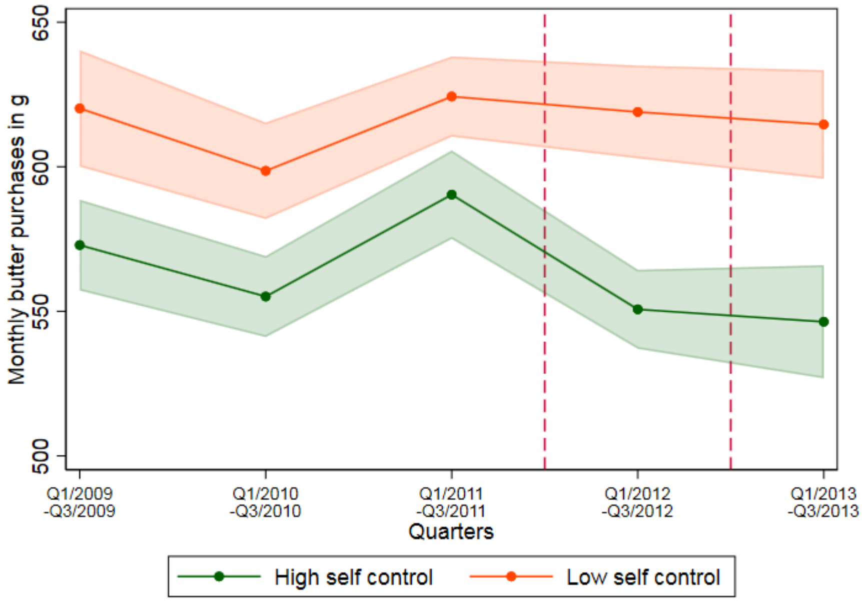
We run the same estimations as described in Section 4 on the data for butter.[7] Figure 3 shows predicted values for butter purchases over time.[8] Since the tax was in place from the beginning of the fourth quarter 2011 (starting October 2011) until the end of the fourth quarter 2012 (ending December 2012), we must exclude one of the taxed quarters to compare entire years.[9] We observe that in the pre-tax years, consumers with low self-control purchase more butter than those with high self-control. When the tax is introduced, we find, once again, that consumers with high self-control reduce their purchases significantly more than

[7]The estimations mirror the estimations for soft drinks. The only notable differences are, first, that we restrict the sample to households who report a butter purchase in the years 2010 through 2013. Second, we do not include the average temperature as a control variable since temperature is arguably less relevant for butter demand than it is for soft drink demand.

[8]Figure D.2 shows the figure without controlling for household and quarter fixed effects as well as demographic controls.

[9]In Figure 3, we exclude the fourth quarter of every year. In Figure D.3 we compare entire years but exclude the fourth quarter in 2012 to make the years comparable. However, the pattern that emerges is very similar.

Figure 3: Predicted values of monthly butter purchase quantity by self-control



Notes: Graph shows predicted values after controlling for household and quarter fixed effects and controls (household size, income, labor market status, number of kids), using GfK data. The shaded areas represent 95% confidence intervals from standard errors clustered on the household level. The vertical lines indicate the timing of tax changes.

Table 4: Butter purchases in response to fat tax by self-control

	(1) Quantity	(2) Extensive Margin	(3) Intensive Margin	(4) Quantity	(5) Extensive Margin	(6) Intensive Margin
Panel A: Tax Introduction						
Tax Introduction	-25.141**	-0.011	-0.040***	-21.930**	-0.010	-0.037***
	(10.373)	(0.008)	(0.013)	(10.438)	(0.008)	(0.013)
High self-control × Tax	-30.118**	-0.019*	-0.005	-30.972**	-0.020*	-0.005
	(14.276)	(0.011)	(0.018)	(14.274)	(0.011)	(0.018)
Households	1324	1324	1297	1324	1324	1297
Household Months	28162	28162	18026	28162	28162	18026
Panel B: Tax Repeal						
Tax Repeal	22.452**	0.016**	0.028**	26.766**	0.016*	0.044***
	(10.069)	(0.007)	(0.013)	(11.361)	(0.008)	(0.015)
High self-control × No Tax	-11.606	0.003	-0.023	-11.036	0.003	-0.020
	(13.810)	(0.010)	(0.018)	(13.894)	(0.010)	(0.018)
Households	1323	1323	1302	1323	1323	1302
Household Months	28829	28829	18782	28829	28829	18782
Controls	No	No	No	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Table shows OLS regression results with standard errors clustered on household level, using GfK data. In columns (1) and (4) the dependent variable is monthly quantity in grams. In columns (2) and (5) it is purchase incidence in a given month. In columns (3) and (6) it is log-transformed quantity. Controls include household size, income, labor market status, number of kids, and quarter FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

those with low self-control. Furthermore, when the tax is repealed, both consumer groups respond to a similar extent.

We show estimation results of the coefficients of interest from the empirical model in Table 4. Panel A illustrates that, in response to the fat tax introduction, consumers with high self-control reduce their purchases significantly more than consumers with low self-control. As seen in columns (2) and (4), the difference is mainly driven by a response on the extensive margin. The predicted values from the two-part model in Panel A in Table 5 illustrate that both in relative and absolute terms, the purchase response by high self-control consumers is stronger. While consumers with low self-control reduce their purchases by 5.6 percent, purchases by high self-control consumers drop by 8.8 percent.

In Panel B of Table 4, we run the estimation for the tax repeal. As before, we find little evidence for a differential response to the tax repeal. If anything, consumers with low self-control increase their purchases more than those with high self-control, but the differential response is not significant. In the two-part model in Panel B of Table 5 we observe that consumers with low self-control increase their purchases by 5.7 percent and those with low self-control by 3.5 percent.

Table 5: Change in butter purchases based on predicted values from two-part model by self-control

	Low self-control	High self-control
Panel A: Tax Hike		
Relative change	-0.056***	-0.088***
	(0.012)^b	(0.012)^b
Absolute change	-30.827**	-48.621***
	(9.933)^b	(10.235)^b
Panel B: Tax Repeal		
Relative change	0.057***	0.035***
	(0.012)^b	(0.013)^b
Absolute change	29.631**	18.001*
	(9.776)^b	(10.384)^b

Notes: Table shows predicted values from the two-part model as described in Section 4, using GfK data. The predicted values are based on the extensive and intensive margin shown in Table 4. For the absolute change, the unit of measurement is in monthly grams. ^{b} Standard errors are bootstrapped with 2,000 replications and clustered on the household level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In Table D.2, the results of placebo tax changes in January 2010 and October 2010 are shown. Most importantly, the interaction coefficients, which measure differential changes in response to the placebo tax changes, are insignificant and close to zero. Both groups increase their purchases from 2009 to 2010, but the trend does not differ between consumer groups, as shown in Figure 3.

In sum, we find evidence supporting the findings of the soft drink tax analysis. In response to the fat tax, consumers with low self-control respond less to increasing prices. While the general pattern persists, the results appear slightly noisier than in the case of soft drinks. This could be explained by stronger controversies about the adverse health effects of saturated fat (see the summary of the Danish public discourse in Vallgårda *et al.* (2015)).

Robustness

In Appendix D.2, we conduct further robustness checks for the fat tax variation. Figure D.4 shows coefficients from a permutation test with 10,000 iterations. While for the tax introductions only 1.34 percent of estimates are more negative than the actual interaction coefficient, this is true for 20.5 percent of coefficients for the tax repeal. Hence, while the differential response for the tax introduction is unlikely to be purely random, this cannot be rejected for the tax repeal. In Table D.3, we collapse the pre- and post-tax month and find the standard errors to be very similar to those for the main specification.

In Table D.4, we assess the sensitivity to the sample split in the main specification. Instead of a median split, we split the sample into three quantiles and observe that consumers with the lowest level of self-control respond the least to the tax hike. However, the difference is only significant on the extensive margin. After the tax repeal, we again do not observe a systematic differential response by self-control. In Table B.5, we use the alternative measure of self-control described in Section 3.3. The results for the main specification in the first column are similar to those obtained for the original self-control scale.

5.3 Alternative explanations

In the following, we investigate other potential explanations for the differential response by self-control. Therefore, we interact the tax indicator with other observable characteristics, such as income, education, tastes for unhealthy foods, and nutritional knowledge. Moreover, we employ a bounding approach to assess the importance of selection on unobservables and we show that cross-border shopping is unlikely to explain the differential response by self-control.

5.3.1 Education and nutritional knowledge

First, we address the concern that self-control is correlated with education and that education is responsible for the differential response. In the second column of Table 6, we interact the soft drink tax dummy additionally with an indicator for high education. High education means that the panelist has attended at least one year of tertiary education whereas the reference category is no tertiary education. The interaction coefficients of self-control and the tax change indicators are almost unaffected compared to the main specification. In the second column of Table 7, we conduct the same exercise for the fat tax. Also here, including education does not change the interaction coefficient of self-control and tax indicators.

Second, it is conceivable that our measure of self-control is associated with knowledge about the healthiness of food and that this drives the differential response. To account for that we add the interaction of the tax change dummy with an indicator if consumers approve to the statement "I believe I would make healthier food choices if I had more information on how to eat healthy." In the third column of Table 6, we show the results for the soft drink tax variation. For both the tax hike and the tax repeal, the interaction with self-control remains of similar magnitude. Further, in Table 7, we observe that a similar pattern is observed for the fat tax variation.

5.3.2 Income

As self-control is positively correlated with income, it could be that tighter budget constraints are the reason for the differential response. However, if that was the case, we would expect consumers with low self-control (and low income) to reduce purchases *more* than consumers with high self-control (and high income). Hence, the finding that low self-control consumers

Table 6: Soft-drink purchases in response to soft drink tax changes

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Tax hike						
Tax hike	-9.622	-9.545	-13.564	-3.699	-29.305	-24.885
	(0.010)	(20.331)	(18.621)	(20.410)	(21.752)	(27.407)
Tax hike						
× High self-control	-58.208***	-58.196***	-55.619**	-58.517***	-50.462**	-50.919**
	(21.051)	(20.934)	(21.991)	(20.991)	(22.385)	(22.550)
× High education		-0.203				10.239
		(19.912)				(20.995)
× Lacks knowledge			14.034			4.929
			(33.332)			(34.235)
× High income				-12.441		-15.970
				(22.616)		(24.673)
× Unhealthy taste					36.396	35.499
					(22.851)	(23.033)
Households	1278	1278	1278	1197	1197	1197
Household Months	22197	22197	22197	20887	20887	20887
Panel B: Tax repeal						
Tax repeal	92.683***	97.502***	94.996***	90.934***	90.454***	88.224***
	(18.660)	(22.335)	(19.469)	(22.437)	(24.413)	(27.908)
Tax repeal						
× High self-control	-2.741	-1.911	-0.275	-3.474	1.643	1.208
	(23.920)	(23.764)	(24.053)	(23.768)	(25.784)	(25.122)
× High education		-12.691				-20.186
		(23.494)				(25.398)
× Lacks knowledge			-14.715			-14.804
			(32.392)			(33.780)
× High income				3.404		21.066
				(23.740)		(25.896)
× Unhealthy taste					2.737	5.541
					(26.414)	(27.429)
Households	1278	1278	1278	1197	1197	1197
Household Months	22747	22747	22747	21389	21389	21389
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Table shows OLS regression results with standard errors clustered on household level, using GfK data. The dependent variable is monthly quantity in centiliters. "High education" means tertiary education (ref.: vocational education), "Lacks knowledge" identifies consumers who agree to the statement "I believe I would make healthier food choices if I had more information on how to eat healthy", "High income" are in the top half of the distribution of equivalized incomes, "Unhealthy taste" indicates that consumers agree to the statement "I believe I would make healthier food choices if unhealthy food was less tasty". Controls include household size, income, labor market status, number of kids, temperature, and quarter FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Butter purchases in response to fat tax changes

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Tax hike						
Tax hike	-21.930**	-27.985**	-19.347*	-21.642*	-11.523	-14.300
	(10.438)	(12.133)	(11.550)	(12.961)	(13.049)	(16.772)
Tax hike						
× High self-control	-30.972**	-31.941**	-29.961**	-30.941**	-32.109**	-34.573**
	(14.274)	(14.253)	(14.931)	(14.276)	(15.007)	(15.163)
× High education		15.882				17.203
		(14.410)				(15.265)
× Lacks knowledge			-27.041			-18.267
			(22.717)			(22.902)
× High income				-2.313		-3.596
				(15.278)		(16.191)
× Unhealthy taste					-26.769*	-24.621
					(15.510)	(15.419)
Households	1324	1324	1324	1241	1241	1241
Household Months	28162	28162	28162	26504	26504	26504
Panel B: Tax repeal						
Tax repeal	26.766**	27.350**	30.607**	25.173*	29.130**	33.098*
	(11.361)	(13.281)	(12.212)	(14.614)	(13.802)	(17.967)
Tax repeal						
× High self-control	-11.036	-10.942	-13.215	-10.966	-12.393	-12.488
	(13.894)	(13.903)	(14.296)	(13.867)	(14.210)	(14.229)
× High education		-1.459				-9.337
		(13.914)				(14.611)
× Lacks knowledge			-11.992			-12.054
			(19.979)			(20.374)
× High income				2.790		1.433
				(15.759)		(16.824)
× Unhealthy taste					-1.860	0.466
					(14.375)	(14.635)
Households	1323	1323	1323	1241	1241	1241
Household Months	28829	28829	28829	27144	27144	27144
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Table shows OLS regression results with standard errors clustered on household level, using GfK data. The dependent variable is monthly quantity in grams. "High education" means tertiary education (ref.: vocational education), "Lacks knowledge" identifies consumers who agree to the statement "I believe I would make healthier food choices if I had more information on how to eat healthy", "High income" are in the top half of the distribution of equivalized incomes, "Unhealthy taste" indicates that consumers agree to the statement "I believe I would make healthier food choices if unhealthy food was less tasty". Controls include household size, income, labor market status, number of kids, and quarter FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

respond *less* to the tax hike already suggests that budget constraints do not drive the differential response.

In the fourth column of Table 6, we re-run the main specification for the soft drink tax variation but add an interaction with a dummy indicating whether a panelist is in the top half of the distribution of equivalized incomes. We observe that the coefficients for the interaction of soft drink tax hike and repeal with self-control are of a similar magnitude compared to our main specification. In Table 7, we conduct the same exercise for the fat tax and observe that the coefficients of interest also move very little when including interactions with income.

5.3.3 Tastes for unhealthy food

It is conceivable that measured self-control is correlated with tastes for unhealthy food. To check if the differential response by self-control can be attributed to differences in taste, we add the interaction with a dummy variable that indicates if consumers approve to the statement "I believe I would make healthier food choices if unhealthy food was less tasty." In the fifth column of Table 6, we observe in Panel A that the interaction of the tax hike with self-control becomes slightly smaller but remains sizeable and significant. Consumers who like unhealthy food seem to be less likely to reduce their purchases in response to the tax hike, but the interaction is only marginally significant. In Panel B, there is – as in the main specification – not much evidence for a differential effect by self-control.

In Table 7, we add the interaction with a preference for unhealthy food to the fat tax estimation. We observe, in contrast to the case of soft drinks, that consumers with a preference for unhealthy foods decrease their purchases more in reaction to the fat tax introduction. Nevertheless, controlling for tastes leaves the differential response by self-control almost unaffected. In Panel B, we observe that there is not a differential response to the tax repeal by taste differences.

5.3.4 Selection on unobservables

While we cannot directly test for the influence of selection on unobservables, we can draw some inferences based on the movement of coefficients and explained variance when controlling for observables. We adapt the approach suggested by Oster (2019), which builds on Altonji *et al.* (2019). The idea is to bound the estimates by making assumptions about the relative importance of unobserved relative to observed variables and about the highest explainable variance.

We aim to determine whether within-in household changes in purchases vary due to differences in self-control or due to unobserved differences between self-control groups. Hence, the baseline estimate is a fixed-effect regression of purchases on only a tax dummy and the tax dummy interacted with the self-control indicator. In the controlled specification, we additionally control for time-varying controls and interactions of the tax dummy with education, nutritional knowledge, income, and unhealthy taste (i.e., the specification in the last columns of Tables 6 and 7). We assume that selection on unobservables is as important as selection on observables and that it can either go into the same or into the opposite direction. The argument is that if controlling for informative observables does not change the coefficients much, controlling for unobservables would not do so either. In Appendix E, we describe the approach in detail.

Table E.1 presents the results of the bounding exercise. For the soft drink tax hike, we obtain bounds of $[-67.639, -30.751]$. Since the bounds do not contain zero, proportional selection on unobservables is unlikely to explain the differential effect by self-control. In contrast, for the tax repeal, the bounds are $[-6.324, 8.759]$, which corroborates the finding that there is no differential response by self-control for the tax repeal. When the fat tax is introduced, the bounds are $[-48.212, -22.723]$, suggesting that the differential response to increasing taxes is not due to selection on unobservables. For the tax repeal, the bounds are $[-12.581, -12.380]$, however, despite the tight bounds the coefficient is not significant as discussed above. Taken together, the bounding results suggest that there is little evidence that selection on unobservables drives the results.

5.3.5 Cross-border shopping

As mentioned above, the tax on soft drinks was principally repealed to reduce cross-border shopping in Germany. In general, this should not be a concern for our analysis since in the GfK Consumertracking data, consumers also report purchases abroad. However, one may be concerned that cross-border purchases are underreported and consumers engage differently in border-shopping depending on self-control. To assess the importance of this channel, we distinguish if consumers have access to the German border without using a toll bridge or ferry.[10] Thus, the "No Toll" indicator is a proxy for how easy and economic it is to buy groceries in Germany.

Hence, in Table 8, we separately estimate the model on "Toll" and "No toll" households to assess heterogenous effects by distance to border. For the soft drink tax hike, we observe in Panel A that among consumers in the "Toll" region (i.e. where the border is not easily accessible) the difference between low and high self-control is somewhat stronger compared to consumers in the "No toll" region. However, even in the "No toll" region the interaction is not substantially smaller compared to the main specification and remains significant at the 10 percent level despite the reduced sample size. This seems to suggest that consumers with

[10]While households in Jutland and Funen do not have to use a toll bridge or ferry to reach the German border, households in Sealand, Copenhagen, and Bornholm must. The costs to use the ferry or bridge for a standard car start at 30 Euros each way. In Schmacker and Smed (2020), we provide descriptive evidence that this distinction is informative about the propensity to engage in cross-border shopping.

Table 8: Soft drink and butter purchases by access to German border

	Soft drink tax		Fat tax	
	No toll	Toll	No toll	Toll
Panel A: Tax Introduction				
Tax Introduction	-7.015	-13.939	-24.632*	-17.519
	(20.447)	(27.353)	(14.850)	(14.162)
High self-control × Tax	-47.445*	-73.316**	-30.953	-32.436
	(27.174)	(31.834)	(19.379)	(20.860)
Households	730	547	755	569
n	12752	9425	16064	12098
Panel B: Tax Repeal				
Tax Repeal	76.889***	111.706***	26.244*	27.505*
	(22.522)	(31.743)	(15.534)	(16.340)
High self-control × No Tax	-0.811	-7.519	-14.567	-6.041
	(31.099)	(37.770)	(19.234)	(19.661)
Households	734	544	756	565
n	13043	9704	16419	12391
Controls	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes

Notes: Table shows OLS regression results with standard errors clustered on household level, using GfK data. The estimations are performed separately on the sample of “toll” and “no toll” households. “Toll” indicates that a consumer has to use a toll bridge or ferry to reach the cross-border shops in Germany. Controls include household size, income, labor market status, number of kids, temperature, and quarter FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Correlations of self-control with habit and addiction

	(1) "I am addicted to sugar"	(2) "I am addicted to fat"	(3) "Hard to establish healthy eating habits"
Low self-control	0.098***	0.066***	0.177***
	(0.026)	(0.020)	(0.026)
Controls	Yes	Yes	Yes
Mean	0.297	0.131	0.287
Households	1197	1197	1197

Notes: The dependent variable in each column is a dummy indicating whether panelists in the GfK Consumer-Tracking panel answer "Somewhat agree" or "Totally agree" to the respective statement. The regressions control for income, age, education, labor market status, and number of children. The complete statement in Column (3) is "I find it harder to establish healthy eating habits than to establish unhealthy eating habits". Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

high self-control do not reduce their purchases as much when there are close-by opportunities to avoid the tax. In Panel B, we see that purchases increased more in the "Toll" region after the tax repeal but there is again not much evidence for a differential response by self-control.

Cross-border shopping is arguably less important for butter purchases since butter is not as storable as soft drinks. In line with this argument, we observe that the interaction of self-control and the fat tax dummy is similar in magnitude for "Toll" and "No toll" consumers. The magnitude of the interaction coefficient in Panel A is almost the same compared to the main specification, but does not have the statistical power to reach significance due to the reduced sample size.

5.4 Proposed mechanism: Habit formation

Ultimately, we argue that habit formation is the most likely mechanism to explain the asymmetric pattern to tax increases and cuts. First, we show that theoretical models of self-control and habit formation predict the observed empirical pattern. Second, we provide empirical evidence supporting that habit formation shapes the differential response by self-control.

In the empirical analysis, we document an asymmetry in responses to tax increases and decreases depending on self-control. This asymmetry is hard to reconcile with a standard model of time-separable utility since price elasticities are typically symmetric to prices going up or down. Hence, if consumers with low self-control respond less to increasing taxes, they should also respond less to decreasing taxes. However, when there are intertemporal complementarities in consumption due to habit formation or addiction (Becker and Murphy, 1988), this is not necessarily the case.

Habit formation or addiction can, for example, be modelled in the form of withdrawal costs that must be incurred if an individual stops consuming a habituating good that she

Table 10: Soft drink and butter purchases by reportedly addicted to sugar/fat

	Soft drink tax		Fat tax	
	"Not addicted to sugar"	"Addicted to sugar"	"Not addicted to fat"	"Addicted to fat"
Panel A: Tax Introduction				
Tax Introduction	-42.387*	45.848*	-31.283***	8.647
	(21.614)	(27.112)	(11.333)	(31.355)
High self-control × Tax	-37.453	-75.525*	-17.392	-97.823**
	(25.538)	(39.488)	(15.435)	(45.652)
Households	842	355	1077	164
n	14838	6049	23045	3459
Panel B: Tax Repeal				
Tax Repeal	74.392***	121.564***	28.831**	18.855
	(21.838)	(35.482)	(13.174)	(26.258)
High self-control × No Tax	18.850	-32.350	-14.235	1.359
	(28.413)	(46.351)	(15.188)	(44.991)
Households	842	355	1077	164
n	15084	6305	23598	3546
Controls	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes

Notes: Table shows OLS regression results with standard errors clustered on household level, using GfK data. The estimations are performed separately on the sample of panelists who respond "Somewhat agree" or "Totally agree" to the statement "I am addicted to sugar" and "I am addicted to fat", respectively. Controls include household size, income, labor market status, number of kids, temperature, and quarter FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

previously consumed (O'Donoghue and Rabin, 2002). If consumers with low self-control are more habituated (because they underweigh the long-term health costs of sin good consumption) and, thus, have larger withdrawal costs, they are less likely to reduce their consumption when prices go up. In contrast, since withdrawal costs do not have to be incurred when consumption is increased, a differential response to tax cuts is not expected.

This result does not depend on a difference in the initial habit stock by self-control. In Appendix F, we build on the model of O'Donoghue and Rabin (2002) and show theoretically that an asymmetric response is also expected when the initial habit stock and self-control are independent and consumers are forward-looking. In the model, consumers are aware that a tax does not just change the instantaneous price but also all prices in the future. Since consumers with low self-control discount the future (and, hence, the future price changes) more, they react in general less strongly to tax changes. However, the differential response is predicted to be smaller for a tax cut compared to a tax hike since the tax hike induces high self-control consumers to reduce their habit stock more.

To investigate empirically whether habit formation is a potential mechanism behind the results, we first check if consumers with high and low self-control consider themselves to be addicted to sugar and fat. In Table 9, we show that self-control is associated with self-reported addiction to these goods after controlling for demographic characteristics. We observe that consumers with low self-control are substantially more likely to agree to the statements "I am addicted to sugar/fat" and "I find it harder to establish healthy eating habits than to establish unhealthy eating habits".

Second, we investigate if self-control has heterogenous effects among consumers who consider themselves addicted to the taxed good. In Table 10, we split the sample into consumers who agree that they are addicted to sugar (for the soft drink tax estimations) or fat (for the fat tax estimations). Among those who report not to be addicted to sugar, there is a reduction in purchases by both consumers with low and high self-control. Here, the differential response is smaller in magnitude and no longer significant. In contrast, among those who report being addicted to sugar, consumers with high self-control respond significantly stronger to the tax hike. Those with low self-control even slightly increase their soft drink purchases. For the fat tax, we observe a similar pattern: Those who report not being addicted to fat reduce their purchases irrespective of their level of self-control, while among those who report that they are not addicted, only those with high self-control significantly reduce their purchases.

Overall, these results suggest that self-control is required to reduce sin good consumption whereas self-control is not necessary for increasing sin good consumption. We find indication that this relationship generates the observed pattern with a differential response to increasing taxes but no systematic differential response to decreasing taxes.

6 Conclusion

In both policy debates and in the economic literature, it is often argued that sin taxes can help consumers with low self-control to act more in accordance with their own long-run interest. However, this requires that consumers with low self-control respond to tax changes by reducing consumption. This paper presents evidence that consumers with low self-control respond systematically less to increasing soft drink and fat taxes than do high self-control consumers. However, we find no difference between the groups when the tax is reduced, indicating that it is not just a difference in price elasticity between the groups. We show theoretical and empirical evidence that this pattern can be explained by (rational) habit formation, an aspect largely neglected in the existing literature. If the taxed good is habituating (which is reasonable for many sin goods), sin taxes of modest magnitude may be less effective than previously thought in correcting internalities.

Our results suggest that other policy measures may be required to help consumers with low self-control to act in accordance with their long-run interests. It is worth considering, for example, time- and place-based restrictions regarding the sale of sugar sweetened beverages, as many jurisdictions have implemented for alcohol. Governments may also consider limiting the amount of sugar that beverages are allowed to contain or think about a ban on advertising sugary products.

It must be noted that sin taxes can still correct externalities on public health, even if consumers with low self-control are not successfully targeted by these taxes. Sin taxes can make those consumers, who do not reduce their purchases, compensate the arising social costs of consumption. Furthermore, while consumers with low self-control may not respond to the price incentives themselves, smart sin tax design can still improve the diets of individuals with low self-control. If taxes are proportional to the harmful ingredient (e.g. sugar in soft drinks), producers are incentivized to make their product less unhealthy, as documented for the tiered soft drink tax in the UK (Public Health England, 2019). Since the Danish soft drink tax was volumetric, this incentive was not given. Moreover, taxes that increase the prices of the unhealthiest products the most may encourage consumers to substitute with less unhealthy alternatives (Grummon *et al.*, 2019).

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Appendix (for online publication)

A Derivation of optimal sin taxes

The following model closely follows O'Donoghue and Rabin (2003, 2006) and Haavio and Kotakorpi (2011) and derives the optimal tax formula in section 2.

An individual i in period t has intertemporal utility from consumption that is given by

$$U_t(u_1, ..., u_T) = u_t + \beta \sum_{\tau=t+1}^{T} \delta^{\tau-t} u_\tau \tag{5}$$

Each period she receives instantaneous utility u_t and future utility is discounted by time-consistent discount factor δ and by hyperbolic discounting factor β_i that differs between individuals. If $\beta_i < 1$, the agent has a preference for immediate gratification (low self-control) and if $\beta_i = 1$ the agent behaves time-consistent. For simplicity, we assume $\delta = 1$, i.e. there is no time-consistent discounting.

The instantaneous utility can be expressed as

$$u_t = v(x_t) - c(x_{t-1}) + z_t \tag{6}$$

and consists of the utility $v(\cdot)$ from consuming a sin good, e.g. soft-drinks, in the current period x_t, the health costs $c(\cdot)$ with $c'(\cdot) > 0$ from having consumed soft-drinks in the past x_{t-1} and utility from a numeraire good z_t. The price of soft-drinks is p while the price of the numeraire is normalized to one. Thus, the per-period budget constraint is $px_t + z_t = y$, where y is income.

Since decisions are independent from other periods, each period the agent chooses x such as to maximize $u(x^*) = v(x^*) - \beta_i c(x^*) + z$, which yields the first order condition $v'(x^*) - \beta_i c'(x^*) = p$. However, if the agent had perfect self-control she would maximize $u(x^o) = v(x^o) - c(x^o) + z$ and consume according to the first order condition $v'(x^o) - c'(x^o) = p$. It can immediately be seen that a present-biased consumer with $\beta < 1$ overconsumes soft-drinks compared to their long-run optimal consumption x^o. Assuming that taste for soft-drinks $v(x)$ is independent of self-control β, we can expect that consumers with low self-control ($\underline{\beta}$) consume on average more soft-drinks than consumers with high self-control ($\bar{\beta}$) since they underweigh the costs.

A social planner may now decide to impose a tax t on soft-drinks in order to correct for the internality that is due to the low self-control. The social planner redistributes the tax revenues lump-sum back to consumers and the individual budget constraint becomes $(p + t)x_t + z_t = y + t\bar{x}$ where $\bar{x}$ is the average soft-drink consumption in the economy. The tax is chosen such as to maximize the social welfare function

$$\Omega(t) = \sum_i [v(x_i) - c(x_i) + (y + t\bar{x} - (p+t)x_i)] \tag{7}$$

which is the sum of individual long-run utility of all individuals. Solving for the first order condition yields

$$\frac{\partial \Omega(t)}{\partial t} = \sum_i [(v'(x_i) - c'(x_i) - (p+t))\frac{\partial x_i}{\partial t}] + Nt\frac{\partial \bar{x}}{\partial t} = 0 \tag{8}$$

where $\frac{\partial \bar{x}}{\partial t}$ is the average response in soft-drink consumption due to the tax change. Inserting the demand condition that allows for imperfect self-control $v'(x^*) - \beta c'(x^*) = p + t$ and rearranging gives (similar to Haavio and Kotakorpi, 2011):

$$t = \frac{1}{N}\sum_i (1-\beta_i)c'(x_i) + \frac{\text{cov}((1-\beta)c'(x), \frac{\partial x}{\partial t})}{\partial \bar{x}/\partial t}. \tag{9}$$

B Factor structure of self-control scale

In order to extract the latent dimension of self-control that matters for food choices, we perform a principal component factor analysis. Following the original study by Tangney *et al.* (2004), we extract five factors. In Table B.1, we show the rotated factor loadings of the five factors. The first factor (13.4 percent of the variance) measures a general capacity for self-discipline and loads high on a variety of factors, e.g. "I blurt out whatever is on my mind" (0.647). The second factor (9.1 percent of the variance) is related to healthy habits and resistance against temptations. It has the highest loadings on "I eat healthy food" (0.712), "I have many healthy habits" (0.708), "I am good at resisting temptations" (0.644), and "I have a hard time breaking bad habits" (0.608). The third factor (7.4 percent of the variance) is related to reliability, e.g. it has the highest loading on "I am always on time" (0.738). The fourth factor (6.6 percent of the variance) relates to self-restraint and has the highest loading on "I am self-indulgent at times" (0.620). The fifth factor (4.0 percent of the variance) describes being impulsive and loads highest on "People would describe me as impulsive" (0.552). Thus, the factor structure is very similar to that of Tangney *et al.* (2004).

B.1 Robustness of self-control factor

In order to make sure that the self-control factor is not merely picking up revealed preferences about healthy food consumption, we check robustness to excluding the item "I eat healthy foods" from the factor analysis. In Table B.3, we re-run the factor analysis without the respective item and show the rotated factor loadings of the five factors. The table shows that the factor loadings change slightly compared to Table B.1. Factor 2 now loads highest on "I am good at resisting temptations" (0.695), "I have a hard time breaking bad habits" (0.694), and "I wish I had more self-discipline" (0.623).

We conduct a median split using this newly generated self-control factor and re-run the estimations for the soft drink tax and the fat tax. In Table B.4, we show the estimation results for the soft drink tax. The results turn out to be similar compared to the main specification in Table 6. The same holds true for the fat tax estimations in Table B.5, which yield similar results compared to the main specification in Table 7. This leads us to conclude that the results are not driven by an item in the self-control scale that captures revealed preferences for healthy nutrition.

Table B.1: Rotated factor loadings (varimax), N=2,387

	Factor1	Factor2	Factor3	Factor4	Factor5
I am good at resisting temptations	0.213	0.644	0.109	0.022	0.051
(R) I have a hard time breaking bad habits	0.298	0.608	0.004	0.069	-0.224
(R) I am lazy	0.273	0.439	0.286	0.135	-0.299
(R) I often say inappropriate things	0.551	0.129	0.130	0.030	-0.003
I never allow myself to lose control	-0.150	0.005	0.111	-0.152	0.533
(R) I do certain things that are bad for me, if they are fun	0.205	0.231	0.055	0.539	0.036
(R) Getting up in the morning is hard for me	0.292	0.173	0.306	0.084	-0.405
(R) I have trouble saying no	0.476	0.234	0.029	-0.057	-0.218
(R) I change my mind fairly often	0.586	0.104	0.159	0.009	-0.154
(R) I blurt out whatever is on my mind	0.647	0.057	-0.011	0.063	0.105
I refuse things that are bad for me	0.114	0.347	0.152	-0.284	0.254
(R) I spend too much money	0.340	0.367	0.177	0.307	-0.024
I keep everything neat	0.082	0.258	0.512	0.005	0.088
(R) I am self-indulgent at times	0.074	0.029	-0.024	0.620	-0.030
(R) I wish I had more self-discipline	0.472	0.459	0.130	0.054	-0.142
I am reliable	0.087	0.058	0.468	-0.343	0.306
(R) I get carried away by my feelings	0.557	0.134	-0.062	0.151	0.043
(R) I do many things on the spur of the moment	0.330	-0.054	-0.054	0.500	0.190
(R) I don't keep secrets very well	0.470	-0.041	0.215	0.045	-0.040
(R) I have worked or studied all night at the last minute	0.349	0.097	0.410	0.300	-0.208
I'm not easily discouraged	0.258	0.293	0.245	-0.514	0.014
(R) I'd be better off if I stopped thinking before acting	0.527	-0.007	0.128	0.037	0.064
(R) Pleasure and fun sometimes keep me from getting work done	0.338	0.104	0.314	0.399	0.004
(R) I have trouble concentrating	0.550	0.178	0.230	-0.076	-0.253
I am able to work effectively toward long-term goals	0.170	0.305	0.325	-0.408	0.122
(R) Sometimes I can't stop myself from doing something, even if I know it is wrong	0.433	0.316	0.119	0.407	0.047
(R) I often act without thinking through all the alternatives	0.575	0.198	0.106	0.186	0.220
(R) I lose my temper too easily	0.537	0.049	-0.042	0.010	0.029
(R) I often interrupt people	0.597	0.062	0.013	0.071	-0.027
I am always on time	0.010	-0.031	0.738	-0.011	-0.043
People can count on me to keep the schedule	0.048	0.072	0.719	-0.014	-0.042
(R) People would describe me as impulsive	0.232	-0.101	-0.050	0.307	0.552
People would say that I have an iron self-discipline	0.157	0.397	0.448	-0.157	0.083
I have many healthy habits	-0.054	0.708	0.019	-0.061	0.021
I eat healthy foods	-0.013	0.712	0.026	0.007	-0.015
(R) I sometimes drink too much alcohol	0.085	0.122	0.139	0.210	0.189

Notes: Table shows rotated factor loadings after principal component factor analysis (varimax rotation), using GfK data. We extract five factors following the original study by Tangney *et al.* (2004). (R) indicates that the item is reverse coded.

Table B.2: Correlations of self-control factors with characteristics and attitudes

	(1) Body Mass Index (BMI)	(2) Obesity (BMI>30)	(3) Intention to reduce weight	(4) "I should eat less sugar"	(5) "I should eat less animal fat"
Low SC (Factor 1)	0.494*	0.032	0.089***	0.085***	0.057**
	(0.283)	(0.021)	(0.028)	(0.029)	(0.028)
Low SC (Factor 2)	2.124***	0.094***	0.202***	0.112***	0.115***
	(0.269)	(0.021)	(0.028)	(0.029)	(0.028)
Low SC (Factor 3)	0.453	0.026	0.021	-0.009	0.011
	(0.283)	(0.021)	(0.028)	(0.029)	(0.028)
Low SC (Factor 4)	0.727**	0.035	0.018	0.034	0.025
	(0.287)	(0.022)	(0.029)	(0.029)	(0.028)
Low SC (Factor 5)	0.175	-0.002	0.000	-0.063**	0.012
	(0.288)	(0.022)	(0.028)	(0.029)	(0.028)
Controls	Yes	Yes	Yes	Yes	Yes
Mean	26.021	0.175	0.620	0.483	0.354
Households	1237	1236	1197	1197	1197

Notes: Table shows results from regressing the dependent variable in the respective column on the self-control factor and controls, using GfK data. The controls are income, age, education, labor market status, and number of children. Columns (1) and (2) are based on weight and height data from 2011. BMI is calculated as ([weight in kg]/[height in m]^2). The dependent variable in column (3) is an indicator whether respondents indicate in the 2013 survey that they would like to weigh at least 1 kg less. The dependent variable in columns (4) and (5) are indicators whether respondents approve that they should eat "A lot less" or "A little less" sugar or animal fat to eat healthier. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table B.3: Rotated factor loadings (varimax) without item "I eat healthy foods", N=2,387

	Factor1	Factor2	Factor3	Factor4	Factor5
I am good at resisting temptations	0.068	0.695	0.092	0.063	0.104
(R) I have a hard time breaking bad habits	0.158	0.694	-0.021	0.084	-0.175
(R) I am lazy	0.199	0.489	0.278	0.123	-0.315
(R) I often say inappropriate things	0.579	0.149	0.150	0.032	-0.084
I never allow myself to lose control	-0.175	-0.016	0.108	-0.088	0.583
(R) I do certain things that are bad for me, if they are fun	0.139	0.235	0.051	0.543	-0.046
(R) Getting up in the morning is hard for me	0.255	0.259	0.286	0.079	-0.373
(R) I have trouble saying no	0.357	0.430	-0.027	0.003	-0.084
(R) I change my mind fairly often	0.520	0.274	0.120	0.060	-0.086
(R) I blurt out whatever is on my mind	0.663	0.105	-0.001	0.094	0.065
I refuse things that are bad for me	0.016	0.419	0.130	-0.220	0.343
(R) I spend too much money	0.249	0.420	0.163	0.333	-0.031
I keep everything neat	0.043	0.267	0.511	0.025	0.077
(R) I am self-indulgent at times	0.028	0.030	-0.035	0.617	-0.095
(R) I wish I had more self-discipline	0.323	0.623	0.084	0.109	-0.055
I am reliable	0.133	0.022	0.492	-0.316	0.293
(R) I get carried away by my feelings	0.448	0.306	-0.112	0.233	0.146
(R) I do many things on the spur of the moment	0.242	0.055	-0.096	0.570	0.226
(R) I don't keep secrets very well	0.494	0.018	0.215	0.067	-0.049
(R) I have worked or studied all night at the last minute	0.302	0.190	0.386	0.319	-0.203
I'm not easily discouraged	0.219	0.371	0.236	-0.476	0.098
(R) I'd be better off if I stopped thinking before acting	0.528	0.069	0.121	0.080	0.079
(R) Pleasure and fun sometimes keep me from getting work done	0.299	0.147	0.303	0.427	-0.017
(R) I have trouble concentrating	0.495	0.330	0.199	-0.042	-0.190
I am able to work effectively toward long-term goals	0.110	0.378	0.311	-0.359	0.203
(R) Sometimes I can't stop myself from doing something, even if I know it is wrong	0.326	0.402	0.095	0.450	0.037
(R) I often act without thinking through all the alternatives	0.523	0.269	0.098	0.245	0.211
(R) I lose my temper too easily	0.569	0.074	-0.025	0.018	-0.031
(R) I often interrupt people	0.631	0.091	0.031	0.071	-0.110
I am always on time	0.026	-0.010	0.732	0.002	-0.030
People can count on me to keep the schedule	0.047	0.094	0.715	-0.001	-0.036
(R) People would describe me as impulsive	0.239	-0.134	-0.040	0.365	0.506
People would say that I have an iron self-discipline	0.089	0.435	0.441	-0.121	0.121
I have many healthy habits	-0.079	0.538	0.073	-0.094	-0.020
(R) I sometimes drink too much alcohol	0.090	0.066	0.160	0.206	0.090

Notes: Table shows rotated factor loadings after principal component factor analysis (varimax rotation), using GfK data. We extract five factors following the original study by Tangney *et al.* (2004). The items exclude the item "I eat healthy foods". (R) indicates that the item is reverse coded.

Table B.4: Soft-drink purchases in response to soft drink tax changes, alternative self-control variable

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Tax hike						
Tax hike	-9.760	-8.929	-14.193	-3.699	-30.237	-26.118
	(17.145)	(20.590)	(18.374)	(19.419)	(21.180)	(25.090)
Tax hike						
× High self-control	-53.468**	-53.401**	-51.129**	-53.217**	-44.849**	-44.499**
	(21.176)	(21.151)	(21.639)	(21.297)	(21.965)	(21.998)
× High education		-2.118				8.644
		(20.034)				(21.183)
× Lacks knowledge			15.798			7.247
			(32.826)			(33.985)
× High income				-13.279		-16.493
				(22.702)		(24.716)
× Unhealthy taste					35.925	34.603
					(22.300)	(22.621)
Households	1278	1278	1197	1278	1197	1197
Household Months	22197	22197	20887	22197	20887	20887
Panel B: Tax repeal						
Tax repeal	94.734***	99.421***	93.242***	92.433***	89.750***	88.894***
	(19.479)	(23.190)	(20.642)	(22.958)	(24.982)	(28.591)
Tax repeal						
× High self-control	-19.776	-19.318	-13.012	-19.719	-11.542	-11.827
	(24.348)	(24.253)	(24.680)	(24.315)	(26.075)	(25.738)
× High education		-11.974				-20.484
		(23.564)				(25.449)
× Lacks knowledge			-16.730			-19.204
			(32.489)			(33.971)
× High income				3.704		19.163
				(23.862)		(25.975)
× Unhealthy taste					-0.049	3.149
					(26.183)	(27.358)
Households	1278	1278	1197	1278	1197	1197
Household Months	22747	22747	21389	22747	21389	21389
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Table shows OLS regression results with standard errors clustered on household level, using GfK data. The dependent variable is monthly quantity in centiliters. The "High self-control" factor excludes the item "I eat healthy foods". "High education" means tertiary education (ref.: vocational education), "Lacks knowledge" identifies consumers who agree to the statement "I believe I would make healthier food choices if I had more information on how to eat healthy", "High income" are in the top half of the distribution of equivalized incomes, "Unhealthy taste" indicates that consumers agree to the statement "I believe I would make healthier food choices if unhealthy food was less tasty". Controls include household size, income, labor market status, number of kids, temperature, and quarter FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table B.5: Butter purchases in response to fat tax changes, alternative self-control variable

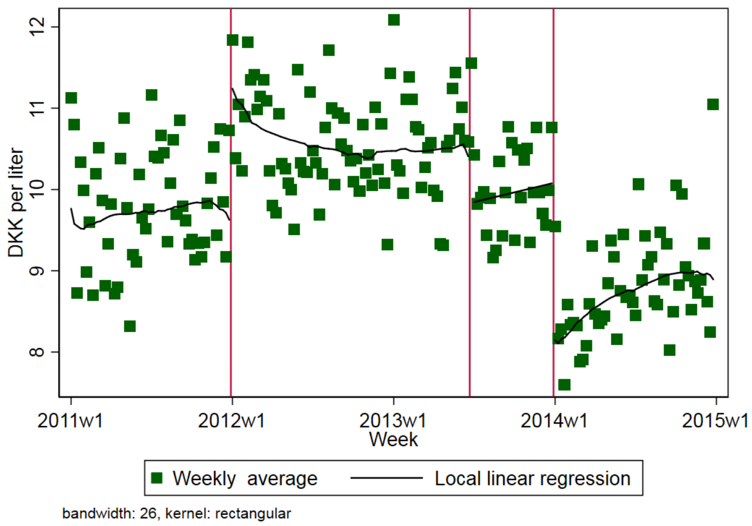
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Tax hike						
Tax hike	-24.601**	-30.411**	-20.796*	-23.832*	-11.570	-14.156
	(10.650)	(12.382)	(11.630)	(13.063)	(13.476)	(17.149)
Tax hike						
× High self-control	-24.566*	-25.050*	-26.172*	-24.693*	-29.881**	-31.531**
	(14.299)	(14.288)	(14.889)	(14.303)	(15.201)	(15.312)
× High education		14.713				16.078
		(14.424)				(15.279)
× Lacks knowledge			-25.859			-17.055
			(22.688)			(22.874)
× High income				-3.037		-4.040
				(15.290)		(16.192)
× Unhealthy taste					-27.513*	-25.455
					(15.705)	(15.621)
Households	1324	1324	1241	1324	1241	1241
Household Months	28162	28162	26504	28162	26504	26504
Panel B: Tax repeal						
Tax repeal	30.531***	31.155**	34.381***	28.931**	33.939**	38.669**
	(11.406)	(13.313)	(12.450)	(14.643)	(14.336)	(18.493)
Tax repeal						
× High self-control	-17.866	-17.810	-19.790	-17.694	-19.527	-20.423
	(13.872)	(13.889)	(14.385)	(13.899)	(14.444)	(14.638)
× High education		-1.513				-9.522
		(13.916)				(14.618)
× Lacks knowledge			-12.674			-12.426
			(20.090)			(20.382)
× High income				2.741		1.271
				(15.750)		(16.800)
× Unhealthy taste					-3.812	-1.652
					(14.645)	(14.841)
Households	1323	1323	1241	1323	1241	1241
Household Months	28829	28829	27144	28829	27144	27144
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Table shows OLS regression results with standard errors clustered on household level, using GfK data. The dependent variable is monthly quantity in grams. The "High self-control" factor excludes the item "I eat healthy foods". "High education" means tertiary education (ref.: vocational education), "Lacks knowledge" identifies consumers who agree to the statement "I believe I would make healthier food choices if I had more information on how to eat healthy", "High income" are in the top half of the distribution of equivalized incomes, "Unhealthy taste" indicates that consumers agree to the statement "I believe I would make healthier food choices if unhealthy food was less tasty". Controls include household size, income, labor market status, number of kids, and quarter FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

C Soft Drink Tax

C.1 Pass-through of soft drink tax to prices

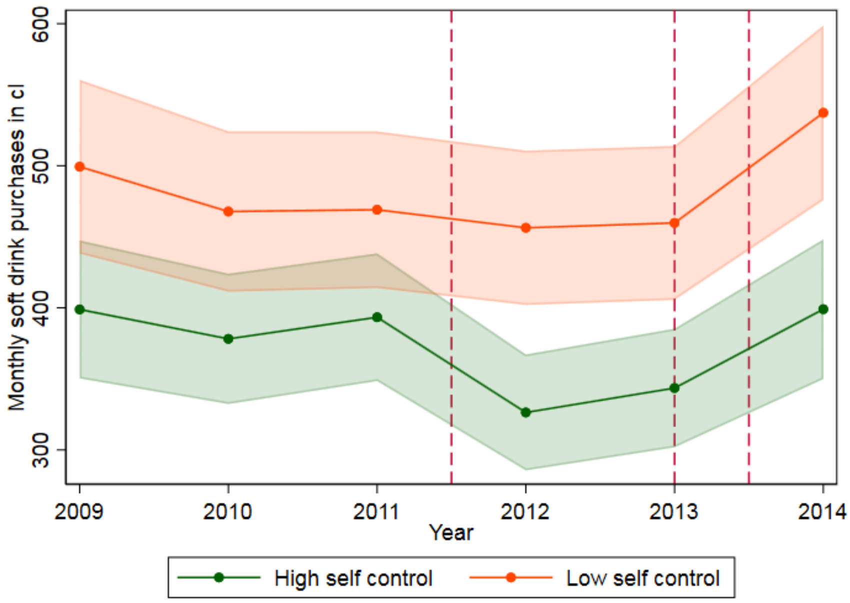
Figure C.1: Average soft drink prices over time (based on Schmacker and Smed (2020))



Notes: Graph shows weekly average soft drink prices around the tax increase in January 2012 and the tax cuts in July 2013 and January 2014, using GfK data. Dots represent weekly averages and the lines local polynomials (rectangular weights and 26 week bandwidth). The vertical lines indicate the timing of tax changes. The graph is reproduced from Schmacker and Smed (2020).

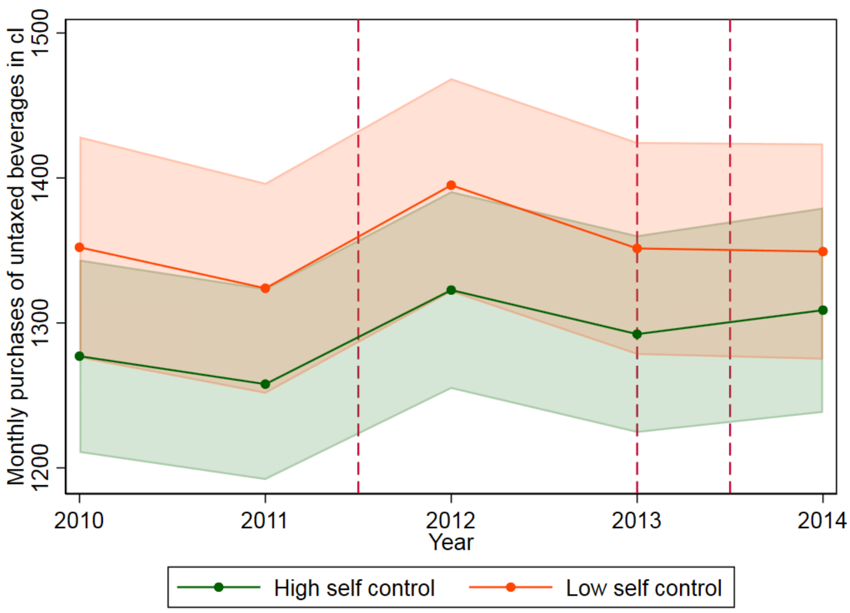
C.2 Robustness of soft drink tax estimations

Figure C.2: Predicted values of monthly soft drink purchase quantity by self-control, without household fixed effects and demographic controls



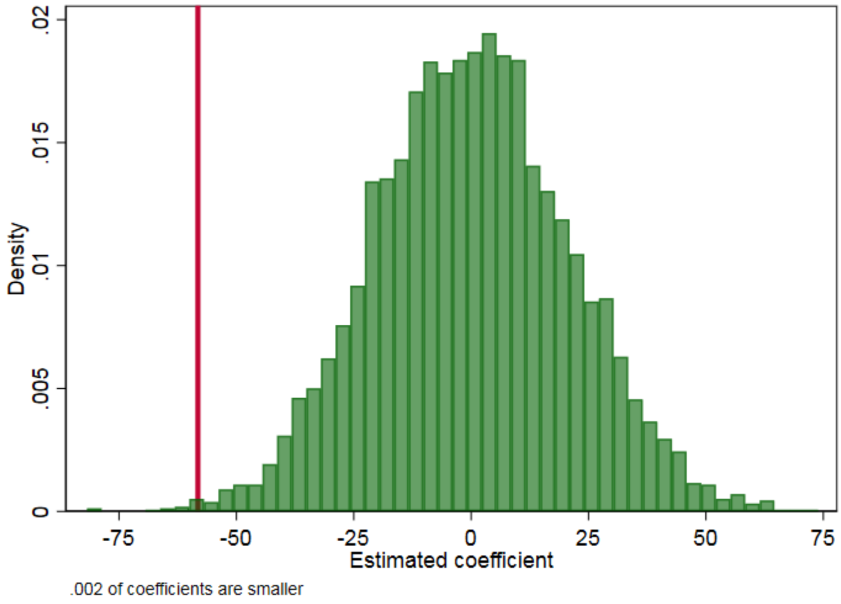
Notes: Graph shows annual predicted values only controlling for household size, using GfK data. The shaded areas represent 95% confidence intervals from standard errors clustered on the household level. The vertical lines indicate the timing of tax changes.

Figure C.3: Predicted values of monthly purchase quantity of untaxed beverages by self-control

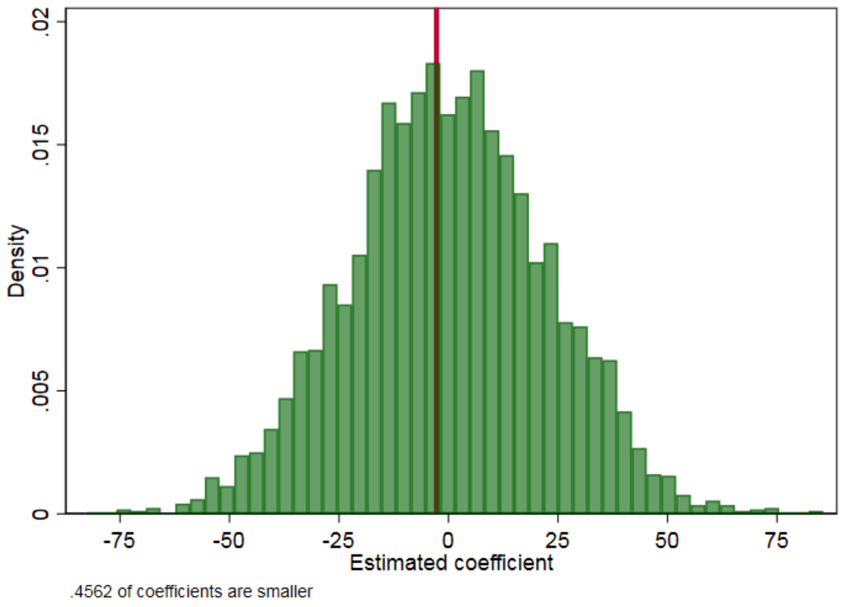


Notes: Graph shows annual predicted values only controlling for household size, using GfK data. The shaded areas represent 95% confidence intervals from standard errors clustered on the household level. The vertical lines indicate the timing of tax changes.

Figure C.4: Permutation test for soft drink tax



(a) Tax increase



(b) Tax repeal

Notes: Graph shows the distribution of estimated interaction coefficients "Tax change x High self-control" when randomly reshuffling the classification in high and low self-control 10,000 times. The red line shows the estimated coefficient from the main specification. Source: GfK Consumertracking.

Table C.1: Soft drink purchases in response to placebo tax changes by self-control

	(1) Quantity	(2) Quantity	(3) Quantity	(4) Quantity
Tax Placebo	-23.163	-8.343	-8.341	-21.928
	(16.106)	(16.153)	(16.813)	(16.870)
High self-control × Tax Placebo	-3.234	-4.325	23.538	25.332
	(20.326)	(20.079)	(20.690)	(20.835)
Households	1171	1171	1260	1260
Household Months	20674	20674	21622	21622
Placebo	January 2010	January 2010	January 2011	January 2011
Controls	No	Yes	No	Yes
Household FE	Yes	Yes	Yes	Yes

Notes: Table shows OLS regression results with standard errors clustered on household level, using GfK data. The dependent variable is monthly quantity in centiliter. Controls include household size, income, labor market status, number of kids, temperature, and quarter FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table C.2: Soft drink purchases in response to soft drink tax changes, collapsed standard errors

	Tax hike		Tax repeal	
	(1) Quantity	(2) Quantity	(3) Quantity	(4) Quantity
Tax Hike	-10.564	-14.024	81.455***	96.980***
	(16.189)	(16.401)	(17.375)	(19.741)
High self-control × Tax Change	-54.873***	-52.789***	-13.449	-3.724
	(20.345)	(20.459)	(22.955)	(22.863)
Households	1278	1278	1278	1278
Observations	2532	2532	2543	2543
Controls	No	Yes	No	Yes
Household FE	Yes	Yes	Yes	Yes

Notes: Table shows OLS regression results with robust standard errors in parentheses, using GfK data. The dependent variable is monthly quantity in centiliter. Controls include household size, income, labor market status, number of kids, temperature, and quarter FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table C.3: Soft drink purchases in response to soft drink tax changes, only single households

	(1) Quantity	(2) Extensive Margin	(3) Intensive Margin
Panel A: Tax Hike			
Tax Hike	7.997	0.003	0.044
	(11.441)	(0.016)	(0.069)
High self-control × Tax Hike	-36.567**	-0.051**	-0.112
	(14.804)	(0.021)	(0.085)
Households	467	467	391
Household Months	7881	7881	2454
Panel B: Tax Repeal			
Tax Repeal	39.102***	0.041**	0.104*
	(14.230)	(0.018)	(0.062)
High self-control × Tax Repeal	-10.256	0.003	0.027
	(15.831)	(0.023)	(0.084)
Households	467	467	394
Household Months	8055	8055	2514
Sample	Single HH	Single HH	Single HH
Controls	Yes	Yes	Yes
Household FE	Yes	Yes	Yes

Notes: Table shows OLS regression results with standard errors clustered on household level, using GfK data. In columns (1)the dependent variable is monthly quantity in centiliter. In columns (2) it is purchase incidence in a given month. In columns (3) it is log-transformed quantity. Controls include household size, income, labor market status, number of kids, temperature, and quarter FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table C.4: Soft drink purchases in response to soft drink tax by self-control, continuous measure of self-control

	(1) Quantity	(2) Extensive Margin	(3) Intensive Margin
Panel A: Tax Hike			
Tax Hike	-36.123***	-0.030***	-0.064***
	(10.787)	(0.007)	(0.024)
Self-control (cont.) × Tax Hike	-28.620***	-0.018***	-0.042*
	(10.572)	(0.007)	(0.024)
Households	1278	1278	1158
Household Months	22197	22197	9667
Panel B: Tax Repeal			
Tax Repeal	92.517***	0.047***	0.143***
	(13.906)	(0.008)	(0.025)
Self-control (cont.) × Tax Repeal	-13.627	-0.005	-0.008
	(14.333)	(0.008)	(0.023)
Households	1278	1278	1164
Household Months	22747	22747	9919
Controls	Yes	Yes	Yes
Household FE	Yes	Yes	Yes

Notes: Table shows OLS regression results with standard errors clustered on household level, using GfK data. In columns (1) the dependent variable is monthly quantity in centiliter. In columns (2) it is purchase incidence in a given month. In columns (3) it is log-transformed quantity. Controls include household size, income, labor market status, number of kids, temperature, and quarter FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

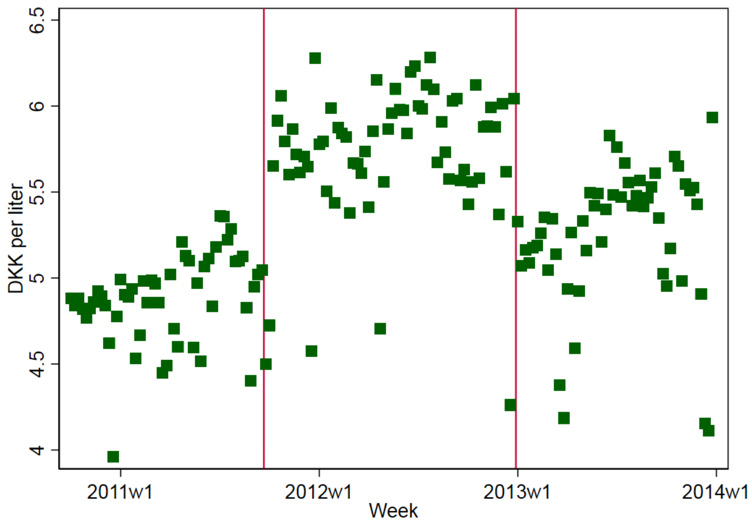
D Fat tax

D.1 Pass-through of fat taxes to butter prices

In this section, we aim to show that the fat tax indeed had an effect on the price of butter. Figure D.1 illustrates the development of prices around the fat tax introduction and repeal. The graph plots average weekly prices. It is apparent that during the time window when the fat tax was enacted, prices for butter were higher than before and after.

In Table D.1 we quantify the extent of the price changes by regressing absolute and log-transformed prices on a tax dummy while controlling for product fixed effects. Since we use a bandwidth of one year around the tax changes, the regression amounts to comparing the average prices one year before the tax change to one year after the tax change. We observe that prices per 100g of butter have increased by DKK 0.761 after the tax introduction and have decreased by DKK 0.611 after the tax repeal. Hence, the magnitude of price changes is indeed very similar for the tax introduction and the repeal.

Figure D.1: Average butter prices over time



Notes: Graph shows butter prices around the tax increase in January 2012 and the tax cuts in July 2013 and January 2014, using GfK data. Dots represent weekly averages. The vertical lines indicate the timing of tax changes.

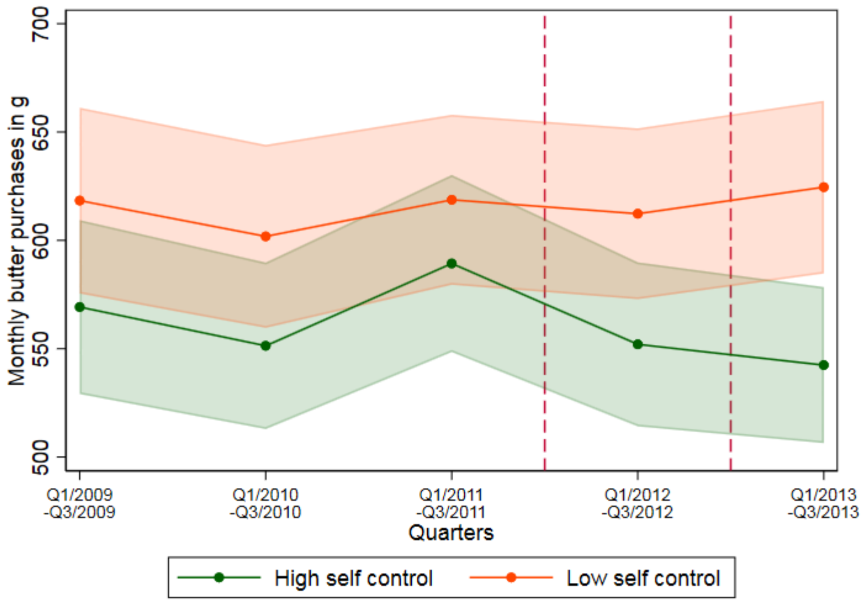
Table D.1: Butter prices in response to tax changes

	Tax introduction		Tax repeal	
	(1)	(2)	(3)	(4)
	Absolute price	Log price	Absolute price	Log price
Tax change	0.761***	0.151***	-0.611***	-0.124***
	(0.042)	(0.010)	(0.051)	(0.009)
Constant	4.905***	1.546***	5.758***	1.710***
	(0.022)	(0.005)	(0.026)	(0.005)
EAN fixed effects	Yes	Yes	Yes	Yes
n	52198	52198	59123	59123

Notes: Table shows results for a regression of absolute price (in DKK per 100g) and relative price (the log of absolute price) on the tax dummy and EAN (product code) fixed effects, using GfK data. In all specifications the sample includes one year before and one year after the respective tax change. Standard errors clustered on EAN level in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

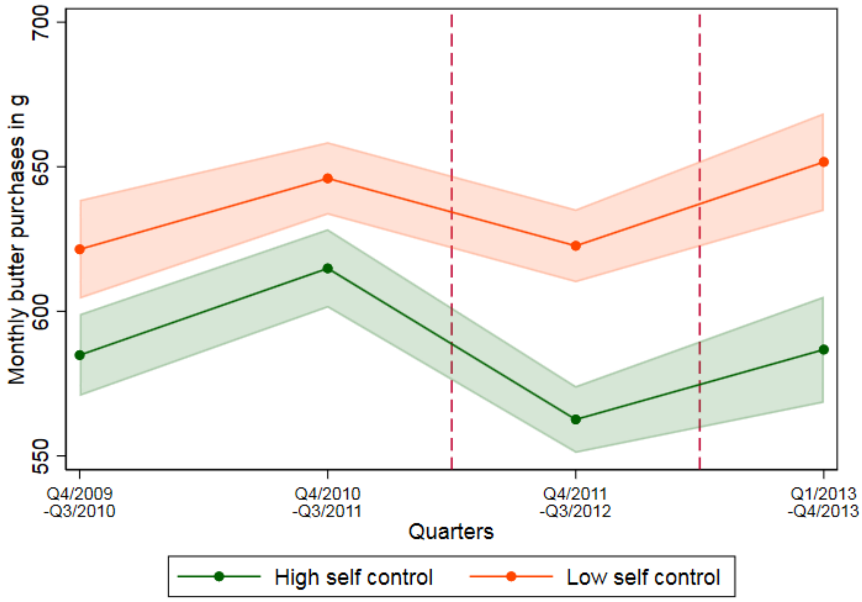
D.2 Robustness of fat tax estimations

Figure D.2: Predicted values of monthly butter purchase quantity by self-control, without household fixed effects and demographic controls



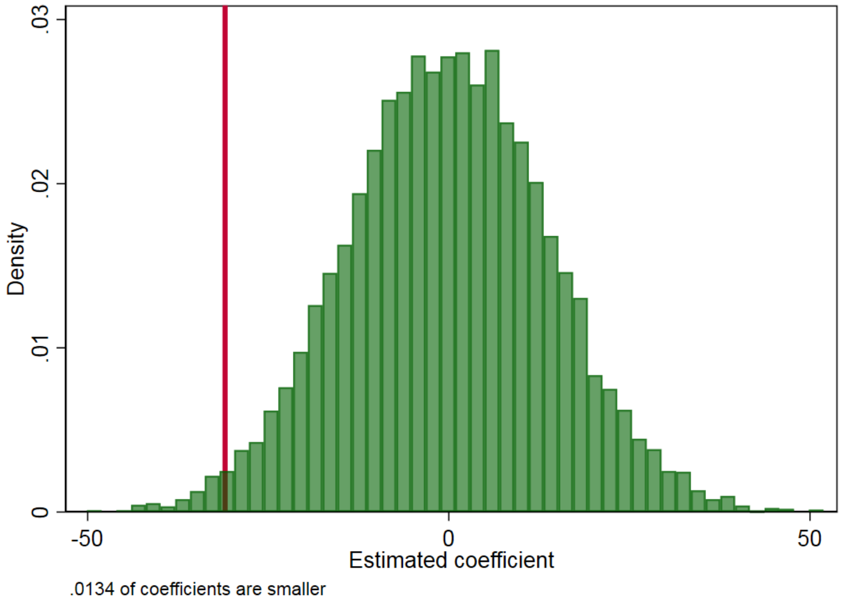
Notes: Graph shows annual predicted values only controlling for household size, using GfK data. The shaded areas represent 95% confidence intervals from standard errors clustered on the household level. The vertical lines indicate the timing of tax changes.

Figure D.3: Predicted values of monthly butter purchase quantity by self-control

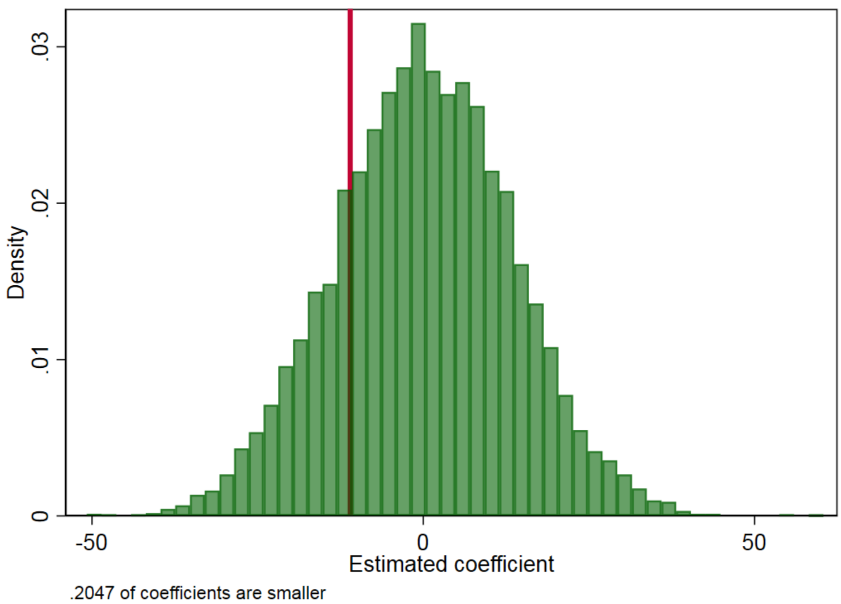


Notes: Graph shows annual predicted values after controlling for household and quarter fixed effects and controls (household size, income, labor market status, number of kids, temperature), using GfK data. The shaded areas represent 95% confidence intervals from standard errors clustered on the household level. The vertical lines indicate the timing of tax changes.

Figure D.4: Permutation test for fat tax



(a) Tax introduction



(b) Tax repeal

Notes: Graph shows the distribution of estimated interaction coefficients "Tax change x High self-control" when randomly reshuffling the classification in high and low self-control 10,000 times. The red line shows the estimated coefficient from the main specification. Source: GfK Consumertracking.

Table D.2: Butter purchases in response to placebo tax changes by self-control

	(1) Quantity	(2) Quantity	(3) Quantity	(4) Quantity
Tax Placebo	16.743***	16.169***	-2.208	-3.170
	(5.969)	(5.908)	(6.040)	(6.031)
High self-control × Tax Placebo	-0.011	-0.255	1.846	2.813
	(8.250)	(8.202)	(8.000)	(7.951)
Households	1284	1284	1217	1217
Household Months	26139	26139	25355	25355
Placebo	January 2010	January 2010	October 2010	October 2010
Controls	No	Yes	No	Yes
Household FE	Yes	Yes	Yes	Yes

Notes: Table shows OLS regression results with standard errors clustered on household level, using GfK data. The dependent variable is monthly quantity in grams. Controls include household size, income, labor market status, number of kids, and quarter FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table D.3: Butter purchases in response to fat tax changes, collapsed standard errors

	Tax introduction		Tax repeal	
	(1) Quantity	(2) Quantity	(3) Quantity	(4) Quantity
Tax Hike	-20.494*	-20.908*	23.544**	28.541**
	(10.588)	(10.781)	(10.135)	(11.404)
High self-control × Tax Change	-30.109**	-30.226**	-11.172	-10.514
	(14.731)	(14.925)	(13.688)	(13.767)
Households	1322	1322	1323	1323
Observations	2596	2596	2632	2632
Controls	No	Yes	No	Yes
Household FE	Yes	Yes	Yes	Yes

Notes: Table shows OLS regression results with robust standard errors in parentheses, using GfK data. The dependent variable is monthly quantity in grams. Controls include household size, income, labor market status, number of kids, and quarter FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table D.4: Butter purchases in response to fat tax changes, sample split in three quantiles

	(1) Quantity	(2) Extensive Margin	(3) Intensive Margin
Panel A: Tax hike			
Tax introduction	-24.283*	-0.006	-0.044***
	(13.699)	(0.009)	(0.016)
Tax introduction			
× Medium self-control	-23.032	-0.017	-0.002
	(18.110)	(0.013)	(0.022)
× High self-control	-17.317	-0.027**	0.008
	(17.902)	(0.013)	(0.022)
Households	1324	1324	1297
Household Months	28162	28162	18026
Panel B: Tax repeal			
Tax repeal	29.075**	0.015	0.050***
	(14.301)	(0.010)	(0.018)
Tax repeal			
× Medium self-control	-3.742	-0.002	-0.007
	(17.159)	(0.012)	(0.022)
× High self-control	-20.020	0.011	-0.037*
	(17.911)	(0.013)	(0.022)
Households	1323	1323	1302
Household Months	28829	28829	18782
Controls	Yes	Yes	Yes
Household FE	Yes	Yes	Yes

Notes: Table shows OLS regression results with standard errors clustered on household level, using GfK data. In columns (1) the dependent variable is monthly quantity in grams. In columns (2) it is purchase incidence in a given month. In columns (3) it is log-transformed quantity. Controls include household size, income, labor market status, number of kids, and quarter FE. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

E Bounding approach

To investigate the impact of potential selection on unobservables, we follow the approach by Oster (2019). The coefficient of interest is the interaction between the tax change indicator and the self-control indicator, α_2. First, we estimate the baseline estimate $\dot{\alpha}_2$ in a fixed-effects regression of purchases on the tax indicator and the tax indicator interacted with the self-control indicator. Second, we estimate the controlled estimate, $\tilde{\alpha}_2$, from a regression that includes the full set of controls and the tax dummy interacted with income, education, nutritional knowledge, and unhealthy taste. We consider proportional selection on unobservables that goes in the same direction as selection on observables ($\tilde{\delta} = 1$) and in the opposite direction ($\tilde{\delta} = -1$). The bound can then be approximated by

$$\alpha_2^* \approx \tilde{\alpha}_2 - \tilde{\delta}\frac{(\dot{\alpha}_2 - \tilde{\alpha}_2)(R_{max} - \tilde{R})}{\tilde{R} - \dot{R}} \tag{10}$$

where $\dot{R}$ is the within R-squared from the baseline regression and $\tilde{R}$ is the within R-squared from the controlled regression. R_{max} is the highest possible R-squared and is set to $R_{max} = min(2.2\tilde{R}, 1)$ following Hener *et al.* (2019). Hence, the movement in coefficients is weighted by the movement in R-squared relative to the potential change in R-squared.

Table E.1: Coefficient bounds based on Oster (2019)

	Soft drink tax		Fat tax	
	Tax hike	Tax repeal	Tax introduction	Tax repeal
Baseline estimate $\dot{\alpha}_2$	-58.370	-5.710	-30.118	-11.6059
	(20.218)	(23.317)	(13.937)	(13.4896)
Baseline Within R-squared $\dot{R}$	0.0015	0.0038	0.0014	0.0002
Controlled estimate $\tilde{\alpha}_2$	-51.196	0.251	-34.573	-12.4877
	(21.822)	(24.464)	(14.803)	(13.9000)
Controlled Within R-squared $\tilde{R}$	0.0034	0.0073	0.0069	0.0089
Bound α_2^* for $\delta = 1$	-30.7514	8.7586	-48.2122	-12.3802
Bound α_2^* for $\delta = -1$	-67.6385	-6.3235	-22.7227	-12.5806
Bounds include zero?	No	Yes	No	No

Notes: Table shows results for bounding approach based on (Oster, 2019) with $R_{max} = min(2.2\tilde{R}, 1)$, using GfK data. The baseline estimate corresponds to the coefficient of "Tax change x High self-control" from a fixed effects regression of purchases on the tax dummy interacted with self-control. The controlled estimate is obtained from a fixed effects regression including the full set of controls and interactions with the tax dummy as in the sixth column of Tables 6 and 7. The bounding estimates are computed using the Stata ado-file psacalc (Oster, 2019).

F Price Responsiveness in a Model of Habit Formation

In the empirical analysis, we find suggestive evidence that habit formation is a mechanism behind the differential response to sin taxes between high and low self-control individuals. In the following, we derive results about the price responsiveness by self-control when rational habit formation is taken into account. In such a model, habit formation and addiction can be used interchangeably since they rest on the same mechanism: Consumption today increases the utility from consumption in the future due to intertemporal complementarities. If an individual is aware of this property and takes it into account, we call it rational habit formation. The model of rational habit formation is based on the exposition in O'Donoghue and Rabin (2002). From here on, we adopt their approach to model the discrete choice of an agent to either engage in a habit-forming activity or not (i.e. an individual can consume or abstain). However, unlike in that paper, we introduce heterogeneity in self-control and focus on differential responses to tax variation by self-control.

Agents get utility in each period $t = (1, ..., T)$ with $T \to \infty$ from either consuming a sin good ($a_t = 1$) or abstaining ($a_t = 0$). By consuming the sin good they build up a habit stock k that evolves according to

$$k_t = \gamma k_{t-1} + a_{t-1}. \tag{11}$$

The habit stock in period t depends on the stock in the previous period, which decays with $\gamma \in [0, 1)$ and replenishes if the agents have consumed in the previous period (Becker and Murphy, 1988). The instantaneous utility of consumption is given by

$$u_t(a_t, k_t) = \begin{cases} v_t - p_t - c(k_t) & \text{if } a_t = 1 \\ -c(k_t) - g(k_t) & \text{if } a_t = 0 \end{cases} \tag{12}$$

and depends on an exogenous preference for the sin good v_t, the level of habituation k_t, and the price p_t. Consuming sin goods is associated with a negative internality ($c(k_t) > 0$), i.e. having consumed sin goods in the past has a negative effect on utility today. The internality costs of past consumption are incurred irrespective of today's consumption as, for example, the adverse health effects of being obese. For simplicity, we assume the internality costs to be linearly increasing in k with $c'(k_t) > 0$ and $c''(k_t) = 0$. Moreover, quitting consumption is associated with withdrawal costs ($g(k_t) > 0$), which are higher the more habituated an agent is, i.e. consumption is habit-forming. We assume that the withdrawal costs increase with the habit level ($g'(k_t) > 0$) and are weakly convex ($g''(k_t) \geq 0$).

In this model, v_t is exogenously given and assumed to be constant over time: $v_t = (\bar{v}, ...)$. The price p_t can be changed by the policy-maker by changing the tax rate but the individual takes p_t as given and assumes that it will not change in the future. In contrast, k_t depends on past decisions. Forward-looking agents anticipate that their current decisions will impact their future utility and will maximize for all periods s in $t, t+1, ..., T$ with $T = \infty$:

$$(13) \qquad U_t(a, k_t) = \begin{cases} u_t(a_t, k_t) + \beta \sum_{\tau=t+1}^{T} \delta^{\tau-t} u_\tau(a_\tau, \overbrace{\gamma k_{\tau-1} + 1}^{k_\tau}) & \text{if } a_t = 1 \\ u_t(a_t, k_t) + \beta \sum_{\tau=t+1}^{T} \delta^{\tau-t} u_\tau(a_\tau, \gamma k_{\tau-1}) & \text{if } a_t = 0 \end{cases}$$

where in the first case the consumer decides to consume and in the second case to abstain in period t. We assume that consumers follow the strategy to either consume forever or to abstain forever. The reason is that if consumption is habit-forming (if $g(k_t) > 0$), it becomes harder to quit tomorrow compared to today. Hence, a consumer who decides to quit would rather quit today than at some point in the future.[11] An agent who consumes will eventually reach the steady-state habit stock $k^{max} \equiv \sum_{t=1}^{\infty} \gamma^{t-1} = \frac{1}{1-\gamma}$, while an individual who abstains approaches $k^{min} = 0$. In the following, we consider the case of naïve present-biased consumers, i.e. the consumers are not aware of their present-bias problem and believe they will behave as time-consistent individuals from the next period on.[12]

Assume consumers differ in their initial habit level k_{ti} and in their self-control β_i. Their initial habit level k_{ti} is independently drawn from a distribution that is characterized by a function K and their self-control β_i is independently drawn from a distribution F. Both K and F are continuous and have strictly positive density over their support $\beta \in (0, 1]$ and $k_t \in [0, k^{max}]$, respectively. Given their habit level k_{ti} and self-control β_i, a consumer would decide to consume if the utility from consumption starting today (i.e. $a_t = 1$ for all periods) exceeds the utility from abstaining starting today (i.e. $a_t = 0$ for all periods) :

$$(14) \quad \bar{v} - p_t - c(k_{ti}) + \beta_i \sum_{\tau=t+1}^{\infty} \delta^{\tau-t}[\bar{v} - p_\tau - c(\sum_{n=1}^{\tau-t} \gamma^{n-1} + \gamma^{\tau-t} k_{ti})]$$
$$\geq -c(k_{ti}) - g(k_{ti}) + \beta_i \sum_{\tau=t+1}^{\infty} \delta^{\tau-t}[-c(\gamma^{\tau-t} k_{ti}) - g(\gamma^{\tau-t} k_{ti})]$$

Intuitively, an individual consumes the sin good if the utility from consumption, less the price and the internality costs in the current and all discounted future periods, are weakly

[11] O'Donoghue and Rabin (2002) show that for stationary preferences this is indeed the only perception-perfect strategy for time-consistent individuals with $\beta = 1$. For consumers with imperfect self-control ($\beta < 1$) there is another perception-perfect strategy where they plan to consume once and abstain thereafter (although they will not actually stop consuming). However, in this context, we do not consider the latter strategy.

[12] Naïve present-bias is a reasonable assumption for consuming soft-drinks as there are no effective commitment devices known that a sophisticated consumer could employ. Instead, time-inconsistent have an incentive to circumvent commitment ex post (by buying soft drinks in any store). See Gottlieb (2008) for a discussion.

larger than the internality and withdrawal costs incurred in this and the following periods due to the current level of k_{ti}.

We ensure a cut-off equilibrium in the sense that, for all k_{ti}, every individual (weakly) above a certain threshold ($\beta_i \geq \tilde{\beta}$) consumes the sin good ($a = 1$) and below the threshold ($\beta_i < \tilde{\beta}$) does not ($a = 0$). Formally, this threshold is defined by equation (14) with equality, or equivalently, by

$$\tilde{\beta} = -\frac{\bar{v} - p_t + g(k_t)}{\sum_{\tau=t+1}^{\infty} \delta^{\tau-t}[\bar{v} - p_\tau - c(\sum_{n=1}^{\tau-t} \gamma^{n-1}) + g(\gamma^{\tau-t} k_t)]}. \tag{15}$$

While the numerator in (15) describes the utility from consumption in the current period and is positive, the denominator describes the utility from consumption in all future periods and is negative.[13] Define the utility from future consumption by Ψ.

To investigate how the cut-off type changes with a surprising price change, we differentiate (15) with respect to the price:

$$\frac{\partial \tilde{\beta}}{\partial p} = \frac{1 + \frac{\delta}{1-\delta}\tilde{\beta}}{\Psi} < 0 \tag{16}$$

For every k_{ti}, a price increase reduces the level of self-control, below which an individual finds it still worthwhile to consume. The reason is that an increasing price decreases utility from consumption today and in all future periods. Hence, we expect a tax hike to decrease consumption and a tax cut to increase consumption.

In the following, we focus on the question whether consumers with high and low levels of self-control are more likely to respond to price changes. Therefore, we differentiate (16) with respect to $\tilde{\beta}$:

$$\frac{\partial^2 \tilde{\beta}}{\partial p \partial \tilde{\beta}} = \frac{\frac{\delta}{1-\delta}}{\Psi} < 0 \tag{17}$$

[13] Define the cut-off implicitly by $J(k_t, \tilde{\beta}) = \bar{v} - p_t + g(k_t) + \tilde{\beta} \sum_{\tau=t+1}^{\infty} \delta^{\tau-t}[\bar{v} - p_\tau - c(\sum_{n=1}^{\tau-t} \gamma^{n-1}) + g(\gamma^{\tau-t} k_t)]$. To ensure existence and uniqueness, we assume that for every k_t, an individual with $\beta \to 0$ consumes the sin good ($J(k_t, \beta) > 0$) and an individual with $\beta = 1$ does not ($J(k_t, \beta) < 0$). If $J(k_t, \beta)$ is monotonically falling in β, the cutoff $\tilde{\beta}$ exists and is unique. We know that this is fulfilled since the denominator in (15) is negative. The proof is by contradiction: Suppose not. Since $\beta \in (0, 1]$, we know that either the numerator or denominator is positive while the other is negative. If the assumption was true, the numerator would be negative and the denominator positive. But since $\gamma \in [0, 1)$, every individual summand in the denominator is smaller than the numerator. However, then the numerator cannot be negative while the denominator is positive, which contradicts the assumption.

For every k_{ti}, a higher level of self-control implies a more negative price responsiveness. The reason is that individuals with high self-control take the future price change more into account. Hence, we predict that consumers with high self-control respond more to taxes than consumers with low self-control.

Result 1. *Consumers with high self-control are more likely to react to price changes than consumers with low self-control.*

Next, we are interested in the question if consumers react symmetrically to a tax hike and a subsequent tax cut. Here, we have to take into account that the habit stock k_t changes from one period to the next. Since we expect more consumers with a high level of self-control to respond to a tax hike (cf. Result 1), there are more high self-control consumers whose habit stock decreases. To make predictions regarding the question whether the response to a tax cut is symmetric, we have to evaluate how the price responsiveness depends on the habit stock.

Therefore, we differentiate (16) with respect to k_t:

$$\frac{\partial^2 \tilde{\beta}}{\partial p \partial k_t} = -\frac{(2\delta\beta + (1-\delta))\sum_{\tau=t+1}^{\infty}(\delta\gamma)^{\tau-t} g'(\gamma^{\tau-t}k_t) + \delta g'(k_t)}{(1-\delta)\Psi^2} < 0 \quad (18)$$

The derivative is negative. Hence, the lower the habit stock, the less negative is the price responsiveness. The intuition is as follows: Suppose an individual with $(\beta_i, k_{ti}) = (\tilde{\beta}, k_{ti})$ consumes. A tax is introduced that increases the price, leading the individual to stop consuming. Hence, the habit stock k_{ti} goes down. In the next period, the tax is repealed, leading the price to return to its original level. However, since the individual now has a lower habit stock, she no longer finds it appealing to resume consumption again. The described effect is more pronounced for individuals with high self-control since, according to Result 1, we expect them to respond more strongly to the tax hike.

Result 2. *The difference in price responsiveness between low and high self-control is smaller when a tax cut follows a tax hike.*