Don’t go nuts over nuts

An analysis of policy to reduce water scarcity caused by nuts

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Abstract

The aim of this paper is to investigate the potential possibilities of reducing water scarcity, by targeting the water intensive consumption of nuts. Therefore, the research question is if consumption-based policies can decrease the consumption of nuts in Sweden, in order to reduce water scarcity in sensitive areas. This is of particular importance as Swedish health authorities promote nuts as a substitute to meat, creating a conflict between global sustainability goals, when aiming to curb food consumptions climate footprints, hence risk overlooking the rapidly growing issue of water scarcity. To answer the question an instore dataset was used, which provided information on snack products including nuts, and products similar to nuts. Nuts are currently seen as mainly a snack, though the risk of nuts being viewed as a main course is prevalent, as consumption is increasing. Using the Quadratic Almost Ideal Demand System model, consumers' price sensitivity was estimated. The elasticities were further used to calculate demand curves for the included products. The last step was linking consumption to the environmental impact in order to examine the effect of consumption sided policies. Two scenarios were simulated to test the possible effect of policies targeting nut consumption. *Scenario 1* allowed for a 10% tax on nuts, and an additional 5% subsidy was introduced on legumes in *Scenario 2.* The results indicate a reduced water scarcity in both scenarios, with about 5%. Implementation of a tax on nuts can be through increasing the VAT rate. However, an implementation of a subsidy on legumes may be difficult to implement because of the partly complicated nature of the policy instrument, and possible leakage. To conclude, a dietary transition away from nuts is possible by the use of consumption sided taxation.

Keywords: Consumption, demand, dietary change, elasticity, food policy, nuts, water footprint, water scarcity.

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1. Introduction

The background and problem to this paper is presented, and the section ends with introducing the aim and question of the research.

Climate change is one of the most pressing challenges of today, with global warming as a result. The global food system has a significant effect on climate change, around 21-37 percent (IPCC 2019). The high levels of greenhouse gas emissions from animal production is in focus when addressing how to reduce carbon footprints, and often solutions tend to be on how to reduce meat consumption by substituting towards plant-based alternatives (World Wide Fund for Nature n.d.). Other environmental challenges, such as the rapidly growing issue of water scarcity in sensitive areas, are easily overlooked when attempting to reduce the impacts of climate change. While an increasing number of individuals are switching to plant-based diets for climatic and environmental reasons, they risk forgetting other sustainability targets that might be in conflict with climate issues. One example is the issue of nut consumption, and its negative effect on water scarcity. As a result, this paper proposes to add to the field of research by investigating the effect of economic instruments on nut consumption in Sweden, with the aim of reducing water shortages.

With the current rate of consumption, water scarcity increases. By 2025, two-thirds of the world's population may face water scarcity (WWF n.d.). Furthermore, food production is dependent on water as a resource, and with the expanding population, food production will have to meet demand, which will be impossible due to water scarcity (Sentlinger n.d.). Water footprint (WF) is a relatively new tool for assessing water usage and thus in extent water shortage. WF's calculates the water use of a product along its supply chain. The underlying reason for highlighting WF's is to raise awareness of the complexities of water usage among producers and consumers. Whether or not water scarcity is a local or global issue has been specifically debated. Given the gravity of the situation, and the importance of water as a fundamental resource, it is critical to consider all possible solutions to reduce water scarcity, including a global perspective. The fact that there are hotspots for water shortages across the world, often where nut production is concentrated, and further aggravated by demand in other countries, is an important element to remember (Hoekstra 2017). Because water scarcity is a worldwide issue, solutions should be developed from a global point of view.

So where to begin? Acknowledging that agriculture accounts for 72 percent of all water abstractions is a good place to start (UN-Water n.d.). Looking at specific productions, the production of nuts stands out, and is considered among the most water-intensive productions (Ritchie & Roser 2020), making nuts problematic products. This study focuses on the water usage in nut production, but we also acknowledge the fact that production has other negative aspects regarding environmental such as bio waste (International Nut & Dried Fruit Council (INC) 2019)), as well as ethical aspects of the working conditions in cashew production is problematic (Palasz 2020).

Regarding consumption, a tendency can be seen in terms of dietary transformation, away from meat-based in favour of plant-based food, as people try to adjust their dietary habits in response to climate change. As a result of the shift away from meat, there is a risk of increasing nut consumption for three main reasons. First, there is a positive correlation between the share of people eating plant-based food and consumption of nuts (Orlich et al. 2014), thus when the share of people eating plant-based food increases, an increased consumption of nuts is also expected. Second, nuts are seen a good alternative to meat (Elzerman et al. 2021). Third, the Swedsih Food Agency proclaims the health benefits with nuts, containing protein, good fats, minerals and vitamins among other nutrients (Swedish Food Agency n.d.). These factors risk enhancing nut consumption further.

The survey Vegobarometern (Axfood 2022) shows an increase in consumption of plant based products in Sweden, and along with the observing trend claims that the reason for choosing more plant based consumption is primarily out of climate and environmental concerns. In this situation where consumers try to do good with respect to the climate, and at the same time are being encouraged by an authority, there is a risk of overlooking the negative consequences of consuming nuts and its contribution to water scarcity. Sweden does not produce nuts and therefore it is only possible to implement consumption-sided measures such as taxes, which is a common policy instrument studied to reduce externalities caused by food production (Röös et al. 2021).

Although nuts are considered an alternative to meat (Elzerman et al. 2021) they are not seen as a part of a main course, but rather as a snack. Thus, this paper makes it possible to compare and analyze nut products with other snack alternatives. With respect to that, the paper aims to contribute to this research field by analysing the question if consumption sided policies can decrease the consumption of nuts in Sweden, in order to reduce water scarcity. To achieve answering the question a instore dataset specified on snacks were used, including nuts, dried fruit, peanuts, legumes and mixes of nuts. Using real market data looking at the effect of a tax on nuts is an unexplored research field. The empirical framework of the Quadratic Almost Ideal Demand System (QAIDS) made it possible to estimate the expenditure functions, and further income and price elasticities using a two-staged budgeting process, allowing consumption to shift outside the group of snacks (Edgerton 1997). To analyze how demand shifted as a response to price variation the elasticities were used to calculate demand curves. The last step, was linking the products environmental impact to consumption to be able to examine the effect of consumption sided policies.

In the next chapter the paper provides the theoretical foundation of negative environmental externalities. Followed by chapter 3 presenting the field of research. Next, chapter 4 is about the data and policy scenarios of this paper. Chapter 5 provides the empirical framework and chapter 6 presents the final results. Lastly, in chapter 7 the paper finishes with a discussion and conclusions of the results.

2. Negative environmental externalities

With respect to the aim of the research this section provides knowledge about the theoretical foundation of environmental externalities.

Water scarcity is a problem arising from a collective of externalities strongly connected to water usage, such as water pollution, and reducing water reservoirs and aquifers resulting in depletion and contamination of water supplies (Jordan 1999). In economic theory, an externality occurs when consumption and/or production of a commodity causes negative effects of a third party, i.e. external costs which are not considered in the market price of the product. Therefore, externalities are a source of market failure, where the unregulated market is in a suboptimal point, inefficient with social welfare losses (Pindyck & Rubinfeld 2012). The high-water use connected with nut consumption causes negative environmental effects, increasing water scarcity affecting society (Jordan 1999). The external costs associated with water scarcity is however not accounted for in the output price meeting the consumer on the market.

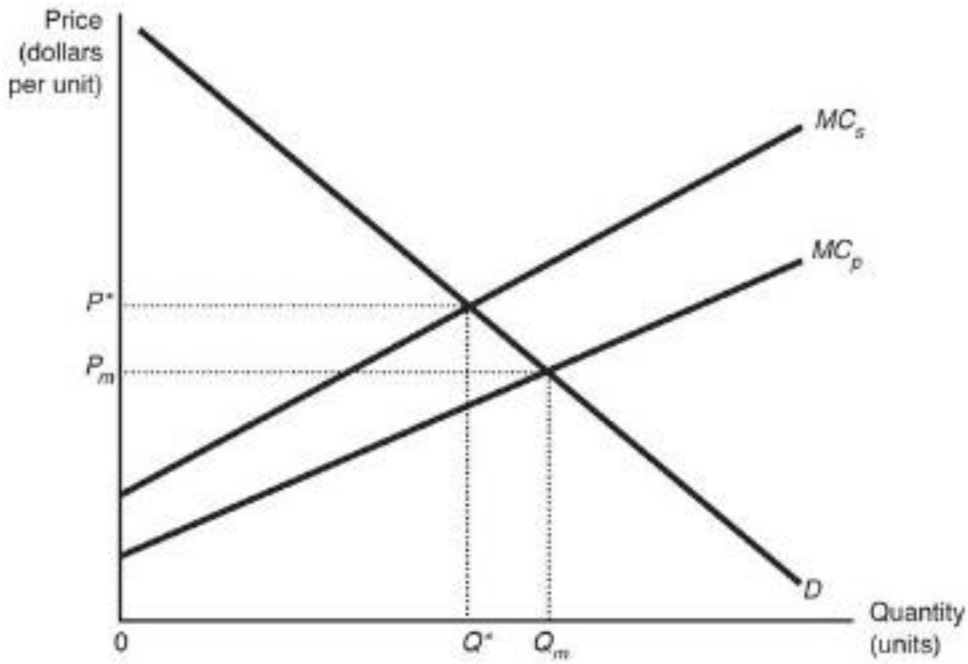

Figure 1. Market with negative externalities (Tietenberg & Lewis 2018:25).

Figure 1 shows the external costs occurring as a result of negative externalities, as well as their influence on a third party. The figure originates from Tietenberg & Lewis (2018), and is used to describe the market of water intensive nut consumption with negative externalities. Therefore, the one major difference is the demand, denoted D, in the figure above, which further on in this example is known as the marginal private benefits (MB_P). Social optimum, denoted Q*, is located where the marginal social costs (MC_s) equals the marginal private benefits (MB_p). Accordingly, the social optimum illustrates the optimal quantity of consumed nuts as a result consumers meeting higher prices, denoted P*, accounting for the external costs. On the other hand, when consumers meet prices, P_m, which not includes costs emerging from water externalities, their purchase power don't equal Q*, instead they consume at $Q_{m,}$ where it equals the marginal private cost, rather than the marginal social cost. Consequently, a too low price causes the consumption to exceed the socially optimal consumption ($Q^*<Q_m$).

As shown in Figure 1, an inefficient market with negative environmental externalities necessitates regulatory responses to compensate for the social welfare losses resulting from consumer decisions (Tietenberg & Lewis 2018). The choice of policy instruments to achieve a dietary shift away from nuts to reduce negative environmental externalities is properly discussed in Section 4.3.

3. Literature review

This section provides a broad overview of the research field. It will review the literature on the external effects of the production of nuts, and food policy.

In recent years, the external implications of nut production in terms of water footprint have received attention. The majority of the research on the subject has been focused on the production side. According to Vanham et al. (2020) 63% of irrigated nuts are produced in areas suffering from severe water stress, with almonds and pistachios having the highest WF. The article suggests that only groundnuts, i.e. peanuts, should be cultivated due to the lower total and blue WF. The blue WF is a measurement of the surface- and groundwater usage. However, tree nuts can bring benefits such as contributing to biodiversity. Zucchinelli et al. (2021) investigates how the effects of different diets in Denmark differs in water scarcity footprint. The findings suggest that a vegan diet is best diet from an environmental perspective, but on the other hand have the highest potential blue water scarcity footprint. The authors further states that tree nuts, as well as groundnuts have a large WF per unit of mass and protein.

The water intensive consumption of nuts thus needs to be addressed. Looking at water policies for food production in general, current focus is on how to use water in a more sustainable manner, hence policies target the production of agricultural goods (Gordon et al. 2010; Mancosu et al. 2015; Rockström et al. 2009). Targeting the consumer and its impact on water resources is uncommon, mainly due to the limited research done on linking the consumption of a product to water footprints or water stress scarcity in another country (Ercin et al. 2013). Looking particular at the field of research on the demand system of nuts and policy implementation is limited, if not non-existent. As a result, policies regarding nuts will be based on general food taxation. Although it is evident that cultivation of nuts causes considerable water shortages, to the best of our knowledge, there has been no study looking into the possibility of mitigating externalities of nuts using policy instruments. However, various studies have linked food taxation to decreased consumption, and dietary changes. The focus is on the necessity of decreasing animal source foods, when designing sustainable diets to reduce climatic, and environmental impact. As a result, a policy commonly studied is the taxation aiming to reduce carbon emissions (Edjabou & Smed 2013; Wirsenius et al. 2011).

Food policies have also been studied in the case of Sweden. Säll & Gren (2015) looks specifically on the effects of an environmental tax on the consumption of meat and dairy in Sweden. The study in line with similar studies showed a possible decrease in consumption resulting in reduced emissions by up to 12%. Säll et al. (2020) is a working paper which differs from other studies by estimating elasticities for all food categories in Sweden, using the Quadratic Almost Ideal Demand System (QAIDS) model. Furthermore, Moberg et al. (2021) looks at the effects of environmental taxation by increased VAT rates of Swedish food. The authors show a decrease in consumption, and thus a decreased environmental burden for the majority of foods.

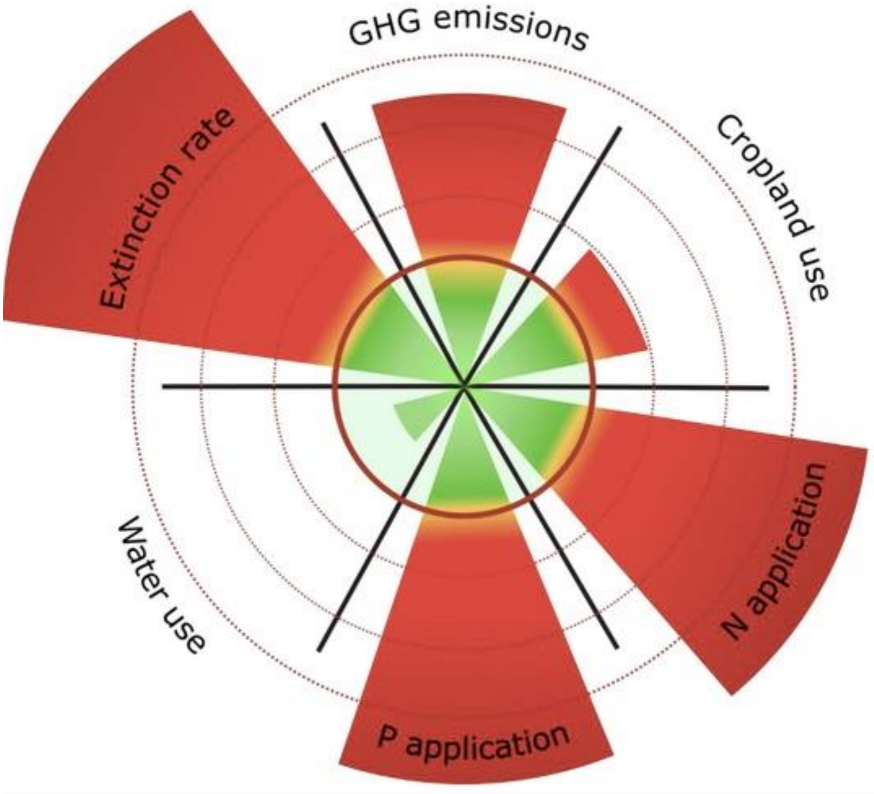

Figure 2. Environmental impacts of the average Swedish diet relative to the boundaries in the EAT-Lancet framework. The red inner circle shows the per capita boundaries. i.e., 100% of the 'allowed' boundary, and each dotted circle shows transgression of the boundary by another 100%. Water use refers to consumptive water use (Moberg et al. 2020).

It is also worth remembering that severe climate change has an effect on water availability, and quality (WWF n.d.). With this in mind, it is critical for local, as well as global actors to contribute to reducing water scarcity. Moberg et al. (2020)

studied the Swedish diet in relation to global and national environmental footprints. According to the authors the diet exceeded all global and national environmental goals, except for water use (see Figure 2). Although Sweden has a very small, if any, production of nuts, and doesn't have an unsustainable water use, as research on food policies shows, Sweden may contribute to the solution by reducing the intake of nuts through governmental intervention.

There are other types of food policies that have shown promising effects. Firstly, knowledge and support policies have an informational aim, trying to make it easier for consumers to make conscious food purchases with respect to the environment. This by building knowledge and supporting consumers to change habitats through positive, negative and eco-labelling (Röös et al. 2021). Although Röös et al. (2021) states that information and increased awareness of consumers is not enough to cause large dietary changes. Secondly, policy instruments categorized regulation and requirements foremost targets food production, including environmental laws, and regulations. For example, in Sweden there are laws on how to household animals, and regulations on usage of fertilizers in production. However, these categories of policy instruments can't be found on the consumption side. There are possibilities of future implementation of regulation in the retail sector, directing consumers towards sustainable food.

It's important to note that the Pigovian tax is a common tax when it comes to addressing negative environmental externalities (Pigou 1947). However, because the Pigovian tax is based on a product's social cost of one kilo GHG emission, there is limited information, therefore a Pigovian tax for the products of interest in this study is not an option.

Furthermore, research has shown negative effects of plant-based consumption. The EAT-Lancet commission highlights the benefits of a planetary health diet, but they also state that due to the higher consumption of nuts, this type of diet has a higher water usage. They expect a 1-9 % increase of the blue WF's. They believe, however, that the increased WF's can be compensated by reduced food waste and increased water efficiency (Willett et al. 2019). According to Tom et al. (2016) and Meier & Christen (2013) some vegetarian diets may have larger environmental impact than omnivorous diets due to the water-intensive use associated with a higher consumption of nuts, fruits and vegetables.

The results of Elzerman et al. (2021) indicates that nuts are a good alternative to meat because of their numerous health benefits, as well as the fact that they are a good source of protein and lipids, and have a low CO_2 emission. The findings show that nuts and legumes are good meat substitutes, ranking higher than meat substitutes in several circumstances such as family, vegetarians, friends, little time and flavoring. Legumes are another source of protein that has a variety of health benefits (Semba et al. 2021). The assortment of legumes is expanding and are mainly seen as a snack. Legumes, are high in protein and emit less greenhouse gases (Semba et al. 2021). The fact that legumes have a minimal water footprint and fix nitrogen, which improves the soil, distinguishes them from nuts and makes them a sustainable source of protein. The authors further states that while legume consumption is low, incorporating them into daily dietary patterns requires investment.

With respect to the literature, there is a gap regarding consumption patterns of nuts, and particularly how consumers react to changes in the price of nuts. Water footprint is a relatively new developed tool, mapping the water usage along the supply chain, but the fact that nut production is highly water-intense is not. However, this assessment of the literature reveals a lack of understanding regarding nut consumption patterns, specifically how consumers react to price changes of nuts. Nonetheless, the findings suggest that a climate tax on nuts, as well as subsidies on similar snack substitutes, could influence dietary changes to mitigate issues related to water scarcity, which is what this paper aims to investigate further.

4. Data

The following section gives an overview of the data management and thereafter the descriptive statistics is presented and lastly the policy scenarios.

According to current dietary patterns, nuts are mostly viewed as a snack, and to some extent also as a baking ingredient. The dataset was collected secondary from an aggregated dataset, divided with respect to groups of products. The final data used in this paper included products from the snack- and baking shelves. The data was gathered in a grocery store in Sweden over an eight months period, from August 2020 to March 2021. The data was gathered daily and included information on total items sold, the weight of the product and total worth of items sold excluding value added tax (VAT). The store represents a middle to high income population in Sweden.

4.1 Data management

In Excel, the data was categorized and processed to answer the research question. First, the data of interest was collected from four different datasets. Products comparable to bars, chopped nuts and nut butter were excluded to limit the paper. Returned items were also removed. Second, the dataset needed to include "sum of kilos sold" in order to allow for estimation of interest at a later stage. Third, the data was organized by product type. The datasheet was converted into a pivot table making the data easily managed. The final stage in the data processing was to calculate weighted price/unit per group, taking into account the VAT rate of 12%, which corresponds to Swedish normal food taxation.

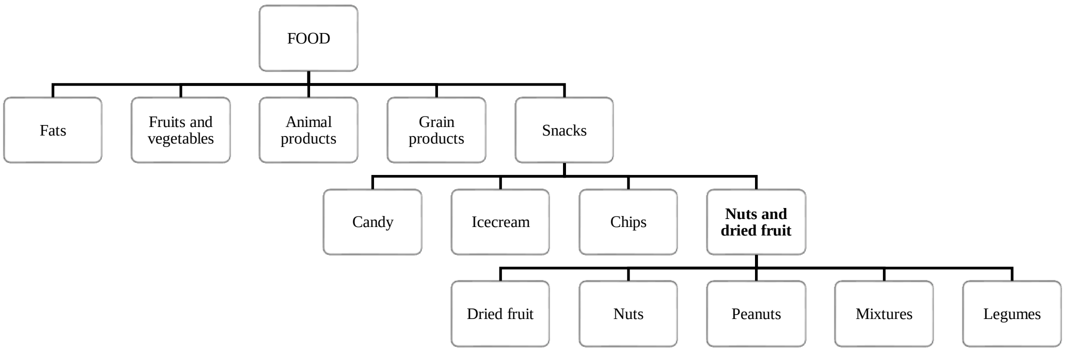

Figure 3. Food system.

The division into groups was based on how consumers might classify the products in the store. As a result, the dataset was separated into five groups (see Figure 3): legumes, mixtures, peanuts, nuts, and dried fruit, with the goal of reducing nut consumption by substituting other similar snack products. The following types of nuts were included in the group Nuts; almond, brazil nut, cashew, hazelnut, macadamia nut, pecan nut, pine nut, pistachio and walnut. Mixtures included various combinations of nuts, fruits and chocolate. The group Legumes included board bean, chickpea, edamame bean, green pea and soybean. Dried fruit, as the name suggests, contained a variety of dried fruit in various formats such as fruit sticks, fruit balls. Lastly, peanuts were separated as its own group for two main reasons. There were two key reasons for separating peanuts from other nuts. To begin with, even though the name implies that peanuts are nuts, they are actually legumes (Swedish Food Agency n.d.). Second, peanuts are the most popular nut (INC n.d.), therefore it was only natural to segregate them from the other commodities.

4.2 Descriptive statistics

The descriptive statistics of the data used in this paper is presented in Table 1 below. The data consists of 243 observations per commodity group gathered between August 2020 to March 2021. Nuts are the products sold the most of the five groups, on average 92 kilograms per day. Dried fruit sold on average 66 kg per day, while mixtures and peanuts sold 48 kg, and 42 kg respectively. Whereas, legumes only sold 4 kg on average per day. The relatively high standard deviations can be explained by spikes in quantity associated with price campaigns, and/or holidays, further resulting in a wide range between minimum and maximum values.

The price of the products in Table 1 vary greatly. The product most expensively sold was nuts with an average price of 191 SEK per kilograms per day, meanwhile peanuts was the product sold least expensive for 70 SEK per kg per day on average. Legumes and mixtures were similar in average price per kg per day, with 151, and 155 respectively. Dried fruit were on average sold for 117 SEK per kg per day. The standard deviation for legumes, mixtures, and nuts were relatively high, and thus their minimum and maximum values vary greatly. As explained for the quantities this mainly depends on spikes related to price campaigns and holidays. Whereas, the standard deviation for peanuts, and dried fruit were lower resulting in a smaller gap between minimum and maximum values.

Table 1 Descriptive statistics.

Variable	Mean	Std. Dev.	Min	Max	Obs.
Qlegumes	4,23	8,19	0,3	62,26	243
Qmixtures	48,86	20,67	11,54	121,50	243
Qpeanuts	42,94	13,19	15,17	91,09	243
Qnuts	92,52	44,08	29,39	314,15	243
Qdriedfruit	66,51	26,19	25,79	193,40	243
Plegumes	151,06	11,33	98,45	172,17	243
Pmixes	155,13	15,83	71,94	174,78	243
Ppeanuts	69,98	4,43	55,01	79,81	243
Pnuts	191,36	25,72	67,14	237,43	243
Pdriedfruit	117,66	8,53	93,55	147,76	243

4.3 Environmental impact

To enable investigating the effect of policy instruments on the possibilities of mitigating water usage connected with the consumption of nuts, it requires data on the commodities environmental impact. *The Green, blue and grey water footprint of crops and derived crop products* conducted by Mekonnen & Hoekstra (2010) and Röös (2014) lay the foundation of this paper’s analysis of changes in the environmental impact as an effect of price changes in nuts.

The main report for UNESCO's (United Nations Educational, Scientific, and Cultural Organization) Institute of Water Education is Mekonnen & Hoekstra (2010) linking consumption to global water footprints. For the years 1996-2005, the study measured the green, blue, and grey water footprint, calculating the global average water footprint for 126 different crops. The grid-based dynamic model measured the water usage over a period taking into account the grid cell's daily soil water balance and meteorological circumstances. Röös (2014), like Mekonnen &

Hoekstra (2010), estimated average CO_2 emissions from various fresh food categories in order to quantify the relationship between human consumption and climate change. The estimated values include emissions from primary production to transportation to Sweden.

Table 2 The global average water footprints, kg water/ kg product, and the climate impact in kg CO2-eq/ kg product.

	Water footprint	**Carbon footprint**
	Total	CO2
Legumes	1899,2	0,7
Mixtures	4668	0,93
Peanuts	3974	0,7
Nuts	9063	1,5
Dried fruit	967	0,6

The only environmental footprints observed for these five categories were the water and carbon footprints. Table 2 shows two measurements of agricultural production's environmental impact. First, table 2 shows the water footprint of various crops. Second, the table shows the carbon footprint for each group of crops, measured in *kilograms CO_2-eqvivalents per kilogram*. The water footprints were calculated in cubic meters per tonne and then converted into *kilograms of water per kilogram*. Since one litre of water equals one kilogram of water, the values remained unchanged. Mixtures are different combinations of nuts, peanuts, and dried fruit, and was not found in any research. Thus, the group was determined as the average water usage of mentioned values for each estimated footprint.

One of today's issues as a consumer is keeping track of the food's overall environmental impact; by including the commodity groups' carbon footprint, as well as the water footprint a more comprehensive view may be obtained.

As seen in Table 2, nuts have the highest carbon footprint, and dried fruit have the lowest. The total WF varies greatly, where dried fruit again has the lowest value, and nuts the highest WF with 9063 kg water per kg output.

4.4 Policy scenarios

Government intervention of some kind is required to address market failures, and there we simulate the intervention in the form of price changes, as described previously in section 2 regarding negative environmental externalities. The literature shows the possibility of influencing consumers to induce dietary changes by policy instruments. Röös et al. (2021) presents three main categories of consumption sided policies; knowledge and support, regulation and requirements, and changed relative prices. According to the findings economic instruments are of value providing good support. Which is a suitable measure since e.g. labels cannot be controlled for with the dataset, and previous literature show promising possibilities.

According to Röös et al. (2021), economic price shifting policies targeting consumption have the power of steering consumption towards more sustainable food options, and therefore reducing negative environmental effects. The two prominent policies in this field are subsidies and taxes, since according to the authors various studies have shown positive effects of implementation. According to the authors, studies raise the question of uncertainties implementing economic instruments regarding consumers' attitude towards implementation of them, and the fact that the demand for food which is that consumers demand for food is relatively price insensitive. In addition, taxation requires greatly increased relative prices to achieve significant results in terms of reduced environmental impact, which can affect consumers' attitude towards the policy. Thus, the authors claim that a possible alternative is implementing a bonus-malus system changing the VAT rate of commodities.

Consequently, this research looked into the effects of taxes and subsidies on reducing water scarcity. To begin with, the application of carbon footprints in the implementation of environmental policies aiming at reducing negative externalities generally focuses on reducing greenhouse gas emissions. As a result, according to theory, the reference scenario in this study will be based on each group's carbon footprint (see Table 2).

However, since water use is the main focus of this paper two other scenarios are set up targeting specifically the products water footprints. With respect to the products water footprints (see Table 2) nuts have the highest WF. Thus, the second scenario (Scenario 1) investigates the effect of a tax on nut consumption, with the aim of reducing water usage. The third scenario (Scenario 2) wants to further analyze the possibilities of reducing water scarcity. With respect to legumes' very high own-price elasticity, a subsidy on legumes is implemented. The policy scenarios aim at giving a guideline for future policies, showing the linear effect of arbitrary chosen tax levels.

4.5 Limitations

Because of the data, this paper has some limitations. To begin with, the information was acquired from a single retailer. As a result, the data does not reflect a representative sample of grocery stores and consumers in Sweden. This particular store is located just outside of Stockholm, and it represents a middle to upper-income urban population, as opposed to, say, a low-income or rural one. Second, the window for data collecting is limited. The data was gathered over eight months, including the major holiday, Christmas, when consumer patterns may differ from other times of the year. It's important to remember that the high intake of nuts and dried fruit around the holidays causes the data to rise. In further research, a better dataset would encompass a longer time period, with less emphasis on Christmas consumption. Another constraint of this dataset was the exclusion of nut butter and bars in order to make the data more manageable when calculating their environmental impact.

Furthermore, the data obtained on water and carbon footprints is limited to estimations of production stages rather than a full life cycle assessment (LCA), particularly carbon footprints. As a result, the carbon footprints were finally collected from Röös (2014). However, the study had not separated groupings for each commodity group, unlike other sources. Thus, because the peanut is a legume, this study chose to use the same estimate for both legumes and peanuts. Another key restriction of this paper's data is that Röös (2014) warns the reader that the estimations are current till 2015 and should be assessed after then. This could indicate that the CO_2 values are inaccurate and so misleading.

5. Quadratic Almost Ideal Demand System

In this section, the empirical framework QAIDS model is presented.

Estimating consumers' price sensitivity is the initial stage in assessing the effect of consumption-based policies on nut consumption. The vast in-store dataset with a wide range of commodities, together with first stage estimations from Säll et al. (2020), sets the foundation for a two-staged QAIDS model (Quadratic Almost Ideal Demand System). The model was first developed by Deaton & Muellbauer (1980) and further enhanced by Banks et al (1997) to the quadratic model used in this paper. There are various models to estimate demand systems, such as the Translog model, and the Rotterdam model (Deaton & Muellbauer 1980). However, for a variety of reasons, this paper uses the QAIDS model. The QAIDS model simple to operate, and in contrast to the AIDS model, allows for a non-linear Engel curve. Moreover, the model has a large variety of eligible attributes, can offer first order arbitrary estimates, and finally, follows the theory of rational choice (Deaton & Muellbaurer 1980). Furthermore, the reason for the two stage QAIDS model is to estimate elasticities allowing for consumption to shift between similar goods, but also shift consumption outside the group, to other groups of commodities. The two-staged budgeting system comes with the condition of weak separability (Edgerton 1997). The condition allows commodities to be separately grouped, saying that the consumption of two commodities within a group is independent of consumed quantities outside the group (Sellen & Goddard 1995).

The following set up of the QAIDS model was used to estimate the elasticities of demand:

$$s_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_j + \beta_i (lnX - lnP) + \frac{\mu_i}{Q} (lnX - lnP)^2 \qquad (1)$$

where s_i, is the budget share for commodity i depending on both commodity i ($i = 1 \dots n$) within a group, and commodities j ($j = 1 \dots m$). The budget shares are $s = p_i q_i \,/\, X$, p_j, are regressed on prices of included commodities, and the total expenditure X which is defined as $X = \sum_{i=1}^{n} p_i q_i$.

The aggregated price, P, in equation 2 takes the form as an adjusted version from the AIDS model. Hence, is the non-linear version of the aggregated price index.

$$lnP = \alpha_0 + \sum_{i=1}^{n} \alpha_i lnp_i + \frac{1}{2}\sum_i^n \sum_j^n \gamma_{ij} \ln\left(p_i + p_j\right) \quad (2)$$

The definition of the quantity Q is as follows.

$$Q = \prod_i^n p_i^{\beta_i} \quad (3)$$

The estimated parameters need to fulfil the constraints of the QAIDS model, which are adding up, homogeneity, and symmetry. Following, the adding up condition implies that the logarithmic share of initial consumption α_i, sums up to 1, $\sum_i^n \alpha_i = 1.$ Further the response to a changing total expenditure, β_i, equals 0, $\sum_i^n \beta_i = 0$. Consequently, the quadratic parameter sums up to 0, $\sum_i^n \mu_i = 0$. Next, the constraint of homogeneity of degree zero implies $\sum_{j=1}^n \gamma_{ij} = 0$. γ_{ij} describes how changes in price affect budget share, s_i. Lastly, the condition of symmetry, $\gamma_{\mathrm{ij}} = \gamma_{ji}$, implies that the marginal effect on budget share of commodity j obtained by a price change in commodity i, equals the marginal effect on the budget share of commodity i of a change in price for commodity j (Edgerton 1997).

Equation 1-3 is applied for each of the five groups in the second stage (see Table 1). Same is to be done for the first stage, but only one system for the snack group in wholesome, aggregate from many cuts Säll et al. (2020). Since this analysis is based on two-stage budgeting, further on the indexes *r* and *u* will be included indicating two commodity groups, whereas the subscripts *i* and *j* are used to denote commodities within a group (Edgerton 1997).

For the analysis the short-term income-, uncompensated-, and compensated elasticities are calculated. The income elasticities are calculated as follows $\varepsilon_{\mathrm{i}}^{I} = 1 + \frac{\beta_i}{s_i}$ and the uncompensated elasticities as $\varepsilon_{\mathrm{ij}}^{M} = \left[\left(\gamma_{ij} - \beta_i s_j\right)/s_j)\right] - \delta_{ij}$. The last term in the uncompensated elasticity is the Kronecker delta δ which equals one when r=s, zero otherwise. The compensated elasticities are calculated as $\varepsilon_{ij}^{H} = \varepsilon_{ij}^{M} + s_j \varepsilon_i^{I}$, and captures consumption choices as a result of the substitution effect due to price changes. The constraint of the QAIDS model of homogeneity implies elasticities as $\varepsilon_{\mathrm{i}}^{I} + \sum_{i=1}^{n} \varepsilon_{ij}^{M} = 0$.

Taking all levels of the demand system into account the income elasticity is depending on both the within expenditures and between groups expenditures. Thus, the uncompensated income elasticities for the *i*th commodity is $\varepsilon_i^{I*} = \varepsilon_i^{I} \varepsilon_{ir}^{I}$.

Regarding the uncompensated own-price and cross-price elasticities, taking account for the demand system is defined as follows.

$$\varepsilon_{ij}^{M*} = \delta_{ru}\varepsilon_{rij}^{M} + \varepsilon_{ri}^{I} s_{uj}[\delta_{ru} + \varepsilon_{ru}^{M}] \qquad (4)$$

Since, $\delta_{ru} s_{rj} = \delta_{ru} s_{uj}$ the equation above can be rearranged as follows.

$$\varepsilon_{ij}^{M*} = \delta_{ru}\varepsilon_{rij}^{H} + \varepsilon_{ri}^{I} s_{uj}\varepsilon_{ru}^{M} \qquad (5)$$

By rearranging equation 5, the set-up of the compensated elasticities related to the other elasticities is the following (Edgerton 1997).

$$\varepsilon_{ij}^{H} = \delta_{ru}\varepsilon_{rij}^{H} + \varepsilon_{ri}^{I} s_{uj}\varepsilon_{ru}^{H} \qquad (6)$$

Furthermore, the last step of the analysis is to capture the change in consumption caused by price changes, by calculating the difference between initial consumption, superscript 0, and the demanded level when policies affect prices to change, superscript 1, as $\Delta q = q_i^1 - q_i^0$. As well as assuming consumers demand to be linear functions of own prices and cross prices as $q_i = k_i p_i + m_i + \Delta h_i$. In other words, the demanded quantity is a function of the slope k_{ij} originating from the uncompensated elasticities $\varepsilon_{ij}^{M*} = \frac{\Delta q_i}{\Delta p_j}\frac{p_j^0}{q_i^0} = k_{ij}\frac{p_j^0}{q_i^0}$ when $i = j$, the intercept m_i, of course the price of commodity i, and the shifters of demand due to the introduction of taxes, Δh_i.

$$\Delta h_i = \sum \Delta p_j \frac{\varepsilon_{ij}^{M*} q_i^0}{p_j^0} + \sum \Delta p_r \frac{\varepsilon_{ru}^{M} q_u^0}{p_r^0} s_u \qquad (7)$$

Price changes within a commodity group cause shifts in demand curves. Other group elasticities are another issue to consider since it also affects shifts in demand curves. Lastly, there is one assumption to make and remember: consistent budget shares within groups, as well as each commodity's expenditure flows between groups are allocated appropriately (Säll et al. 2020).

6. Results

Firstly, this section will provide an overview of the final elasticities in order to present the possibilities of mitigating water scarcity as a result of decreased consumption of nuts. Lastly, the model specification will be discussed.

The results were estimated using two different programs. Based on the two-staged budgeting approach of the QAIDS model provided in chapter 5, TSP was used to estimate the elasticities. The final uncompensated elasticities were determined using the elasticities estimated in TSP. The final stage, which involved calculating the uncompensated elasticities, was completed in Excel. In addition, demand curves based on uncompensated elasticities were calculated in Excel, allowing to correlate the consumption of the five aggregated food groups to their environmental impact in terms of water footprint and carbon footprint.

6.1 Model specification

Using the methodology outlined in chapter five, four models were estimated, which formed the basis for the fifth model. To manage autocorrelation the models included lagged variables to reflect consumers' purchases consistency, as well as an autocorrelation parameter, rho. The significance among the coefficients were strong, 16 out of 23 variables were significant at 5%. The obtained R^2 for each model varied between only 19% and up to 74% indicating a low to relative high explained variance within the models. Lagrange multiplier (LM) tests were performed to look for autocorrelation. Although the model was designed to check for autocorrelation, one model did not pass the test indicating autocorrelation. However, it is important to note that over hundred lags were estimated, and values of the elasticities were robust, indicating that the elasticities can be used to at least indicate the consumers' price sensitivity and what the effects of a possible taxation would have. The test results of the models and variables are found in Table 1 and Table 2 in the Appendix.

6.2 Consumers price sensitivity

Table 3 presents the uncompensated elasticities, including the two stages, allowing for consumption outside the five groups in this paper. The uncompensated elasticities were based on the two-stage budgeting process explained in chapter 5 which resulted in compensated within group elasticities. These, together with the first stage elasticity, collected from Säll et al. (2020), were used to manually calculate the uncompensated price elasticities of demand according to equation 6 in chapter 5. The paper estimated the price elasticity of snacks to -0,249, hence a relatively inelastic demand for snacks.

As seen in Table 3, each group own-price elasticity is negative, in line with theory of the inverse relationship between price and quantity, as the price rises the demand falls, and vice versa. Legumes, mixtures, and peanuts are seen as relatively elastic with values between -1 and -7. Worth noticing is legumes high own-price elasticity. Whereas, nuts, and dried fruit have values indicating relatively inelastic demand, less than zero. The group's cross-price elasticities vary greatly, with values both smaller and larger than 1. Almost all goods have positive cross-price elasticities, indicating that the goods classify as substitutes. There are two goods differentiating, having a negative cross-price elasticity, legumes and dried fruit, which indicates that these two are complements. When looking at both the factors of elastic or inelastic, and complementary or substitutional nuts, mixtures, peanuts, and dried fruit are cross-price inelastic and positive making the goods relatively substitutable. However, the cross-price elasticity for legumes to mixtures, peanuts, and nuts are positive and elastic making the goods highly substitutional.

Table 3 Final uncompensated elasticities for aggregated food groups.

	Legumes	Mixtures	Peanuts	Nuts	Dried fruit
Legumes	**-6,982**	1,868	4,101	1,291	-0,507
Mixtures	0,145	**-1,153**	0,118	0,421	0,178
Peanuts	0,349	0,126	**-1,442**	0,368	0,289
Nuts	0,05	0,241	0,198	**-0,912**	0,211
Dried fruit	-0,029	0,139	0,203	0,274	**-0,822**

6.3 Mitigation possibilities of taxes on nuts

The three figures presented below provide three scenarios, where the economic instruments have been implemented. The figures show the percentage changes in prices and consumption of each commodity group, but with different policy scenarios.

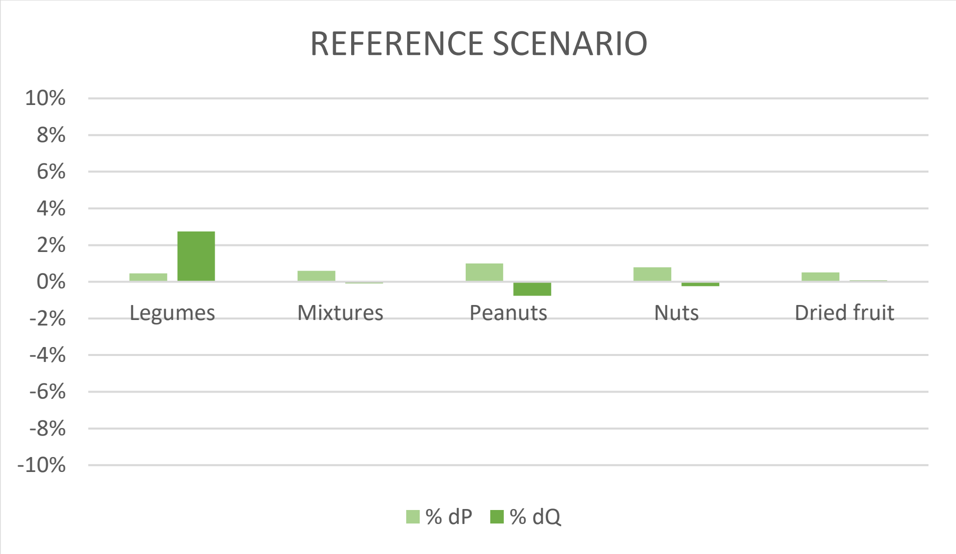

Figure 4. Reference scenario. The figure presents the percentage changes in prices and consumption of the commodity groups, after taxes based on each group CO2-eq. value.

Figure 4 is the reference scenario, as explained in chapter 4.4, in line with theory where a taxation on each group is based on corresponding CO_2-eq. value is implemented. This ties the environmental impact of nuts to their related CO_2 emission in line with the theory of negative externalities. The reference scenario shows that in the case of nuts, targeting the GHG emission has a limited effect on consumption.

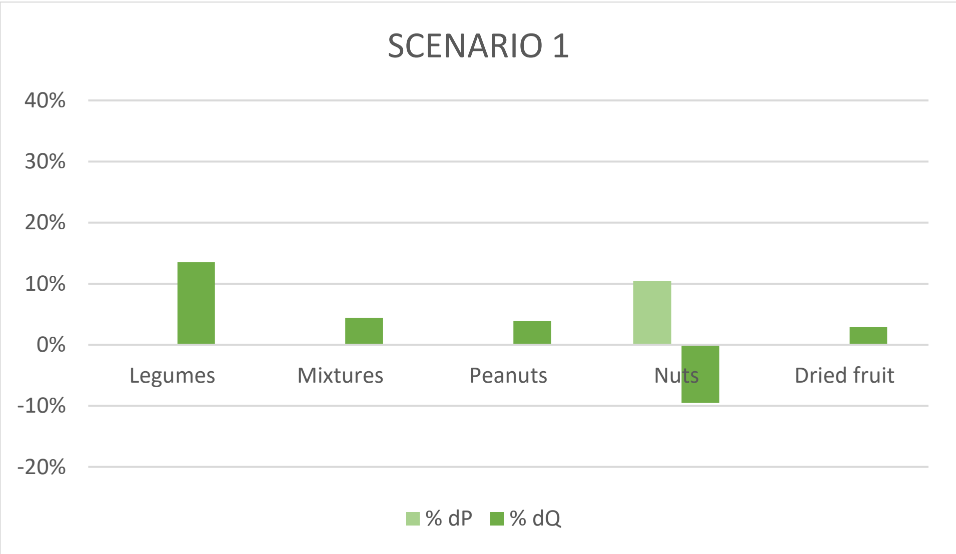

Figure 5. Scenario 1. The figure illustrates the percentage changes in prices and consumption of the commodity groups, after taxing nuts.

Figure 5 illustrates the effect of only implementing a tax on nuts, whereas Figure 6 presents Scenario 2 showing the total effect of both a tax on nuts, and a subsidy on legumes. Figure 5 shows a significant effect of an environmental tax on the consumption of the commodities. Moreover, implementing an environmental tax (Scenario 1), and both a tax and subsidy (Scenario 2) have similar effect on the consumption of the products. The exception is the consumption of legumes which spikes when adding a subsidy, in line with the commodity's high own-price elasticity. Scenario 1 and Scenario 2 simulate a taxation representing a price change of 10%, and in addition it tests for a subsidy of a 5% price change on legumes. As said previously in section 4.4 the tax levels were chosen arbitrary, and due to the linear properties of the system of demand curves, a change in prices will lead to linear changes in demand.

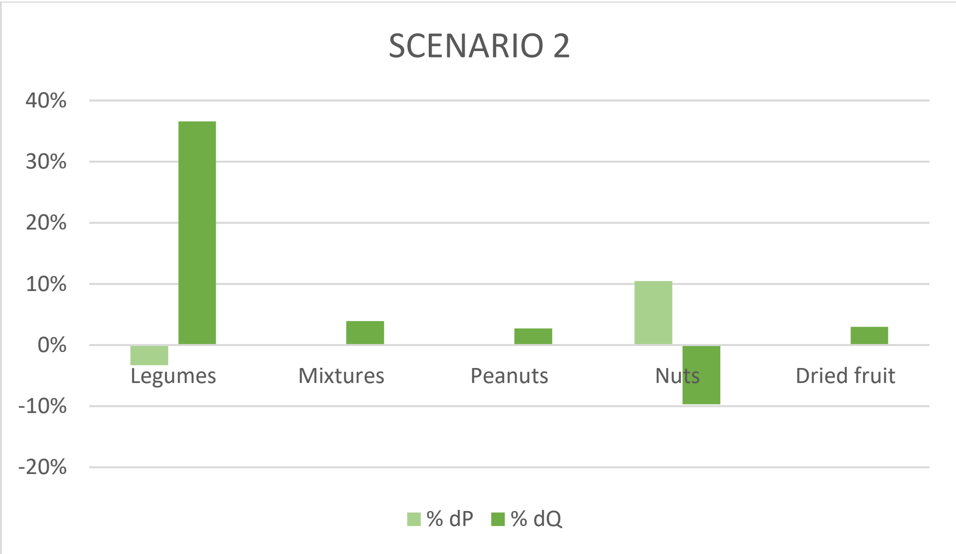

Figure 6. Scenario 2. The figure presents the percentage changes in prices and consumption of the commodity groups, after a tax on nuts, and a subsidy on legumes.

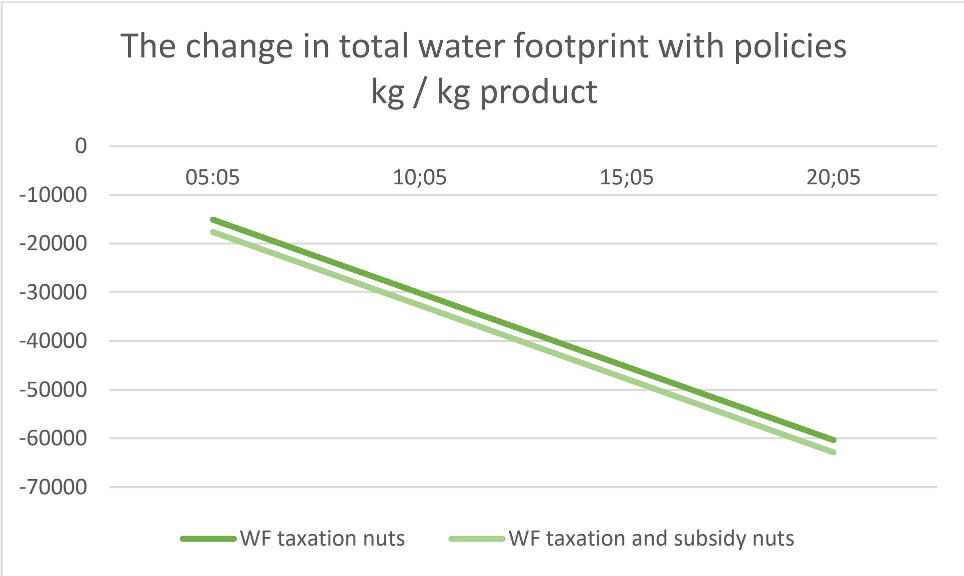

Figure 7. The change in total water footprint with policies, kg water/kg product.

Figure 7 illustrates the results of the two policy scenarios presented in chapter 4.4, directly targeting nuts' water footprint by firstly, taxing nuts and secondly, simultaneously taxing nuts and subsidizing legumes. The figure illustrates the change in total WF for all groups together. The scenario when only taxing nuts shows the effect of reduced water scarcity in three stages; with a price change of 5, 10, 15, and 20 SEK/kg respectively. The scenario when both taxing nuts and subsidizing legumes, legumes stay constant with a price change of -5 SEK/kg, while nuts tax accordingly to the first scenario. As seen in Figure 7 the effect on the total WF is greater with both a tax on nuts and a subsidy on legumes, however not significantly higher, with a reduction of -60354, and -62879 kg water/kg product, both equal about 5%.

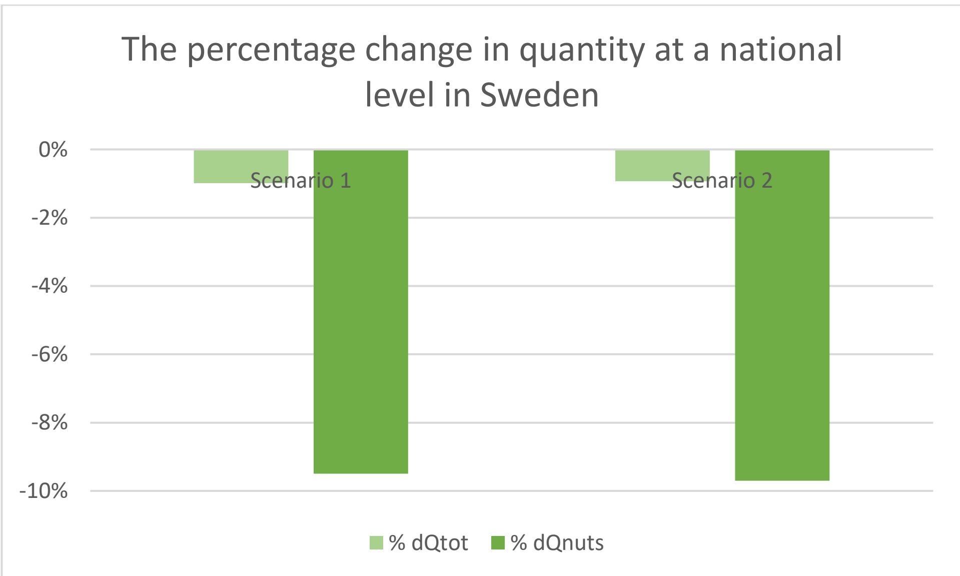

Figure 8. The percentage change in total consumed and nuts consumed quantity respectively, on a national level in Sweden per year, for each scenario at tax of 10% and subsidy at 5%.

Now looking at the effect of these policy instruments on the consumption in a greater perspective presented in Figure 8, which is Sweden. The 5% mitigation of water usage in both scenarios, represents a total consumption reduction of the products in Sweden by 0,99% in Scenario 1, and -0,93% in Scenario 2. The difference in percentage is due to the subsidy causing an increased consumption of legumes, as a result of legumes' high own-price elasticity. However, looking at the consumption of nuts alone, a taxation on nuts causes the demand on nuts to decrease with 9,50%, and with additional subsidy on legumes in Scenario 2 with -9,70%. This decrease in demand for nuts as a result of consumption sided policies, will further reduce total water usage in Sweden by 5% as seen earlier in Figure 7.

7. Discussion and conclusion

The objective of this paper was to investigate the possibility of using consumption sided policies in order to reduce water scarcity from nut production. In particular, the effect of taxes and subsidies on the consumption of nuts in Sweden was examined. The estimated elasticities were applied to investigate policy scenarios testing the impact of taxes and subsidies effect on water scarcity. The intention was to simulate a shift of demand away from nut products. The first scenario, *reference scenario*, tested taxation of each group in line with negative externalities. *Scenario 1* directly targeted nut products with taxation, and *Scenario 2* in addition added a subsidy on legumes. In light of the research aim, the findings indicate reduced consumption of nuts as a result of governmental intervention in the form of taxation by 9,5% yearly in Sweden. The additional subsidy on legumes, in Scenario 2, resulted in a 9,7% decrease of nut consumption. Whereas, the decreased consumption of nuts in the first as well as the second scenario can generate reduced water usage equal to 5% yearly from Swedish food consumption. The little difference between Scenario 1 and Scenario 2 regarding the effect on water usage, indicates that the choice of implementing policies, depends not on the possible reduced water scarcity, but instead on additional reasoning behind a policy. A reason for implementing a subsidy on legumes could be for aiming to shift the consumption towards a product with low water footprint, as well as low GHG emissions compared to nuts. Nevertheless, subsidies can appear unnecessary as it is partly a complicated instrument due to possible leakage and are costly for the state, but also because it does not have such a large effect on the environmental impact as the findings suggests. Semba et al. (2021) further states that a dietary change incorporating legumes to a larger degree would require investment, which also argue against implementation of a subsidy on legumes. Therefore, as to the question of how a tax could be implemented with increasing the VAT rate, in line with Röös et al. (2021) to reduce the risk of consumers' attitude towards the prices change to alter the effects significantly. Now the VAT level on the commodities is 12%, but could be increased to 25%.

However, to solely base a policy scheme to reduce water scarcity on this paper would be insufficient. According to Axfood (2021) consumers' choice of dietary change towards plant based food are mainly for climatic and environmental reasons.

In addition, Orlich et al. (2014) indicate a positive correlation between plant based food and consumption of nuts can indicate consumers having low knowledge of nuts' negative effects. Thus, knowledge based policies may be implemented raising awareness such as labelling, and nudging etc. By increasing consumers awareness and knowledge, the dietary shift away from nuts may be favored, in line with Röös et al (2021) which show positive results of these policies. Nonetheless, in accordance with Säll & Green (2015), and Säll et al. (2020), consumption sided taxes on nuts according to the findings can reduce water shortages related to Swedish consumption.

This is a new and relatively unexplored research field, enabled by the large dataset including all products in a grocery store, allowing future research looking more in detail on consumers' price sensitivity, and drivers of consumers. Although, it is also important to remember the established limitations of this paper. First, the period of about eight-month worth of data is great, but at least one month is affected by holidays, causing the quantity of nuts and dried fruit to spike. Second, the store where the data was gathered represents middle to high income consumers, not taking into account all socioeconomic backgrounds, which can affect consumers' price sensitivity in the sense that this sample is less price sensitive. However, the demand for food is relatively insensitive. This could be included in further research, with respect to that households with lower income should be more sensitive to price changes, while they maybe don't consume nuts to the same extent as households with greater income.

Today, nuts are classified as a snack, which is another factor in this paper that can be seen as a limitation. The findings of Elzarmen et al. (2021) show that meat alternative, which includes nuts and legumes, ranks higher than meat substitutes in several situations. This can indicate changing consumption patterns, where nuts may classify as a protein alternative. Thus, the next step of further research to investigate when nuts might be classified as a protein option for a main course. With the respect to that, discussing the conflict between sustainability goals when nuts are seen as worthy meal options.

Even though the focus of this article was on nuts' high-water consumption, the other negative effects of nut production are worth acknowledging. One perspective, also lifted by Willett et al. (2019) is the major bio waste in the production. Along the supply chain, much of the produce is thrown away as waste to get the final product. Nuts are only the kernel of the fruit, whereas the pulp is not used. It has recently emerged that what is thrown away today can be used to create products, such as Cashewmeetly which explores the possibility of cashew residue to be a meat substitute (Cashewmeetly n.d.). But there are also studies investigating the possibility of using nut bio waste as an energy catalyst, and as fuel (Orooji et al.

2022; Suwanmanee et al. 2020). With the necessary ongoing dietary change, all aspects are to be thought of to eventually accomplish sustainable food patterns.

Consumer behavior is gradually evolving, and the field of research is yet to explore. This paper is a good start, and has presented a guideline of the effects of taxing nuts, with the goal of reducing water scarcity. Certain is that, given the global water scarcity and the fundamental necessity of water, a starting point is acknowledging the potential in the global perspective for future solutions. Where the high-water use associated with nut intake contributes to the problem, and therefore, our food patterns must change. Future study should focus on finding an effective policy making strategy to achieve dietary transition towards sustainable food.

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Appendix

Tabell 4. Estimates of parameters in the second stage.

Number of Obs.: 236	Log likelihood=2208.55	Schwarz B.I.C.=-2129.77		
Parameter	Estimate	Standard Error	t-statistic	P-value
C11	-.089058	.733713E-02	-12.1380	[.000]
C12	.025574	.615038E-02	4.15815	[.000]
C13	.058948	.808630E-02	7.28986	[.000]
C14	.015103	.451693E-02	3.34374	[.001]
C22	-.054909	.015884	-3.45690	[.001]
C23	-.105483E-02	.015064	-.070024	[.944]
C24	.032159	.012145	2.64785	[.008]
C33	-.097717	.022944	-4.25887	[.000]
C34	.021326	.014000	1.52324	[.128]
C44	-.068962	.017093	-4.03452	[.000]
B1	-.116595E-02	.251723E-02	-.463187	[.643]
B2	.032511	.822012E-02	3.95507	[.000]
B3	.042294	.683117E-02	6.19132	[.000]
B4	-.059200	.011928	-4.96314	[.000]
A1	.014661	.124375E-02	11.7880	[.000]
A2	.194527	.407596E-02	47.7254	[.000]
A3	.178402	.352937E-02	50.5479	[.000]
A4	.345619	.602288E-02	57.3843	[.000]
RHO	.403680	.024115	16.7398	[.000]
D1	-.182720E-02	.237362E-02	-.769795	[.441]
D2	-.017837	.010651	-1.67473	[.094]
D3	-.012409	.670516E-02	-1.85064	[.064]
D4	.027479	.011963	2.29696	[.022]

Tabell 5. Estimated models of the second stage.

	EQAIDS1 Dependent variable: S1	EQAIDS2 Dependent variable: S2
Mean of dep. var.	.014710	.189838
Std. dev. of. dep. var.	.018685	.040286
Sum of squared residuals	.021171	.249751
Variance of residuals	.897094E-04	.105827E-02
Std. error of regression	.947151E-02	.032531
R-squared	.744274	.352992
LM het. test	10.0340 [.002]	.107834 [.743]
Durbin-Watson	1.57858	1.73590

	EQAIDS3 Dependent variable: S3	EQAIDS4 Dependent variable: s4
Mean of dep. var.	.172850	.356332
Std. dev. of. dep. var.	.035086	.051536
Sum of squared residuals	.173898	.509840
Variance of residuals	.736858E-03	.216034E-02
Std. error of regression	.027145	.046479
R-squared	.403886	.191417
LM het. test	.095073 [.758]	.386846 [.534]
Durbin-Watson	1.84656	.981494

Tabell 6. Estimated income elasticities of the second stage.

Parameter	Estimate	Standard Error	P-value
INC1	.921534	.169404	[.000]
INC2	1.17060	.043134	[.000]
INC3	1.24320	.039280	[.000]
INC4	.833740	.033499	[.000]
INC5	.945427	.042298	[.000]

Tabell 7. Estimated uncompensated elasticities of the second stage.

Parameter	Estimate	Standard Error	P-value
ME11	-6.99225	.494092	[.000]
ME12	1.73604	.417541	[.000]
ME13	3.98072	.552161	[.000]

ME14	1.04437	.298386	[.000]
ME15	-.690413	.546309	[.206]
ME21	.131661	.032286	[.000]
ME22	-1.32064	.084463	[.000]
ME23	-.035203	.080571	[.662]
ME24	.108004	.062065	[.082]
ME25	-.054420	.108235	[.615]
ME31	.335347	.046518	[.000]
ME32	-.052413	.087278	[.548]
ME33	-1.60419	.132944	[.000]
ME34	.036033	.079754	[.651]
ME35	.042019	.134344	[.754]
ME41	.044888	.012708	[.000]
ME42	.122002	.035208	[.001]
ME43	.088807	.040305	[.028]
ME44	-1.13448	.047841	[.000]
ME45	.45039	.049789	[.366]
ME51	-.39128	.031390	[.213]
ME52	.371483	.078789	[.962]
ME53	.079402	.089531	[.375]
ME54	.020842	.066093	[.000]
ME55	-1.01026	.143517	[000]

Tabell 8. Estimated compensated elasticities of the second stage.

Parameter	Estimate	Standard Error	P-value
HE11	-6.97856	.493773	[.000]
HE12	1.91166	.413907	[.000]
HE13	4.14098	.544191	[.000]
HE14	1.37250	.303980	[.000]
HE15	-.446582	.558081	[.424]
HE21	.149055	.032273	[.000]
HE22	-1.09755	.083348	[.000]
HE23	.168373	.079044	[.033]
HE24	.524814	.063730	[.000]
HE25	.255311	.108223	[.018]
HE31	.353821	.046498	[.000]
HE32	.184508	.086619	[.033]
HE33	-1.38798	.131934	[.000]

HE34	.478694	.080505	[.000]
HE35	.370961	.134726	[.006]
HE41	.057277	.012686	[.000]
HE42	.280891	.034110	[.000]
HE43	.233801	.039320	[.000]
HE44	-.837610	.48005	[.000]
HE45	.265641	.049046	[.000]
HE51	-.025080	.031341	[.424]
HE52	.183888	.077948	[.018]
HE53	.243819	.088551	[.006]
HE54	.357477	.066002	[.000]
HE55	-.760105	.143652	[.000]

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