THE FINNISH EXCISE TAX ON SUGAR-SWEETENED BEVERAGES AND ITS EFFECT ON THEIR PRICES AND DEMAND

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ABSTRACT

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Abstract

The consumption of sugar-sweetened beverages (SSBs) is associated with overweight, obesity and related illnesses, such as type 2 diabetes. Excise tax on SSBs is seen as an effective tool to reduce their consumption and improve population health. Because there are possible market failures associated with the consumption of SSBs, taxing them might be preferable to other taxes.

In January 2014, Finland doubled its excise tax rate for SSBs from 0.11 euros to 0.22 euros per litre. Considering the 14 percent ad valorem tax, this translates into a price increase of 0.125 euros. To understand the possible beneficial health effects of the tax, it is essential to estimate, first, its effect on prices (pass-through) and, second, how responsive is consumption to changes in prices (price elasticity of demand). Data, provided by HOK-Elanto, from S-Market stores is used to analyse these two effects. Data consists of daily price and sales records of beverage items from four separate stores for the period 2013-2014.

The pass-through of the tax is estimated by applying the differences-in-differences method. It is estimated that the prices of taxed beverages rose somewhere between 0.17 and 0.19 euros per litre, indicating overshifting of the tax by approximately 36-52 percent. Then, the tax change is used as an instrument for prices to estimate the price elasticity of SSBs, which is estimated to be -0.78 for all SSBs and -0.82 for regular sodas. Obtained pass-through and price elasticity estimates would indicate that the consumption of all SSBs fell by approximately 6.5-7.3 percent and that the consumption of regular sodas fell by approximately 7.5-8.5 percent. The yearly consumption of SSBs was already at a comparatively low level (53.9 litres of regular sodas per capita) prior to the tax change. The tax is calculated to have reduced the yearly consumption by 4.0-4.6 litres.

Key Words
soft drinks, sugar-sweetened beverages, excise tax, pass-through, price elasticity of demand, corrective taxation, public health, overweight and obesity

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Tiivistelmä

Sokerilla makeutettujen juomien kulutus on yhteydessä ylipainoon, liikalihavuuteen ja niihin liittyviin sairauksiin, kuten tyypin 2 diabetekseen. Sokerillisten juomien valmisteveroa pidetään tehokkaana keinona vähentää kulutusta ja parantaa väestön terveyttä. Koska virvoitusjuomien kulutukseen liittyy potentiaalisia markkinahäiriöitä, niiden verotuksella on mahdollista parantaa yhteiskunnallista kokonaishyvinvointia.

Tammikuussa 2014 Suomi kaksinkertaisti virvoitusjuomien valmisteveron sokerillisten juomien osalta 0,11 eurosta 0,22 euroon litralta. Kun otetaan huomioon verosta maksettava 14 prosentin suuruinen arvonlisävero, tämä merkitsee noin 0,125 euron hinnankorotusta sokerillisten juomien osalta. On tärkeää ymmärtää, mikä on veron vaikutus hintoihin (läpikulku), ja toisaalta miten kysyntä reagoi hintojen muutokseen (kysynnän hintajousto). HOK-Elannolta saatua aineistoa juomien päivittäisistä myynneistä ja hinnoista käytetään näiden hinta- ja kysyntävaikutusten analysoimiseksi. Aineisto on peräisin neljästä helsinkiläisestä S-Market myymälästä ja kattaa vuodet 2013-2014.

Veron läpikulkua hintoihin arvioidaan differences-in-differences regressiomenetelmällä, käyttäen eri kontrolliryhmiä. Estimointitulosten mukaan sokerillisten juomien hinnat nousivat suunnilleen 0,17-0,19 euroa litralta, mikä viittaa siihen, että hinnat ylireagoivat veromuutokseen noin 36-52 prosenttia. Tämän jälkeen veromuutosta käytettiin instrumenttimuuttujana hinnalle, sokerillisten juomien hintajouston estimoimiseksi (-0,78 kaikki sokerilliset juomat ja -0,82 sokerilliset virvoitusjuomat). Tulosten mukaan sokerillisten virvoitusjuomien kulutus laski noin 7,5-8,5 prosenttia. Kulutus oli jo suhteellisen alhaisella tasolla (53,9 litraa henkilöä kohden) ennen veromuutosta. Siten veromuutoksen arvioidaan laskeneen vuosittaista kulutusta noin 4,0-4,6 litralla.

Asiasanat
virvoitusjuomat, sokerilla makeutetut juomat, valmistevero, veron hintavaikutus, kysynnän hintajousto, haittavero, kansanterveys, ylipaino ja lihavuus

Säilytyspaikka
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1 INTRODUCTION

1.1 Soft Drink Consumption and Health

Obesity is the cause of many health problems in the world and it has rapidly become more common. Worldwide obesity has nearly tripled since 1975. In 2016, it was estimated that there were over 1.9 billion overweight adults of which 650 million were obese. Obese people have an increased risk[1] of illnesses such as: cardiovascular diseases, type 2 diabetes, multiple cancers and musculoskeletal disorders. (WHO 2017.)

Obesity is a considerable problem in Finland as well, where the latest national-level health study (FINRISKI) was conducted in 2012. At that time, one fifth of both males and females of the working age population (aged 25-64) were obese. In addition, 65 percent of males and 46 percent of females were overweight. (Männistö et al. 2015.)

Sugar-sweetened beverages (SSBs) have been found to be associated with weight gain and diabetes in numerous studies. For example, Mourao, Bressan, Campbell and Mattes (2007) found that sugar-containing soft drinks increased people´s daily intake of energy because they did not produce a sense of satiety corresponding to the calories they contained. Schulze et al. (2004) found an individual level connection between consumption of sugar-sweetened soft drinks and weight gain as well as type 2 diabetes. Basu, McKee, Galea and Stuckler (2013) performed a cross-country comparison of the consumption of soft drinks and occurrence of overweight as well as diabetes involving 75 countries. In their dataset (1997-2010), the consumption of soft drinks per person increased from 36 litres to 43 litres. They estimate that a 1%-increase in the consumption of soft drinks was associated with an increase of 4.8 overweight adults in a

[1] More specifically, Abdullah, Peeters, Courten de and Stoelwinder (2010) find that being obese ($BMI > 30$) causes a 7.19 times larger risk ratio of type 2 diabetes compared to being normal weight ($BMI < 25$). For overweight people ($25 < BMI < 30$) the same risk ratio is 2.99. In turn, Bogers et al. (2007) estimate that the risk ratio of cardiovascular disease is 1.81 times larger for obese people and 1.32 times larger for overweight people.

population of 100 people. The corresponding figures for obese and diabetic adults were 2.3 and 0.3, respectively. Furthermore, two meta-analyses that systematically evaluated other studies concluded that the consumption of soft drinks is associated with weight gain and various health problems (Malik, Schulze & Hu 2006; Vartarian, Schwartz & Brownell 2007).

In addition, sugar-sweetened beverages have a negative effect on dental health. Jensdottir et al. (2004) found that people who drank a lot of soft drinks had a significantly higher risk of dental erosion.

In Finland, the average person consumed around 69 litres of soft drinks in 2016, whereas the average person in EU consumed 95 litres. Figure 1 graphs the evolution of soft drink consumption in Finland, EU and Belgium, which has one of the highest levels of per capita consumption in EU. (UNESDA[2] 2017.)

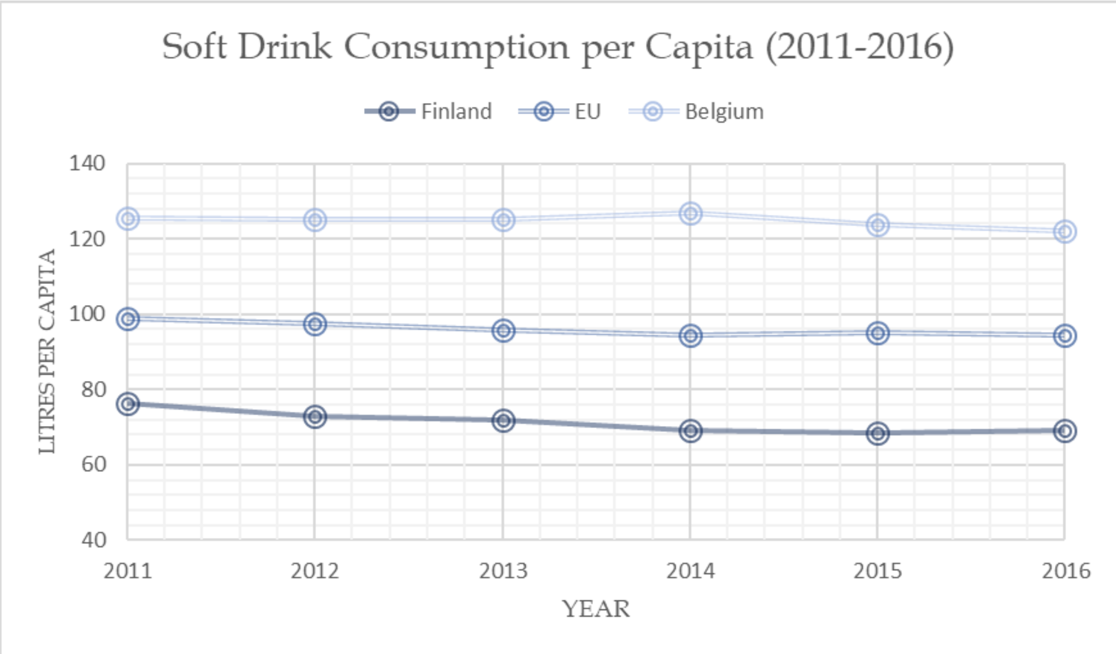

FIGURE 1 Soft drink consumption per capita in Finland, EU and Belgium. (UNESDA 2017.)

The level of soft drink consumption in Finland is around 27 percent lower than the EU average. It is also significantly lower than the levels of the world´s highest consuming countries, which are in the Americas. For example, in the U.S. average person consumes 154 litres of soft drinks, in Mexico average person consumes 137 litres and in Argentina 155 litres. (World Atlas 2017.)

The Finnish consumption of soft drinks has decreased roughly nine percent during the six-year period (2011-2016) from figure 1. One factor contributing to this decrease has been taxation. The Finnish soft drink tax increased three times during this period. First in 2011, it increased from 4.5 cents per litre to 7.5 cents per litre. Then in 2012, it increased from 7.5 cents to 11 cents per litre. This thesis studies the effects of the most recent tax hike that took place in Janu-

[2] UNESDA (Union of European Beverages Association) represents the European soft drinks industry.

ary 2014. Then, the tax for beverages that contained more than 0.5 grams of added sugar per 100 millilitres increased to 22 cents per litre. The tax for all sugar-free beverages remained at 11 cents per litre.

1.2 Taxing Sugar-Sweetened Beverages

Excise tax on SSBs has often been suggested as an effective policy tool to curb the negative effects of excess soft drink consumption (see e.g. WHO 2016). The mechanism by which taxing SSBs could reduce their adverse health effects begins with the tax shifting to prices by some degree. Thus, it is important to have an estimate for the size of the price increase (pass-through rate of the tax). The demand for most goods obeys the law of demand, which states that there is an inverse relationship between quantity demanded and price; when the tax on SSBs causes their price to increase, their demand goes down. However, it is important to have an estimate of the price elasticity of demand, i.e. how large of a reduction in consumption is caused by the tax induced price increase.

To assess the tax´s impact on public health, the reduction in consumption it causes must be linked to beneficial health outcomes. Most of the adverse health effects caused by the consumption of SSBs are due to increased weight gain. Therefore, it seems reasonable to calculate the reduction in average caloric intake associated with the reduction in consumption. These calculations are complicated if there exist other unhealthy, untaxed substitute products; their increased consumption undermines the positive health effects resulting from reduced consumption of taxed products. The Finnish tax covers all SSBs but there may exist other unhealthy food items that are either substitutes or complements to them. Second complication could be that the consumers response to price increase is possibly heterogenous. It might be that people who would benefit the most from reducing their consumption are less sensitive to price increases. Then, the positive health effects may not be as large as the reduction in total consumption implies.

This thesis analyses the effects of the 2014 Finnish tax on 1) prices and 2) demand of SSBs. The second chapter discusses the theoretical and institutional background relevant to this work. It includes discussion about possible market failures associated to soft drinks and how taxation can potentially be used to correct or alleviate them. Then, the specific details of the Finnish tax are discussed. Lastly, the chapter describes some theoretical models about the incidence of taxes, the pass-through rate, and the factors that determine them.

Third chapter summarises the previous empirical research 1) on the pass-through of soft drink taxes and 2) on the price elasticity of demand of soft drinks. In addition, it includes descriptions of important concepts and discussion of likely problems (endogeneity of prices) in demand estimation. Furthermore, it considers the potential problem of unhealthy, untaxed non-beverage items as possible substitutes and complements.

Then, the fourth chapter describes the data and the methods used in this thesis. Data is provided by HOK-Elanto and comes from four of their S-Market stores. It includes daily sales and price records for soft drinks and waters. All their S-Market stores use the same prices and have around 15 percent market share of their region´s (broader Helsinki) grocery trade. Differences-in-differences regression is used to estimate the pass-through rates, while instrumental variables regression is used to estimate the price elasticities of demand.

The fifth chapter discusses the results and presents some rough calculations for the tax´s possible effects on population weight. Based on the pass-through estimations, there is evidence of overshifting of the tax. Prices of SSBs increased of somewhere between 0.17-0.19 euros per litre, indicating overshifting by 36-52 percent. The price elasticity is estimated to be -0.78 for all SSBs and -0.82 for regular sodas. These estimates indicate that the consumption of all SSBs fell somewhere between 6.5-7.3 percent and that the consumption of regular sodas fell by about 7.5-8.5 percent. Based on the pre-tax consumption level of regular sodas (53.9 litres per capita in 2013), their yearly consumption could have fell by 4.0-4.6 litres. The calculated effects on the steady-state of the average population weight are of somewhere between -0.26 and -0.34 kilograms.

Finally, chapter six concludes, and appendix presents some additional figures and tables.

2 THEORETICAL BACKROUND

2.1 Corrective Taxes

Economists have been considering *the excess burden of taxation* since Adam Smith (1776, 825) first wrote in his book the Wealth of Nations: *"Every tax ought to be so contrived, as both to take out and to keep out of the pockets of the people as little as possible, over and above what it brings into the public treasury of the state."* Smith argued that the excess burden of a tax, i.e. the difference between the tax revenue and the amount of money it either takes or keeps out of people´s pockets, should be made as small as possible. The amount of money a tax takes or keeps out people´s pockets is known as the economic burden of the tax. It can be measured as *equivalent* or *compensated variation*. The former is the amount of money people would be willing to pay to avoid the tax entirely and the latter is the amount of money people should be paid so that their after-tax utility would be equal to their pre-tax utility.

Most taxes have an excess burden larger than zero. This is because taxes introduce distortions and wedges between the prices of sellers and buyers. Generally, tax changes cause people to adapt their behaviour to avoid a part of the new tax. If for example the government introduces an increase to the existing soft drink tax for beverages that contain sugar, people will likely consume less sugar-sweetened beverages (SSBs) in the future. Because taxes cause people to change their behaviour, the economic burden of a tax is often larger than its generated revenue. This is the reason why Smith talked separately about the amount of money the tax takes and the amount it keeps out of people´s pockets.

However, sometimes taxes can be used to help correct market failures. *Corrective taxes* can be used as a tool to improve social welfare when consumption or production imposes cost on others. *Negative externality* is a cost that affects a party that did not voluntarily choose to incur that cost. A classic example of a negative externality is pollution. The polluting plant imposes costs on others by impairing the air quality, but these external costs are not reflected in its production decision. Thus, in the case of negative externalities privately optimal level of production exceeds the social optimum. Policy maker can try to correct this by imposing a sufficiently large tax on the producer so that the external costs would be internalised in its production decision.

Other potential source of market failure is *asymmetric information*. Often the parties of a transaction differ in terms of the quality of information they possess. For example, usually firms know more about their products than do customers. Excess consumption of some goods such as alcohol beverages, cigarettes and products with a lot of sugar or fat has harmful effects. Some consumers may have *imperfect information* about the consequences of their consumption decisions and consume too much of the unhealthy products. In addition, these unhealthy products are often addictive. By taxing the unhealthy goods, the policy maker can try to influence consumers to substitute into healthier options.

However, if one assumes that consumers are rational, then the policymaker should only be concerned about the externality-type interpersonal costs. Becker and Murphy (1988) modelled the consumption of addictive goods over time. In their model, many phenomena that were previously thought of as irrational would follow from optimisation under stable preferences. Consumers are *rational addicts*: they understand the full cost of addictive goods, both the current monetary price and the future costs associated with harm and addiction.

On the other hand, assuming all people enjoy this level of rationality might be neither reasonable or realistic. Some consumers may have some degree of *self-control problems*. In the pursuit of immediate gratification, people might act in a way that they themselves would disapprove in the long run. Thus, their present consumption might harm their future selves. This is often formalised as time-inconsistent preferences for immediate gratification. Laibson (1997) was the first to use the following simple and convenient functional form for person´s intertemporal utility in the present-biased preferences research:

$$U^t(u_t, \dots, u_{\mathrm{T}}) \equiv u_t + \beta \sum_{\tau=t+1}^{\mathrm{T}} \delta^{\tau-t}\, u_\tau, \qquad (1)$$

where u_t is agent´s immediate utility at period t. The parameter δ represents the standard discount factor, that is, future consumption is less valuable than present consumption. If β is exactly one, there will be no time-inconsistency and preferences from equation (1) reduce to standard exponential discounting. However, if $\beta < 1$, there will be extra bias for the now over future because the discount factor between two consecutive future periods will be larger than the discount factor between the current and the next period: $\delta > \beta\delta$.

The agent is therefore impatient when facing a choice between now and tomorrow. She would like to also be patient in the future, but the problem is that in the future the future is now, and she will be impatient then as well. This creates conflict between the agent´s current self and future selves. If the agent is *naïve*, she will not know that she will be impatient in the future and changes her plans again and again. At the other extreme, the agent is *sophisticated* and realises that she will change her mind, takes this into account and behaves strategically. (Gruber & Koszegi 2004.)

This type of tendency to behave in a way that your future self would not agree with is commonly referred as *"hyperbolic discounting"*. It may seem surprising but there is some good experimental evidence that most people in fact behave this way in certain situations. In their experiment, Read, Loewenstein and Kalyanaraman (1999) asked their subjects to pick a movie for today, for a week from now and for two weeks from now. They had 24 movie options of which some were fun and simple "lowbrow" movies and some more serious "highbrow" movies. One example of the former was the Groundhog Day and example of the latter was the Schindler´s List. Sixty-six percent of the participants chose a lowbrow movie for tonight but only 37 and 29 percent chose a lowbrow movie for next and second week, respectively.

In a similar fashion, Read and van Leeuwen (1998) asked their subjects whether they would like to have a healthy or unhealthy snack today and similarly for next week. Seventy-four percent of the participants chose the healthy snack for next week, whereas 70 percent chose the unhealthy snack for to be eaten immediately.

Della Vigna and Malmendier (2006) analysed consumer behaviour with a dataset from three U.S. health clubs and find their results hard to reconcile with the standard preference assumption. They learn that members who pay a flat monthly fee of over 70 dollars visit the club on average 4.3 times in a month. This means that they pay over 17 dollars per expected visit, even though they could pay 10 dollars per visit by buying a 10-visit pass. Authors argue that one possible explanation of this behaviour is overconfidence in future self-control.

2.1.1 Sin Taxes and the Self-Control Problem

O'Donoghue and Rabin (2006) investigate the welfare effects of *"sin taxes"* on unhealthy products, such as fatty or sugary foods. They note that with the standard economic approach there is no overconsumption because consumers are assumed to be rational. Then, the only reasons for taxing consumption are raising tax revenue, correcting externalities and redistributing wealth. Things are different, however, when some consumers do not possess a 100 percent full self-control. Authors show that when some consumers have self-control problems, taxing unhealthy products and distributing the tax revenue back to consumers can generally increase the total social surplus.

In their model there are two goods: "potato chips" and a composite good. The production of both goods has constant returns to scale and the units of both goods are normalised to have the same marginal costs. The price of composite good is normalised to one and markets are assumed to be competitive so that marginal costs are also equal to one. In the model potato chips represent a *"sin good"*: a good whose consumption provides immediate enjoyment but negative future consequences, such as bad health. Sugar-sweetened beverages are another good example of such a good.

O'Donoghue and Rabin assume that individual´s instantaneous utility in period t takes the form:

$$u_t \equiv v(x_t;\rho) - c(x_{t-1};\gamma) + z_t,$$

where x_t is the consumption of sin good and z_t is the consumption of composite good. The function $v(x_t;\rho)$ gives the amount of immediate utility from consumption of the sin good and the function $c(x_{t-1};\gamma)$ gives the negative health consequences from past consumption. They assume decreasing marginal benefits to consumption but allow marginal health costs to be increasing, constant or decreasing. Parameters ρ and γ represent population heterogeneity in tastes. Authors assume that $v_{x\rho} > 0$, so higher value of ρ means higher marginal benefit of consumption and that $c_{x\gamma} > 0$, so higher value of γ means higher marginal health costs.

They use equation (1) to represent the individual´s preferences. In every period, the individual chooses his desired level of consumption (x, z) to maximize her utility:

$$u^*(x,z) \equiv v(x;\rho) - \beta c(x;\gamma) + z, \tag{2}$$

subject to budget constraint: $x + z \leq I$, where I is the per-period income. The authors refer the case of $\beta < 1$ as a "self-control problem" because it represents a short-term desire that the individual disapproves in every future period.

O'Donoghue and Rabin write the individual´s long term utility as

$$u^{**}(x,z) \equiv v(x;\rho) - c(x;\gamma) + z, \tag{3}$$

where β is now equal to one. They note that the individual is not maximising her own welfare or experienced utility $u^{**}(x,z)$, instead, she is maximising her decision utility $u^*(x,z)$ and these differ when $\beta < 1$. The optimal best long run allocation for the individual comes from maximising equation (3) subject to constraint $x + z \leq I$. This yields the following first order conditions:

$$v_x(x^{**};\rho) - c_x(x^{**};\gamma) - 1 = 0 \tag{4}$$
$$z^{**} = I - x^{**}. \tag{5}$$

Now, O'Donoghue and Rabin consider the effects of taxes. Without taxes the price of sin good was $p_x = 1$. Then, the government introduces new per-unit excise tax t for the sin good making the new price $p_x = 1 + t$. The government pays the tax revenue back to consumers in the form of a lump-sum transfer ℓ making the new budget constraint $(1+t)x + z \leq I + \ell$. When the individual has self-control problems, she maximises equation (2) instead of (3); with the new budget constraint this yields the following first order conditions:

$$v_x(x^*(t);\rho) - \beta c_x(x^*(t);\gamma) - (1+t) = 0 \tag{6}$$
$$z^*(t,\ell) = I + \ell - (1+t)x^*(t). \tag{7}$$

From these conditions, one can see that self-control problem ($\beta < 1$) leads to overconsumption of the sin good in the absence of taxes ($t = 0$). In other words, the actual potato consumption $x^*(0)$ is larger than the long-term optimum x^{**} for people with self-control problems. This can be interpreted as a negative externality imposed to future selves by current consumption. Current self does not account for the whole of future costs because she ignores a proportion $(1 - \beta)$ of them.

If the population is homogenous in terms of the parameters β, ρ and γ, a simple tax and transfer policy can be used to correct the problem of overconsumption. It can be easily seen that a tax rate of $t^{**} = (1 - \beta)c_x(x^{**})$ will induce the consumers to choose $x^*(t^{**}) = x^{**}$.

In the remainder of their paper, O'Donoghue and Rabin analyse situations where there is heterogeneity in the population. They find that when only some people have self-control problems, it is still optimal to tax the sin good; tax induced distortions for fully self-controlled people are a second order of magnitude compared to the benefits for people with overconsumption problems.

Furthermore, the authors consider the Pareto efficient taxation of sin goods. They find that with quite reasonable assumptions, *it is possible to tax sin goods in a way that on average will help both the people who have self-control problems and the people who do not*. Intuitively, this can happen because taxes benefit the people who suffer from self-control problems by counteracting their tendencies to overconsume and people with full self-control by redistributing income. The latter effect is possible because people with self-control problems will consume more of the sin good and thus pay larger share of the tax. In certain situations, sin good taxes may even constitute a Pareto improvement.

Finally, O'Donoghue and Rabin discuss the applicability and limitations of their results. First, they note that the condition $\beta < 1$ can interpreted in the context of other behavioural models as well. The individual can, for example, be irrationally optimistic about the future health costs, or she may otherwise under-appreciate them and $\beta < 1$ can be interpreted as a degree of this optimism or under-appreciation.

The authors also consider the distinction between "cognitive" and "visceral" motivations as explanations of consumer behaviour. If visceral or emotional motivations explain large part of consumer behaviour, consumption might be relatively price insensitive. In this case, taxes might just further punish people with overconsumption problems. This may especially be a problem when the sin good in question is addictive.

One important limitation the authors consider is when there are substitutes available for the taxed sin good. Then, if the government is not taxing those substitutes, taxation is not going be very effective. It may even prove harmful if the substitutes in question are unhealthier than the taxed good.

In a related work, Haavio and Kotakorpi (2011) analyse the political economy and determination of such taxes. They show that optimal sin taxes will typically exceed the average distortion caused by self-control problems in the economy. Authors remark that this is due to asymmetric effects the tax causes to people with severe self-control problems on the one hand and to rational individuals on the other hand. Under the assumption that the demand of irrational large-scale consumers is in absolute terms more elastic than the demand of rational low-scale consumers, the positive welfare effects of taxation on irrational consumers exceed the negative distortions caused to rational consumers.

However, the median voter does not take these asymmetries into account. Thus, *the majority voting equilibrium tends to be below the socially optimal level of taxation*. The authors argue that this difference is quite small when the harmful effects of consumption are mild. At low levels of harm, the redistributive effects of sin taxes work well in aligning the median voters´ preferences with those of a utilitarian social planner. Instead, when the harmful effects of consumption are severe, these redistributive effects contribute to a larger difference between the equilibrium and social optimum. Now, the median voter consumes very little or none of the harmful good and is mainly interested in maximising tax revenue and the redistribution of income from large-scale consumers to herself. In this case, the socially optimal sin tax is very high and likely exceeds the tax rate that maximises revenue.

Throughout their analysis, Haavio and Kotakorpi assume that individuals are sophisticated: they are aware of their self-control problems and value sin taxes as a useful self-control device. If some individuals are instead fully or partially naïve, they prefer lower levels of taxation and the problem of too low equilibrium sin tax rates is exacerbated.

2.1.2 Soft Drinks and Market Failure

As discussed in the first chapter, excess consumption of SSBs is associated with numerous negative health outcomes. Soft drinks are particularly connected to increased overweight and obesity, type 2 diabetes and deteriorating dental health. One consequence of excess consumption is, thus, increased *contemporaneous* health care costs. Because Finland has a tax-payer funded public health care system, these costs are not entirely borne by the individuals themselves. It should be noted, however, that it is not clear whether *life time* health care costs for obese people will be higher because they live on average about 9 years less than non-obese people (Morris 2007).

There are three possible types of sources of market failure in SSBs: externalities, imperfect information and time-inconsistent preferences or consumer irrationality. These and the associated rationales for government intervention will be discussed in turn. Individuals do not typically try to maximise their life-expectancy but their general well-being. Soft drinks may be unhealthy, but they taste good and people want to drink them regardless. If consumers are rational, fully informed about the risks and bear the full costs of their decisions, there is no basis for government intervention. However, it may be that excess consumption of soft drinks has a negative externality in the form of increased health care costs.

Finnish National Institute for Health and Welfare calculated that obesity and related illnesses cost 330 million euros in 2011. They also note that the estimated health care costs of obese people are 25 percent higher than those of people with normal weight. (Männistö, Laatikainen & Vartiainen 2012.) It is hard to tell whether the fact that obese people die younger is taken into consideration for these calculations. For example, van Baal et al. (2008) found with their simulation model that, although decrease in obesity leads to smaller health care costs from obesity-related illnesses, this is completely offset by increased costs from other non-obesity-related illnesses due to increased life expectancy.

However, it is also possible that the traditional OLS-estimates for the health care costs of obesity are biased because of the endogeneity of overweight and the measurement error in reported weight. To correct for this bias, Cawley and Meyerhoefer (2012) use the weight of a biological relative as an instrument for reported weight. Their IV-estimate of health costs is roughly four times higher than the corresponding OLS-estimate.

If obesity causes increasing health care costs, then unhealthy foods, such as sugar-sweetened beverages, have a negative externality. Their privately optimal level of consumption exceeds the socially optimal level because individuals do not pay the full costs of their actions. To determine the size of the possible externality, one should have some insight about the relationship between weight gain and the consumption of SSBs.

In their meta-analysis Vartarian et al. (2007) looked at 88 different studies about the effects of soft drink consumption on nutrition and health. First, they find clear and consistent evidence that people do not compensate for the added calories they get from soft drinks by reducing calories from other sources resulting in added energy intake. Second, they conclude that there is clear evidence that soft drink consumption is connected to increased body weight and adverse health outcomes, such as type 2 diabetes and hypocalcaemia. They note that estimated weight gain effects were stronger in experimental and longitudinal versus cross-sectional studies.

In addition to externalities, there is the possibility that some consumers have imperfect information about the negative health effects of SSBs. Most adults likely know that consuming high amounts of sugar is not particularly healthy. There is in fact a large market for diet or sugar-free sodas. In Finland, their share of total consumption was 31 percent in 2016, which is larger than the EU-average of 23 percent. In 2014, when the tax for sugar-sweetened soft drinks was introduced, their consumption share increased from 25 percent to 30 percent. (UNESDA 2017.)

However, some groups of consumers might be especially vulnerable and not know or think about the adverse health consequences. Children and younger people could be a good example of such a group. Bad nutritional choices are often quite persistent; for example, Whittaker, Wright, Pepe, Seidel and Dietz (1997) found that children who were obese at the age of six had a 50 percent chance of being obese when they were adults. It is possible that younger people are more sensitive to price changes (see e.g. Ding 2003). In this case, taxing sugar-sweetened beverages would be an effective tool for alleviating this problem.

Finally, it is possible that some people have time-inconsistent preferences (the self-control problem discussed earlier). This type of lack of rationality can be thought as another rationale for government intervention. However, soft drinks are not particularly addictive, so it is not clear how serious these type of self-control problems are in their case. One piece of evidence that could indicate the presence of this problem, is that most people would in fact like to lose weight but seem not to be able to do so. In a recent survey, only 22 percent of Finnish men and 16 percent of women were happy at their current weight. Eighty-three percent of Finnish women and 71 percent of men would have liked to lose some weight. (Tiessalo 2017.)

This combined with the fact, as emphasized by Mourao et al. (2007), that dietary compensation for beverages is weaker than for solid foods with comparable nutrient content. In addition, Willett and Ludwig (2013) find that consumption of sugar in beverages does not produce the satiety compared to sugar in solid form. This means that calories from soft drinks are not as likely to be compensated by reducing the caloric intake from other food sources. Mourao et al. note that the reason for this is that beverages have a weaker effect on satiety[3] than satiation. Because soft drinks have a weaker effect on satiety, they increase the risk of overconsumption and weight gain.

If part of the reason why people are not able to lose the amount of weight they would like is connected to self-control problems, taxes can be used as a valuable self-control device. In some cases, appropriately planned taxes could then be used to increase social welfare as discussed in the previous section.

High excise taxes on unhealthy products are often criticised for being *regressive*: taxes hurt low-income people more because they spend a larger share of their income. However, this loss could be compensated with complementary transfer and benefit -schemes. Furthermore, Kotakorpi (2008) shows that when people have self-control problems these type of sin taxes can be even *progressive*. With fully rational consumers, the burden of a tax falls most heavily on individuals with highest level of consumption. On the other hand, when people have self-control problems a tax hike has two effects: a monetary cost and a self-control benefit. If self-control benefits increase more rapidly[4] than monetary costs, the tax falls, in fact, least heavily on those with high levels of consumption.

2.1.3 The Finnish Soft Drink Tax

The Finnish soft drink tax came into force for the first time in 1940. At that time, products made from domestic fruit, berries and vegetables were exempt from the tax. In recent years, the tax has been raised three times. In 2011, the tax rose from 4.5 cents per litre to 7.5 cents per litre and in the next year it was raised

[3] Satiety refers to a physical feeling of fullness and satiation refers to end of desire to eat after a meal.

[4] This is more likely if self-control problems are: extensive, consumption causes a lot of harm, demand is more elastic for low-income individuals or future utility is discounted little.

further to 11 cents per litre. At that point, the tax was the same size for sugar-free products and for sugar-sweetened products. (Ministry of Finance 2013.)

This thesis analyses the effects the most recent change that took place in 1st of January 2014. Then, the tax was raised to 22 cents per litre for those beverages that contain over 0.5 grams of sugar per 100 millilitres. The tax applies to a large number of different types of products. In practice all non-alcoholic beverages, apart from milk, are subject to the tax. (HE 109/2013.)

The tax raised 144 million euros in revenue in 2016 (Ministry of Finance 2017). Table 1 compares the Finnish tax to similar taxes that have been introduced around the world. Finland has one of the largest nationwide taxes for sugar-sweetened beverages. It is comparable in size to the one that was in place in Denmark, before it was abolished in 2014.

TABLE 1 Similar excise taxes for soft drinks from around the world

Country/state	Taxed products	Tax size per litre	Tax size/litre in USD	PPP USD2	PPP-adjusted tax size
Finland	Sugar-sweetened beverages	€0.22	$0.243	0.905	0.24
Finland	Sugar-free beverages	€0.11	$0.122	0.905	0.12
France	All Sweetened beverages	€0.075	$0.083	0.804	0.09
Mexico	Sugar-sweetened beverages	MXN 1	$0.054	8.570	0.12
Berkeley, CA	Sugar-sweetened beverages	$0.34	$0.34	1	0.34
Denmark1	Soft drinks	DKK 1.64	$0.243	7.263	0.23

1 Denmark´s soda tax before it was abolished in 2014. 2 Data for exchange rates and purchasing power parities from (OECD 2016).

It was mentioned earlier that if there are unhealthy substitutes that are exempt from the tax, its effects on public health are limited. The Finnish tax on SSBs applies to a broad range of products and there are no unhealthy, untaxed substitute beverages but it is conceivable that there could be other non-beverage food items that are either substitutes or complements to SSBs. This potential complication is discussed in more detail in section 3.2.4.

Moreover, the effects of the tax on nutrition may be limited for a couple of other reasons. First, the beverage manufacturers do not have an incentive to reduce the sugar content of their products, unless they can get it down to 0.5 g/100 ml threshold[5]. Most soft drink manufacturers have sugar-free versions of their products that have at most 0.5 g/100 ml sugar content. In fact, it seems that the Finnish manufacturer Hartwall changed the recipe of one its product because of the tax change. Hartwall´s soda Jaffa Ananas Light had two percent of sugar before the tax but zero percent after. Second, although the tax provides consumers an incentive to substitute their consumption to sugar-free beverages,

[5] The tax on regular Coca-Cola (10.6% sugar) is the same size as the tax on fructose-sweetened waters, for example, Hartwall´s Novelle Friss (2% sugar).

it creates no incentive to switch to products that have less added sugar, unless the product´s sugar content is less than the tax threshold.

If it were feasible to tax nutrients such as sugar, taxes could have even larger effects on people´s nutritional intake. These kind taxes would have a broader tax base: all products containing the nutrient taxed would be liable to the tax. Furthermore, if the amount of the tax depended linearly of the sugar content, the manufacturers would have a powerful incentive to reduce the sugar content of their products. Harding and Lovenheim (2017), using a large sample of US consumer transactions, learn from their analysis that nutrient-based taxes have larger impact on consumer behaviour than do product-based taxes because of their broader base. Importantly, they also find that their costs in terms of consumer utility are not higher.

Originally, the Finnish tax was a more general "sweets tax" and had a broader base of taxed products. These included candies as well as ice cream but importantly biscuits were exempt from the tax. This lead to some manufacturers to categorise their candy-like products as biscuits. Then, in 2015, the EU commission deemed the tax as discriminatory and distorting competition. Therefore, it was abolished in 2017 for candies and ice cream but not for beverages.

As mentioned, the Finnish tax applies to beverages without sugar as well. These include natural and mineral waters unless the size of the retail package is over five litres. It is difficult to imagine legitimate reasons for taxing bottled water in this way. Regarding the artificially sweetened beverages, it is argued in the justifications of the law that it is reasonable to continue their taxation because their adverse effects on dental health (HE 109/2013).

Finally, it is important to consider how different taxes influence the prices together. The Finnish soft drink tax is a *specific* tax: its size depends only on the volume of the product and not its price. If the price p is measured in litres, its price after tax t will be $p + t$. In addition, Finland has a 14 percent *ad valorem* tax on food. Value added tax is a certain percentage τ of product´s price. It raises product´s price p to $p(1 + \tau)$. Then, the soft drink tax change in 2014 raised the price of affected products depending on their volume V by $1.14 * (V * €0.11)$. In prices per litre, this would be approximately 12.5 cents. This translates into roughly 6 percent of the mean pre-tax per litre price[6] of SSBs.

2.2 Tax Pass-Through and Incidence

To assess the potential impact of a single tax reform, it is essential to know how the tax affects the prices of taxed products. This is usually referred by economists as the *pass-through rate* of the tax. Full pass-through of a tax is where pric-

[6] Sales weighted average of the pre-tax price per litre was €2.03 for all SSBs, €1.84 for regular sodas and €1.63 for products with sugar-free versions.

es rise by exactly the amount of the tax. Taxes can also *under*- or *overshift* to prices depending on the market conditions.

The *incidence* of taxation refers to the fact who ultimately bears the economic burden of the tax. This cannot be deduced from the fact who is legally obliged to pay the tax. When prices respond little to a tax change, producers bear most of the economic burden of the tax. The opposite is true when prices are very responsive to the tax change. In this case, consumers face the economic burden of the tax.

2.2.1 Perfect Competition

When the government chooses to raise the excise tax for certain products, the effect on prices depends on the interaction between producers, retailers and consumers. If one assumes perfect competition, the incidence of taxes depends on the relative elasticities of supply and demand. In the normal case[7], the more *elastic* (inelastic) is demand (supply) the smaller is the share of the tax that passes through to prices. Conversely, the more *inelastic* (elastic) is demand (supply) the larger is the share of the tax that passes through to prices. (Fullerton & Metcalf 2002.)

In the short run, full pass-through is only possible if either demand is perfectly inelastic or supply is perfectly elastic (constant marginal costs). In the long run, entry of new firms makes the supply completely elastic and prices shift the full amount of the tax. (Fullerton & Metcalf 2002.)

Weyl and Fabinger (2013) analyse[8] tax incidence under perfect competition, monopoly and symmetric and general models of imperfect competition. They frame their analysis in terms of *economic vs. physical incidence*, *split of tax burden*, *local incidence formula*, *pass-through* and *global incidence*.

Under perfect competition, the equilibrium quantities are given by $D(p_c) = S(p_s)$, where p_c is price paid by consumers and p_s is the price received by the suppliers. They differ by the amount of the tax $p_s = p_c - t$. It makes no difference whether consumers or producers are obliged to the pay the tax; *the physical incidence does not affect economic incidence*.

As is conventional, Weyl and Fabinger use the notation where producers pay the tax and then some of it is shifted to consumers. They denote p as the price paid by consumers and $p - t$ as the price received by producers. Pass-through $\rho \equiv \frac{dp}{dt}$ is the rate at which consumer prices respond to a tax change. This implies that when a tax is levied from consumers, the price received by producers falls by the amount of $1 - \rho$.

With perfectly competitive markets, consumers and producers take prices as given and choose quantities to maximise their welfare. Then, the consumer surplus can be measured as $CS(p) = \int_p^\infty D(x)dx$ and the producer surplus as

[7] Referring to situations where demand curves slope down and supply curves slope up.

[8] Throughout their analysis Weyl and Fabinger (2013) assume, for simplicity, that demand and supply functions are smooth and that excess supply declines in price so that there is a unique equilibrium.

$PS(p-t) = \int_0^{p-t} S(x)dx$. Now, the consumer surplus responds to taxes by $\frac{dCS}{dt} = -\rho Q$ and the producer surplus by $\frac{dPS}{dt} = -(1-\rho)Q$, where Q refers to the equilibrium quantity. This means that the *tax burden is split among consumers and producers by the ratio* $I = \rho/(1-\rho)$, which measures the share borne by consumers relative to share borne by producers. This is the formula for *local incidence*, which means infinitesimal tax changes starting from zero.

Next, the authors consider the factors that determine the pass-through rate ρ. From the equilibrium $D(p) = S(p-t)$, beginning at zero tax rate and differentiating leads to:

$$\frac{dD(p)}{dp}\frac{dp}{dt} = \left(\frac{dp}{dt} - \frac{dt}{dt}\right)\frac{dS(p-t)}{d(p-t)} = D'(p)\rho = (\rho-1)S'(p-t)$$
$$\Rightarrow \big(S'(p-t) - D'(p)\big)\rho = S'(p-t)$$
$$\Rightarrow \ \rho = \frac{S'}{S'-D'} \ \Rightarrow \ \rho = \frac{S'p/Q}{S'p/Q - D'p/Q} = \frac{1}{1+\epsilon_D/\epsilon_S}, \tag{8}$$

where $\epsilon_D \equiv -(D'p/Q)$ is the elasticity of demand and $\epsilon_S \equiv S'p/Q$ is the elasticity of supply. Alternatively, one can use the fact that the change in quantity demanded due to the tax equals the change in quantity supplied: $\Delta Q_D = \Delta Q_S$. Then,

$$\frac{dS(p-t)}{d(p-t)}\frac{d(p-t)}{dt} = \frac{dD(p)}{dp}\frac{dp}{dt}.$$

Now, multiplying both sides with the equilibrium $\frac{p^*}{Q^*}$ leads to:

$$\frac{dS(p-t)}{d(p-t)}\frac{p^*}{Q^*}\frac{d(p-t)}{dt} = \frac{dD(p)}{dp}\frac{p^*}{Q^*}\frac{dp}{dt} \Longrightarrow \epsilon_S(\rho-1) = -\epsilon_D\rho$$
$$\Longrightarrow \rho(\epsilon_S + \epsilon_D) = \epsilon_S \Longrightarrow \rho = \frac{\epsilon_S}{\epsilon_S+\epsilon_D} = \frac{1}{1+\epsilon_D/\epsilon_S}.$$

From the above expression (8), it can be seen that *the pass-through is a decreasing function of* ϵ_D *and an increasing function of* ϵ_S; the higher the elasticity of demand relative to supply, the lower the pass-through and, conversely, the higher the elasticity of supply relative to demand, the higher the pass-through rate. From this expression, one can also see that under perfect competition, *pass-through can never exceed unity*. However, as will be discussed in the next sections, under imperfect competition taxes can under-, fully- or overshift to prices.

Finally, Weyl and Fabinger discuss how to integrate these local results into finite or global tax changes. They consider a tax increase from t_0 to t_1. With market equilibrium and pass-through rate as functions of tax, this implies that changes in consumer and producer surpluses can be written as

$$\Delta CS_{t0}^{t1} = -\int_{t0}^{t1} \rho(t)Q(t)dt$$
$$\Delta PS_{t0}^{t1} = -\int_{t0}^{t1} [1-\rho(t)]Q(t)dt.$$

They then define the *quantity-weighted average pass-through* between t_0 and t_1 to be:

$$\bar{\rho}_{t0}^{t1} \equiv \frac{\int_{t0}^{t1} \rho(t)Q(t)dt}{\int_{t0}^{t1} Q(t)dt},$$

and incidence between t_0 and t_1 as $I_{t0}^{t1} \equiv \Delta CS_{t0}^{t1}/\Delta PS_{t0}^{t1}$. After combining these, they have:

$$I_{t0}^{t1} = \frac{-\int_{t0}^{t1} \rho(t)Q(t)dt}{-\int_{t0}^{t1}[1-\rho(t)]Q(t)dt} = \left(\frac{\frac{\int_{t0}^{t1} \rho(t)Q(t)dt}{\int_{t0}^{t1} Q(t)dt}}{1-\frac{\int_{t0}^{t1} \rho(t)Q(t)dt}{\int_{t0}^{t1} Q(t)dt}}\right)\left(\frac{\int_{t0}^{t1} Q(t)dt}{\int_{t0}^{t1} Q(t)dt}\right) = \frac{\bar{\rho}_{t0}^{t1}}{1-\bar{\rho}_{t0}^{t1}}.$$

When comparing this to the formula for incidence in the case of infinitesimal taxes, one can see that the pass-through rate ρ is replaced with the quantity-weighted average pass-through rate $\bar{\rho}_{t0}^{t1}$ over the range of the finite change. If one considers the smallest tax rate $\bar{t}$ than eliminates all possible gains from trade so that $Q(\bar{t}) = 0$, then the average quantity weighted pass-through rate is $\bar{\rho} \equiv \bar{\rho}_0^{\bar{t}}$ and the global incidence of the market is $\bar{I} = CS/PS = \bar{\rho}/(1-\bar{\rho})$.

Additionally, Weyl and Fabinger importantly point out the factors that determine the pass-through - relative elasticities of supply and demand - also determine the global division of surplus. When demand (supply) is globally more elastic than supply (demand), most of the market´s surplus will accrue to suppliers (demanders). If the pass-through rates do not vary that much as the tax rates change, then taxing a market hurts most the side that benefits the most from its existence in the first place.

2.2.2 Monopoly

Next, Weyl and Fabinger (2013) consider the case of monopoly. Monopolist has a cost function $C(q)$ and faces the inverse demand curve $p(q)$. Her revenues are then $p(q)q$ with marginal revenue $MR(q) = p(q) + p'(q)q$ and marginal cost $MC(q) = C'(q)$. Now, a tax on consumers reduces the price received by the monopolist by the amount of the tax $p - t$ and a tax on producers raises marginal costs uniformly $C'(q) + t$. Monopolist maximises her profits by equating her marginal revenue and cost $p(q) + p'(q)q = C'(q)$. Therefore, as is the case under perfect competition, it does not matter which side physically pays the tax in terms of its incidence.

Because consumer continue to be price takers under monopoly, their surplus still responds to tax changes in the same way as with perfect competition $dCS/dt = -\rho q$. Monopolist maximises her profit function $[p(q) - t]q - c(q)$. Using the envelope theorem, one can write how producer surplus responds to change in taxes: $dPS/dt = -q$. In this case, the tax is not simply shared between consumers and producers. Instead, the monopolist pays the burden of the tax fully out of her welfare, but consumers also bear an excess burden. The size of this excess burden per-unit of tax revenue raised is the pass-through rate ρ. Thus, the incidence of the tax is now $I = \rho$.

With the tax, monopolist maximises profits by equating $MR(q) = MC(q) + t$. Differentiating this respect to t leads to

$$MR' \frac{dq}{dt} = MC' \frac{dq}{dt} + \frac{dt}{dt} \Rightarrow \frac{dq}{dt} = \frac{1}{MR'-MC'}$$
$$\Rightarrow \rho = \frac{dp}{dt} = \frac{dp}{dq}\frac{dq}{dt} = \frac{p'}{MR'-MC'}. \tag{9}$$

Weyl and Fabinger point out that marginal revenue $MR = p + p'q$ consists of two terms: the price p and the negative of the marginal consumer surplus $MCS \equiv -p'q$. Substituting this into (9) leads to

$$\rho = \frac{p'}{p'+MCS'} = \frac{1}{\frac{p'-MCS'}{p'} - \frac{MC'}{p'}} = \frac{1}{1 - \frac{MCS'qp}{q*MCS*p'}\frac{q*MCS}{qp} - \frac{MC'qp}{p'q*MC}\frac{q*MC}{qp}}$$
$$\Rightarrow \rho = \frac{1}{1 + \frac{\epsilon_D}{\epsilon_{MCS}}\frac{MCS}{p} + \frac{\epsilon_D}{\epsilon_S}\frac{MC}{p}}, \tag{10}$$

where $\epsilon_D = -(p/p'q)$ is the elasticity demand, $\epsilon_S = MC/MC' * q$ is the elasticity of the inverse marginal cost curve and $\epsilon_{MCS} = MCS/MCS' * q$ is the elasticity of the inverse marginal surplus function.

The expression (10) for pass-through can be further simplified using the fact that

$$\frac{MCS}{p} = -\frac{p'q}{p} = \frac{1}{\epsilon_D},$$

and the fact that monopolist sets her price to maximise her profits by equating marginal revenue and cost

$$MR = p\left(1 + \frac{1}{\frac{p}{p'q}}\right) = MC \Rightarrow MC = p - \frac{p}{\epsilon_D} \Rightarrow \frac{MC}{p} = 1 - \frac{1}{\epsilon_D} = \frac{\epsilon_D - 1}{\epsilon_D}.$$

Substituting these into (10) yields:

$$\rho = \frac{1}{1 + \frac{\epsilon_D - 1}{\epsilon_S} + \frac{1}{\epsilon_{MCS}}}. \tag{11}$$

There are two differences in this expression for pass-through when compared to the one with perfect competition. First, in the place of ϵ_D there is now $\epsilon_D - 1$. However, as Weyl and Fabinger mention, monopolist always operates in the part of demand curve were elasticity of demand is above unity, so this does not change any previous qualitative results or introduce any new determinants of pass-through.

Second, there is an entirely new term $\frac{1}{\epsilon_{MCS}}$, which is the inverse elasticity of marginal surplus. Authors point out that ϵ_{MCS} measures the curvature of the logarithm of demand because[9]

$$\frac{d(\log D(p))}{dp} = \frac{D'(p)}{D(p)} = \frac{q'(p)p'(q)}{p'(q)q} = \frac{1}{p'(q)q} = -\frac{1}{MCS}$$

so that

$$\frac{d^2(\log D(p))}{dp^2} = -\frac{dMCS^{-1}}{dp} = MCS^{-2}\frac{dMCS}{dp} = MCS^{-2}\frac{dMCS}{dq}\frac{dq}{dp} = \frac{MCS'}{MCS^2}\frac{1}{p'}$$
$$\Rightarrow \frac{d^2(\log D(p))}{dp^2} = -\frac{1}{\epsilon_{MCS}}\frac{1}{MCS}\left(-\frac{1}{p'q}\right) = -\frac{1}{\epsilon_{MCS}}\frac{1}{MCS^2}.$$

Concave functions have a negative second derivative and, contrary, convex functions a positive second derivative. Thus, log-concave demand always has $1/\epsilon_{MCS} > 0$ and log-convex $1/\epsilon_{MCS} < 0$.

Another important threshold is $1/\epsilon_{MCS} > 1$ for concave demand and $1/\epsilon_{MCS} < 1$ for convex demand. This follows from

$$\frac{1}{\epsilon_{MCS}} = \frac{MCS'q}{MCS} = \frac{(p''q + p')q}{p'q} = 1 + \frac{p''q}{p'},$$

given that $q > 0 > p'$; then, if $p'' < 0$ (concave demand), the second term is positive and $1/\epsilon_{MCS} > 1$; conversely, if $p'' > 0$ (convex demand), the second term is negative and $1/\epsilon_{MCS} < 1$. Therefore, the pass-through under monopoly depends also on the convexity of demand. The more positively log-curved the demand, the higher is the pass-through. Under monopoly, if costs are linear, *pass-through can exceed unity* if the term $\frac{1}{\epsilon_{MCS}}$ is negative and large enough in absolute value so that the denominator in (11) becomes smaller than one.

Finally, Weyl and Fabinger use the same logic as with the case of perfect competition to extent the local incidence results to allow finite and global tax changes. They note that the relevant average pass-through rate is now the *markup-weighted average pass-through*:

$$\tilde{\rho}_{\tilde{q}0}^{\tilde{q}1} \equiv \frac{\int_{\tilde{q}0}^{\tilde{q}1} \rho(\tilde{q})m(\tilde{q})d\tilde{q}}{\int_{\tilde{q}0}^{\tilde{q}1} m(\tilde{q})d\tilde{q}},$$

where $\tilde{q}$ is exogenous entrance of more of the same good into the market; see Weyl and Fabinger (2013) for details.

[9] Third equality sign comes from the fact that the product of the derivative of the function and the derivative of its inverse is equal to one; known as the inverse function theorem: $(f^{-1})(y) = 1/f'(x)$.

2.2.3 Symmetric Oligopoly

Thirdly, Weyl and Fabinger (2013) consider incidence under symmetric, imperfect competition. There are n firms in the industry, indexed by i, each producing a single good. These products can be different from one another, but the demand system is assumed symmetric.

Every firm has the same cost function $C(q_i)$ associated with producing quantity q_i. Marginal cost is the derivative of the cost function $MC(q_i) \equiv C'(q_i)$. The market price for which each firm sells its product depends on the quantities[10] produced and sold by all firms q_j with $j \in \{1,2 \dots, n\}$.

Weyl and Fabinger define, again, the elasticity of market demand as $\epsilon_D \equiv -(p/p'q)$. The authors also utilise the elasticity adjusted Lerner index $[(p - MC - t)/p]\epsilon_D$ in their analysis by setting it equal to a *conduct parameter* θ. They use this condition to model firm conduct rather than model it directly.

First, as before, economic incidence of taxes is independent of physical incidence. Likewise, one can again apply envelope theorem to consumers and see how consumer surplus responds to taxes $dCS/dt = -\rho Q$. This cannot be done with firms since they are nor price-takers nor joint profit-maximising price-setters. The incidence on firms must, thus, be computed.

Symmetric profits for each firm are $[p(q) - t]q - c(q)$. Using the fact that

$$\rho = \frac{dp}{dt} = \frac{dp}{dq}\frac{dq}{dt} = p'\frac{dq}{dt} \Rightarrow \frac{dq}{dt} = \frac{\rho}{p'}$$

leads to the impact on per-firm producer surplus ps:

$$\begin{aligned} \frac{dps}{dt} &= \left(\frac{dp}{dt} - \frac{dt}{dt}\right)q + (p - t)\frac{dq}{dt} - \frac{dC(q)}{dq}\frac{dq}{dt} \\ \Rightarrow \frac{dps}{dt} &= (\rho - 1)q + (p - t)\frac{\rho}{p'} - MC\frac{\rho}{p'} \\ &= \left(\rho - 1 - \rho\frac{p-t-MC}{p}\frac{p}{-p'q}\right)q \\ &= -[1 - \rho(1 - \theta)]q, \end{aligned} \tag{12}$$

where $\theta \equiv [(p - MC - t)/p]\epsilon_D$.

Aggregating (12) across firms leads to $dPS/dt = -[1 - \rho(1 - \theta)]Q$. Weyl and Fabinger point out that this is just a linear combination[11] of perfect competition and monopoly-formulas with weights $1 - \theta$ and θ, respectively. From this formula, one can see that firms less than fully bear the cost of tax if $\theta < 1$ because then $dPS/dt > -Q$, and that they more than fully bear the cost of tax if $\theta > 1$ because then $dPS/dt < -Q$. In addition, the tax has an excess burden if

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[10] If these quantities are set to be the same number q, then the corresponding price is $p(q)$. Its derivative $p'(q)$ captures how the price changes in response to an infinitesimal, symmetric increase in all quantities.

[11] $-(1 - \rho)Q(1 - \theta) - Q\theta = -Q + \rho Q + Q\theta - \rho Q\theta - Q\theta = -Q + \rho Q - \rho Q\theta$
$\Rightarrow dPS/dt = -[1 - \rho(1 - \theta)]Q$

$\theta > 0$ because the burden on consumers more than fully completes the burden on producers $(1-\rho(1-\theta))+\rho > 1$.

This leads to the local tax incidence formula under symmetric oligopoly: $I = \rho/[1-\rho(1-\theta)]$. Authors note that when ρ is held fixed, $\partial I/\partial\theta < 0$ if $I > 0$. This means that the less competition (greater θ) there is, the more heavily does the incidence of taxation fall on producers.

Next, Weyl and Fabinger analyse the factors determining the pass-through under symmetric oligopoly. Under imperfect competition, quantity is chosen according to $p(q) - \theta MCS(q) = MC(q) + t$, where $MCS(q)$ is the marginal surplus per firm. Differentiating this respect to t leads to

$$p'\frac{dq}{dt} - \frac{d\theta}{dq}\frac{dq}{dt}MSC - \theta MSC'\frac{dq}{dt} = MC'\frac{dq}{dt} + \frac{dt}{dt}$$
$$\Rightarrow \frac{dq}{dt} = \frac{1}{p' - \frac{d\theta}{dq}MCS - \theta MCS' - MC'}$$

Then, using the fact that $\rho = \frac{dp}{dt} = \frac{dp}{dq}\frac{dq}{dt} = p'\frac{dq}{dt}$

$$\rho = \frac{1}{1 - \frac{d\theta}{dq}\frac{MCS}{p'} - \theta\frac{MCS' q * p}{q * MCS * p'}\frac{MCS}{p} - \frac{MC' q * p}{p' q * MC}\frac{MC}{p}}$$
$$= \frac{1}{1 + \frac{d\theta}{dq}q + \theta\frac{\epsilon_D}{\epsilon_{MCS}}\frac{MCS}{p} + \frac{\epsilon_D}{\epsilon_S}\frac{MC}{p}}.$$

This can be further simplified using $(p - MC)/p = \theta/\epsilon_D$ so that $MC/p = (\epsilon_D - \theta)/\epsilon_D$, and defining $\epsilon_\theta \equiv \theta/[q(d\theta/dq)]$ to

$$\rho = \frac{1}{1 + \frac{\theta}{\epsilon_\theta} + \frac{\epsilon_D - \theta}{\epsilon_S} + \frac{\theta}{\epsilon_{MCS}}}. \tag{13}$$

Weyl and Fabinger remark that this formula nests and generalises both the homogenous products conjectural analysis by Delipalla and Keen (1992) and the differentiated products Nash-in-prices analysis by Anderson, de Palma and Kreider (2001) and facilitates essentially the same conclusions. One exception is the term $\frac{\theta}{\epsilon_\theta}$, but because in these models θ is invariant to changes in q this additional term is absent because $1/\epsilon_\theta = 0$. In this case, the denominator of the expression (13) is, again, a linear combination[12] of that of perfect competition and monopoly with weights $1-\theta$ and θ, respectively. Like in the case of monopoly and with linear costs, the sign of ϵ_{MCS} determines if pass-through can exceed unity.

When θ depends on q, the new term $\frac{\theta}{\epsilon_\theta}$ leads to lower (higher) pass-through when $\epsilon_\theta > (<) 0$. In the former case, θ rises with q: higher prices create more competitive conduct that offsets the impetus for a price increase. In the

[12] $\theta[1 + (\epsilon_D - 1)/\epsilon_S + 1/\epsilon_{MCS}] + (1-\theta)[1 + \epsilon_D/\epsilon_S]$
$= \theta + \theta(\epsilon_D - 1)/\epsilon_S + \theta/\epsilon_{MCS} + 1 + \epsilon_D/\epsilon_S - \theta - (\theta\epsilon_D/\epsilon_S) = 1 + (\epsilon_D - \theta)/\epsilon_S + \theta/\epsilon_{MCS}$

latter case, θ falls with q, i.e. higher prices create less competitive conduct that exacerbates the initial momentum for a price increase.

Finally, following the same logic as before, Weyl and Fabinger extend the analysis to allow for finite tax changes and global incidence. They remark that, now, one needs to average not just over the pass-through but over the product of pass-through and θ if they are not independent of one another. For incidence this leads to the following expression: $\bar{I} = \bar{\rho}/(1 - \bar{\rho} + \overline{\theta\rho})$, and one example for pass through is:

$$\overline{\theta\rho} \equiv \frac{\int_0^\infty \theta(t)\rho(t)Q(t)dt}{\int_0^\infty Q(t)dt}.$$

2.2.4 General Model

The most general model in Weyl and Fabinger (2013) relaxes the assumption of symmetric firms by allowing for asymmetric, imperfectly competitive firms. In the model, each firm i produces quantity q_i and earns profits $p_i(\boldsymbol{q})q_i - c_i(q_i)$, where $\boldsymbol{q}$ is the vector of quantities produced by all firms. Similarly, $\boldsymbol{p}$ denotes the vector of prices, $\boldsymbol{MC}$ the vector of marginal costs and $\boldsymbol{m} \equiv \boldsymbol{p} - \boldsymbol{MC}$ the vector of markups, where $mc_i(q_i) \equiv c_i'(q_i)$. Additionally, the authors assume a single dimensional strategic variable σ_i that determines firm´s actions. It may be price, quantity or a supply function of some sort. In the model, each firm takes the strategies of other firms as given when changing their own strategies. Putting the prices, quantities and strategies of all firms together, they obey the demand system $\boldsymbol{q}(\boldsymbol{\sigma}) = \boldsymbol{q}(\boldsymbol{p}(\boldsymbol{\sigma}))$.

Now, the conduct parameter is firm specific. With the introduction of taxes, it is defined as

$$\theta_i \equiv \frac{(\boldsymbol{m}-\boldsymbol{t}) * \partial\boldsymbol{q}/\partial\sigma_i}{-\boldsymbol{q} * d\boldsymbol{p}/d\sigma_i}.$$

The numerator in this expression is the set of all real or nonpecuniary effects of firm i changing its strategy. These include the effect on firm´s profits it earns by selling more units at its markup and the nonpecuniary externalities it exerts on other firms by altering their optimal quantities. In turn, the denominator includes the pecuniary effects that happen because the changes in firm´s strategy affect prices. If firms are symmetric $\theta_i = \theta$ for all i, this expression collapses to the one in the previous section. To see this, note that increasing all q_i symmetrically affects the per firm quantity by dq and the per firm price by dp satisfying $mdq = \theta q dp$[13]. Then,

$$\theta = -\frac{m}{q}\frac{dq}{dp} = -\frac{m}{p}\frac{p(dq/dp)}{q} = \frac{p-MC}{p}\epsilon_D.$$

[13] This follows from:
$mdq = \theta qdp = (p - MC)/p * dq/dp * p/q * qdp$
$mdq = pdq - MCdq$

With asymmetric firms, Weyl and Fabinger allow tax $\boldsymbol{\tau}$ to fall heterogeneously on firms. They normalise the tax to have a total quantity-weighted size of one: $(\boldsymbol{\tau} * \boldsymbol{q})/Q = 1$, where $Q = \mathbf{1} * \boldsymbol{q}$. They denote the size of the tax imposed as t_τ, and total tax is, therefore, $t_\tau * \boldsymbol{\tau}$. Now, pass-through is a vector dependent on the $\boldsymbol{\tau}$ considered: $\boldsymbol{\rho}_\tau \equiv d\boldsymbol{p}/dt_\tau$. Authors point out that any $\boldsymbol{\tau}$ is a linear combination of $\boldsymbol{\tau}_i$. They collect the coefficients from these linear combinations and label them $\boldsymbol{\lambda}^\tau$. Intuitively, this tells us who pays the tax, not physically, but in terms of the tax induced changes in firms´ economic strategies. This extends the principle of the independence of economic and physical incidence to asymmetric imperfect competition.

Similarly, as before, the cost of the tax borne by consumers can be written by utilising the definition of consumer surplus:

$$\frac{dCS}{dt_\tau} = -\boldsymbol{\rho}_\tau * \boldsymbol{q} = -\rho_\tau Q\,,$$

where $\rho_\tau \equiv \boldsymbol{\rho}_\tau / Q$ is the *quantity-weighted average pass-through rate*, averaged across firms. Using similar logic as in the previous section and the decomposition above, the cost borne by producers can be written as

$$\begin{aligned}\frac{dPS}{dt_\tau} &= \textstyle\sum_i \lambda_i^\tau \frac{dPS}{dt_{\tau_i}} \\ &= \textstyle\sum_i \lambda_i^\tau \left[\frac{d\boldsymbol{p}}{dt_{\tau_i}} * \boldsymbol{q} + \frac{d\boldsymbol{q}}{dt_{\tau_i}}(\boldsymbol{m} - \boldsymbol{t})\right] - Q \\ &= \textstyle\sum_i \lambda_i^\tau \left(\boldsymbol{\rho}_{\tau_i} * \boldsymbol{q} - \theta_i \boldsymbol{\rho}_{\tau_i} * \boldsymbol{q}\right) - Q \\ &= Q\left[\textstyle\sum_i \lambda_i^\tau \left(\rho_{\tau_i} - \theta_i \rho_{\tau_i}\right) - 1\right] \\ &= -Q\left[1 - (1-\theta)\rho_\tau + Cov\left(\lambda_i^\tau \rho_{\tau_i}, \theta_i\right)\right], \end{aligned} \tag{14}$$

where $\theta \equiv \sum_i \theta_i / n$ and $Cov(\lambda_i^\tau \rho_{\tau_i}, \theta_i)$ is the covariance between the product of the targeting of the tax and the pass-through rate $\lambda_i^\tau \rho_{\tau_i}$ and the conduct parameter θ_i.

Weyl and Fabinger remark that with certain assumptions about θ_i, this expression collapses to the three special cases discussed above. Specifically, with $\theta_i = 0$ for all firms it collapses to $dPS/dt_\tau = -(1-\rho_\tau)Q$, just as in the case of perfect competition. In this expression, the pass-through rate is replaced with the quantity-weighted average pass-through rate. Therefore, it allows for multiple products and heterogeneously applied taxes. Second, with $\theta_i = 1$ for all firms, the expression collapses to $dPS/dt_\tau = -Q$, just as under monopoly. Therefore, a perfect cartel with multiple products has the same expression for incidence as a single product monopoly. Thirdly, with the same $\theta_i = \theta$ for all firms, it collapses to the symmetric oligopoly case $dPS/dt_\tau = -[1-(1-\theta)\rho_\tau]Q$.

The only truly novel term in (14) is, therefore the covariance term. Authors note that this term means that firms benefit if taxes fall on firms with small θ_i. This happens because these firms have socially relatively undistorting strategies, so if their prices rise it has less harmful effects. The harm on consumers depends only on the overall pass-through, so their burden is not changed. It is also beneficial socially if taxes are targeted to firms with low average pass-through. Similarly, the more the pass-through is concentrated to firms with small θ_i, the more beneficial it is to firms. The expression for pass-through under this asymmetric model is not derived here. Discussion and the derivation can be found in the appendix C of Weyl and Fabinger (2013). However, as the authors note, even in this general case pass-through is largely determined by the very same forces.

2.2.5 Multiproduct Retailers

In his model, Hamilton (2009) considers an industry with n multiproduct retailers that are differentiated in terms of their spatial proximity to consumers and where competition is localised: consumers consider only neighbouring retailers when deciding where to shop. Each retailer is represented as a point on a unit circle and they are spaced equally. Consumers are distributed around the circle with constant per-unit density, incur increasing transport costs over distance to visit retailers and purchase multiple products per visit.

Hamilton describes consumers´ preferences by aggregate utility function $U(z, y) = G(z) + y$, where z is a composite commodity, y is the consumption level of a numeraire good and $G(z)$ is an increasing function with constant elasticity $(1-\epsilon) \in (0,1)$. The consumption of composite good is determined by the sub-utility function $z = \int_{i=0}^{\infty} f(x_i)di$, where x_i is the amount consumed of variety $\boldsymbol{i}$. The function $f(x_i)$ is smooth, increasing and strictly concave for all $x > 0$.

Hamilton states that to develop insights on the effect of excise taxes on multiproduct retailers, it is essential to characterize the intensity of preferences for product variety. This depends on the elasticities of $f(x)$ and $f'(x)$. Hamilton denotes these as $\theta(x) = f'(x)x/f(x)$ and $\gamma(x) = -xf''(x)/f'(x)$, respectively. He writes the inverse demand for variety $\boldsymbol{i}$ for the representative consumer as $p(z, x_i) = G'(z)f'(x_i)$, and denotes the indirect utility function $v(m, p)$, where m is the number of products at a given retailer and p is their price vector.

In the model, aggregate demand faced by the representative retailer depends on consumers´ decisions where to shop. Consumer located at a distance of $\delta \in (0,1)$ from this retailer could achieve a surplus of $v(m, p) - \delta t$ by shopping there, where $\boldsymbol{t}$ denotes transportation costs. Hamilton points out that if there are n retailers, then consumers located on the interval $0 \leq \delta \leq 1/n$ between a retailer and her nearest neighbour could earn a surplus of $v(\bar{m}, \bar{p}) - t(1/n - \delta)$ by purchasing from the rival. Here, $v(\bar{m}, \bar{p})$ denotes the indirect utility from the prices and the product variety of the rival. If δ^* denotes the location where consumer is indifferent between these two retailers, then it solves $v(m, p) - \delta t = v(\bar{m}, \bar{p}) - t(1/n - \delta)$ so that

$$\delta^*(m, p; \bar{m}, \bar{p}) = \frac{1}{2n} + \frac{1}{2t}[v(m, p) - v(\bar{m}, \bar{p})].$$[14]

All consumers located at a distance of $\delta \leq \delta^*$ will prefer to shop at the representative retailer and customers located further than that will prefer to shop somewhere else.

Hamilton frames the retailer´s problem as follows: each retailer pays a fixed set-up cost F and a constant unit cost c to stock a product. All products are subject to taxation and excise taxes are levied through some combination of specific τ and ad valorem taxes α. Then, the variable profit per consumer to the representative retailer is:

$$\pi^m(m, p) = \int_{i=0}^{\infty} \left((1 - \alpha)p_i - c - \tau\right) x_i(m, p)di,$$

and the total profit is then:

$$\Pi(m, p; \bar{m}, \bar{p}) = 2\delta^*(m, p; \bar{m}, \bar{p})\pi^m(m, p) - \int_{i=0}^{\infty} Fdi. \qquad (15)$$

This formula shows that profits are decomposed into intra- and interretailer margins. The term $\delta^*(m, p; \bar{m}, \bar{p})$ tells us that, on the interretailer margin, the number of customers the representative retailer gets depends on its relative prices and product variety. Then, on the intraretailer margin, the term $\pi^m(m, p)$ tells us the allocation of sales per customer given prices and the product variety available at the representative retailer.

Differentiating (15) with respect p_i, leads to the following necessary first-order condition for profit maximisation:

$$-\frac{x_i}{t}\pi^m(m, p) + 2\delta^*(m, p; \bar{m}, \bar{p})\left(\frac{\partial \pi^m(m,p)}{\partial p_i}\right) = 0.$$[15] $$(16)$$

The first term in this expression is the effect of change in price on the interretailer margin due to customers shifting to rival retailers. Small change in price of dp_i reduces the number customers by $-(x_i/t)dp_i$, which in turn reduces profits by $-(x_i/t)\pi^m dp_i$. The second term is the effect on the intraretailer margin. If the retailer faced a constant number of customers, it would set its prices like a monopolist, $\partial \pi^m/\partial p_i = 0$ for all i. However, because of competition from other retailers, too high prices bring too few customers. Consequently, prices are set below the monopoly prices.

Retailers also compete with their product variety, increasing it also intensifies price competition. If a rival retailer extends her product line, consumers

[14] To avoid situations where equilibrium may fail to exist, Hamilton (2009) focuses only on retail markets in which at least a subset of consumers is willing to change retailers based on changes in prices and product variety. This means that the following inequalities always hold: $v(\bar{m}, \bar{p}) - t/n < v(m, p) < v(\bar{m}, \bar{p}) + t/n$.

[15] First term in the condition has been derived using Roy´s identity $\partial\delta^*/\partial p_i = -x_i/2t$.

gain more utility from shopping there and the representative retailer loses customers. Differentiating (15) with respect to m leads to the other necessary first-order condition for profit maximisation:

$$\frac{p_m x_m}{t}\left(\frac{1-\theta(x)}{\theta(x)}\right)\pi^m(m,p) + 2\delta^*(m,p;\bar{m},\bar{p})\left(\frac{\partial \pi^m(m,p)}{\partial m}\right) - F = 0.^{16} \tag{17}$$

This condition has a similar interpretation as (16). Now, the latter two terms give the optimal width of the product line for a retailer facing a given number of customers. Monopolist facing no competition would set the sum of these equal to zero. However, the first term is the effect of introducing a new product on the interretailer margin. This term is positive: wider product variety attracts customers from rival retailers. This incentivises retailers to provide wider product ranges than a monopoly would.

In the short run, the number of retailers is constant. Then, the equilibrium price per product p_e and the equilibrium number of products m_e are the solutions to equations (16) and (17). The long run equilibrium (p_c, m_c, n_c) is determined by these two equations and the entry condition, which states that profits are zero. With symmetric firms, this implies:

$$\big((1-\alpha)p(m,x) - c - \tau\big)\frac{x}{n} - F = 0.$$

Hamilton notes that to analyse equilibrium effects of excise taxes, it is vital to know how consumer preferences for product variety are influenced by changes in the level of consumption per product. This is measured by the elasticity of $\theta(x)$, $e^{\theta}(x) = \theta'(x)x/\theta(x)$. When $e^{\theta}(x) < 0$, it can be thought as the case of increasing preferences for variety: an additional product provides greater utility at higher levels of consumption per product. This is assumed to be the normal case, and the propositions Hamilton derives rely on this assumption.

He remarks that is helpful to express this elasticity as $e^{\theta}(x) = \beta(x) - \sigma(x)$, where $\beta(x) = 1 - (1-\varepsilon)\theta(x)$ and $\sigma(x) \equiv \gamma(x) + \theta(x)\varepsilon$, which is the output elasticity of inverse demand with respect to price. Conversely, ε denotes the same elasticity with respect product variety. Hamilton points out that $\beta(x)$ can be interpreted as the net effect of additional product on consumer surplus, taking into account the effect of changes in per-product inverse demands caused by increased product variety. In the case of $\varepsilon = 0$, new products do not alter the value of existing products because demand per product is perfectly elastic in m, $\beta(x) = 1 - \theta(x)$. When $\varepsilon > 0$, new products get part of their sales by cannibalizing sales of existing products.

[16] The first term comes from the fact the effect of change in product variety to consumer utility is $\partial v(m,p)/\partial m = [(1-\theta(x)/\theta(x)]p_m x_m$. The proof can be found in the online appendix to Hamilton (2009), available at https://assets.aeaweb.org/assets/production/articles-attachments/aer/data/mar09/20071037_app.pdf

Before deriving his specific propositions about the effects of taxes in his model, Hamilton makes two restricting assumptions he deems helpful. The first assumption is that $E \leq 2$, where $E \equiv -p_{xx}x/p_x$ is the elasticity of the slope of inverse demand p_x. This assumption rules out cases of highly convex demand, specifically, cases in which the marginal revenue curves slope upward. The second assumption is that $2\varepsilon \geq 1$[17].

The derivations of the comparative statics behind the model propositions about the effects of taxation are omitted here. They can be found from the online appendix to Hamilton (2009). Hamilton separates the model effects to short- and long run -effects. The first proposition states that, in the short-run, an increase in excise taxes: 1) reduces equilibrium output per product, 2) narrows the equilibrium range of product variety and 3) increases per product prices.

In the long run with free entry of new retailers, it states that an increase in excise taxes: 1) reduces equilibrium output per product in case of specific taxes but increases it in case of ad valorem taxes, 2) narrows the width of product range, 3) increases prices in case of specific taxes, and in case of ad valorem taxes when $\sigma(x^c) > 1$[18] and 4) stimulates entry of new retailers. The last effect happens because taxes decrease the equilibrium level of product variety, which in turn softens price competition and facilitates entry of new retailers by lowering the fixed costs of maintaining the equilibrium level of product variety.

The second proposition states that, in the short run: 1) specific taxes are overshifted into prices when $E < 1 + \varepsilon + \sigma(x)/\beta(x)$ and 2) ad valorem taxes are overshifted when $E < 1 + \sigma(x) - (\theta(x)\sigma(x))/\beta(x)$. In the long run, 1) specific taxes are overshifted into prices when $E < 1 + 2\varepsilon$ and 2) ad valorem taxes are overshifted when $E < 1 + \sigma(x)$. Therefore, if demand is not highly convex ($E > 2$), *specific excise taxes are overshifted into prices in the long run*. Furthermore, Hamilton remarks that *excise taxes overshift into prices for a wider range of cases in the short run than in the long run*. The reason for this is the effect of excise taxes on the equilibrium width of the product variety range, as mentioned above. Hamilton points out that this opposite of the result by Anderson et al. (2001) concerning single-product retailers.

Therefore, in Hamilton´s model of multiproduct retailers, taxes are shifted forward more than one-on-one into consumer prices, expect in highly convex demand conditions. In the model, retailers often respond to excise taxes by narrowing their product variety ranges. This suppresses price competition, which in turn facilitates the shifting of taxes into prices. With highly convex demand, the associated high price-cost margins and larger profits in response to higher excise tax rates provide firms an incentive to introduce new products. In this

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[17] This guarantees that the subutility function is strictly concave at arbitrarily small values of $\gamma(x)$. These and the assumption of $e^{\theta}(x) < 0$ together ensure that firm and industry profits are concave in x and m. The proof can be found in the online appendix of Hamilton (2009).

[18] Hamilton (2009) notes that it is conceivable that ad valorem taxes reduce prices but that this requires highly convex demand combined with constant or weakly increasing preferences for variety.

case, the increase in product variety intensifies price competition and leads excise taxes to shift into prices less than one-on-one.

Hamilton notes that this also the opposite result compared to the models with single-product firms where taxes are more likely to overshift with higher convexity of demand. For example, Anderson et al. (2001) show that excise taxes are only overshifted to prices in their model of differentiated product oligopoly when $\tilde{E} > 1$ (which is, as they note, analogous to $E > 1$), and Delipalla and Keen (1992) show that ad valorem taxes are overshifted only when $E > 2$.

2.2.6 Summary

In conclusion, the most important factors determining the pass-through rate of excise taxes are the elasticities of supply and demand and the degree of competition in the market. As discussed, under perfect competition pass-through is always between zero and one. Under different models of imperfect competition, however, shifting of excise taxes into customer prices more than one-on-one is possible. In fact, in Hamilton`s (2009) model of multiproduct retailers, excise taxes are overshifted into prices unless demand is highly convex. The pass-through results from his model could apply to many real-world markets, possibly including the Finnish grocery retail market.

Nonetheless, different models of imperfect competition have various predictions about the effect of excise taxes on prices: excise taxes can under-, fully- or overshift into customer prices. In contrast to Hamilton´s (2009) model, the single-product oligopoly models by Delipalla and Keen (1992) and Anderson et al. (2001) predict overshifting only when demand is highly convex. Therefore, the question how excise taxes pass-through to prices in different market contexts is ultimately an empirical matter. For example, Besley and Rosen (1999) find empirical support for the overshifting of excise taxes on many commonly purchased retail products in the USA. These include such products as bananas, bread, milk, shampoo and soda.

The existing empirical evidence on the pass-through of taxes on soft drinks and SSBs will be discussed in the next section. In some cases, there is evidence of overshifting, in some cases the tax is fully shifted into prices and in the case of regional taxes there is evidence of undershifting.

3 PREVIOUS LITERATURE

3.1 Empirical Studies on the Pass-Through

This section discusses the existing empirical evidence on the pass-through rate of excise taxes levied on soft drinks. It includes one study each from Denmark (Bergman & Hansen 2017) and France (Berardi, Sevestre, Tepaut & Vigneron 2012), three studies each from Mexico (Grogger 2017; Campos-Vázquez & Medina-Cortina 2015; Colchero et al. 2015(a)) and from Berkeley, California (Cawley & Frisvold 2017; Falbe, Rojas, Grummon & Madsen 2015; Silver et al. 2017).

3.1.1 Evidence from Denmark

Bergman and Hansen (2017) studied the shifting of excise taxes on both alcoholic and non-alcoholic beverages using micro data collected by Statistics Denmark. For sodas, they studied three different tax changes. In January 1998, tax on sodas was increased from 0.80 DKK per litre to 1.00 DKK per litre. Then, it was further increased to 1.65 DKK in January 2001. Finally, in October 2003 the tax was cut to 1.15 DKK.

Bergman and Hansen use the following panel regression to estimate tax pass-through for different type of beverages:

$$\Delta p_{ijt} = \sum_{k=0}^{4} \beta_k \Delta\tau_{i,t-k} + \alpha_i + \alpha_t + \sum_{k=1}^{N} \gamma_k X_t + \varepsilon_{it},$$

where Δp_{ijt} is the change in the price of product i sold in store j between t and $t-1$, $\Delta\tau_{i,t}$ is the change in excise tax, α_i and α_t are product and time fixed effects and X_t is a vector of controls[19] that are constant across stores. Pass-through is given by β_k. The identifying assumption is that, with appropriate controls,

[19] Bergman and Hansen (2017) controls include: change in consumer price index (CPI), change in CPI squared, change and squared change in unit labour costs, rent price index and energy price index.

prices before a tax change would have been the same as prices after a tax change in the absence of the tax change.

Bergman and Hansen allow for lagged effects because some retailers may take few months to adjust prices. They also consider asymmetric effects of tax hikes and cuts. This is done by adding the term $\sum_{k=0}^{4} \gamma_k D_t \Delta\tau_{i,t-k}$ to above equation, where D_t is a dummy-variable for a tax increase.

Finally, they consider whether the proximity of the German border affects the pass-through. It is possible that stores close to the border would not be able to raise their prices as much because of competition from German retailers. To see this, Bergman and Hansen interact the natural logarithm of distance from border with the change in excise tax.

In case of soda taxes, they find evidence[20] of overshifting for tax hikes and possible undershifting in the case of tax cuts but cannot reject full pass-through. In the case of border effects, they find differences[21] in pass-through between retailers close to the border and retailers far from it. Retailers further away from the border increased their prices more when taxes were raised.

3.1.2 Evidence from France

Berardi et al. (2012) studied the pass-through of the French "soda tax" that was put into effect 1st of January 2012. It applies to all non-alcoholic beverages that contain either added sugar or artificial sweetener. The tax was set to be 7.16 cents per litre. They use a large micro-level dataset from Prixing: a price comparator start-up that produces price information for consumers. Their sample[22] covers the months from August 2011 till June 2012, thus, they have 6 months of both pre-tax and after-tax data.

Berardi et al. divide their sample into three different groups of products: 1) sodas (liable to tax), 2) flavoured waters (liable to tax) and waters and 3) fruit drinks and ready-to-drink teas (liable to tax) and fruit juices. They implement a differences-in-differences approach by estimating the following regression:

$$P_{ijt} = \sum_{\substack{\tau=jan,feb,mar,\\ apr,may,jun}}^{3} \beta_\tau D_{it\tau} + \lambda_t + \alpha_i + \delta_j + \varepsilon_{ijt},$$

where P_{ijt} is the monthly modal price of product i sold in store j at time t. $D_{it\tau}$ is a dummy variable for the tax change, i.e. it is equal to one when the product is liable to tax and the year is 2012 but is otherwise zero; λ_t, α_i and δ_j are time, product and store fixed effects, respectively. β_τ is the coefficient of interest, measuring the effect of the tax change.

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20 Contemporaneous estimate for tax cuts is 0.689 with standard error of 0.214 and 2.083 for tax hikes with standard error of 0.200. Estimates for the total effect are 0.188 (SE 0.613) for tax cuts and 2.644 (SE 0.624) for tax hikes.

21 Estimate of the pass-through for retailers closest to border is 2.068 (SE 0.411) and 2.564 (SE 0.265) for retailers farthest from the border.

22 Berardi et al. (2012) sample has 51,855 observations per month and data for 845 products from 804 shops.

The identification is based on the assumption that in the absence of the tax change the prices of products in the treatment group (liable to the tax) would have evolved similarly to those in the control group (not liable to the tax). All sodas were liable to the tax, so Berardi et al. use their own previous prices as the control group. As in Bergman and Hansen (2017), the authors allow for lagged effects if prices adjust gradually.

Berardi et al. find no evidence[23] for overshifting. Instead, they find that the tax was fully shifted to soda prices in May 2012. However, the tax did not fully shift into the prices of flavoured waters and fruit drinks and ready to drink teas. They also find that the shifting patterns were heterogenous across different brands and retailers. For example, they find that pass-through was generally higher for store-owned private labels.

3.1.3 Evidence from Mexico

Grogger (2017) estimates the impact of the Mexican soft drink tax, imposed beginning of January 2014. It amounts to one Mexican peso per litre and applies to nearly all beverages that contain added sugar[24]. The tax translates to roughly nine percent of the mean of pre-tax price of sodas. Grogger uses monthly price data collected by Mexico´s Consumer Price Index Program. Data consists of records of average prices of each product for each city.

Grogger analyses the evolution of prices of taxed products that contain sugar and untaxed sugar-free products. He divides his sample into six distinct product groups: regular sodas (taxed), other beverages with added sugar (taxed), diet sodas, bottled water, milk and pure juice for which he constructs separate price indices. He is concerned about using the prices of untaxed products as controls. They are potential substitutes for taxed products; therefore, the tax induced price increase of sugar-sweetened products might have increased their demand. This, in turn, might have encouraged retailers to increase their prices as well.

Grogger considers two different methods that potentially do not suffer from this problem: synthetic control method and intervention analysis. Synthetic control is a convex combination of comparison goods that are neither substitutes or complements. It is combined with weights so that it tracks the pre-tax price of treatment products as closely as possible. Specifically, it minimises $(Y_{1B} - Y_{0B}W)'V(Y_{1B} - Y_{0B}W)$, where Y_{1B} is a vector of pre-tax prices of a treatment good and Y_{0B} is matrix of pre-tax prices for comparison goods. W is a matrix of weights that are non-negative and sum to one. V is a diagonal, non-negative matrix and can be chosen to give more weight to some observations.

In intervention analysis, one specifies a time series model that adequately follows the evolution of pre-tax prices. This model is then used to predict what

[23] Estimated tax change coefficient for sodas is 7.2 (SE 0.2), while it is 6.5 (SE 0.5) for flavoured waters and 6.2 (SE 0.3) for fruit drinks and ready-to-drink teas.

[24] Milk products, even the ones with added sugar, are excluded from the tax.

the prices would have been if there had not been a tax change. Grogger estimates an ARIMA-model of the form:

$$\left(1-\phi(L)\right)(1-L)^{d}Y_{1t}=\left(1-\theta(L)\right)\varepsilon_{t},$$

where L is a lag operator so that $L^{d}Y_{t}=Y_{t-d}$. The autoregressive $\phi(L)$ and the moving average $\theta(L)$ terms are pth- and qth-order polynomials in the lag operator: $\phi(L)=1-\rho_1 \dots -\rho_p L^p$ and $\theta(L)=1-\theta_1 \dots -\theta_q L^q$. He chooses the values for d, p and q that minimise the Bayes´ Information Criterion.

Grogger finds that based on the synthetic control method the prices of sodas increased 1.61 pesos, while they increased 1.41 pesos based on the results from the intervention analysis. For sodas, this is evidence of overshifting of the tax by 61 and 41 percent, respectively. However, for other beverages with added sugar both estimates are not statistically significantly different from zero. Furthermore, there did not seem to be any effect on the prices of potential tax-free substitutes.

Campos-Vázquez and Medina-Cortina (2015) use a different dataset to analyse the same Mexican 2014 tax reform. Their data comes from the Federal Agency of Consumer Protection (PROFECO). It includes weekly price records for soft drink products from 607 supermarkets, from 27 municipalities and around 80 percent of the products are liable to the tax.

They estimate the following panel regression to identify the pass-through effect:

$$P_{ijt}=\psi_{FE}+\alpha_1\sigma_{it}+u_{ijt},$$

where P_{ijt} is the price of product $\boldsymbol{i}$ sold in store $\boldsymbol{j}$ at time $\boldsymbol{t}$, ψ_{FE} are their chosen fixed effects[25] and $\boldsymbol{\sigma_{it}}$ is the product specific tax change; α_1 is the coefficient of interest and equals unity in the case of full pass-through. The authors also use differences-in-differences estimation with waters as the control group when analysing heterogenous effects across different product types.

Based on their estimates, Campos-Vázquez and Medina-Cortina conclude that there was overshifting in soft drink prices. They rose approximately 1.31 pesos. Similarly, to Grogger (2017), they find larger effects[26] for soda than for other types of soft drinks. In addition, they find heterogenous price responses depending on the market structure where the product is sold. Shifting was lower the higher the elasticity of demand and the higher the degree of competition in each market, measured as number of competitive stores in a given radius.

The third study about the pass-through of the Mexican soft drink tax is by Colchero et al. (2015a). They obtained price data from the National Institute of Statistics and Geography (INEGI), which is the entity responsible for collecting

[25] Campos-Vázquez and Medina-Cortina (2015) fixed effects include: store, brand, product type, brand*product type, month and product type*month fixed effects.

[26] Soda prices rose approximately 1.39 pesos, while powder-mix prices decreased 0.02 pesos, juice prices rose 0.52 pesos and sports drink prices rose 0.75.

the data to estimate the Consumer Price Index. Their dataset consists of average monthly prices of all ready to drink beverages from January 2011 to December 2014.

Colchero et al. estimate the following fixed effects – regression model:

$$P_{itj} = \delta Y + \beta_y Y + \beta_m M + \beta_{m2} M2 + \beta_s S + \beta_p Do + \beta_g G + \alpha_i + u_{itj},$$

where P_{itj} is the price per litre of beverage i at month t year j, Y is a vector of year-dummies, M is a count variable (month/year) for the whole period, $M2$ is this variable squared, S is a dummy variable equal to one for months from April to September (season of higher sales), Do is the total annual population, G is the gross domestic product in the previous year and α_i are the time-invariant product fixed effects. Authors explore the possibly heterogeneity of the pass-through on two product categories: carbonated (CSBs) and non-carbonated sugar-sweetened beverages (NCSBs), on different regions, and on different package sizes. They also present weighted and unweighted pass-through estimates; for weights, they use purchase data from Nielsen´s Mexico´s Consumer Panel Services.

The authors find that there is statistically significant heterogeneity by region[27]. They find undershifting of the tax in some areas and overshifting in others. Furthermore, they find the pass-through to be higher for products with smaller packages[28]. Their unweighted estimates (in pesos per litre) of the pass-through for all SSBs, CBSs and NCSBs were 1.03, 1.20 and 0.66, respectively. Conversely, the weighted estimates were 1.08, 1.09 and 0.74, respectively. All estimates were reported to be statistically significant at 1 percent level.

3.1.4 Evidence from Berkeley, California

Cawley and Frisvold (2017) study differs from the ones mentioned above; they analysed a city-wide tax change that took place in Berkeley, California on March 2015. The tax was originally intended to come into force two months earlier in January but was delayed due to administrative reasons. The tax is levied in the amount of 1 cent per ounce (1.00 ¢/oz) on sweetened beverages, excluding alcohol and milk products. This translates to 0.34 dollars per litre.

The authors collected data on the prices of sugar-sweetened beverages from the near-universe of stores in Berkeley and from a random sample of stores in San Francisco, which was their chosen control city. The data was collected in two different occasions: one prior and one after the tax change took place. Cawley and Frisvold collected data on the most commonly sold products and typical sizes.

[27] Colchero et al. (2015a) find overshifting in Mexico City, Central North, North Border and Northwest and undershifting in the remaining 3 regions.

[28] Their pass-through for CSBs estimates by product volume were: 1.50 (0.12) for V<600 ml, 1.23 (0.04) for V=600 ml, 1.13 (0.10) for 600<V<1000 ml and 1.08 (0.04) for V>1 l.

They performed the following differences-in-differences regression to see how the tax affected beverage prices in Berkeley:

$$P_{st} = \alpha + \beta_{DD} Post_t * Treat_s + \beta_t Post_t + \beta_s Store_s + \beta_{day} Day + \varepsilon_{st},$$

where P_{st} is the price per ounce of product in store s at time t, $Post_t$ is a dummy variable equal to one for the after-tax periods, $Treat_s$ is a dummy variable equal to one if the store is in Berkeley, $Store_s$ is a vector of store-specific controls and Day is an indicator variable for the day of the week. The coeffient β_{DD} of the interaction term is the differences-in-differences estimator of interest. The identifying assumption is that stores in San Francisco make a good control group for what would have happened to beverage prices in Berkeley without the tax change.

Cawley and Frisvold find that on average 43 percent of the tax was passed through into prices. They also found that prices rose on average less the closer the store was to the border of Berkeley. Intuitively, it makes sense why the effect on prices is smaller than in the case of nation-wide taxes. Retailers in Berkeley face more competition because consumers can avoid the tax by shopping outside the city. Consequently, the retailers cannot raise their prices as much as they would if the tax applied to a larger area.

Falbe et al. (2015) analyse the same Berkeley tax change with similar methods. They collect data on the prices of the same products sold in the same stores, in Berkeley and in the two control cities: Oakland and San Francisco, for a pre- and an after-tax period. They then compare the changes in prices between the pre- and after-tax periods in Berkeley to those of San Francisco and Oakland.

Falbe et al. estimate that the pass-through for all SSBs was 47 percent. This very similar to the 43 percent result estimated by Cawley and Frisvold (2017). However, Cawley and Frisvold note that there are a couple of potentially important differences in their approaches. The sample of Berkeley stores that Falbe et al. (2015) used was primarily drawn from stores from low-income neighbourhoods, while in contrast they had a much broader sample of stores. Cawley and Frisvold collected data for many different sizes as Falbe et al. collected data only for 20-ounce bottles but when data for that was not available they collected the price of another size. Furthermore, their estimation methods[29] differ slightly.

In addition of analysing the pass-through of the Berkeley tax, Silver et al. (2017) looked its effects on sales, store revenue/consumer spending and usual beverage intake. The authors had three separate datasets for their analysis. First, they performed store price surveys[30] by telephone. They surveyed the prices of taxed and untaxed beverages in December 2014 (pre-tax), June 2015 (4 months

[29] Falbe et al. (2015) do not have store fixed effects and do not control for the day of the week or the size of the product. Instead, they examine the changes in prices per ounce for products of varying size without controlling for the size of product.

[30] Silver et al. (2017) were able to collect 313 prices for 55 products for all three survey rounds for the same stores.

post-tax) and March 2016 (13 months post-tax) from 26 stores of different types[31]. Second, the authors obtained a point-of-sale electronic scanner data from two chains of large supermarkets covering the period from January 2013 through February 2016. These chains also provided data on six Bay area control stores. Third, Silver et al. used data from dietary and shopping behaviour surveys, conducted by telephone in November-December 2014 (pre-tax) and in November-December 2015 (post-tax), where participants were asked[32] to recall their 24-hour beverage intake.

For the store survey data, pass-through was analysed using paired t-tests on the price changes of both taxed and untaxed beverages. The authors find that the difference in price changes between these groups was larger between the period[33] of December 2014 to June 2015 than it was between December 2014 and March 2016. Therefore, the pass-through seems to have been higher in the short term. However, the standard errors and associated confidence intervals are very large due to small sample sizes[34]. The tax was more than fully passed onto prices in large (1.07 ¢/oz) and small chain groceries and gas stations (1.31 ¢/oz), especially for carbonated beverages, and partially passed on in pharmacies (0.45 ¢/oz) and not passed on in small gas stations and independent corner stores where the pass-through was actually negative (-0.64 ¢/oz).

For the scanner data, the authors implement a fixed effects approach. They use the price of taxed beverages (per barcode, month and store) – measured in cents per ounce – as the outcome variable. From their model[35], they obtain adjusted beverage prices for Berkeley and for non-Berkeley control stores by different beverage categories. They find that the sales unweighted[36] difference in price changes for taxed products between Berkeley and non-Berkeley control stores was 0.67 cents per ounce, which implies a 67 percent pass-through rate. Meanwhile, there were no statistically significant differences in the price changes of untaxed products. Furthermore, the researchers find that the pass-through was complete for sodas and energy drinks (1.09 cents per ounce) but incomplete for other beverage groups.

Next, Silver et al. modelled the change in store sales and revenue using two outcome variables: store-day data on the volume of taxed and untaxed beverages sold (ounces per transaction) and average daily store revenues (CPI-

[31] Different store types were: large supermarkets, small chain supermarkets, pharmacies, independent gas stations and corner stores.

[32] In addition, surveyors collected information on demographics and beverage shopping locations and behaviours of the participants.

[33] For large supermarkets, the pass-through rate was 102 percent with a 95 percent confidence interval of 39 to 166 percent in the shorter period, while the pass-through rate was 56 percent with a 95 percent confidence interval of -35 to 146 percent for the longer period.

[34] The authors have data from 6 large supermarkets, 2 small chain supermarkets and 2 chain gas stations, 2 pharmacies and 13 independent corner stores and 1 independent gas station.

[35] Silver et al. (2017) have the following control variables in their model: month-year indicators, store located or not located in Berkeley, interaction of Berkeley store and month-year, and an indicator variable of underreported sales data from each store in a particular month.

[36] Sales weighted estimate for the overall pass-through was similar: 0.65 cents per ounce.

adjusted dollars per transaction). The authors examine whether there are differences in these outcomes between Berkeley and control stores[37]. They estimate their models[38] with ordinary least squares and use them to test whether post-tax trend in sales differed significantly from the pre-tax trend by setting the post-tax indicator to zero, as if the tax had not been implemented. The researchers find that compared to their model generated counter-factual the sales of taxed beverages fell by 9.6 percent in Berkeley, whereas they rose by 6.9 percent in non-Berkeley stores. The sales of untaxed beverages rose by 3.5 percent in Berkeley and by 0.5 percent in non-Berkeley stores. In addition, they find that the sales of taxed and untaxed beverages rose most in the neighbouring stores of Berkeley. Furthermore, Silver et al. find that consumer spending per transaction (average grocery bill) fell $0.18 less in Berkeley (-$0.36) than in comparison stores (-$0.54) and that reductions in self-reported consumption of SSBs in grams and calories were not statistically significant.

Table 2 summarises the previous studies on the pass-through of excise tax on soft drinks and SSBs, described above. Table shows the main findings, the tax change studied, and the data and methods used. Most of the studies about national tax reforms find evidence of some type of overshifting. The regional studies from Berkeley find evidence of undershifting but also full pass-through for sodas.

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[37] The authors place their control stores onto three zones depending on their distance from Berkeley: zone 1 was adjacent to Berkeley (two stores and two cities), zone 2 was San Francisco (one store) and zone 3 was over 20 miles from Berkeley (three cities and stores).

[38] Silver et al. (2017) models include controls for store-id, day of week, holiday and holiday eve, month, year, number of transactions (linear and quadratic but excluded from revenue per transaction -models), a post-tax indicator, and interactions of store ID with the post-tax indicator, month, and year.

TABLE 2 Summary of previous studies on soft drink tax pass-through

Author(s)	Tax change(s) studied	Data used	Method(s) of study	Main findings
Bergman & Hansen (2017)	0.20 kr/litre tax hike (1998) 0.65 kr/litre tax hike (2001) 0.50 kr/litre tax cut (2003)	monthly price records from Statistics Denmark (1997-2005; # of obs. for sodas 4755)	panel data fixed effects regression	overshifting of tax hikes undershifting or full pass-through of tax cuts
Berardi et al. (2012)	new tax of €0.716/litre for beverages with added sugar or artificial sweetener (2012)	mostly daily price records from Prixing (August 2011 - June 2012; # of 570,405 obs.)	differences-in-differences regression	full pass-through for sodas slight undershifting for flavoured waters and fruit drinks
Grogger (2017)	new tax of 1 peso/litre for beverages with added sugar (2014)	monthly price records from Mexico´s CPI program (January 2011 - June 2015)	synthetic control method and intervention analysis	evidence of overshifting for sodas no effect on other beverages with sugar
Campos-Vázquez & Medina-Cortina (2015)	new tax of 1 peso/litre for beverages with added sugar (2014)	weekly price records from PROFECO (2013-2014; # of obs. 1,019,712)	panel data regression and differences-in-differences regression	overshifting for sodas undershifting for other products types
Colchero et al. (2015a)	new tax of 1 peso/litre for beverages with added sugar (2014)	monthly average price data from INEGI (2011-2014)	panel data fixed effects -regression	overshifting for CSBs in some regions
Cawley & Frisvold (2017)	new tax of $0.34/litre for sweetened beverages (2015)	two occasions of hand collected price records from Berkeley and San Francisco	differences-in-differences regression	evidence of undershifting, about 43 percent pass-through
Falbe et al. (2015)	new tax of $0.34/litre for sweetened beverages (2015)	collected price records for pre- and after-tax periods (Berkeley, San Francisco and Oakland)	differences-in-differences regression	evidence of undershifting, about 47 percent pass-through
Silver et al. (2017)	new tax of $0.34/litre for sweetened beverages (2015)	store price survey (n=26), point-of-sale scanner data (2013-2016) and dietary survey	fixed effects regression with differences in differences	evidence of undershifting for all SSBs (67 %) and full pass-through for sodas (109 %)

3.2 Demand Estimation

The second component that constitutes the effect of a tax increase on consumption is the responsiveness of the demand of the taxed goods to price changes. In economics this is called the *price elasticity of demand*. More specifically, the elasticity used here is the *own price elasticity of demand*. It tells how good´s demand responds to changes in its own price.

Normally, demand functions are decreasing in price so that higher prices indicate less demand. This means that the price elasticity of demand with respect to own price is negative. There are few exceptions to this however. First, are the *Giffen goods*, which are products that people consume more of when their prices rise and vice versa. This happens because the *income effect* dominates the *substitution effect*. Second, are the *Veblen goods*, which are luxury products whose price decrease could, in fact, lower their demand because people associate their high price with greater status and higher quality.

For any sort of good, when its price rises the substitution effect makes people by less of it and more of its substitute goods. However, the price increase also reduces people´s income available for purchasing other goods. For most products, this income effect is negative as well and further reinforces the substitution effect. These goods are labelled *normal goods*: their demand increases when people´s incomes go up. The opposite happens for *inferior goods*. Giffen goods are goods that consumers deem so inferior that income effect dominates the substitution effect. *Superior goods* are goods that make up a larger share of consumption when incomes rise because they have high *income elasticities of demand*.

Related to substitution and income effects is the difference between *compensated* and *uncompensated* demand curves. The compensated demand curve, also known as *Hicksian*, shows how demand responds to price changes keeping utility or real income constant. The uncompensated demand curve, also known as *Marshallian*, is related to the Hicksian curve by the *Slutsky equation*, which states that the total price effect (Marshallian) is equal to the sum of substitution effect (Hicksian) and the income effect. One can then estimate both the uncompensated and the compensated price elasticities. However, the budget shares of many products are small and so are their associated income effects.

One can also be interested in what happens to product´s demand when prices of other products change. Two goods are called *substitutes* if one´s price increase leads to more demand for the other good. A good example would be sugar-sweetened sodas and their sugar-free versions. Conversely, two goods are called *complements* if one´s price increase leads to less demand for the other good. The *cross-price elasticity of demand* measures what happens to a good´s demand when the price of some other good changes. This is positive for substitutes and negative for complements.

As mentioned, the own price elasticity of demand measures how product´s demand responds to changes in its own price. Approximately, it tells us the percentage change in quantity demanded for a percentage change in price moving along the demand curve. It is defined as

$$e_p \equiv \frac{dQ/Q}{dP/P} = \frac{d\ln(Q)}{d\ln(P)} \approx \frac{\%\Delta Q}{\%\Delta P}, \tag{18}$$

where Δ denotes change. For most goods, this is negative; exceptions are goods that do not conform to the law of demand, such as Giffen and Veblen goods. The demand for goods is generally said to be elastic for products that have $|e_p| > 1$ and inelastic for goods with $|e_p| < 1$.

The definition (18) above shows, that expressing the elasticity in terms of natural logarithms gives its interpretation as the approximate percentage change in quantity demanded when price increases by one percent. Thus, it seems that one can perform a simple *ordinary least squares*-regression on log-transformed variables to obtain estimates for price elasticity:

$$\ln(Q) = \alpha + \beta \ln(P) + \gamma X + u,$$

where β is the estimate of price elasticity and $\boldsymbol{X}$ is a vector of control variables. (Wooldridge 2010, 16-17.)

However, there is a problem: the combinations of prices and quantities observed in the data reflect the forces of both supply and demand. Therefore, generally the relationship estimated from the OLS-equation is neither the demand or supply curve but a complex mix of shifting demand and supply curves. Price P is called an *endogenous* variable because it is correlated with the error term u in the equation above. This correlation arises from the fact that prices are determined partly as a function of demand. This correlation causes coefficient β to be biased because unobserved factors that shift demand tend to also affect prices. For example, increased demand for some products will likely induce retailers to raise the prices of those products. (Wooldridge 2010, 54-55.)

To deal with this problem, one can apply a method called *instrumental variables* -regression. This will be discussed in more detail in section 4.3. The basic intuition is to find variables that shift only either the supply or the demand curve. Phillip Wright (1928) was the first to apply instrumental variables to the problem of demand estimation. He was trying the estimate the elasticities of supply and demand for flaxseed, the source of linseed oil. The variable he used as an instrument for demand was the price of substitute goods, such as cottonseed. He assumed that these prices affect only demand and not supply. For supply he used yield per acre, which can be assumed to be primarily determined by the weather and should not affect demand.

3.2.1 Price Elasticity of Soft Drinks - Two Systematic Reviews

In their review article, Andreyeva, Long and Brownell (2010) analysed 160 different studies on the price elasticity of demand for major food categories of which one was soft drinks. They reviewed all US-based studies[39] published between 1938 and 2007. They used only uncompensated elasticity estimates because the majority of studies reviewed included only those. Of the studies reviewed, 14 presented an estimate of the elasticity of demand for soft drinks.

Overall, their results support the usual characterisation that the elasticity of demand for food is inelastic; all their mean price elasticity estimates were below one in absolute value. Soft drinks seemed to be less inelastic than other food categories, with the lowest mean price elasticity[40] of -0.79. Only one of the studies provided separate price elasticity estimates for diet or sugar-free and

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[39] Andreyeva et al. (2010) segmented the studies into three categories based on the data used in estimation. These were: time-series data (the most common with 62 %), household surveys (21 %) and retail scanner data (17%).

[40] Separate estimates ranged from -0.13 to -3.18. Authors calculate the 95% confidence interval to be (-0.33, -1.24).

regular soft drinks. Bergtold, Akobundu and Peterson (2004) estimate the elasticity of demand to be -1.05 for regular and -1.26 for diet soft drinks.

Andreyeva et al. note that the definition of the category "soft drinks" varied somewhat between the studies. Thus, they also applied a more conservative approach and used only 7 separate studies with a narrower set of products[41] categorised as soft drinks. Using only these studies resulted in a mean price elasticity of -1.00.

Cabrera Escobar, Veerman, Tollman, Bertram and Hofman (2013) reviewed studies published between the years 2000 and 2013 that had estimated the price elasticity of demand for sugar-sweetened beverages. Nine articles met their criteria for meta-analysis. They excluded articles that did not, for example, include clear definition of the beverages included in the category "SSBs" or did not provide standard errors for their elasticity estimates. Of these nine studies, six were from the USA and one each from Mexico, Brazil and France; all were published between 2008 and 2013. Their meta-analysis shows the pooled price elasticity estimate[42] to be -1.30.

3.2.2 Evidence from Finland

Kotakorpi et al. (2011) estimate a modern demand system for food consumption using Finnish data. This demand system is then used to simulate the impact of tax changes on food consumption and energy intake. These effects are then linked with existing nutrition-epidemiological studies to assess the impact of tax changes on the prevalence of overweight, type 2 diabetes and coronary heart disease.

The authors estimate their demand system with data from four separate household budget surveys (years 1995-1996, 1998, 2001 & 2006) conducted by Statistics Finland. This dataset has relatively detailed information about consumption expenditures per household, collected during a two-week reporting period. In addition, it includes socio-economic background variables and information on household incomes. Overall, they have information on 17,200 Finnish households.

First, Kotakorpi et al. analyse the relationships between the expenditure shares per product group and available income. They find that expenditure shares of fruits and vegetables and fish increase slightly and that expenditure share on fat decreases with increased income. There is no clear pattern on the expenditure share of sugar. The expenditure share of sugar is a little higher for people with the lowest education (8 %) compared to people with more education (7.3-7.5 %).

Then, the authors estimate a QAIDS-model based on a system of simultaneous demand equations. This a quadratic version of the Almost Ideal Demand System developed by Deaton and Muellbauer (1980). It adds a quadratic ex-

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[41] These included: soft drinks, carbonated soft drinks, soda and soda or fruit ades.

[42] Cabrera Escobar et al. (2013) estimates from individual studies ranged from -0.85 to -4.45. Authors calculate the 95% confidence interval of their pooled estimate to be (-1.01, -1.51).

penditure term to model possible non-linear effects (Banks, Blundell & Lewbel 1997). They estimate the following regression for 8 separate food categories[43]:

$$w_i^h = \alpha_i + X^h \beta_i + \sum_j \gamma_{ij} \ln p_j^h + \delta_i m^h + \varphi_i (m^h)^2 + e_j^h,$$

where w_i^h is the expenditure share of product i for household h, X^h is a vector of control variables[44], p_j^h is a vector of prices and m^h are the total real expenditures per household[45], n^h is the number equivalent adults in the household and $\ln a(p)^h$ is a household-specific price index. For its place, as an approximation, Kotakorpi et al. use the Stone index: $\sum_i w_i^h \ln p_i^h$.

Because total expenditure is an endogenous variable, the authors use the real yearly income as its instrument. They estimate the equations as a system of simultaneous equations using 3SLS (three-stage least squares). Kotakorpi et al. note that this is important because consumers evaluate their consumption choices as a whole. Further, this also ensures that certain restrictions[46] from consumer theory hold.

Kotakorpi et al. estimate the compensated own price elasticity of sugar products to be -2.54 with a standard error of 0.56. They find the income elasticity of sugar products to be relatively small 0.33 with a standard error of 0.05. Uncompensated price elasticities can be calculated from compensated elasticities by adding the income effects, which are calculated as the product of income elasticities and the corresponding expenditure shares. In this case, the expenditure shares are very small, thus, uncompensated elasticities are close to compensated ones; for sugar products they are essentially the same. The authors also estimate separate price elasticities[47] for small-, middle- and high -income groups and find that the people in low-income groups have more elastic demands.

Finally, Kotakorpi et al. use these elasticities and previous epidemiological studies on nutrition to estimate the effects of a hypothetical sugar tax (€1.00/kg of sugar). They estimate that this tax could prevent up to six percent of new cases of type 2 diabetes per year and approximately 1.5 percent of new cardiovascular disease cases.

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[43] These categories were: bread, meat, fish, milk, fat, fruit and vegetables, sugar products including soft drinks and other products.

[44] Kotakorpi et al. (2011) controls include: household type, number of children of different ages, type of neighbourhood, level of schooling, socio-economic status, gender for one-person households, average age and the time of year.

[45] Real expenditures per household are calculated as $m^h = \ln M^h / n^h - \ln a(p)^h$, where M^h is the total nominal expenditures per household.

[46] First of these restrictions is that the sum of different expenditures must add up to total expenditures. The second is that of zero-degree homogeneity; multiplying all prices and expenditures with the same constant does not affect the choice set and, thus, demand. And the third is that the cross terms of compensated demands with respect to prices are symmetric $\gamma_{ji} = \gamma_{ij}$.

[47] For the lowest income group, the price elasticity was -3.05 with a standard error of 1.25. For the middle-income group, the price elasticity was -2.59 with a standard error of 1.04, and for the highest income group, it was -1.90 with a standard error of 1.27.

3.2.3 Evidence from Chile and Mexico

In a recent study, Guerrero-López, Unar-Munguía and Colchero (2017) analysed the elasticities of demand of soft drinks, other sugar-sweetened beverages and energy dense foods in Chile. The authors used data from the VII Family Budget Survey collected between November 2011 and October 2012 by the National Institute of Statistics in Chile. Their dataset includes information on beverage and food and other household expenditures and socio-demographic variables for 10,527 households.

They estimated the following linear approximation of the Almost Ideal Demand System (LA/AIDS):

$$w_{hzi} = \alpha_i + \sum_{j=1}^{i} \beta_{ij} \log p_{zj} + \gamma \log\left(\frac{E}{P}\right) + \sum_{k=1}^{k} \delta_{ik} \eta_{hzk} + u_{jzi},$$

where w_{hzi} is the food or beverage expenditure on food or beverage group i for household h living in zone[48] z, p_{zj} is unit value[49] of food or beverage j at zone level, E is total household expenditure, η_{hzk} includes household-level control variables[50] and $\log P$ is the Laspeyres price index, which is defined as: $\log P_j = \sum_{i=1}^{j-1} \bar{w}_i * \log p_{mj}$. There, P_j is the unit value of beverage or food category j, $\bar{w}_i$ is the mean expenditure share in the category and m is the number of zones. The authors estimate this system for 8 separate food or beverage categories[51].

Guerrero-López et al. calculated the uncompensated own and cross-price elasticities of demand from the following formula:

$$\varepsilon = -\delta_i + \frac{\hat{\gamma}}{\bar{w}_j} \frac{\hat{\beta}}{\bar{w}_j} \bar{w},$$

where δ_i equals one for own price elasticities and zero for cross-price elasticities and $\bar{w}$ is the mean expenditure share; $\hat{\gamma}$ and $\hat{\beta}$ are estimated model parameters. They estimate the own price elasticity of demand for soft drinks to be -1.37 with a standard error of 0.03. The authors also estimate the own price elasticity of other flavoured beverages as -1.63 with a standard error of 0.06. Furthermore, they find that demand for soft drinks is more elastic[52] for people with lower incomes.

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[48] Guerrero-López et al. (2017) dataset distinguishes between two zones: the capital city of Gran Santiago and the rest of the regional capital cities.

[49] Unit value is estimated as the ratio between purchases in kilograms and expenditure in category j, where the jth good is the composite numéraire that includes unit values of goods not considered in the demand system.

[50] Their controls include: education, sex and age of the head of the household and adult equivalent to reflect household size and composition.

[51] These categories were: milk, coffee and tea, plain water, soft drinks, other SSB, sweet snacks, sugar and honey and desserts.

[52] Their price elasticity estimates ranging from lowest to highest income-quintile are as follows: -1.49, -1.55, -1.26, -1.29, -1.29.

In their study, Colchero, Salgado, Unar-Munguía, Hernández Ávila and Rivera-Dommarco (2015) used survey data collected by the Mexican National Institute of Statistics and Geography. This survey is conducted every two years and it collects household-level information on income and expenditures as well as household characteristics and socio-economic data. The authors used three waves of the survey (2006, 2008 & 2010) making their total sample size 73,311 households.

Similarly, to Guerrero-López et al. (2017), the authors estimate the Linear Approximation of the Almost Ideal Demand System:

$$w_{hmit} = \alpha_i + \sum_{j=1}^{j} \beta_{ij} \log p_{mjt} + \gamma \log\left(\frac{E}{P}\right) + \sum_{k=1}^{K} \delta_{ik} \eta_{hmtk} + u_{hmit},$$

where w_{hmit} is the expenditure share for beverage or food group i for household h living in municipality m during wave t. The authors derived prices p_{mjt} for beverage or food j by dividing the household´s daily expenditures by the quantity spend in litres or kilograms and then averaging them at the municipality-level. The rest of the variables[53] are defined similarly to Guerrero-López et al. (2017). Their 8 food or beverage categories[54] were also similar. The author estimated this system of structural equations by an equation-by-equation ordinary least squares estimation.

Colchero et al. (2015b) estimate the own price elasticity of soft drinks to be -1.06 with a standard error of 0.02. For other SSBs the authors estimate a price elasticity of -1.17 with a standard error of 0.03. They also find that demand for sugar-sweetened beverages is slightly more elastic[55] in lower income-quintiles. In addition, the authors constructed a marginality index divided into five categories: very high, high, medium, low and very low level of marginality. It is a measure of social deprivation: areas with higher levels of marginality have, for example, high levels of illiteracy, low levels of education, poor housing conditions etc. The authors find that demand for SSBs is generally more elastic in areas with higher levels of marginality.

Colchero, Popkin, Rivera and Ng (2016) use a somewhat different approach to answer a similar question. They try to estimate directly the effect of the Mexican soft drink tax on the purchases of both taxed and untaxed beverages. The authors obtained data from Nielsen Mexico´s Consumer Panel Services of beverage purchases of 6,253 households from January 2012 to December 2014. This dataset was an unbalanced panel with 205,112 observations.

The Mexican excise tax for sugar-sweetened soft drinks took place in January and according to the authors translated into a 10 percent price increase of

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[53] Colchero et al. (2015b) controls include: education of the head of the household, round of the survey, urban/rural residence and adult equivalent to reflect household size and composition.

[54] These categories were: soft drinks, other SSBs, natural and mineral water, milk, candies, snacks, sugar and traditional Mexican snacks.

[55] For soft drinks the estimated elasticities were from lowest to highest income-quintile: -1.12, -1.10, -1.02, -0.96, -1.06 and for other SSBs: -1.16, -1.22, -1.16, -1.10, -1.06.

the mean pre-tax price of taxed beverages. The authors tried to test whether the pre-tax trend of beverage purchases differs significantly from the post-tax trend using a type of differences-in-differences approach[56] with household fixed effects.

Relative to their model generated counterfactual, purchases of taxed beverages decreased by an average of 6 percent and decreased at an increasing rate up to 12 percent decline in December. Colchero et al. find that households with low socio-economic status reduced their purchases more, by an average of 9 percent. Furthermore, they find that purchases of untaxed products increased by an average of 4 percent. As the authors acknowledge, one major limitation to their study is that they cannot establish causality of their results because of other possible changes occurring concurrent with the tax. These could include economic changes, health campaigns about sugar-sweetened beverages and anti-obesity programs.

Table 3 summarises the previous estimates of the own price elasticity of soft drinks/SSBs from the studies discussed above. It includes the two systematic meta-analyses, which are based on 23 separate studies in total. In addition, it includes the two more recent studies from Mexico and Chile by Colchero et al. (2015b) and Guerrero-López et al. (2017).

TABLE 3 Soft drink price elasticity estimates from previous studies

Author(s)	Data used	Method of study	Category of products	Price elasticity estimate (95 % confidence interval)
Andreyeva et al. 2010	14 studies published between 1938-2007	Meta-analysis	Soft drinks	-0.79 (-0.33, -1.24)
Cabrera Escobar et al. (2013)	9 studies published between 2008 and 2013	Meta-analysis	Sugar-sweetened beverages	-1.30 (-1.01, -1.51)
Colchero et al. (2015b)	Household survey (Mexico, 2006-2010)	LA/AIDS	Soft drinks	-1.06 (-1.02, -1.10)
			other SSBs	-1.17 (-1.11, -1.23)
Guerrero-López et al. (2017)	Family Budget Survey (Chile, 2011-2012)	LA/AIDS	Soft drinks	-1.37 (-1.31, -1.43)
			other SSBs	-1.63 (-1.51, -1.75)

3.2.4 The Case of Untaxed, Unhealthy Substitutes

The availability of possible untaxed substitutes is an important factor when considering the possible health effects of the tax. If there are untaxed, unhealthy substitutes, people will switch some of their pre-tax consumption of sugar-sweetened beverages to those substitute products. The tax´s effects on public

[56] Colchero et al. (2016) model includes control variables for quarter of the year, demographic information on household, socio-economic status (low, middle, high), state quarterly unemployment rate and state yearly minimum salary.

health then depend on the cross-price elasticities and the healthiness of these substitutes. Tax might even have adverse effects if the substitutes are unhealthier than taxed products.

As discussed in section 2.1.3, the Finnish tax applies to all non-alcoholic SSBs. However, it is possible that there are untaxed, unhealthy non-beverage substitute products. Opposite to previous studies, Finkelstein et al. (2013) try to account for this. Their concern is that, while tax induced switching to other beverages from SSBs reduces the total caloric intake, this might not happen when substitution to non-beverage items is allowed; SSBs are among the most energy dense beverages but some food items like candies or cookies are higher in calories per dollar than SSBs. Hence, in addition to tax´s effects on taxed goods, one needs to consider its effects on the consumption of all potential substitutes and complements.

Finkelstein et al. use data[57] from the 2006 Nielsen Homescan panel, which includes a representative sample of US households and contains information on their purchases by Universal Product Code level. It reports quantities purchased, dollars paid and socio-demographic factors of the households. The authors consider 19 separate beverage or other food item categories[58] that they consider possible substitutes or complements to SSBs. The authors use the US Department of Agriculture´s National Nutrient Database to include nutritional information of each product.

The authors estimate empirical models that explain quantities of nutrients demanded as a function of food and beverages prices and other control variables[59]. Because there are many zeros in their sample – many households do not purchase a given item at a given quarter – the authors use first a logit model to model the probability of purchasing nutrients. To model the effects of a SSB tax, the key covariates the authors use are the logarithm of the price index of the different SSB categories[60].

The authors implement an instrumental variables approach to account for possible endogeneity problem arising from omitted variables and measurement error. They estimate instrumental variable models with instruments for the 19 price indices. Their Homescan data includes information of the census tract number of each household's residence. The instrument[61] they use for the price

[57] Finkelstein et al. (2013) aggregate their sample at the household-level for each quarter of 2006 resulting in a sample of 28,584 households with 114,336 observations.

[58] There were in total 7 beverage categories and 12 non-beverage categories, which were: candy, cookies, salty snacks, ice cream, yoghurt, ready-to-eat cereal, French fries, pizza, frozen dinners, canned soups, canned fruits and canned vegetables.

[59] Their control variables include: the prices of all the other categories, household per capita income quartiles, the proportion of adults per household and an indicator variable for the 52 separate Nielsen market. In addition, they control for age, educational degree and ethnicity of the head of the household. They also include a dummy variable equal to one, when the household head is a woman below 35 years of age.

[60] These categories were: regular soda, fruit drinks and sports drinks. Other beverage categories were: fruit juices, skim and whole milk and diet sodas.

[61] Specifically, their instrument is calculated as the weighted average of the price indices of all other households in the same Nielsen market and quarter excluding those living in the same census tract. The weights are the inverses of Euclidian distances to the household, so price indices faced by households that are closer get a bigger weight.

faced by each household is the price faced by households in neighbouring tracts. Finkelstein et al. note that with this instrument identification of the model parameters is achieved when the measurement error in neighbours' prices and neighbours´ idiosyncratic demand shocks are uncorrelated with those of the household.

With this model, the authors estimate the effect of a SSB tax that increases their prices by 20 percent on the purchases of energy, sodium and fat. They find that such a tax would result in a daily reduction of store bought energy of 24.3 kcal per person, which in turn would translate into weight loss of 1.3 kilograms in the long run. Importantly, they find no evidence of substitution to sugary foods. Instead, they find that ice cream and salty snacks were complements to SSBs; the tax generated decreases in daily energy purchases by 6.3 and 4.8 kcal for these two categories, respectively. Because the products in these two categories have high fat contents, the SSB tax is estimated to also slightly reduce purchases of fat. The researchers find that the tax has no impact on the purchases of sodium.

4 DATA AND METHODS

4.1 S-Market Data

Data used in this thesis was provided by HOK-Elanto[62], which is the largest of the regional cooperatives belonging to the co-operative group S-Ryhmä, with over 600,000 owner-customer households. It operates in the broader Helsinki region in Southern Finland, which has a population of almost 1.5 million. Biggest cities in the region are Helsinki, Espoo and Vantaa. (HOK-Elanto 2017.)

One of their major areas of business is grocery trade. HOK-Elanto has three different retailer chains that focus on groceries. In terms of store size[63], from smallest to largest, they are: Alepa, S-Market and Prisma. Alepa is a small convenience store and has 111 locations, S-Market is a supermarket with 57 locations and Prisma is a department store with 12 locations. HOK-Elanto is the region´s largest firm in grocery trade with 42.8 percent market share. (HOK-Elanto 2017.)

Specifically, data consists of daily sales and price records of products that are in the product category “Soft drinks and waters” and covers the years 2013 and 2014. Data comes from four separate S-Market locations. These are all in Helsinki but for confidentiality reasons their specific locations are not disclosed. HOK-Elanto uses the same prices in all its S-Market stores, which together account for about 15 percent of the region´s grocery sales.

In the dataset products are identified by their EAN-barcodes. In addition, there is information on product name, manufacturer, more specific product category, volume and packaging. Daily price records consist of average prices of the same products sold that day in a given store (including taxes). Because of the policy to use same prices in every location, these are usually the same across

[62] HOK-Elanto has over 300 locations, which include supermarkets, department stores, restaurants and service shops and an annual turnover of more than 1.9 billion euros, with more than 5,500 employees.

[63] In terms of turnover value, from smallest to largest, they are: Alepa (382 million euros), S-Market (559 million euros) and Prisma (682 million euros).

stores. Very few small differences can occur due to discounts on flawed products. For the analysis, one common price vector is used for all stores because most of the products sold are not discounted and the non-flawed products are the objects of interest. This price vector was built by choosing the largest observed average price across the four stores. Finally, observations were EAN-numbers were missing were removed.

To perform the analysis, some additional variables[64] were created. Promotional campaigns are identified by a dummy-variable. It is equal to one when the price of a product decreases over 20 percent for a maximum period of a month and is zero otherwise. To determine the sugar content, manual Google-searches were performed using the products´ EAN-codes. For most of the products precise information was found. For the remainder, the sugar content was deduced from the product name (word light implying no sugar). Sugar is a dummy variable equal to one if the product has more than 0.5 g/100 ml of sugar and is zero otherwise. Finally, the products were divided into four distinct product groups so that every group has only sugary or sugar-free products. These are: sugar-sweetened sodas and waters, and sugar-free sodas and waters.

4.1.1 Descriptive Statistics

The dataset has information on 407 products of which 153 are sugar-free. The number of observations is 622,857. Table 4 presents some descriptive statistics by product type. It shows that the consumption and the consumption shares of sugar-sweetened beverages decreased in 2014 compared to 2013 as the consumption of sugar-free beverages increased. The average prices of SSBs increased, the price of sugar-free sodas stayed relatively the same and the price of waters decreased.

[64] In addition, another variable for product category was created. Original category variable had a separate category for products of different sizes and packaging. Because of this, it had over 100 separate categories. These were aggregated over different sizes and packages, which reduced their number to 13. Second, a variable identifying the brand of a product was created manually. This variable identifies 35 separate beverage brands. Third, a dummy-variable identifying the subset of products with close sugar-free substitutes available was created.

TABLE 4 Descriptive statistics by product type

Product type	Number of products	Number of observations	2013 sales (%-share of total sales)	2014 sales (%-share of total sales)	2013 average price/litre[1] (avg price)	2014 average price/litre (avg price)	Average size 2013 (2014)	Average tax[2]
Sodas	184	270,243	363,092 (40.7 %)	355,855 (38.9 %)	€1.87/l (€1.64)	€2.01/l (€1.75)	1.32 l (1.33 l)	€0.166
Sugar-free sodas	55	104,279	208,607 (23.4 %)	217,255 (23.7 %)	€1.49/l (€1.77)	€1.53/l (€1.70)	1.77 l (1.63 l)	-
Sugar-sweetened waters	70	95,244	84,251 (9.4 %)	79,201 (8.6 %)	€2.88/l (€1.81)	€3.07/l (€1.91)	0.82 l (0.85 l)	€0.103
Waters	98	153,091	236,865 (26.5 %)	263,522 (28.8 %)	€1.34/l (€1.13)	€1.11/l (€1.00)	1.37 l (1.46 l)	-
All	407	622,857	892,815 (100 %)	915,833 (100 %)	€1.76/l (€1.55)	€1.73/l (€1.53)	1.32 l (1.34 l)	€0.077

1 Average prices are weighted averages with average monthly sales as weights. 2 Average tax calculations are based on the average size of products and shares of total sales in 2013.

Generally, the most sold products in the dataset are 1.5 litre soda bottles. Table 5 presents information of the sugar content and price changes for some of these products. Table includes three different flavours of sodas (cola, orange and citrus) and three brands. Rainbow is S-group´s private label, which is the cheapest option available. In the table, the average price change for beverages with over 0.5 g/100 ml of sugar was 0.23 euros and 0.02 euros for beverages with less sugar than that. Furthermore, the difference in 2014 prices between sugar-sweetened beverages and their sugar-free substitutes is on average 0.21 euros, which is about 11 percent more than the tax change of 0.19 euros.

TABLE 5 Prices for some individual sodas and their sugar-free versions (1.5 litre bottles)

Product	Sugar content per 100 ml	Average price (2013)	Average price (2014)	Change in price	Difference in change in prices	Tax change[2]
Coca Cola	10.6 g	€2.31	€2.57	€0.26	€0.18	€0.19
Coca Cola Zero	0 g	€2.31	€2.39	€0.08	-€0.18	-
Pepsi	11 g	€2.04	€2.30	€0.26	€0.22	€0.19
Pepsi Max	0 g	€2.04	€2.08	€0.04	-€0.22	-
Rainbow Cola	10 g	€0.99	€1.17	€0.18	€0.20	€0.19
Rainbow Cola Light	0.1 g	€0.99	€0.97	-€0.02	-€0.20	-
Fanta Orange	10.6 g	€2.21	€2.50	€0.29	€0.25	€0.19
Fanta Orange Zero	0.5 g	€2.21	€2.25	€0.04	-€0.25	-
Jaffa Orange	9.1 g	€2.25	€2.40	€0.15	€0.21	€0.19
Jaffa Orange Light	0.2 g	€2.25	€2.19	-€0.06	-€0.21	-
Rainbow Orange	11 g	€0.99	€1.17	€0.18	€0.20	€0.19
Rainbow Orange Light	0.5 g	€0.99	€0.97	-€0.02	-€0.20	-
Sprite	6.6 g[1]	€2.46	€2.69	€0.23	€0.19	€0.19
Sprite Zero	0 g	€2.46	€2.50	€0.04	-€0.19	-
7UP	11 g	€2.11	€2.44	€0.33	€0.25	€0.19
7UP Free	0.1 g	€2.11	€2.19	€0.08	-€0.25	-
Rainbow Citrus	10.8 g	€0.99	€1.17	€0.18	€0.20	€0.19
Rainbow Citrus Light	0 g	€0.99	€0.97	-€0.02	-€0.20	-

1 Sprite changed their recipe in 2014, it previously had 10.1 g of sugar. 2 Tax Change is calculated as 1.14*1.5*€0.11.

Figure 2 compares the evolution of prices in the dataset to price records collected by Statistics Finland. More specifically, it compares the evolution of the prices of regular and sugar-free sodas. Statistics Finland did not have a separate index for sugar-free products prior to 2014, so both set of products are drawn to have the same index in 2013. The indices[65] for this dataset are drawn as a weighted average of the monthly modal value of prices with monthly average sales as weights.

Looking at the figure, it seems that both sets of prices have followed quite similar patterns. They even have the same distinct drop in October 2014. In this dataset, this drop is explained by a month-long promotional campaign where popular Jaffa and Jaffa Light 1.5 litre bottles were sold by 0.80 euros per bottle (regular price was €2.56 for Jaffa and €2.32 for Jaffa Light). In the S-Market data, prices of sugar-sweetened sodas have risen a bit more than in the Statistics Finland data since January 2013 but the tax induced jump from December 2013 to January 2014 has about the same size in both.

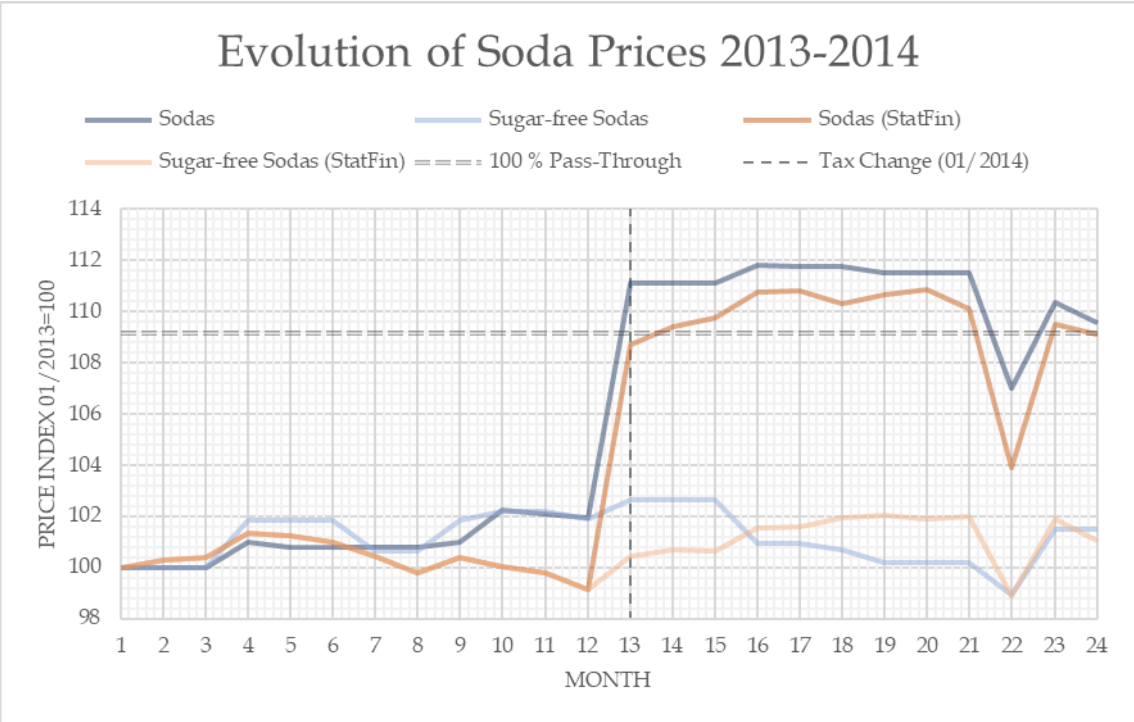

FIGURE 2 Evolution of soda prices (S-Market[66] versus Statistics Finland[67] data)

[65] The indices are calculated using the subset of the products that were sold each month during the whole two-year period.

[66] S-Market indices are calculated as weighted averages from the monthly mode of prices (€/l) with average monthly sales as weights. They include all sodas that had price records for every month. Full pass-through is calculated as the 12/2014 average price per litre of sugar-sweetened sodas plus the tax change €0.1254.

[67] Statistics Finland has had a separate price index for sugar-free products since January 2014 because of the tax change that treated them differently from the ones with added sugar. In the figure, StatFin index for 2013 includes both products.

Figures A1 and A2 (in the appendix) illustrate the evolution beverage sales during the two-year period. They offer some indication that consumers switched from sugar-sweetened beverages to sugar-free ones. This can be seen more clearly in figure A2, which plots the sales of regular and diet sodas.

4.2 Differences-in-Differences Regression

To estimate the pass-through, *differences-in-differences regression* is chosen as the method of analysis. In the simplest case, there are two time-periods, say year one and year two. Then, there are a *control group* and a *treatment group*. In year two, some of the units of observation find themselves, as if by accident, in the treatment group and the others remain in the control group. For example, in 2014, the tax change put SSBs in the treatment group and sugar-free beverages remained in the control group. Then, one compares the difference in prices for both groups between the two periods and takes the difference from these differences. If the prices of both groups of products would have evolved similarly in the absence of the tax change, this gives the causal effect of the tax change on prices.

More formally, letting A denote the control group and B the treatment group; dummy variable dB equals unity for those products in the treatment group and zero otherwise and dummy variable $d2$ denotes the second after-policy period. Then, the simplest equation for the impact of the policy change is:

$$y = \beta_0 + \beta_1 dB + \beta_2 d2 + \delta d2 * dB + u,$$

where y is the outcome of interest. The dummy variable dB captures possible differences between the control and treatment groups prior to the tax change. The time dummy $d2$ captures the aggregate factors that would affect the outcome of interest even in the absence of the policy change. The interaction term $d2 * dB$ is the same as a dummy variable that equals unity for observations in the treatment group in the after-policy period. (Wooldridge 2010, 147-148.)

The OLS-estimator $\hat{\delta}$ is called the differences-in-differences estimator. Letting $\bar{y}_{B,1}$ denote the sample average of y for the treatment group in the first year and $\bar{y}_{B,2}$ for the second year and similarly $\bar{y}_{A,1}$ and $\bar{y}_{A,2}$ for the control group. Then, $\hat{\delta}$ can be expressed as

$$\hat{\delta} = \left(\bar{y}_{B,2} - \bar{y}_{B,1}\right) - \left(\bar{y}_{A,2} - \bar{y}_{A,1}\right).$$

Unbiasedness of $\hat{\delta}$ requires that there are no unobserved factors in u, that are related to the policy change and affect y. (Wooldridge 2010, 148.)

To identify the causal change of the tax hike on the prices of SSBs, following regressions are estimated for different treatment and control groups:

$$P_{it} = \alpha + After_t + \delta_{DD} After_t * Sugar_i + \Pi_{it} + \mathrm{B}_i + \mathrm{M}_t + e_{it}, \tag{19}$$

where P_{it} is the monthly/weekly modal price per litre of beverage i at month/week t, $After_t$ is a dummy variable equal to one for periods after the tax change and zero otherwise, $Sugar_i$ is a dummy variable equal to one for products that have more sugar than $0.5g/100\ ml$ and zero otherwise and Π_{it} is a dummy-variable for promotional campaigns. All regressions are estimated with product B_i and month M_t fixed effects.

The coefficient δ_{DD} gives the causal effect of the tax if in the absence of the tax the prices of products in the treatment and control groups would have followed common trends. Intuitively, it would seem plausible that the prices SSBs and sugar-free beverages are highly correlated; especially sodas are largely products from the same manufacturers so that factors determining their production costs are similar. In fact, the prices of sodas and their sugar-free variants were generally the same in the data before the tax change.

However, as discussed previously, it is possible that the tax change induces retailers to increase the prices of untaxed substitutes as well due to their increased demand. Intuitively, it is more likely that the prices of diet sodas rose more likely due to this effect compared to sugar-free waters because they can be considered closer substitutes to SSBs. Therefore, both groups are used as controls separately as well as together. In addition, the group of sugar-free versions of regular sodas, although very similar to the group of all diet sodas, is used as control. Lastly, the prices of the taxed beverages from previous year are likewise used as controls.

Figure 3 graphs the evolution of prices of different types of beverages in the dataset, indexed from January 2013. The tax increase for SSBs in January 2014 introduces a clear jump in the price indices of taxed products. Based on the average prices of 2013, the tax seems to overshift to SSB prices by some degree.

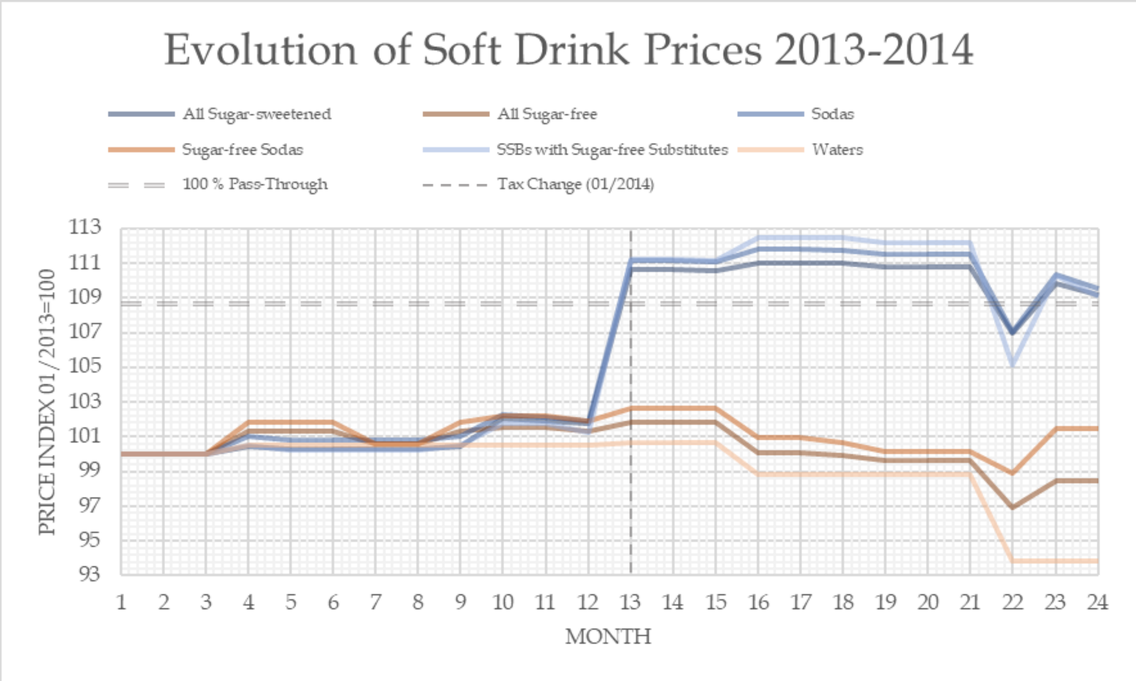

FIGURE 3 Evolution of soft drink prices[68] (in S-Market data)

Pass-through estimates from (19) using ordinary least squares -estimation are averaged across products, i.e. every product has the same weight. However, not all products are created equal: some are sold in much greater quantities than others. The estimates can made to reflect this fact by giving some observations more weight using an estimation procedure called *weighted least squares* in which all of the terms in the residual sum of squares are given a chosen weight. Thus, all regressions are also estimated with per-product average monthly/weekly sales across stores as weights. This generates sales-weighted averages of the pass-through rates were highly sold products are given more weight.

4.3 Instrumental Variables Regression

To estimate the own price elasticity of SSBs, the method of *instrumental variables* (IV) is used. As discussed in section 3.2.1, price is an endogenous variable because it is determined simultaneously by the forces of supply and demand. Thus, estimating a simple equation like:

$$\ln(Q) = \alpha + \beta \ln(P) + \gamma X + u \tag{20}$$

[68] Indices are calculated as weighted averages from the monthly modal values of prices (€/l) with average monthly sales as weights. They include all products that had price records for every month. Full pass-through is calculated as the 12/2014 average price per litre of all sugar-sweetened beverages plus the tax change €0.1254.

with ordinary least squares leads to a biased elasticity estimate because price is correlated with unobserved factors that are in the error term u.

To correct for this, the tax change for SSBs is used as an instrument for their prices. This assumes, quite reasonably, that the tax change influences demand only through its effect on prices. Intuitively, this would leave only the exogenous variation in prices, i.e. the tax instrument shifts only the supply curve.

A valid instrument is an observable variable that is not in the equation (20) and that fills two conditions: first, the instrument z must be uncorrelated with u: $Cov(z, u) = 0$, it should be exogenous in (20); second, it should be correlated with the endogenous variable P once the other exogenous variables X in have been netted out. In other words, the coefficient θ from:

$$\ln(P) = \delta + \phi X + \theta z + v \tag{21}$$

should be non-zero. Equation (21) is called the reduced form for $\ln(P)$ or the *first-stage* regression. Combining (20) and (21) leads to the *reduced form* for $\ln(Q)$:

$$\ln(Q) = \pi + \kappa X + \lambda z + e, \tag{22}$$

where $\pi = \alpha + \beta\delta$, $\kappa = \gamma + \beta\phi$, $e = u + \beta v$ is the reduced form error and $\lambda = \beta\theta$. Now, with the assumptions stated above, the error from (22) is uncorrelated with all the explanatory variables and OLS estimates the parameters consistently. (Wooldridge 2010, 89-90.)

In practice, IV is usually estimated with *two-stage least squares* (2SLS). This amounts to first estimating the reduced form for the endogenous variable (first-stage) and then using the fitted values from there to estimate the second stage:

$$\ln(Q) = \alpha + \beta_{2SLS}\widehat{\ln(P)} + \eta X + \varepsilon \,,$$

where β_{2SLS} is the IV-estimator. Simplifying the notation by losing the logarithm signs, it can be written as:

$$\begin{aligned}\beta_{2SLS} &= \frac{Cov(Q,\hat{P})}{Var(\hat{P})} = \frac{Cov(Q,\delta+\phi X+\theta z)}{Var(\delta+\phi X+\theta z)} \\ &= \frac{\theta Cov(Q,\tilde{z})}{\theta^2 Var(\tilde{z})} = \frac{\lambda}{\theta},\end{aligned}$$

where $\tilde{z}$ is the residual from regression of z on X. Thus, the IV-estimator is the ratio between the coefficients from the reduced form and the first stage. (Wooldridge 2010, 96-97.)

As mentioned, the validity of the IV-approach depends on the two assumptions. First, the instrument should be *relevant* in a sense that it is statistically significant in the first stage. This assumption can be tested by calculating the t-test (or the F-test in the case of many instruments) on the first-stage coefficient. Unlike OLS under the zero conditional mean assumption, IV-methods are never unbiased, which is why one should have a relatively large sample and strong instruments. Weak instruments can make IV-estimators ill-behaved even in large samples. (Wooldridge 2010, 107-108.)

The second assumption, usually referred as the *exclusion* restriction, cannot be directly tested. The instrument should not be correlated with other unobservable factors that affect the dependent variable. In the context of this study, this assumption seems reasonable. It might fail if the tax affected the price of sugar-free substitutes as well. If this was the case, then the obtained elasticity estimates would be biased upward (true elasticity would be more negative) because the residual term would contain the price increase of the substitute beverages; demand of taxed products would have decreased more if the price of untaxed substitutes had not increased as well. However, as will be discussed in the next section, there is no clear evidence of this happening.

Nevertheless, one cannot completely rule out the possibility that there are some unobserved factors correlated with both the tax change and the demand of SSBs. Related point is that, the IV-method gives the average price elasticity of demand for those products whose prices were affected by the tax but tells nothing about the rest. In the data, there were few SSBs (for example can of Coca-Cola 0.33 l) whose price remained the same during the whole period.

Specifically, to implement the IV-approach the following regression is estimated with 2SLS, using the tax change as an instrument for the logarithm of price, for different beverage groups:

$$\ln(Q_{ist}) = \alpha + \beta_{2SLS}\ln(P_{it}) + \Pi_{it} + \mathrm{B}_i + \mathrm{M}_{month} + \Gamma_s + u_{ist},$$

where $\ln(Q_{ist})$ is the logarithm of the quantity[69] sold of beverage i in store s at day t, $\ln(P_{it})$ is the price of given beverage at a given day (prices are uniform across stores) and Π_{it} is the dummy variable for promotional campaigns; B_i, M_{month} and Γ_s are product, month and store fixed effects, respectively.

[69] Because some products were not sold at all in some days and natural logarithm is not defined for $x \leq 0$, one was added to all the quantities before taking logarithms: $\ln(Q + 1)$.

5 RESULTS

5.1 Pass-Through Estimates

This section presents the pass-through estimates for different treatment groups of SSBs using various control groups. To be more precise, all estimates are expressed in cents per litre and represent the price effect of the tax. To obtain estimates of the pass-through they must be divided by the tax change $\Delta t = 12.5$. In addition, it explores the heterogeneity of the pass-through by brand and product volume.

Table 6 presents the pass-through rate estimates for all the SSBs in the sample. In the first two columns, the dependent variable is the mode of observed prices (per litre) in a given month[70], whereas it is the weekly[71] modal value of the available prices in the last two. The first four lines provide pass-through estimates with different control groups; these are the differences-in-differences estimates. In the last line, prices of the same products from previous year act as the control group. These estimates include just the one difference and are, therefore biased upward if the prices would have increased even in the absence of the tax hike.

Estimates are expressed in cents per litre so that the full pass-through rate would translate into an estimate of 12.5. Hence, these estimates indicate overshifting of the tax. The estimates using monthly and weekly modal values of prices differ slightly, especially, when sugar-free sodas or variants are in the control group. However, the difference is smaller with weighted estimates. Because the price of sugar-free waters should not have risen due to the tax – in fact their price seems to have decreased slightly – using them as the control

[70] There were monthly price records (for the whole two-year period) available for 82 different SSBs, 68 sugar-free beverages, 40 natural and mineral waters, 28 sugar-free sodas and 26 sugar-free variants (subset of the sugar-free sodas group).

[71] There were weekly price records (for the whole two-year period) available for 67 different SSBs, 63 sugar-free beverages, 37 natural and mineral waters, 26 sugar-free sodas and 24 sugar-free variants.

group gives an upper bound for the pass-through estimates. With this, the prices of SSBs have increased at most approximately €0.20 due to the tax change.

On the other hand, the prices of the sugar-free versions of sodas could have possibly increased due to increased demand from substitution. Therefore, using them as the control group gives the lower bound for the pass-through estimates: approximately €0.17-€0.18 with weighting and €0.15-€0.18 without. These estimates (apart from column three) are strikingly similar to the ones in the last line where the prices of SSBs from 2013 were used as controls. This would indicate that the prices of diet sodas were not affected by the tax that much. This can further be seen from table A3 (in the appendix), which presents similar regressions for the different untaxed beverage groups were their own prices from 2013 act as controls.

Based on all the estimates, the average price of all SSBs has increased of somewhere between €0.17-€0.19. This would translate into a pass-through rate of somewhere between 136-152 percent, indicating overshifting of the tax by 36-52 percent. With monthly data, using the sugar-free sodas as the control, prices of all SSBs rose approximately 0.18 euros, indicating 44 percent overshifting of the tax.

TABLE 6 Pass-through estimates[1] for all sugar-sweetened beverages

Control group:	(1)	(2)	(3)	(4)
All sugar-free beverages	19.3 (1.53)	19.1 (1.60)	18.5 (1.46)	18.4 (1.67)
Sugar-free waters	20.3 (1.90)	20.4 (1.79)	20.5 (1.95)	19.9 (1.95)
Sugar-free sodas	17.9 (1.99)	17.9 (2.38)	15.6 (1.51)	17.4 (2.38)
Sugar-free variants	17.8 (2.10)	17.8 (2.53)	15.3 (1.58)	17.2 (2.54)
All SSBs (previous year)	17.9 (0.94)	18.0 (0.85)	17.5 (0.84)	17.7 (0.85)
Weights[2]	**No**	**Yes**	**No**	**Yes**

1 In columns 1 and 2 data is aggregated at the month level, while in columns 3 and 4 weekly data is used. The estimates are reported in cents per litre. To obtain pass-throughs, the presented estimates must be divided by the tax change $\Delta t = 12.5$. All regressions contain product and month fixed effects. Standard errors (in parenthesis) are clustered by product. 2 Weights are the average monthly or weekly sales across products and stores, respectively.

Table 7 presents similar estimates for regular sodas. Again, in the first two columns the dependent variable is the monthly[72] modal value of prices (per litre) and the weekly[73] modal value of prices in the last two. The different control groups are defined as before. Now, the pass-through rate estimates are slightly lower across the board. The reason for this is that the prices of flavoured waters seem to have risen even more than the prices of regular sodas. Pass-through estimates for sugar-sweetened waters can be found from table A1 (in the ap-

[72] There were monthly price records (for the whole two-year period) available for 68 different sodas.

[73] Fifty-four sodas had weekly price and sales records available for the whole two-year period.

pendix). However, they are based on quite a small sample of products (14 in the monthly and 13 in the weekly data).

Based on the pass-through estimates from regressions with diet sodas as the control group, the prices of sodas have risen of somewhere between €0.151 and €0.176. The estimates from the monthly data show a price effect of €0.175-€0.176, which would indicate overshifting of the tax by approximately 40 percent. Corresponding estimates for flavoured waters were: €0.200 (weighted) and €0.210 (unweighted). Using the monthly modal value of prices as the response variable might be preferable because there is less variation due to promotions and other temporary price changes.

TABLE 7 Pass-through estimates[1] for regular sodas

Control group:	(1)	(2)	(3)	(4)
All sugar-free beverages	18.9 (1.58)	18.8 (1.65)	17.9 (1.47)	18.1 (1.71)
Sugar-free waters	19.9 (1.94)	20.0 (1.83)	20.0 (1.96)	19.6 (1.99)
Sugar-free sodas	17.5 (2.02)	17.6 (2.41)	15.1 (1.51)	17.0 (2.41)
Sugar-free variants	17.4 (2.14)	17.5 (2.56)	14.8 (1.59)	16.9 (2.57)
All regular sodas (previous year)	17.5 (1.01)	17.6 (0.93)	16.9 (0.85)	17.3 (0.93)
Weights[2]	**No**	**Yes**	**No**	**Yes**

1 In columns 1 and 2 data is aggregated at the month level, while in columns 3 and 4 weekly data is used. The estimates are reported in cents per litre. To obtain pass-throughs, the presented estimates must be divided by the tax change $\Delta t = 12.5$. All regressions contain product and month fixed effects. Standard errors (in parenthesis) are clustered by product. 2 Weights are the average monthly or weekly sales across products and stores, respectively.

Table 8 presents estimates for sodas with sugar-free variants[74]. This group is a subset of sodas and includes those beverages that have a sugar-free version from the same brand. It is possible that retailers cannot raise their prices as much due to the availability of close substitutes. However, the pass-through estimates of table 8 are only marginally lower than those of table 7.

Now, using the sugar-free sodas again as the control group, prices of these products have increased of somewhere between €0.139 and €0.173. Focusing again only on the monthly data, prices have risen €0.170 (weighted) or €0.173 (unweighted), which translates into a pass-through rate of somewhere between 136 and 138 percent. Table A2 (in the appendix) presents pass-through estimates for sodas that do not have a sugar-free version available. Their prices have risen roughly €0.01 more; corresponding estimates were: €0.179 (weighted) and €0.184 (unweighted).

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[74] In the dataset, there were 29 and 25 sodas that have a sugar-free version in the monthly and in the weekly data, respectively.

TABLE 8 Pass-through estimates[1] for sodas with sugar-free variants

Control group:	(1)	(2)	(3)	(4)
All sugar-free beverages	18.4 (2.03)	18.5 (1.85)	16.7 (1.89)	17.8 (1.90)
Sugar-free waters	19.5 (2.33)	19.8 (2.02)	18.7 (2.30)	19.3 (2.16)
Sugar-free sodas	17.0 (2.40)	17.3 (2.57)	13.9 (1.93)	16.7 (2.55)
Sugar-free variants	16.9 (2.50)	17.2 (2.71)	13.6 (1.99)	16.6 (2.70)
Same products (previous year)	17.1 (1.66)	17.4 (1.27)	15.8 (1.49)	17.0 (1.25)
Weights[2]	**No**	**Yes**	**No**	**Yes**

1 In columns 1 and 2 data is aggregated at the month level, while in columns 3 and 4 weekly data is used. The estimates are reported in cents per litre. To obtain pass-throughs, the presented estimates must be divided by the tax change $\Delta t = 12.5$. All regressions contain product and month fixed effects. Standard errors (in parenthesis) are clustered by product. 2 Weights are the average monthly or weekly sales across products and stores, respectively.

Table A3 (in the appendix) presents results from similar regressions as the ones from line five in previous tables for products in the control groups to check for possible price effects in untaxed products. There are both negative and positive coefficients depending on the set of products but all of them are relatively small and none are statistically significant. This result is similar to previous studies (see e.g. Berardi et al. 2012; Grogger 2017; Silver et al. 2017).

It should be emphasized that these results generalise immediately only to the 57 S-market stores in the HOK-Elanto operating region. These stores control around 15 percent of the regions grocery sales. As indicated by previous studies, pass-through can be heterogenous across regions (Bergman & Hansen 2017; Colchero et al. (2015a)) and retailers (Berardi et al. 2012). Therefore, pass-through rates can be different from the ones estimated here when considering different regions of Finland and other retailers.

However, figure 2 provides some indication that the pass-through estimates from this dataset might be similar to the average pass-through in Finland. In the figure, the price index from Statistics Finland diverges slightly from the one drawn from the S-market data in September of 2013 but the tax induced jump in prices is of similar size in both.

Next, the question of potential heterogeneity of pass-through across different brands and package sizes is considered. Table 9 presents pass-through estimates for the five largest brands of SSBs in terms of sales. Here, sugar-free sodas are used as the control group, so these estimates can be compared to the first two columns of line three from the previous tables.

TABLE 9 Pass-through estimates[1] by brand

Brand	(1)	(2)
Coca-Cola	13.5	18.4
	(4.36)	(3.12)
Pepsi	26.8	20.4
	(6.09)	(3.80)
Fanta	20.6	21.3
	(1.96)	(2.45)
Jaffa	17.4	19.4
	(2.62)	(3.08)
Rainbow	15.8	14.8
	(1.96)	(2.47)
Weights[2]	**No**	**Yes**

1 All regressions have the monthly modal price per litre as the dependent variable and are estimated with product and month fixed effects. Sugar-free sodas is used as the control group. To obtain pass-throughs, the presented estimates must be divided by the tax change $\Delta t = 12.5$. Standard errors (in parenthesis) are clustered by product. 2 Weights are the average monthly sales per product averaged across stores.

As in Berardi et al. (2012), there seems to be some heterogeneity in the pass-through rates across brands. The prices of Pepsi and Fanta increased more than the other three due to the tax change. Looking at the weighted estimates, the pass-through was lowest for Rainbow, which is a cheap private label. This is opposite to Berardi et al. who find the pass-through to be highest for private store-owned labels. Furthermore, the unweighted estimate for Coca-Cola is the lowest among the five and significantly lower[75] than the weighted one.

Table 10 shows the pass-through estimates by product volume. Again, sugar-free sodas are chosen as the control group. As in Colchero et al. (2015a), pass-through rates are higher for beverages with smaller packages, but the differences are not as large. For small packages (≤ 0.5 l), the pass-through rates are higher than the average pass-through rate and lower than average for larger packages.

TABLE 10 Pass-through estimates[1] by volume

Volume	(1)	(2)
V ≤ 0.5 l	19.2	20.3
	(2.39)	(2.46)
0.5 < V ≤ 1.5 l	16.9	15.8
	(2.08)	(2.45)
V > 1.5 l	16.5	18.1
	(3.03)	(4.01)
Weights	**No**	**Yes**

1 All regressions have the monthly modal price per litre as the dependent variable and are estimated with product and month fixed effects. Sugar-free sodas is used as the control group. To obtain pass-throughs, the presented estimates must be divided by the tax change $\Delta t = 12.5$. Standard errors (in parenthesis) are clustered by product. 2 Weights are the average monthly sales per product averaged across stores.

[75] This is because the prices of two of its products (a 0.33 litre can and a 6-pack) were not affected by the tax that much, although the prices of its most sold products were.

5.2 Price Elasticity Estimates

This section presents the own price elasticity estimates for all SSBs and three different subset groups. In addition, it includes the price elasticity estimates for the five largest brands and for three separate groups of package sizes.

Table 11 shows the estimates for the own price elasticity of demand for the different groups of SSBs. It includes two 2SLS-estimates and one OLS-estimate for each product group. The two 2SLS-estimates differ in terms of the instrument used. In the first case, a dummy variable for the tax change is used as the instrument, and in the second case, a variable that calculates[76] the size of the tax change in euros. The table also reports the 1st stage t-test values that test for the relevance of the instrument. All the t-values are large and the associated p-values close to zero, so the instruments do not suffer from weakness.

The two 2SLS-estimates are of similar size, but the standard errors are slightly larger when using the tax size -variable as the instrument. For this reason, the estimates using the tax-dummy are preferred. The OLS-estimate is larger for all SSBs, sodas and SSBs with sugar-free substitutes and lower for sugar-sweetened waters. Obtained price elasticity estimates (IV) are very close to the -0.79 by Andreyeva et al. (2010) and moderately larger (implying less elastic demand) than the -1.30 by Cabrera Escobar et al. (2013). The demand for sodas (-0.82) seems to be slightly more elastic than for sugar-sweetened waters (-0.66). This could reflect the fact that sodas have closer sugar-free substitutes available. When looking at the subset of sodas that have a sugar-free version available, their demand is a bit more elastic: -0.95 with the tax-dummy as instrument and -1.02 with the other instrument.

As noted in the previous section, pass-through rates were higher for flavoured waters than for regular sodas. This would be in line with the fact, that the elasticity of demand was moderately higher for sodas. Meanwhile, the demand for sodas with sugar-free versions was also somewhat more elastic than the demand for all sodas but their prices rose only marginally less.

[76] This instrumental variable is calculated as $1.14 * Volume * €0.11$.

TABLE 11 Price elasticity estimates for different beverage groups

Model[1]	All SSBs	Sodas	Flavoured waters	SSBs with sugar-free versions
2SLS (instrument:	-0.78	-0.82	-0.66	-0.95
tax-dummy)	(0.12)	(0.15)	(0.16)	(0.24)
1st stage t-test[2]	17.1	14.5	8.98	8.66
(p-value)	($p<0.0001$)	($p<0.0001$)	($p<0.0001$)	($p<0.0001$)
2SLS (instrument:	-0.78	-0.80	-0.70	-1.02
tax size-variable)	(0.18)	(0.22)	(0.16)	(0.39)
1st stage t-test	8.34	7.36	12.6	4.88
(p-value)	($p<0.0001$)	($p<0.0001$)	($p<0.0001$)	($p<0.0001$)
OLS	-0.98	-1.05	-0.56	-1.58
	(0.16)	(0.18)	(0.15)	(0.16)

1 All models are estimated with product, store and month fixed effects. Standard errors (in parenthesis) are clustered by product. 2 This row provides the t-statistic (and associated p-value) from the first stage -regression. The null hypothesis is that the instrument is not correlated with price after other variables have been controlled for.

These results come from the shopping behaviour of customers of four S-market supermarkets in Helsinki. As the pass-through results before, price elasticities can be heterogenous in the population. They can vary across different regions and customer segments. In fact, lower-income groups often have more elastic demands (see e.g. Kotakorpi et al. 2011; Colchero et al. 2015b; Guerrero-López et al. 2017). However, the observed differences are relatively small. Furthermore, the average disposable income that households have in Helsinki is only moderately higher[77] than that of average Finnish household (Official Statistics of Finland 2017). Consequently, these elasticities are potentially useful in predicting the average demand response of Finnish consumers.

In table 12, separate price elasticity estimates are presented for the five largest brands. It includes the same brands as table 9. Based on the reported estimates, the demand for Coca-Cola is the most elastic and the demand for Rainbow is the least elastic. This probably reflects the fact that Rainbow is the cheapest option available. For some reason the IV-estimate for Pepsi is very imprecise. However, these estimates are probably biased upward (true elasticities are more negative) because the tax increased the prices of competing brands as well. This likely means that the observed tax induced price increase would have caused a larger decrease in demand if the competing brands had not also increased their prices[78].

In the previous section, pass-through was lowest for Coca-Cola and Rainbow. For Coca-Cola this makes sense because it has the most elastic demand of

[77] In 2014, the average disposable income was 42 193 euros per household in Helsinki, whereas it was 38 702 euros in the whole of Finland (OSF 2017).

[78] To a lesser extent, this problem is potentially present in the other elasticity estimates as well. The larger the category of products for which the average elasticity is calculated, the lower is the likelihood that there exists a significant number taxed substitutes whose price increase causes upward-bias to the obtained estimates. Thus, the elasticity estimates for larger categories of products (in table 11 and 13) are not as likely to suffer from this bias. Yet, even the estimate for the largest category of products (all SSBs) could be affected by the price increase of taxed substitutes not in the sample (possibly juices).

the five but for Rainbow this is in fact quite surprising because its demand is the least elastic. The demand for Jaffa is slightly more elastic than for Fanta, and correspondingly, the effect on its prices was slightly smaller.

TABLE 12 Price elasticity estimates[1] by brand

Brand	Price elasticity (IV)	First stage (t-test)	Price elasticity (OLS)
Coca-Cola	-2.12	2.42	-2.15
	(0.49)	(p<0.015)	(0.43)
Pepsi	-0.61	8.13	-1.42
	(0.65)	(p<0.001)	(0.18)
Fanta	-0.98	7.65	-1.06
	(0.22)	(p<0.001)	(0.22)
Jaffa	-1.26	10.8	-1.82
	(0.28)	(p<0.001)	(0.44)
Rainbow	-0.48	12.8	-0.46
	(0.18)	(p<0.001)	(0.15)

1 All regressions are estimated with product, store and month fixed effects. Standard errors (in parenthesis) are clustered by product.

Table 13 shows the price elasticity estimates by product volume, similarly to the pass-through estimates in table 10. On average, demand appears to be more elastic for products with larger package sizes. This is line with the fact that the pass-through was higher for products with smaller package sizes.

TABLE 13 Price elasticity estimates[1] by volume

Volume	Price elasticity (IV)	First stage (t-test)	Price elasticity (OLS)
$V \leq 0.5$ l	-0.66	12.1	-0.52
	(0.20)	(p<0.001)	(0.26)
$0.5 < V \leq 1.5$ l	-0.83	17.4	-1.04
	(0.10)	(p<0.001)	(0.18)
$V > 1.5$ l	-0.95	2.79	-1.54
	(0.84)	(p<0.005)	(0.29)

1 All regressions are estimated with product, store and month fixed effects. Standard errors (in parenthesis) are clustered by product.

5.3 From Euros to Litres and Kilograms

The Finnish tax increase in January 2014 is estimated to have caused the prices of SSBs to increase by somewhere in between of €0.17 and €0.19 per litre. In 2013, before the tax change, the sales weighted average per litre price of SSBs was 2.03 euros. Thus, the tax increased their prices by approximately 8.4-9.4 percent. Their price elasticity was estimated to be -0.78. Putting these two estimates together translates into a decrease in consumption of SSBs by 6.5 to 7.3 percent. For sodas, their average pre-tax price per litre was lower 1.84 euros. This means that the tax increased their prices around 9.2-10.3 percent. Their estimated price elasticity was -0.82, which translates into a decrease of consumption[79] of somewhere between 7.5 to 8.5 percent.

Based on the figures from UNESDA (2017), the Finnish total consumption of soft drinks was 391.3 million litres in 2013 of which 75 percent were regular sodas (293.5 million litres) and 25 percent diet sodas (97.8 million litres). In 2014, the total consumption fell to 379.4 million litres. The share of regular sodas fell to 70 percent (265.6 million litres) and the share of diet sodas increased to 30 percent (113.8 million litres). Consequently, the consumption of regular sodas fell by approximately 9.5 percent.

The average Finnish person consumed 53.9 litres of regular soft drinks in 2013 (UNESDA 2017). Based on the estimates presented here, the soft drink tax would have led to a decrease in consumption of somewhere between 4.0 to 4.6 litres. As a matter of fact, the UNESDA figures show a slightly larger decrease of 5.3 litres.

Following Grogger (2017), who uses the Harris-Benedict formula to calculate the mean weight change resulting from the reduction in consumption, the possible weight reduction for the Finnish case is calculated. The per capita soft drink consumption levels of Mexico are significantly higher than those of Finland. In 2013, Mexicans consumed on average 139.4 litres of soda per person. Furthermore, in Mexico, the relative effect the tax had on soda prices was larger and demand is slightly more elastic. Thus, the resulting estimated reductions in consumption are significantly higher, somewhere between 16.7 to 25.4 litres per capita.

To implement the formula, one first calculates the basal metabolic rate (BMR), which is the daily caloric expenditure of the human body at rest. This is calculated as

$$BMR = \alpha + \delta W,$$

where W is weight, the constant term α is a function of age, height and sex and the weight coefficient δ is a function of sex. Grogger uses values: $\delta = 13.4$ for men and $\delta = 9.3$ for women, reported by Roza and Shizgal (1984).

Then, to determine actual energy expenditure, BMR is multiplied by an activity factor γ. Douglas et al. (2007) report values: $\gamma = 1.2$ for persons living sedentary life and $\gamma = 1.5$ living moderately active life. In a steady-state, energy intake I equals energy expenditure: $I = \gamma(\alpha + \delta W)$. The steady-state change in weight owing to change in caloric intake is, then, $\Delta W = \Delta I/(\gamma\delta)$.

[79] In the dataset, excluding promotions, the total beverage sales increased from 851,464 units to 882,507 units from 2013 to 2014, while the share of SSBs of total sales fell from 50.3 to 47.5 percent. If their share would have remained the same in 2014, this would translate in a decrease of their consumption by approximately 5.9 percent. The introduction of new sugar-sweetened products in 2014 complicates these calculations slightly. For example, excluding sales campaigns, the consumption of regular sodas fell only by 4.5 percent, while the decrease was 7.6 percent when looking only the subset of products that were sold in both years.

Grogger assumes that each litre of soda contains 400 kilocalories and that on average Mexicans live moderately active lives $\gamma = 1.5$ and that half of the population are female. The same assumptions are made for these calculations. If the Finnish people are on average less active, the actual weight loss would be larger, while the opposite is true if Finns are more active. Further, it is assumed that the calories reduction resulting from the decrease in soda consumption is not offset by increases in calories from other sources.

Grogger calculates that the Mexican soda tax could have resulted in a mean steady-state weight loss of somewhere between 2.5-3.7 pounds (1.13-1.68 kilograms). Because the Finnish tax had a significantly smaller impact[80] on consumption (in litres), the calculated effects on weight are small. Considering the possible 4.0, 4.6 and 5.3 litre decreases in the consumption of regular sodas, the corresponding effects on the steady-state[81] weight are 0.26, 0.30 and 0.34 kg, respectively.

Consequently, it is not likely that the 2014 tax change has caused significant improvements on public health. Grogger remarks, that the weight effects of the Mexican tax are conceivable large enough[82] to have important health effects. However, based on the same calculations, the Finnish tax did not have a large enough effect on population weight to generate meaningful health improvements. It should be noted that the Finnish tax also reduced the consumption of other SSBs, such as sugar-sweetened waters, and thus these calculations possibly underestimate the total effect on steady-state weight. On the other hand, these other SSBs have a lot less calories than sodas and, therefore, do not contribute as much to the total caloric intake. In conclusion, it is natural that the health effects of the tax are not as large because the consumption of soft drinks was already at a relatively low level in Finland before the tax increase.

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[80] The Finnish tax is estimated to have caused a decrease in consumption of somewhere between 4.0 to 4.6 litres, while the Mexican tax is estimated to have decreased consumption by 16.7 to 25.4 litres. The difference in the relative decreases of consumption is smaller: 7.5-8.5% in Finland and 12.0-18.2% in Mexico.

[81] This means that daily energy expenditure equals energy intake, so weight remains unchanged after the steady-state is reached.

[82] He calculates that mean adult BMI would fall by 1 percent if every Mexican adult were to lose about 1.6 pounds so that the tax could have lowered the Mexican BMI by 1 to 1.7 percent. Grogger notes that previous studies from U.S. suggest that BMI reductions on the order of 1 to 5 percent could be sufficient in generating meaningful improvements in health.

6 CONCLUSIONS

This thesis analysed the effects that the increase in Finnish soft drink tax for sugar-sweetened beverages had on the price and demand of taxed drinks. In January 2014, the excise tax for beverages that had over 0.5 grams of sugar in 100 millilitres increased from 0.11 euros per litre to 0.22 euros per litre. Because Finland has an additional ad valorem tax of 14 percent for food, this translates into a tax increase of 0.1254 euros per litre for SSBs.

There are possible market failures associated to the consumption of SSBs. These include possible negative externalities; the consumption of SSBs is associated with increased rates of obesity (see e.g. Malik et al. 2006; Vartarian et al. 2007), which in turn increases the contemporary health care costs. If this translates into an increase of lifetime medical costs as well, this increases the public health care expenses and creates a negative externality to the tax payer.

It is likely that most consumers in Finland understand the adverse health effects of consuming too much sugar. One signal of this is the large variety of diet or sugar-free soft drinks available. Imperfect information does not seem a major source of market failure. However, it is possible that some segments of consumers, especially children, are not fully informed of the potential harm.

This is connected to the possibility that consumers are not fully rational. Some people may have time-inconsistent preferences: they might make choices today that they themselves would not approve tomorrow. O'Donoghue and Rabin (2006) show that, under certain conditions, when people have self-control problems taxes can be used to increase total social surplus.

Self-control problems are more likely if the substance in question is addictive. There is no decisive scientific evidence on the addictiveness of sugar (Westwater, Fletcher & Ziauddeen 2016). Still, consumption of SSBs is potentially one of the major factors preventing people from fulfilling their aspirations of losing weight.

If these market failures exist, taxation can be used as a tool to alleviate and possibly correct them. Taxing sugar-sweetened beverages will motivate people to consume more of the healthier, sugar-free options. These types of corrective taxes are beneficial because they can potentially increase social welfare.

To understand the effects of a certain tax reform, it is essential to analyse its effect on prices (pass-through) and, then, the effect of this tax induced price change on demand. The economic theory of tax incidence shows that under perfect competition the pass-through cannot exceed unity (see e.g. Weyl & Fabinger 2013). On the other hand, under imperfect competition pass-through can exceed unity, i.e. taxes can overshift to prices. In their models of single-product oligopoly, Delipalla and Keen (1992) and Anderson et al. (2001) show that excise taxes overshift into prices when demand is highly convex. Instead, in Hamilton´s (2009) model of many-product retailers excise taxes overshift into prices in all cases but when demand is highly convex.

The extent that the tax shifts into prices depends on the specific market conditions: elasticities of demand and supply and degree of competition. It is, therefore, ultimately an empirical matter. This thesis applies the differences-in-differences method and finds that the prices of SSBs increased of somewhere between 0.17-0.19 euros per litre. This translates into a pass-through rate of 136-152 percent, so there is evidence of overshifting of the tax by somewhere in between of 36 to 52 percent. This amounts to, on average, 8-10 percent increase in the price of SSBs.

To estimate the own price elasticity of demand for SSBs, tax change is used as an instrumental variable. This isolates the exogenous variation in prices, which is useful because price is an endogenous variable that is determined simultaneously by the forces of supply and demand. The price elasticity for all SSBs is estimated to be -0.78 (and -0.82 for sodas), which means that a ten percent increase in prices decreases the quantity demanded by approximately 7.8 percent.

Because the consumption of SSBs was already at a relatively low level in Finland before the tax increase, the reduction in consumption (measured in litres) was quite modest, somewhere in between of 4.0 to 5.3 litres. Thus, it is unlikely that the Finnish soft drink tax increase generated major health improvements. However, one of the reasons why Finns drink relatively low amounts of soft drinks is probably their comparatively high price, which in turn is caused partly by the high excise tax rate. Therefore, the abolition of the tax could have significant adverse effects on public health. In addition, the tax generates approximately 144 million euros of tax revenue per year (Ministry of Finance 2017) that would have to be collected with a potentially more harmful tax.

Nevertheless, as mentioned, the tax is levied also on bottled waters without any added sugar. Abolishing the tax for these products would seem reasonable, as it could decrease their prices and make them more attractive to consumers who would potentially substitute away from unhealthy beverages.

BIBLIOGRAPHY

Abdullah, A., Peeters, A., Courten de, M. & Stoelwinder, J. (2010). The magnitude of association between overweight and obesity and risk of diabetes: A meta-analysis of prospective cohort studies. *Diabetes Research and Clinical Practice*, 89, 309-319.

Anderson, S., de Palma, A. & Kreider, B. (2001). Tax incidence in differentiated product oligopoly. *Journal of Public Economics*, 81, 173-192.

Andreyeva, T., Long, M. & Brownell, K. (2010). The impact of food prices on consumption: A systematic review of research on the price elasticity of demand for food. *American Journal of Public Health*, 100(2), 216-222.

Banks, J., Blundell, R. & Lewbel, A. (1997). Quadratic Engel curves and consumer demand. *Review of Economics and Statistics*, 79(4), 527–39.

Basu, S., McKee, M., Galea, G. & Stuckler, D. (2013). Relationship of soft drink consumption to global overweight, obesity, and diabetes: A cross-national analysis of 75 countries. *American Journal of Public Health*, 103, 2071-2077.

Becker, G. & Murphy, K. (1988). A theory of rational addiction. *Journal of Political Economy*, 96(4), 675-700.

Berardi, N., Sevestre, P., Tepaut, M. & Vigneron, A. (2012). The impact of a "soda tax" on prices. Evidence from French micro data. *Banque de France*. Working Paper.

Bergman, M. & Hansen, N. (2017). Are excise taxes on beverages fully passed through to prices? The Danish evidence. *Danmarks Nationalbank*. Working Paper.

Bergtold, J., Akobundu, E. & Peterson, E. (2004). The FAST method: Estimating unconditional demand elasticities for processed foods in the presence of fixed effects. *Journal of Agricultural and Resource Economics*, 29(2), 276-295.

Besley, T. & Rosen, H. (1999). Sales taxes and prices: An empirical analysis. *National Tax Journal*, 52(2), 157-178.

Bogers, R., Bemeals, W., Hoogenveen, R., Boshuizen, H., Woodward, M., Knekt, P., van Dam, R., Hu, F., Visscher, T., Menotti, A., Thorpe, R., Jamrozik, K., Calling, S., Strand, B. & Shipley M. (2007). Association of overweight with increased risk of coronary heart disease partly independent of blood pressure and cholesterol levels: A meta-analysis of 21 cohort studies including more than 300 000 persons. *Archives of Internal Medicine*, 167(16), 1720-1728.

Cabrera Escobar, M., Veerman, J., Tollman, S., Bertram, M. & Hofman, K. (2013). Evidence that a tax on sugar sweetened beverages reduces the obesity rate: A meta-analysis. *BMC Public Health*, 13:1072.

Campos-Vázquez, R. & Medina-Cortina, E. (2015). Pass-through and competition: The impact of soft drink taxes using Mexican supermarket stores. *Latin American and Caribbean Economic Association*. Working Paper.

Cawley, J. & Frisvold, D. (2017). The pass-through of taxes on sugar-sweetened beverages to retail prices: The case of Berkeley, California. *Journal of Policy Analysis and Management*, 36(2), 303-326.

Cawley, J. & Meyerhoefer, C. 2012. The medical care costs of obesity: An instrumental variable approach. *Journal of Health Economics*, 31, 219-230.

Colchero, M., Salgado, J., Unar-Munguía, M., Molina, M., Ng, S. & Rivera-Dommarco, J. (2015a). Changes in prices after an excise tax to sweetened sugar beverages was implemented in Mexico: Evidence from urban areas. *PLoS ONE*, 10(12): e0144408.

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

Colchero, M., Popkin, B., Rivera, J. & Ng, S. (2016). Beverage purchases from stores in Mexico under the excise tax on sugar sweetened beverages: observational study. *BMJ*, 352: h6704.

Deaton, A. & Muellbauer, J. (1980). An almost ideal demand system. *American Economic Review*, 70(3), 312-326.

Delipalla, S. & Keen, M. (1992). The comparison between ad valorem and specific taxation under imperfect competition. *Journal of Public Economics*, 49(3), 351-367.

Della Vigna, S. & Malmendier, U. (2006). Paying to not go the gym. *American Economic Review*, 96(3), 694-719.

Ding, A. (2003). Youth are more sensitive to price changes in cigarettes than adults. *Yale Journal of Biology and Medicine*, 76(3), 115-124.

Douglas, C., Lawrence, J., Bush, N., Oster, R., Gower, B. & Darnell, B. (2007). Ability of the Harris Benedict formula to predict energy requirements differs with weight history and ethnicity. *Nutrition Research*, 27(4), 194-199.

Falbe, J., Rojas, N., Grummon, A. & Madsen, K. (2015). Higher retail prices of sugar-sweetened beverages 3 months after implementation of an excise tax in Berkeley, California. *American Journal of Public Health*, 105(11), 2194-2201.

Finkelstein, E., Zhen, C., Bilger, M., Nonnemaker, J., Farooqui, A. & Todd, J. (2013). Implications of a sugar-sweetened beverage (SSB) tax when substitutions to non-beverage items are considered. *Journal of Health Economics*, 32, 219-239.

Fullerton, D. & Metcalf, G. (2002). Tax incidence. *Handbook of Public Economics*, 4, 1787-1872.

Guerrero-López, C., Unar-Munguía, M. & Colchero, M. (2017). Price elasticity of the demand for soft drinks, other sugar-sweetened beverages and energy dense food in Chile. *BMC Public Health*, 17:180.

Grogger, J. (2017). Soda taxes and the prices of sodas and other drinks: Evidence from Mexico. *American Journal of Agricultural Economics*, 99(2), 481-498.

Gruber, J. & Koszegi, B. (2004). Tax incidence when individuals are time-inconsistent: The case of cigarette excise taxes. *Journal of Public Economics*, 88, 1959-1987.

Haavio, M. & Kotakorpi, K. (2011). The political economy of sin taxes. *European Economic Review*, 55, 575-594.

Hamilton, S. (2009). Excise taxes with multiproduct transactions. *American Economic Review*, 99(1), 458-471.

Harding, M. & Lovenheim, M. (2017). The effect of prices on nutrition: Comparing the impact of product- and nutrient-specific taxes. *Journal of Health Economics*, 53, 53-71.

HE 109/2013. Government proposal to Parliament to amend the Act on excise duty on confectionery, ice cream and soft drinks. Submitted in Helsinki 16th of September 2013. Retrieved from: https://www.finlex.fi/fi/esitykset/he/2013/20130109

HOK-Elanto. (2017). About the business, and balance sheet figures. Retrieved from: https://www.s-kanava.fi/web/hok-elanto/yrityksesta and https://www.s-kanava.fi/web/hok-elanto/yrityksesta/luvut [Referred to 12 November 2017]

Jensdottir, T., Arnadottir, I., Thorsdottir, I., Bardow, A., Gudmundsson, K., Theodors, A. & Holbrook, W. (2004). Relationship between dental erosion, soft drink consumption, and gastroesophageal reflux among Icelanders. *Clinical Oral Investigations*, 8(2), 91-96.

Kotakorpi, K. (2008). The incidence of sin taxes. *Economic Letters*, 98, 95-99.

Kotakorpi, K., Härkänen, T., Pietinen, P., Reinivuo, H., Suoniemi, I. & Pirttilä, J. (2011). Terveysperusteisen elintarvikeverotuksen vaikutukset kansalaisten terveydentilaan ja terveyseroihin. *Terveyden ja hyvinvoinnin laitoksen raportti*. Helsinki 7/2011.

Laibson, D. (1997). Hyperbolic discounting and golden eggs. *Quarterly Journal of Economics*, 112(2), 443-477.

Malik, V., Schulze, M. & Hu, F. (2006). Intake of sugar-sweetened beverages and weight gain: A systematic review. *American Journal of Clinical Nutrition*, 84(2), 274-288.

Ministry of Finance. (2013). Sokeriverotyöryhmän loppuraportti. The final report of the Sugar tax working group. *Valtiovarainministeriön julkaisuja*, 3/2013. Retrieved from: https://www.google.fi/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwit8d7h6uHYAhVMiywKHQvPDeIQFggpMAA&url=http%3A%2F%2Fvm.fi%2Fdms-portlet%2Fdocument%2F0%2F266422&usg=AOvVaw12yebf3rUJUA9UwXdUO9Sa

Ministry of Finance. (2017). Soft drink taxation. Retrieved from: http://vm.fi/virvoitusjuomien-verotus [Referred to 9 November 2017]

Morris, S. (2007). The impact of obesity on employment. *Labour Economics*, 14(3), 413-433.

Mourao, D., Bressan, J., Campbell, W. & Mattes, R. (2007). Effects of food form on appetite and energy intake in lean and obese young adults. *International Journal of Obesity*, 31(11), 1688-1695.

Männistö, S., Laatikainen, T., Harald, K., Borodulin, K., Jousilahti, P., Kanerva, N., Peltonen, M. & Vartiainen, E. (2015). Työikäisten ylipainon ja lihavuuden kasvu näyttää hidastuneen: kansallisen FINRISKI-terveystutkimuksen tuloksia. *Suomen lääkärilehti*, 70. Retrieved from: http://www.fimnet.fi/cl/laakarilehti/pdf/2015/SLL142015-969.pdf

Männistö, S., Laatikainen, T. & Vartiainen, E. (2012). Suomalaisten lihavuus ennen ja nyt. *Terveyden ja hyvinvoinnin laitos, Tutkimuksesta tiivisti*, 4.

O'Donoghue, T. & Rabin, M. (2006). Optimal sin taxes. *Journal of Public Economics*, 90, 1825-1849.

OECD. (2016). Data on Purchasing power parities and exchange rates. Retrieved from: https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm#indicator-chart and https://data.oecd.org/conversion/exchange-rates.htm#indicator-chart

Official Statistics of Finland (OSF). (2017). Total statistics on income distribution. Helsinki: Statistics Finland. Retrieved from: http://www.stat.fi/til/tjkt/index_en.html

Read, D., Loewenstein, G. & Kalyanaraman, S. (1999). *Journal of Behavioural Decision Making*, 12, 257-273.

Read, D. & van Leeuwen, B. (1998). Predicting hunger: The effects of appetite and delay on choice. *Organizational Behaviour and Human Decision Processes*, 76(2), 189-205.

Roza, A. & Shizgal, H. (1984). The Harris Benedict equation re-evaluated: Resting energy requirements and the body cell mass. *American Journal of Clinical Nutrition*, 40, 168-182.

Schulze, M., Manson, J., Ludwig, D., Colditz, G., Stampfer, M., Willett, W. & Hu, F. (2004). Sugar-sweetened beverages, weight gain, and incidence of type 2 diabetes in young and middle-aged women. *Journal of the American Medical Association*, 292(8), 927-934.

Silver, L., Ng, S., Ryan-Ibarra, S., Taillie, L., Induni, M., Miles, D., Poti, J. & Popkin, B. (2017). Changes in prices, sales, consumer spending, and beverage consumption one year after a tax on sugar-sweetened beverages in Berkeley, California, US: A before-and-after study. *PLoS Medicine*, 14(4): e1002283.

Smith, A. (1776). *The wealth of nations*. Hertfordshire: Wordsworth Editions Limited.

Tiessalo, P. (2017). Laihuuden ihannoinnin järkyttävä tulos: 84 prosenttia naisista tyytymättömiä painoonsa. Retrieved from: https://yle.fi/uutiset/3-9385699

Union of European Beverages Association (UNESDA). (2017). Soft drink consumption, industry volume data. [Excel file] Retrieved from: http://www.unesda.eu/products-ingredients/consumption/

van Baal, P., Polder, J., de Witt, G., Hoogenveen, R., Feenstra, T., Boshuizen, H., Engelfriet, P. & Brouwer, W. (2008). Lifetime medical costs of obesity: Prevention no cure for increasing health expenditure. *PLoS Medicine*, 5(2): e37.

Vartarian, L., Schwartz, M. & Brownell, K. (2007). Effects of soft drink consumption on nutrition and health: A systematic review and meta-analysis. *American Journal of Public Health*, 97(4), 667-675.

Westwater, M., Fletcher, P. & Ziauddeen, H. (2016). Sugar addiction: The state of science. *European Journal of Nutrition*, 55(2), 55-69.

Weyl, G. & Fabinger, M. (2013). Pass-through as an economic tool: Principals of incidence under imperfect competition. *Journal of Political Economy*, 121(3), 528-583.

Whittaker, R., Wright, J., Pepe, M., Seidel, K. & Dietz, W. (1997). Predicting obesity in young adulthood from childhood and parental obesity. *National English Journal of Medicine*, 337, 869-873.

Willett, W. & Ludwig, D. (2013). Science souring of sugar. *BMJ*, 346: e8077.

Wooldridge, J. (2010). *Econometric analysis of cross section and panel data*. Second Edition. London: The MIT Press.

World Atlas. (2017). Countries with the highest levels of soft drink consumption. Retrieved from: http://www.worldatlas.com/articles/countries-with-the-highest-levels-of-soft-drink-consumption.html [Referred to 13 January 2018]

World Health Organization (WHO). (2016). Fiscal policies for diet and the prevention of noncommunicable diseases. Retrieved from: http://apps.who.int/iris/bitstream/handle/10665/250131/9789241511247-eng.pdf;jsessionid=FC0310EC24EAB4A67A9DEE92154243CB?sequence=1

World Health Organisation (WHO). (2017). Facts about obesity and overweight. Retrieved from: http://www.who.int/mediacentre/factsheets/fs311/en/ [Referred to 7 November 2017]

Wright, P. (1928). *The tariff on animal and vegetable oils*. New York: Macmillan.

APPENDIX

Figure A1 shows the development of monthly sales in the dataset. There are two clear spikes that are driven by promotional sales campaigns (in months 12 and 22). The spike of the summer of 2014 is mainly driven by increased sales of sugar-free waters[83].

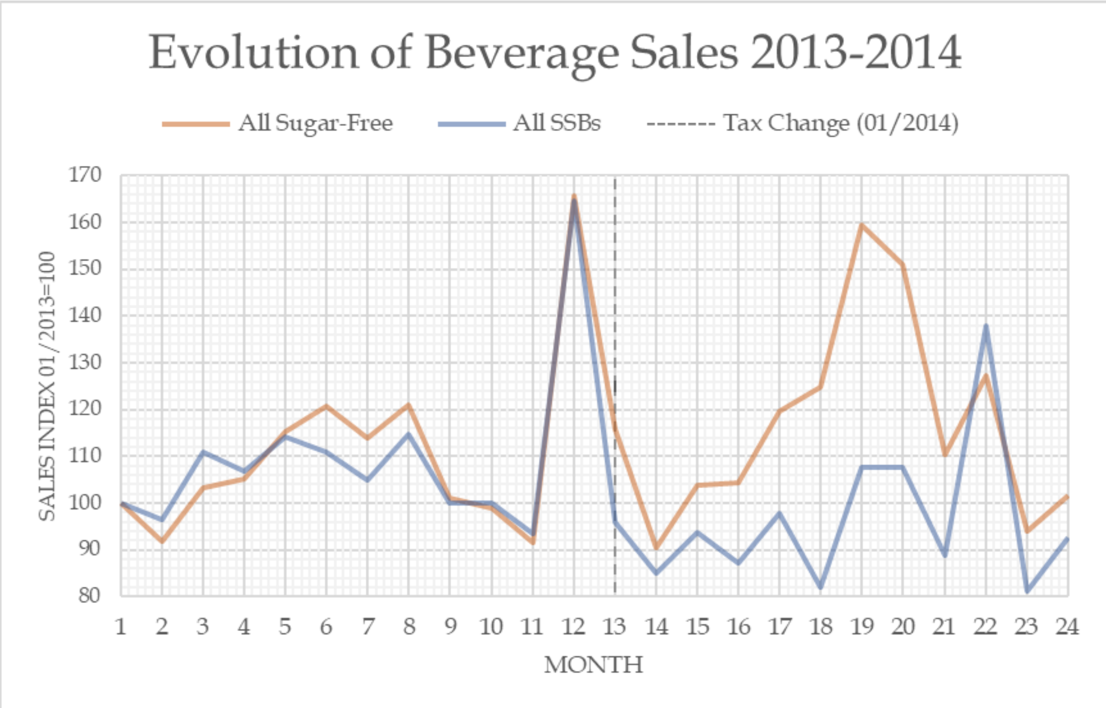

FIGURE A1 Evolution of monthly beverage sales (2013-2014)

Figure A2 graphs the evolution of the sales in the dataset for regular and diet sodas. It has the same spikes caused by promotional campaigns as the figure A1. From this figure, one can see more clearly the substitution from sugar-sweetened to sugar-free sodas.

[83] The summer of 2014 had a quite long heat wave in Southern Finland (by Finnish standards).

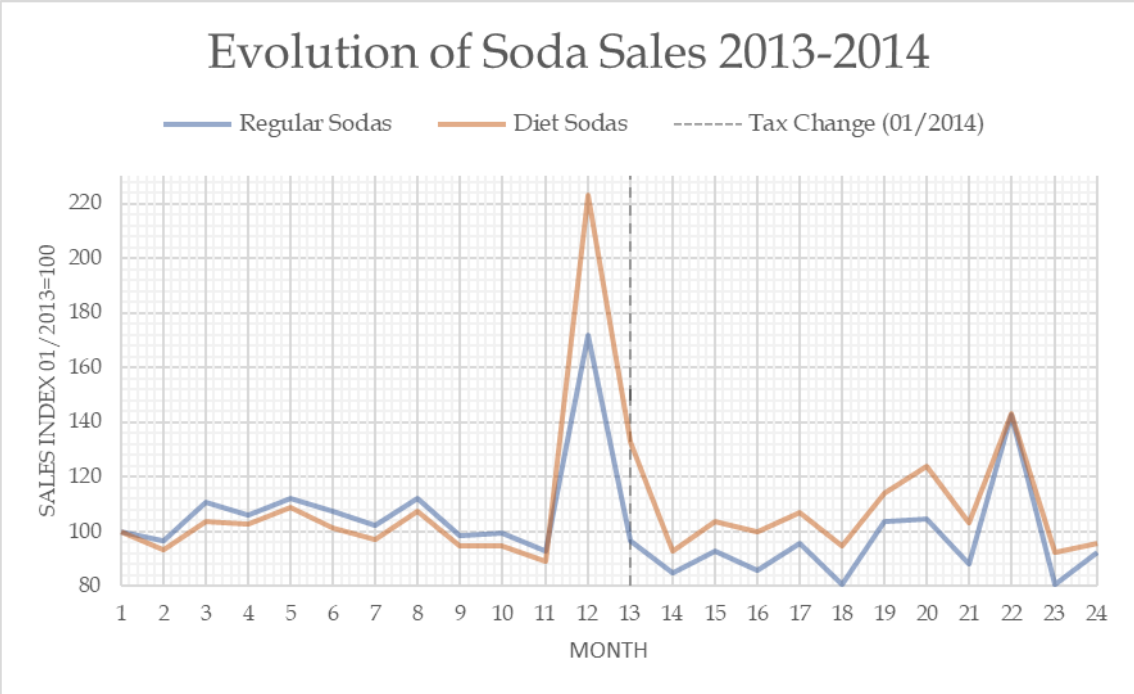

FIGURE A2 Evolution of monthly soda sales (2013-2014)

Table A1 presents the pass-through estimates for sugar-sweetened waters. They appear to be larger than for other product groups; their prices increased approximately €0.20-€0.21 per litre. However, these estimates are based on a quite small sample of products (14 for the monthly and 13 for the weekly price data).

TABLE A1 Pass-through estimates[1] for sugar-sweetened waters

Control group:	(1)	(2)	(3)	(4)
All sugar-free beverages	21.4 (2.66)	22.2 (2.05)	20.8 (2.71)	21.7 (2.15)
Sugar-free waters	22.4 (2.90)	23.4 (2.21)	22.9 (3.01)	23.7 (2.33)
Sugar-free sodas	20.0 (2.97)	21.0 (2.72)	17.9 (2.75)	20.5 (2.74)
Sugar-free variants	19.9 (2.50)	20.9 (2.86)	17.6 (2.79)	20.3 (2.89)
Same products (previous year)	20.0 (2.47)	21.0 (1.59)	19.8 (2.52)	20.8 (1.62)
Weights[2]	**No**	**Yes**	**No**	**Yes**

1 In columns 1 and 2 data is aggregated at the month level, while in columns 3 and 4 weekly data is used. The estimates are reported in cents per litre. All regressions contain product and month fixed effects. To obtain pass-throughs, the presented estimates must be divided by the tax change $\Delta t = 12.5$. Standard errors (in parenthesis) are clustered by product. 2 Weights are the average monthly or weekly sales across products and stores, respectively.

Table A2 shows the pass-through estimates for sodas without a sugar-free variant. Based on the estimates from monthly data, with sugar-free sodas as the control group, their prices have risen €0.179 (unweighted) or €0.184 (weighted). This is approximately €0.01 more than the price increase for sodas that have sugar-free versions.

TABLE A2 Pass-through estimates[1] for sodas without sugar-free variants

Control group:	(1)	(2)	(3)	(4)
All sugar-free beverages	19.4 (1.77)	19.6 (1.68)	19.0 (0.75)	19.0 (0.88)
Sugar-free waters	20.4 (2.10)	20.9 (1.87)	21.3 (0.99)	21.1 (0.98)
Sugar-free sodas	17.9 (2.19)	18.4 (2.44)	16.1 (0.77)	17.8 (1.21)
Sugar-free variants	17.8 (2.30)	18.3 (2.59)	15.8 (0.81)	17.7 (1.29)
Same products (previous year)	18.0 (1.30)	18.4 (0.99)	18.1 (0.46)	18.1 (0.50)
Weights[2]	**No**	**Yes**	**No**	**Yes**

1 In columns 1 and 2 data is aggregated at the month level, while in columns 3 and 4 weekly data is used. The estimates are reported in cents per litre. All regressions contain product and month fixed effects. To obtain pass-throughs, the presented estimates must be divided by the tax change $\Delta t = 12.5$. Standard errors (in parenthesis) are clustered by product. 2 Weights are the average monthly or weekly sales across products and stores, respectively.

Table A3 tests for the possibility that the tax change affected the prices of untaxed substitutes as well. The coefficients are relatively small, especially, when compared to those of taxed products and none are statistically significant at 5 percent significance level.

TABLE A3 Testing for possible price changes in untaxed products[1]

Tested products:	(1)	(2)	(3)	(4)
All sugar-free beverages	-1.42 (1.23)	-1.20 (1.37)	-0.97 (1.21)	-0.88 (1.47)
Sugar-free waters	-2.41 (1.68)	-2.42 (1.60)	-3.17 (1.77)	-2.94 (1.72)
Sugar-free sodas	-0.01 (1.78)	-0.03 (2.27)	1.88 (1.27)	0.32 (2.26)
Sugar-free substitutes	0.09 (1.92)	0.06 (2.44)	2.16 (1.36)	0.45 (2.44)
Weights[2]	**No**	**Yes**	**No**	**Yes**

1 In columns 1 and 2 data is aggregated at the month level, while in columns 3 and 4 weekly data is used. The estimates are reported in cents per litre. All regressions contain product and month fixed effects. Standard errors (in parenthesis) are clustered by product. 2 Weights are the average monthly or weekly sales across products and stores, respectively.