Sustainable meat consumption

A study of policies considering several sustainability pressures.

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Hållbar köttkonsumtion

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Abstract

Global warming, declining biodiversity, overuse of natural resources and social fundamentals such as health and a secure income are all affected by our food consumption. In the last 30 years, global meat consumption has doubled, which has increased the negative effects on these issues. This study assesses the possibilities of changing the negative trend and steer towards a more plant-based diet using economic instruments. When only climate change is considered, taxing beef would be the most efficient instrument. The study, however, also highlights other sustainability aspects such as circular production and biodiversity, making the choice of which type of meat to tax more complex. Therefore, a general taxation of all meat but also a subsidy on plant-based diets is examined. The aim is to give an overview of the consequences for such a policy mix, where the tax system is relatively easy to implement. Three tax scenarios are applied to real market data from one of Sweden's largest ICA stores. Two of the scenarios are based on GHG-emission taxes, where one only includes meat and the other includes all animal protein foods. The third scenario is an increase of VAT (value-added tax) to 25 % for animal goods and a VAT-reduction to 6 % for plant-based goods. A Quadratic Almost Ideal Demand System (QAIDS) is used to estimate the change in budget shares and to estimate Marshallian demand and income elasticities. The parameters are used to construct a system of linear demand curves which then is used to calculate the change in quantities as an effect of the price change. The result indicates that an applied general meat tax has the potential to shift consumption towards an increased plant-based consumption. When the price of meat is increases by 10 and 11.6%, consumption decreases by 11.7, 10.7 and 11.87%, respectively, for the different scenarios. A subsidy on plant-based foods further increases this change by increasing plant-based consumption with 11.2 % for only a 5.4 % decrease in price. Including taxes on other animal protein foods does not show as large potential to further decrease the negative pressures. The third scenario resulted in the largest reduction in greenhouse gas emissions by 3.08 tonnes, but the difference between the scenarios is small. Including other animal goods in the analysis has almost no effect on emission reductions.

Sammanfattning

Global uppvärmning, minskad biologisk mångfald, brist på naturresurser och grundläggande sociala förutsättningar påverkas av vår matproduktion. Under de senaste 30 åren har den globala köttkonsumtionen fördubblats, vilket påverkar ovanstående faktorer. I denna studie undersöks möjligheterna att förändra trenden mot en mer växtbaserad kost med hjälp av ekonomiska styrmedel. När endast klimatförändringar beaktas är beskattning av nötkött det mest effektiva styrmedlet. I denna studie lyfts även andra hållbarhetsaspekter som cirkulär produktion och biologisk mångfald, vilket gör valet av kött som potentiellt ska beskattas mer komplext. Därför undersöks här en generell beskattning av allt kött men även en subvention på växtbaserad kost. Avsikten är att ge en bild av konsekvenserna för en sådan politik där skattesystemet är relativt enkelt att genomföra. Tre skattescenarier tillämpas på marknadsdata från en av Sveriges största ICA-butiker. Två av scenarierna har skatter på utsläpp av växthusgaser där det ena endast inkluderar kött och det andra inkluderar alla animaliska varor. Det tredje scenariot är en höjning av momsen (mervärdesskatten) till 25 % för animaliska varor och en momssänkning till 6 % för växtbaserade varor. Ett Qudratic Almost Ideal Demand System (QAIDS) används för att uppskatta förändringen i budgetandelar och för att uppskatta Marshallian efterfrågan och inkomstelasticiteter. Parametrarna används för att konstruera ett system av linjära efterfrågekurvor som sedan används för att beräkna förändringen i kvantiteter som en effekt av prisförändringen. Resultatet tyder på att en tillämpad generell köttskatt flyttar konsumtionen till ökad växtbaserad konsumtion. När priset höjs med 10 % minskar förbrukningen med cirka 11 till 12 %. En subvention på växtbaserade livsmedel ökar denna förändring ytterligare genom att öka den växtbaserade konsumtionen med 11,2 % för endast en prisminskning på 5,4 %. Då skatter på andra animaliska varor inkluderas blir förändringen något lägre. Det tredje scenariot gav den största minskningen av växthusgasutsläppen på 3,08 ton, men skillnaden mellan scenarierna är liten. Inkluderandet av andra animaliska varor påverkar knappt utsläppsminskningen.

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Abbreviations

AIDS	Almost Ideal Demand System
CO_2-eq	Carbon dioxide equivalents
CO_2	Carbon dioxide
CH_4	Methane
GHG	Greenhouse gases
LCB	Biomass with low potential
LM	Lagrange Multiplier
N_2O	Nitrous oxide
PIGLOG	Price-Independent generalized logarithmic
QAIDS	Quadratic Almost Ideal Demand System
VAT	Value-added tax

1. Introduction

Meat consumption can be unsustainable according to Willett et al. (2019) who emphasize that a changed diet to a more plant-based food can support the growing population better while reducing environmental pressures and being healthier. Today there is a lack of economic instruments for a transformation towards a more sustainable food system (ibid). This research therefore assesses the potential of economic policies for shifting consumption towards more plant-based food. The study highlights several sustainability goals to give the subject a broad perspective. One of these goals is the Paris Agreement, which was created in 2015 to limit global warming to below 2 degrees Celsius compared to pre-industrial levels (UNFCCC, 2022).

The goal of reducing global warming due to greenhouse gas emissions (GHG) is being implemented to reduce the risks of climate change for humans, societies, and ecosystems. IPBES-IPCC report Pörtner et al. (2021) also problematize the changing land use and reduced biodiversity. The report highlights the agricultural role in mitigating climate change and the fact that the agricultural sector accounts for 21–37% of all global carbon dioxide emissions. The collaboration between IPBES and the IPCC was created to both protect biodiversity and to mitigate climate change. They highlight the integration between them as well as the strong connection to consumption habits and the agricultural sector. Emissions can be reduced with a more plant-based diet as animal production is more resource-intensive. Resource-intensive diets also require more cultivated areas and therefore increase deforestation, which could otherwise be a resource for biodiversity and carbon sinks. Furthermore, the food system accounts for a third of global soil acidification and most of the global eutrophication (ibid). Willett et al. (2019) express that the environmental goals can be obtain if the trend is shifted towards an increased plant-based diet where meat consumption is considered as a luxury consumption. Consumption levels, however, seems to have had the opposite trend according to Statista (2022). They report that the global meat consumption has more than doubled since 1990 and that in 2020 it reached 324 million metric tons.

Among studies of reduced meat consumption, the focus is often on beef consumption (Jansson & Säll 2018; Bonnet et al. 2018; Roosen et al. 2022). The reason is that it has the greatest negative climate impact compared to other meat goods, and that taxing beef has the largest effect out of all investigated meat taxes. Lesschen et al. (2011) write that 61% of all emissions from the food industry come from beef and dairy production. At the same time, there are advantages with this industry as it can contribute to biological diversity by animals grazing on natural pastureland. The production can also provide the use of ley cultivation which enhances the soil quality. The high demand for an animal diet and pressured prices makes it difficult for an optimizing farmer to maintain pasture grazing (Larsson et al 2020). Pork and beef production can also be more resource efficient than for example poultry from a circular perspective as residual products can be used for feed (Selm et al. 2020). Biodiversity, changes in land use, water shortages-and acidification, and eutrophication are also affected by consumption patterns as the demand affects production. In addition to these environmental measures that are affected by food production, there are additional sustainability perspectives such as health, animal welfare, food supply and secure livelihood. In the case of animal welfare and biodiversity in Sweden, there are benefits with beef production. Pork and poultry do not provide additional values for biodiversity and the animals are allowed smaller indoor production facilities in worse conditions (Swedish Board of Agriculture 2022). This makes it complicated to prioritize which meat consumption that should be reduced. The complexity of the issue is that decreasing the consumption of one specific group of meat while increasing another group may have both positive and negative consequences. These consequences can be hard to measure because there are difficulties valuing e.g., animal welfare and biodiversity. Given the complexity in prioritizing which sustainability objectives that is most important, a general meat tax is important to investigate. This study will also include taxation of all animal goods as well as examine the effect of a subsidy of plant-based proteins. A further investigation of tax on each production with its advantages and disadvantages would be even more beneficial to study, but the question is too extensive for this thesis.

Previous studies show a varied effect of a Pigovian tax on meat. There are also mixed views on the effect that such a tax may have on human health. Several studies show that a tax on meat can reduce consumption as beef is reduced with 10.8 to 19 % (see e.g., Springmann et al., 2017; Revoredo-Giha et al., 2018; and Roosen et al., 2022). Meat generally, as other food provisions, has a low elasticity which makes the effect of a tax small as the result by Bonnet et al (2018) indicate. Roosen et al. (2022) examines the effect on the societies welfare and how this can be compensated with tax revenues. Moberg et al. (2021) also highlights compensation for goal conflicts that could potentially arise due to a meat tax in form of reduced biodiversity-rich semi-natural pastures. Even if the subject has become more popular in later years, as there are many working papers in the field, the generally low research on meat taxes justifies further research. Other mechanisms such as green education also lack research, but the results by Katare et al. (2020) imply that society requires a strong mechanism such as Pigouvian tax, as the impact of green education is rather low. The next chapter will explore more studies in the field forming a deeper theoretical background to the complexity of the sustainability effects of different meat production.

The specialization of this study is to assess a general meat tax, but taxation of all animal goods will also be included and a subsidy on plant-based food. The categories for this study are *Meat and charcuterie*, *Seafood*, *Plant-based* and *Other* (egg and cheese in food). The dataset used in this study originates from one of the largest ICA stores in Sweden and includes all protein products sold during an eight-month period, from the first of August 2020 to the last of March 2021. This is the first study that treats demand-based policies on real market data with this specific focus. To estimate the effect of a tax on meat consumption, the elasticities for the categories are examined. The elasticities are used to assesses the variations in demand due to price changes. A Quadratic Almost Ideal Demand System (QAIDS) is used to estimate the change in the budget shares as well as estimating the Marshallian demand and income elasticities. The parameters are used to construct a system of linear demand curves. The focus purpose of not separating different types of meat, to include different benefits and disadvantages of their production, provides an insight into the effect of an Pigouvian tax. This is not only relevant as a basis for political decisions, but also relevant for further research of specific taxes where these benefits and disadvantages are included.

To capture the power of the economic instruments, three tax scenarios are applied. The first two taxes are based on the average greenhouse gas emissions from meat consumed in Sweden and the current CO_2 tax. The reason for this is that all sustainable perspectives cannot be measured, therefore all meat is weighted as equally harmful for all sustainable aspects as it is for global warming. This results in a lower cost for beef in comparison to earlier studies due to the potential of improved biodiversity, carbon sequestration and nutrient contents in soil from ley production. It also results in a higher cost compared to previous studies for poultry and pork due to the lower possibility for natural behaviour etc. Since other animal goods also affect sustainability factors, they are also included in the last two scenarios. The third policy scenario is an increased value-added tax (VAT) to capture the different ways in which the tax can be designed. This scenario also includes subsidy to investigate its possibility to change consumption patterns. Therefore, the tax scenarios are as follows:

- Scenario 1: A tax of 14.1 SEK per kilo for *meat and charcuterie*
- Scenario 2: A tax of 14.1 SEK per kilo for *meat and charcuterie*, a tax of 7.32 SEK for *Seafood* and a tax of 2.7 SEK for *Other*
- Scenario 3: A VAT increase from 12% to 25% on *Meat and charcuterie*, *Seafood* and *Other* and a decreased VAT on *Plant-based* with 6%

The goods included in the categories and a motivation for the different tax scenarios is described in Chapter 4. The entire chapter includes the description of the data and data processing. Furthermore, Chapter 2 provides an overall background on sustainable aspects in meat production and a theoretical background on the application of economic instruments. Chapter 3 includes a description of previous studies within the subject. The methods that have been used are described in Chapter 5. In Chapter 6, the results, the analysis, and a sensitivity analysis are included. The research paper ends with a conclusion and a discussion in Chapter 7, which is then followed by appendix and references.

2. Theoretical perspectives

The following chapter presents the effects of different types of meat consumption and the background information that motivates a general meat tax. The chapter also feature the theoretical perspective of negative environmental externalities and how economic instruments can be applied to minimize these.

2.1 Meat consumptions and the effect on sustainability

Food production has a negative effect on greenhouse gas emissions, the use of arable land, nitrogen and phosphorus supply, fresh water supply and biodiversity according to Willett et al. (2019). Animal production has the greatest impact on these factors as livestock requires a larger proportion of cultivated land as it is higher up the food chain. It is therefore more advantageous to reduce meat consumption and shift to a more plant-based consumption. However, it is not clear how to choose which specific meat category to reduce as there are many benefits and disadvantages to different categories. In this chapter several sustainability perspectives are therefore highlighted, and each species will be evaluated from these points of view. The sustainability perspectives are: GHG-emissions and other environmental aspects such as biodiversity, health, and animal welfare. National political interests and social foundations will also be briefly discussed because these perspectives influence and is influenced by the political instruments studied in this research.

2.1.1 GHG-emissions and other environmental aspects

Climate change leads to disturbances such as rising sea levels and an increase in the frequency of extreme weather events (IPCC 2021). These changes are caused by greenhouse gas emissions such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) and about 21–37% of total emissions originate from food production. Willett et al. (2019) writes that GHG-emissions from the agricultural sector is also caused by deforestation, drained wetlands, and cultivated soils. As a larger proportion of cultivated land is required for animal production than plant-based production, these factors are affected by meat-based consumption patterns. Meat production is also an important source of CH_4 and N_2O emissions, which have an around 30 and 280 times respectively as higher warming potential than CO_2 in a 100-year perspective (GWP100). As methane is produced during digestion in ruminant livestock, beef is the most problematic production for decreasing emissions. The EAT-Lancet Commission includes 20 experts in the fields of human health and environmental sustainability Willett et al. (2019). The Commission has been developed to develop global scientific goals for sustainable food production. Their dietary advice highlights reduced consumption of beef and pork for their negative environmental consequences. Their dietary advice advocates poultry over beef and pork and as well as advocate higher plant-based consumption. This diet would then mean that the approximately 40% of global arable land, that is currently used to produce feed, instead could be used to produce provisions for humans (ibid). Furthermore, eutrophication is a problem in the agricultural sectors linear nutritional use, where Säll et al. (2015) estimate that Swedish meat and dairy production accounts for approximately 18.5% of total nitrogen emissions, including nitrogen from ammonia emissions. This production also accounts for 8.3% of the total phosphorus emissions from Sweden to the Baltic Sea.

However, a reduced production of beef can potentially lead to a loss of biological diversity according to Moberg et al. (2021). This is due to that the specific production includes semi-natural grazing, which is important for maintaining habitat for different species (Olén et al. 2021). The effect on biodiversity from beef production, differs depending on where the cattle is raised or where the feed crops are produced. If the production is in South America, for example, it can lead to a reduced diversity as the land use for the production lacks ecological heterogeneity compared to the uncultivated land. In Sweden however, the trend has not only gone from less meadows and semi-natural pastures but also from less cultivated land to more forested land since the 1920s (Morell 2001). Increased or sustained beef production based on semi- natural pasture may on the other hand contribute to important biodiversity. Another advantage from cattle production is that ley production enhances the soil quality by binding nitrogen and improving the structure of the soil. Conditions in Sweden for growing crops for a vegan diet are limited but large areas are more suitable for ley cultivation (Röös et al. 2016). The production of pork is not generally considered to lead to benefits for biodiversity, but according to Selm et al. (2020), there is a large resource efficiency option in both cases of beef and pork production. This is the case as both beef and pork can be fed with the biomass that has low potential (LCB). Beef and pork can transform waste products from the human food industry and thereby follow the principle of circularity. Poultry, on the other hand, can consume similar diets as humans and this type of diet results in the greatest emissions. Selm et al. (2020) show that the principle of circularity leads to reduced greenhouse gas emissions by up to 31% and the use of arable land reduced by up to 42%. Röös et al. (2016) also emphasize that animal feed on resources, like ley produced on marginal land and by-products from crop production leads to resource recovery and constructive management of the landscape. The assumption that the taxation of red meat must have the best environmental impact is hereby challenged. However, it remains to be seen if only rest products and lay can sufficiently produce to support the increase meat consumption. In addition, Röös et al. (2021) points out that the principle of circularity also has some disadvantages such as difficulties to optimize the protein intake of animals that require specific amounts of amino acids. From these perspectives, it becomes clear that a generally reduced meat consumption would have a positive effect, but the choice of type of consumption is complex.

2.1.2 Health perspective

For a more general sustainable perspective, the variations in health can also be highlighted. Springmann et al. (2017) point out that there are health benefits with lower meat consumption as the intake of fat and carbohydrates decreases. They also point out that red meat is the most harmful consumption as health problems from this consumption can be coronary heart disease, stroke, type 2 diabetes mellitus, obesity, and cancer. Moberg et al. (2021) write that the intake of vitamin B12, protein and calcium also can decrease with a lower meat consumption. They note however that in Sweden there is already a surplus of these nutrients. The most negative effect is the reduction in vitamin D, folate, and iron, which mainly decreases if fish and dairy consumption decrease. Röös et al. (2016) believe that more globally, there are certain problems with reduced meat consumption as the content of essential amino acids and micronutrients is important to malnourish people suffering from malnutrition in developing countries. However, overconsumption of meat seems to increase with increasing living standards. It is the overconsumption that is unsustainable and typical western societies consumption patterns are investigated in the most research.

2.1.3 Animal welfare

Another sustainable aspect is animal welfare which varies a lot between countries and animal species. Sweden generally has the highest standard for animal welfare in Europe, especially in the case of poultry and pork. Robins and Phillips (2011) also writes that Europe have the most state regulated production of poultry with a versatile industry where welfare regulation is high. Still, the welfare of poultry is highly criticized in Sweden since the space per poultry is very low (0.01 m^2), they have been bred for rapid growth so that heart and bone problems increases, and they are slaughtered within 60 days (Swedish Board of Agriculture 2022). Pork production in Sweden is generally considered to be better than other countries where the animals often are tied up and it is allowed to cut their tails instead of decreasing stressed situations. It is also higher standard in Sweden for requirements for access to daylight. Although it may seem like a low standard, it is much higher than in other countries and for other animal species. What is most often criticized though is that the animals are anesthetized with carbon dioxide before slaughter. In Sweden, cattle production has a higher animal welfare as regulation against a bound system is increasing and there is also a requirement for three months of pasture. From this perspective, Swedish production is therefore considered more sustainable compared to production in many other countries.

2.1.4 Weighing sustainable aspects

In this chapter, several sustainable perspectives have been highlighted and the high meat consumption affects these factors. These aspects are greenhouse gas emissions, biodiversity, land use, natural resources, health, and animal welfare. From many of these perspectives, imports from certain parts of the world can be considered less sustainable. However, it is important to emphasize the importance of trade and the labour market, as livestock production creates a secure livelihood among the poorest population (Röös et al. 2016). On the other hand, it is also relevant to highlight the national interest in Sweden in maintaining the degree of self-sufficiency and minimizing dependence on imported goods and inputs (The Swedish Board of Agriculture 2014). The consumption of different animal species has many different advantages and disadvantages. It is difficult to value an animal's suffering, the risk to humans' health and biodiversity. The consequences for all aspects are complex. There are attempts to evaluate biodiversity, but how it should be measured is debated. The attempts to measure GHG-emissions are more successful and are described in Chapter 4. This price for the emissions is the tax per kilo of CO_2-eq (CO_2 equivalents) and should match the social cost consuming goods with GHG-emissions. To include all sustainability perspectives even though there is no true price for them, the calculated social cost for GHG-emissions is applied evenly to all meat. This reduces the tax burden for beef and increases it for poultry and pork in relation to individual GHG-taxes for the different animal species. This is to capture the negative sustainability aspects in the production of poultry and pork for the low level of natural behaviour possibilities and low potential of increasing biodiversity etc. This has also been executed on other animal goods as some sustainability aspects also can be applied to some of them. Eggs and dairy are linked to the same sustainability problems as meat production, where the health perspective differs the most. The taxation of these will go under the same principle: That all sustainability factors cannot be priced so GHG-emissions may represent the price. How a social cost is taxed is described in the next section.

2.2 Policies on Externalities

In the previous section, the effect of meat consumption on various aspects of sustainability were investigated. Some of these effects are positive but several of them are negative. As they occur because of production but are not always included in the production cost, there will be an external effect on society when consuming these goods. These effects are defined by Snyder and Nicholson (2012) as an externality as it is an economic actor that influences a third party. The damage that resource-intensive production has on society gives the good a social cost that is not reflected in the price. It is an example of a market failure when the quantity sold on the market is higher than the optimum because the price is too low. The result is thus a misallocation such as a too high consumption of resource-intensive goods and a too low consumption of resource-efficient goods. Externality can also have a positive effect on the third party. Consumption of semi-natural pasturing animals lead to increased biodiversity, which, for example, can lead to reduced costs through natural pollination. Again, the result is a misallocation of resources.

The social impact of consumption can lead to a WTP to avoid the damage or to gain the benefit. If this willingness to pay varies within a population, it can be achieved through green marking, nudging or economic instruments. For this study, economic instruments in the form of Pigouvian taxes are examined based on the description of Snyder and Nicholson (2012). These taxes increase the price to another level that reflects both the cost of production and the social cost. Figure 1 shows the difference in prices and quantities when the social cost is excluded or included. The competitive supply curve for item x, when only production costs are included, is MC = S. The market equilibrium is where MC correlates with demand (D) and gives the price p_1 and the quantity x_1. The supply curve that includes the social cost is MC ', which gives a market equilibrium with a higher price p_2 and a lower quantity x_2. Divergence between private marginal costs (MC) and overall social marginal costs (MC ') is the external cost. The vertical distance between the two curves, MC and MC ', represents the costs that production for the specific quantity has for a third party. Note that the unit costs for these external effects do not have to be constant but can, for example, increase for an increased number of x produced as in the figure. Society's optimal market price is p_2 which it upholds when introducing a Pigovian tax. The tax creates a vertical wedge between the demand and supply curves for commodity x shown in the figure as t. The imposition of this tax reduces production to x_2, which is the social optimum. The tax collection corresponds to the exact amount of external damage that x production causes. These tax revenues can be used to compensate the society for these costs.

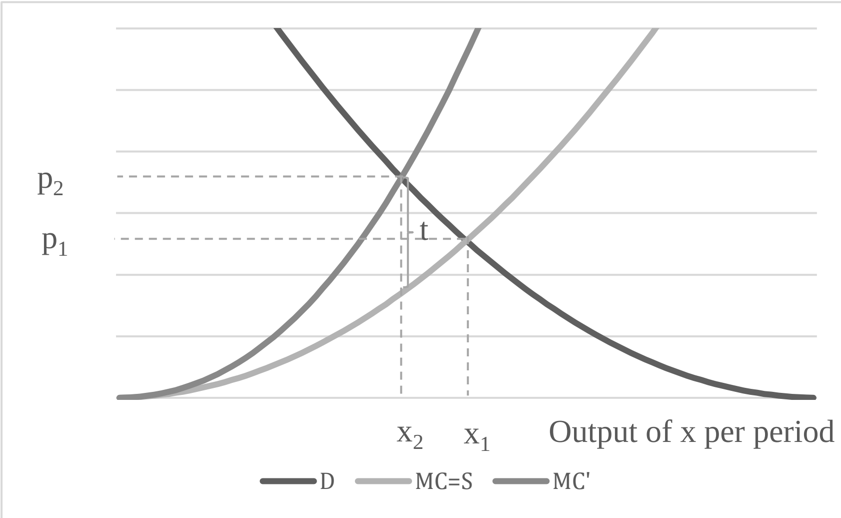


Figure 1. Graphic analysis of an externality
Source: Illustration made in excel, based on the model by Snyder and Nicholson (2012l.

2.2.1 Appling a Pigovian tax on meat consumption

If the Pigouvian tax is applied to a consumption were the external effect affects the consumer directly it will motivate the consumers' willingness to pay to avoid it. When it comes to meat consumption and the increased externality with this resource-intensive production, the external effect does not always affect the consumer in question. It may take place in a completely different part of the world depending on where it has been produced. The effect may also have leakages such as GHG-emissions, which may affect other parts of the world and another generation. For this reason, acceptance of taxes can be difficult to justify. In addition, food consumption generally has low elasticity, which generates a low effect of an increased price (Snyder and Nicholson 2012). Even if the tax would have a low effect, the tax revenue can be used for environmental measures or for welfare compensation, as several previous papers suggest (Moberg et al. 2021; Roosen et al. 2020). The risk is that the tax will reduce the farmers competitiveness on the international market, which Jansson and Säll (2018) highlight. However, they point out that if taxation is imposed on consumer prices and with low elasticity, consumers are most burdened by the tax. Furthermore, the import is only a consequence of Swedish consumers, not Swedish producers as input goods are not taxed, which means that the consumer tax is the only way to capture the import. For this study, therefore, the Pigouvian tax is examined as the result may be important even if it shows a low effect.

3. Literature review

According to Roosen et al. (2022), studies on the potential effects of a carbon dioxide tax on meat consumption are surprisingly rare given the great debate on the issue. Taxes on food are often studied for health purposes, but the number of studies on reduced environmental impact using a tax on food consumption are increasing. Much of the existing research has been published in recent years and more articles will be published in the future such as the working paper of Funke et al. (2021). In this chapter, various studies of GHG-weighted taxes will be presented. There is a focus on meat taxes to provide a background for this research.

One early research that examined both GHG taxes and other sustainable aspects is Säll et al. (2015). The authors highlight the harmful environmental effects of meat and dairy production such as GHG emissions and eutrophication. They investigated a Pigovian tax on three meat products and four dairy products. The taxes were applied to capture the external environmental damage created by the agricultural sector such as GHG gases and eutrophication caused by nitrogen, ammonia, and phosphorus leakages. From this, they made a calculation of average damage costs. The effect of a tax was calculated with econometric estimates of the almost ideal demand system (AIDS). The calculations for the marginal emission costs resulted in 1.8 and 32.5 SEK per kg produce. The tax levels correspond to 8.9% and 33.3% of the initial prices. The results implied that the animal products have relatively low price elasticities but higher income elasticities. If all seven goods are taxed, it could result in a reduction of 12, 1% of pollutants from the animal sector. The change in the damage costs for greenhouse gases varied from a minimum level of SEK 0.55 per kg CO_2 to a maximum level of SEK 2.8 per kg CO_2. Säll et al. (2015) also emphasized that a reduction in meat and dairy products in Sweden could contribute to improved health among Swedish consumers. This is especially true when the consumption of red meat decreases.

A subject relevant for this study are the potential goal conflicts that may arise in the taxation of meat. This subject has been research by Moberg et al. (2021) as they investigated the effect on food consumption in the event of price changes. They used demand system where historical price and consumption data were used to estimate price elasticities. The research has tax scenarios for a reduced environmental effect of resource-intensive edibles. The tax scenarios were based on weighting of GHG emissions and adjusted value-added tax (VAT). One scenario was reduced VAT rates for plant-based products and increased weight for more resource-intensive goods. Several scenarios resulted in a reduction in beef consumption and thus a potential reduction in biodiversity-rich semi-natural pastures. This could potentially create goal conflicts as the reduced beef consumption leads to a reduced global climate change but can also reduce the semi-natural pastures. Moberg et al. (2021) therefore motivates that production on semi-natural pastures can be supported financially by the state (more than current support). The alternative income for the farmers may then compensate the increased tax burden. They emphasize that more knowledge about taxation is needed to reduce the environmental impact and how it affects environmental outcomes more broadly than just the climate impact. This is to avoid implementing instruments that may have negative effects in other areas.

Katare et al. (2020) investigate how the external costs of meat consumption can be minimized with a Pigouvian tax and green label training. They highlight how the increased meat consumption leads to increased GHG emissions, threatens the global food and water supply as well as to soil degradation and deforestation. However, they also highlight the health effects such as obesity, cancer, and antibiotic resistance as well as the lack of animal rights. Even though the social optimum is a more plant-based diet, the demand for meat is still high. To change consumers habit from current levels of meat consumption, a policy is required where a Pigouvian tax and green etiquette education are compared. Tax is a limited measure as it can be difficult to apply and does not always have a high effect. However, they found that there is limited research on what tax revenues can be used for and that there can be equally much green policy as the effect of the tax. Climate labelling is used to raise public awareness and aims to change consumer preferences. The effectiveness of the substance is not as well studied. To measure the consumer's reaction to both government mechanisms, consumer choice theory with elasticity estimates is used. The results indicate that education alone is not likely to provide a high socially optimal level. However, it should be emphasized that education can be a long-term mechanism. Katare et al. (2020) believe that society demands a strong mechanism such as the Pigouvian tax to directly move consumers' meat consumption towards a social optimum.

Bonnet et al. (2018) focus on emissions from beef production because it produces the most greenhouse gases. The authors argue that GHG-emissions will be reduced if households substitute beef for white meat and plant-based food. They emphasize that the EU is one of the largest meat consumers per capita in the world. Where France, the country that they are studying, is the second largest consumer after Germany. The EU has adopted the goal of halving emissions by 2050 and, Bonnet et al. (2018) is examining the introduction of CO_2-eq tax policy as a measure to achieve this goal. They use the recommended carbon price: EUR 56 per tonne of CO_2-eq in 2020 and EUR 200 per tonne of CO_2-eq for 2050. They compare the effects of three factors: taxation of all animal consumption, taxation of only meat consumption from ruminants (beef, veal, lamb); taxation of beef products only. Their results show that the price elasticity of animal products is low (−0.31). The effect of a tax of 56 € is small and increases slightly at a high tax level, 200 €. It does not meet the EU's 20% target, but only reduces greenhouse gas emissions by 6%. Bonnet et al. (2018) proposal is to have the highest tax but only on beef consumption as it has the largest climate impact. It would have the greatest effect without significantly changing household welfare. But the effect is possibly greater on beef alone as it can change consumption to other meat consumption as well into more plant-based consumption. They also mean that the demand for animal products is less elastic at the aggregate level.

Another study which estimates the potential for greenhouse gas reduction is Forero-Cantor et al. (2020) who aim to assesses the introduction of consumption taxes for certain protein-rich foods in Spain. They believe that information campaigns have a long effect and meat is deeply rooted in our diet. They use data from the Spanish panel for the period 2004–2015 regarding household food consumption. The model used was an almost ideal demand system (QAIDS) with moving block bootstrap. This is to estimate the elasticities to calculate the impact of a price change to match the cost for the externalities from consuming seven different type of meat. Literature data on the carbon footprint of meat consumption are used where the tax is based on a prior assessment of the environmental consequences of a Life Cycle Assessment (LCA), and thus the carbon footprint (CFP). The results indicate that taxes on fish are most effective while a tax on pork is least effective in reducing the overall carbon footprint. Forero-Cantor et al. (2020) also write that the results suggest that the highest tax on the most polluted products does not lead to the highest reduction in the carbon footprint. This is the case as the tax generally have a low effect.

Roosen et al. (2022) examines different types of meat taxes in Germany. This is to review an increased value-added tax (VAT) and the effects of two excise tax scenarios, as well as their impact on welfare. They find that there is a need for a change in dietary consumption towards a more plant-based diet and that Germany is the largest meat consumer in the EU. The focus is on purchases of fresh meat as the data is more accessible. The most consumed meat categories are examined (poultry, pork and beef and veal) where four tax scenarios are applied. The tax scenarios are an increased VAT on meat from 7% (the reduced VAT they have now on food provisions) to 14% or to the general level of 19%, and two excise tax scenarios based on carbon emissions per meat category (USD 40 and USD 100 per kg CO_2e). They use an almost ideal demand system in its linear approximation (LA AIDS) to obtain the demand analyzes. The elasticities are group-specific because they estimate the demand system separately for households that differ according to income and age. The results indicate that an increase VAT by 19% leads to an average reduction in purchases of about 11% for all types of meat and all households. However, it also leads to a welfare loss of 0.83 euros per household per month, which can be a difficult policy to achieve as it worsens the conditions for many, especially for low-income households. The scenarios for excise duties show marked changes in consumption levels, especially for beef, where the low excise duty gives a reduction by 8.5% and the high one gives a reduction by 21.3%. Roosen et al. (2022) also points out that the taxes with low effect can provide tax revenues that may support farmers' investments in better methods of animal welfare and may be used by the meat industry to improve working conditions. Finally, they point out that carbon dioxide taxes can lead to changes in the social norms that govern meat consumption.

A study that shows large reductions in greenhouse gases with the introduction of a meat tax in the UK is the study by Revoredo-Giha et al. (2018). Unlike Katare et al. (2020), however, their study shows that the tax also leads to certain negative health effects. The result show positive health effects of a reduced meat consumption but also a reduced nutritional intake. The survey was conducted with unconditional elasticities relating to the total household budget. These were calculated using the 2012 Kantar Worldpanel database for Scotland. The model that they used was the Exact Affine Stone Index (EASI) instead of (AIDS) to estimate the elasticities without assuming homogeneity of preferences. Then two tax scenarios were applied, where one is value taxes determined according to the group's greenhouse gas emissions. The other scenario is carbon dioxide consumption tax rates calculated from different carbon prices. The different coal prices are set by the European Commission (0.0427 £ / kg), by the European Emissions Trading Scheme (ETS) (0.0128 £ / kg) and by the EU's long-term projection (0.1709 £ / kg). Then, four product groups of meat were examined. The results show that taxation of carbonated food products has the potential to reduce both greenhouse gas emissions and to some extent improve health effects by reducing the intake of sugar. The EU's long-term projection tax is the most effective and provides an 18.7% reduction in greenhouse gas emissions. All scenarios a reduction in sugar intake but also a deterioration of recommended nutritional intake.

Springmann et al. (2017) show that a meat tax is significant for reducing climate change but also for better health on a global scale. They also suggest that income losses for the price increases can compensate by using tax revenues for the negative health effects of the most vulnerable groups. They argue that the need for reduced meat consumption increases as the population grow and dietary changes can increase greenhouse gas emissions in the agricultural sector by 80% by 2050. A database of life cycle analyzes were used to estimate the quantity of emissions to determine greenhouse gas taxes on food production. Agricultural data from FAOSTAT were used and 62 food raw materials in 150 areas across the globe were assessed. The main analysis assumed an emission price of USD 52 per metric tonne of CO_2-eq with alternative values of 14 USD, 78 USD and 156 USD. Tax scenarios apply to meat in general, red meat, and beef. The results show that the tax is health-promoting, and that the policy mitigates climate change in high-income countries, middle-income countries, and most low-income countries. The tax will reduce 9% of food-related greenhouse gas emissions by 2020, and about 10% of the emissions gap to limit global warming to below 2˚C. They write that there are problems with estimating the impact of methane and if it could be included, it would result in greater emission estimates. This also applies to the low estimate of nitrogen emissions to watercourses and reduced land use change. The health benefits identified in this study (100,000 - 500,000 deaths avoided globally) can be compared to the health benefits of reduced air pollution. The benefits for the decreased consumption of red meat are coronary heart disease, stroke, type 2 diabetes mellitus, obesity and cancer and account for about half of all deaths due to diet-related risks.

The outlined studies show that there is a potential for GHG-weighted taxes on meat. The effect of such a tax varies for the different research. In cases of low effect, due to the low elasticity that gives high tax revenue, many propose that the revenue can be used for environmental measures. Compensations for losses in welfare is also highlighted.
The type of meat that should be taxed differs although the focus in general is on beef (Bonnet et al. 2018; Roosen et al. 2022). Forero-Cantor et al. (2020) disagrees that tax on beef give the most effect and Moberg et al. (2021) highlight the potential goal conflict with such a tax. All studies criticize the high meat consumption and express that it needs to decrease. In some cases, some authors highlight various reasons why the consumption must be reduced, these reasons are climate change, the environment and human health. Some studies problematize the possible negative consequences of taxation of meat consumption with loss in welfare, possible health problems and potential reduced biodiversity. What all studies are missing is to highlight the whole complexity and that instruments for measuring this complexity need to be developed to include all sustainability perspectives. This is the motivation for including this complexity in the present study.

4. Data

This chapter describes the market data used for this research as well as the process data and collection and processing. Furthermore, the statistics and the GHG emissions impact is presented, and the limitations of the data are lifted.

The market data is collected through the scanning records in an ICA Maxi store in Nacka, Stockholm. It is the information on the total number of packaged goods sold and includes their weight and their VAT-exempt prices from 2020-08-01 to 2021-03-31. The store ICA Maxi is a supermarket with an extra-large assortment of goods in great variety and this specific store has given approval to collect and process the data for research. The store is situated in Nacka, which is a parish in Stockholm County that borders to Tyresö, Lidingö and Stockholm parish. There are 100,000 people living in Nacka, where 52.3% are in good socio-economic conditions and 39.9% are in very good socio-economic conditions according to the Segregation Barometer (2019). The owner of the store has approved the data collection from the store in collaboration with Swedish University of Agricultural Sciences. The daily visits to the store are on average 30000 per week with the largest variations on weekends and before holidays.

4.1 Data process

For this research, goods within the group *meat and other protein goods* have been examined. These goods have been divided into the following categories: *Meat and charcuterie*, *Seafood*, *plant-based* and *Other*. The aim to investigate the effects of a tax on the category *Meat and charcuterie*. The category *Seafood* and O*ther* will also be examined but not to the same extent, which is further explained in chapter 4.3. All four categories include 3026 items totally where every daily purchase of the items has been collected. It includes 106,463 observations from the first of August 2020 to the last of March 2021. All these observations are gathered into seven Excel files where two files, *Meat and charcuterie* and *Plant-based* were already processed for previous studies. Five Excel files were categorized into the groups *Seafood* and *Other*. The category *Other* includes eggs and cheese. Furthermore, the group *Seafood* has been processed with smoothing over certain dates of extreme values.

Before this categorization was made, the number of sold kilograms per observation was calculated. These were then summed daily for all items within their category to obtain the quantity. The daily values per item was summed up and divided with the number of sold kilograms to obtain the prices. This were also summed up for each category by multiplying them whit the number of kilograms sold divided by the quantity. Prices were also multiplied by 1.12 to include the Swedish food VAT rate of 12%. Finally, the data set for all categories was aggregated in an Excel file with the corresponding average units sold and the average prices. The final sum gave 243 observations for each variable which represents the daily collection over the eight months.

4.2 Descriptive Statistic

The average aggregated quantities and prices of the 243 days of purchase of *Meat and other protein goods* are presented in Table 1. The average value of the 243 days of purchase for all four categories shows here. *Meat and charcuterie* are the most sold with an average of 2014.5 kilograms per day. *Other* and *Seafood* were sold in approximately the same quantities, 977.5 and 849 respectively. *Plant-based* were sold in the lowest quantity of 102.8 kilo. These values also show large variations in minimum and maximum values as well as high standard deviations. This may be due to the variation in consumption patterns between days e. g. due to increased food purchases during the weekends.

The highest average price is on *Seafood*, which costs an average of 192.3 SEK per unit sold. *Meat and charcuterie* are the costliest after seafood but is still much cheaper on average, it is 142.1 SEK per unit sold. *Other* has the lowest price and is 78.3 SEK per unit sold while *Plant-based* are slightly more expensive on average at 91.5 SEK. When it comes to prices, the standard deviation is much lower as the interval between the lowest and highest values is small. It also means that prices do not fluctuate as much even if there are high peaks in quantities.

Tabell 1. Descriptive statistics of meat and other protein goods
Source: Based on ICA data.

Variables, Quantity	Obs	Mean	Std. Dev.	Min.	Max.
Meat and charcuterie	243	2014.5	655.2	924.8	6325.3
Seafood	243	650.4	204.8	325.9	1474.6
Plant-based	243	317.9	77.9	107.5	554.7
Other	243	977.5	214.6	340.5	1969.6
Variables, Price	**Obs**	**Mean**	**Std. Dev**	**Min.**	**Max.**
Meat and charcuterie	243	141.1	18.3	113.1	244.2
Seafood	243	195.8	32.8	125.5	320.9
Plant-based	243	54.2	4.4	40.0	69.3
Other	243	78.3	8.7	53.4	97.1

4.3 Calculations for Policy Scenario

This research highlights several different external effects for varying meat consumption and its different production. These external effects are therefore difficult to calculate. There is no price for the value of biodiversity and animal welfare. However, there are several attempts to estimate the climate impact of different food consumption. These have been calculated by Moberg et al. (2019) which is based on LCA. This method is defined as GWP_{100} where gases such as carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and chlorofluorocarbon R22 (HCFC-22) are included. This is a method for weighting different efficient greenhouse gases and rewriting all the gases in CO_2. This is advantageous as agricultural emissions are not dominated by carbon dioxide but by methane and nitrous oxide. Table two describes Potter et al. (2020) estimation of the emission level and the tax for the emission. It is calculated as GWP_{100} in CO_2e and is presented in the total tax level per kilo. This level is based on the Swedish carbon dioxide tax of 1.2 SEK per kilo of CO_2.

The mean value of several crops has been computed for certain values within the group *Plant-based* as they include many crops. All groups are also weighted according to the percentage the group has been consumed within its category. For example, beef constitutes more than one third of the consumers entire meat consumption, while poultry constitutes less than one third. These market shares have been calculated by dividing the total number of kilos sold with the entire quantity for the category, which has then been summed up for an average value. Therefore, the average value of GHG emissions per kilo sum is not divided by number of groups but by the sum of the market value. This sum has then been multiplied by the tax of 1.2 SEK for the average value.

Table 2. CO_2 equivalents for all the categories within the group "Meat and other protein goods" per kg and average unit.
Source: Based on the research by Potter et al. (2020) and Säll et al. (2020).

Per kilo	GHG	Market share	Weighted GHG	Tax in SEK
Beef	23.5	0.329	7.742	28.2
Pork	4.6	0.341	1.567	5.52
Chicken	4.2	0.271	1.138	5.04
Other meat	22.3	0.058	1.300	26.76
Average	**13.7**	**1**	**11.75**	**14.1**
Seafood	6.1	1.0		7.32
Average	**6.1**	**1**		**7.32**
Eggs	2.5	0.730	1.827	3.0
Cheese	10.5	0.269	2.825	12
Average	**6.5**		**2.33**	**2.7**
Legumes	0.8	0.331	0.265	0.96
Meat-like	2.7	0.128	0.346	3.24
Non-Meat-like	0.6	0.021	0.012	0.72
Vegetarian Fish	2.2	0.002	0.004	2.64
Tofu and Tempeh	2.3	0.015	0.033	2.76
Vegetarian charcuterie	2.2	0.004	0.009	2.64
Herbal	2.3	0.5	1.15	2.76
Average	**1.87**		**1.82**	**2.184**

The average taxes are applied for this general meat tax. These calculations do not include other sustainable variables but are on example of how the tax can be applied. The tax leads to an increased price of 14.1 SEK per kilo for the category *Meat and charcuterie*. Since the purpose of this research is to investigate a shift to a more plant-based consumption, tax on the *Plant-based* category is not applied. Even though the focus of this study is on meat consumption, other animal goods also effect similar sustainability issues and are therefore included in the taxation. As mentioned in Chapter 2, however, only meat will be properly evaluated because of the limitation of the study.

Another way to tax externality is through increased VAT. Now the VAT is 12%, which can be increased to 25%, similar to the alcohol tax. Röös et al. (2021) have examined this increase in tax for animal products. This resulted in a reduction in both greenhouse gas emissions and other environmental impacts. It was compared with a carbon tax on all foods where the latter resulted in a 10% emission reduction. The VAT on animal products resulted in an emission reduction of 8% which is therefore considered effective. A change in VAT would mean a change in an already existing tax system, which thus means a reduced administration in comparison with the introduction of a climate tax.

Both taxation options are explored in this research to enable an assessment of which of the tax types that is best to apply and why. They can give similar results and to further explore how financial management can change consumption patterns, VAT tax is also decreased for *Plant-based*. In 4.4 Limitations, the disadvantages of these tax types are also thoroughly discussed and can therefore be compared with the advantages presented here. The taxation alternatives for the research are therefore presented in the following three scenarios:

- Scenario 1: A tax of 14.1 SEK per kilo for *Meat and charcuterie*

- Scenario 2: A tax of 14.1 SEK per kilo for *Meat and charcuterie*, a tax of 7.32 SEK for *Seafood* and a tax of 2.7 SEK for *Other*

- Scenario 3: A VAT-tax increase from 12% to 25% on *Meat and charcuterie*, *Seafood* and *Other* and a decreased VAT on *Plant-based* with 6%

4.4 Limitations

There are some limitations with the data used for this research. All data comes from a specific ICA maxi store in a specific area. This means that the data might not reflect prise and consumer patterns for the whole country, and there may be trends that are specific to the area and this supermarkets supply. The area is relatively centrally located in the country's largest city and the average income is relatively high. The results may differ to another area that does not have these attributes. There may also be different consumption patterns in the countryside that are not reflected in the data. One thing that is remarkable in the data is the small proportion of imported meat. ICA generally provides more Swedish products in its range than some of the other chains of grocery stores. This change in supply is also due to labels such as the *Naturbeteskött* marked labelled for pork that is owned by Coop and is not sold at ICA. All such factors determine how representative the data is for the whole country.

There are also several limitations in the choice of a general tax that does not occur when taxing all types of meat individually. This is to assure that the GHG emission tax represents the accurate external cost per kilograms of meat consumed. Then information and emissions for meat consumption can be the basis for calculating the externalities. In this case, a common tax is used for several sustainability aspects that are more complex to calculate. It requires several assumptions and can lead to different effects than expected. For the three scenarios used for this research, there are different types of advantages and disadvantages. Scenario 1 is problematic as the tax will not be distributed as it does in the case of taxing all animal species individually. According to Röös et al. (2021), it will reduce poultry consumption much more than other animal consumption. Poultry decreases by 26.8%, while beef only decreases by 4.5% at the same tax, which is not proportional to the externalities of the different animal species, even if the benefits of beef consumption is included. A VAT-tax is problematic as this taxation results in a higher increase in prices for more expensive goods, in absolute numbers, because it is a percentage increase. The increased difference between cheaper and expensive goods makes Swedish meat more expensive in relation to the imported meat. This is a problem since there is a relatively high regulation for sustainable agriculture in Sweden. It is also politically difficult to argue for a tax that complicates the conditions for Swedish farmers. There is a certain advantage as about 20% of all lamb meat is imported from New Zealand, whose production has a high proportion of natural pastures. Generally, however, a measure that does not stimulate the Swedish production might be a hard political arrangement to introduce in Sweden.

5. Method

This section covers the foundation of the empirical study with the methodological approach. It includes the categorization of the budget system into a two-stage demand system. This system shows substitutable goods in a utility tree, which is a basis for examining the shift in demand curves. Then the Quadratic Almost Ideal Demand System (QAIDS) is presented which is, for this study, calculated in the program TSP. The model is used for calculating elasticities which are also estimated in the same program. The calculation of the uncompensated Marshallian elasticities is also described in this chapter. Finally, the calculations of demand curves as well as the calculation and impact of price changes because of the tax, are presented.

5.1 Budget system

Demand curves for meat consumption are required to empirically estimate the effect of taxation on these goods. Other goods that can act as substitute for meat also need to be estimated to measure the full effect of the economic instrument. For this study, a budget system is set up where consumers are defined as utility-maximizing individuals, and a two-stage process is integrated into the QAIDS model. Edgerton (1997) writes about a multi-stage budget system where the separability between groups must be weak so that a change in the price of one product affects the demand for the other products. In this study the focus is mainly on one stage, but another stage is included for a broader perspective.

All the groups included in the same budget is used in the demand system on a broader scale. This is to enable the goods to be redistributed between and within groups. The first stage is each broad category within the entire budget. The second stage shows how the redistribution can take place within the groups. The redistribution is affected by the price and the consumer can directly compare goods that are similar within the same group within this group, they can distribute their available budget. Figure 2 presents these two stages in a utility tree. In all food consumption, stage one includes seven groups, where all the goods are not substitutes but are included in the same budget. For the group *Meat and other protein products*, there are four categories that are in stage two. These categories can be substituted for each other. One group may be affected by a price change in any of the other groups. This is the highlight of the research, but the inclusion of the first stage also allows the model to estimate consumption changes to other aggregated food groups. The first stage will be included with old elasticities from Röös et al. (2021) that did similar research but on a larger scale.

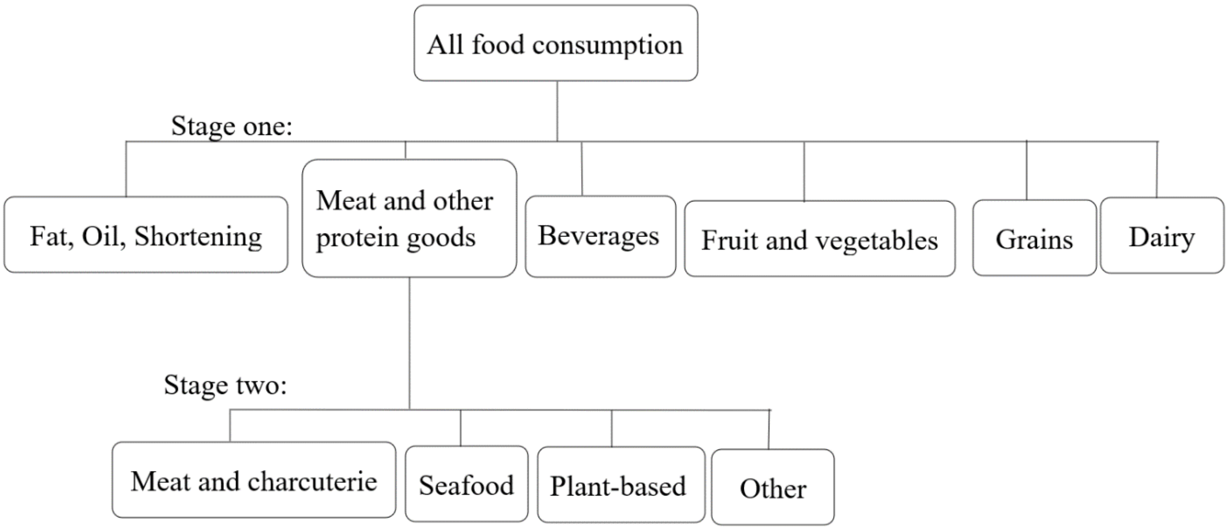


Figure 2. Utility trees for all food consumption.
Source: Based on Edgerton (1997), own illustration

5.2 Quadratic Almost Ideal Demand System

Deaton & Muellbauer (1980) developed the almost ideal demand system which was late expanded by Banks et al. (1997) to a quadratic extension. This model is used to estimate Marshallian uncompensated demand elasticities. The model provides a second order approximation that is arbitrary to several demand systems. The advantage of the model is that it meets the axiom of order, complies with budget constraints and is relatively easy to estimate. With the quadratic extension, the model does not invoke in parallel linear Engel curves and therefore does not have to rely on curves which can then be logarithmic by total expenditure. In addition to this, the model is based on price-independent generalized logarithmic preferences (PIGLOG), which is characterized by the demand of rational individuals. Initially, only stage two is estimated, which was presented in the budgeting system, but Chapter 5.2 also includes the elasticities of the first stage.

The model is based on the expenditure share s_i for goods i (i = 1… n). The expenditure share is regressed on the prices of all the goods that are included. The total expenditure is defined by $X = \sum_{i=1}^{n} p_i q_i$ so the share is $s_i = p_i q_i / X$. Prices are defined by p_j where J = 1… n. The full equation is thus:

$$s_i = \propto_i + \sum_{j=1}^{m} \gamma_{ij} \ln p_j + \beta_i (\ln X - \ln P) + \frac{\mu_i}{Q} (\ln X - \ln P)^2 \qquad (1)$$

The expenditure share is regressed on logarithmic prices for all goods $\ln p_j$ and for the total expenditure X. The parameters are α, β, μ and γ and the goods i in this research refer to the category *Meat and charcuterie* and *j* to the categories *Seafood*, *Plant-based* and *Other*. For the non-linear version of the AIDS model, the aggregate price index is P and are expressed as followed:

$$\ln P = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \frac{1}{2} \sum_{i}^{n} \sum_{j}^{n} \gamma_{ij} \ln (p_i + p_j) \qquad (2)$$

Q is a price aggregator which is described by:

$$Q = \prod_{i}^{n} p_i^{\beta_t} \quad (3)$$

The first three equations consequently become a framework for the theory of demand where all parameters are estimated at the average level. a_i is the logarithmic proportion of initial consumption and is therefore summarized to $\sum_{i=1}^{n} \alpha_i = 1$. The reaction to the change in total expenditure appear in β_i and its thus summarized to $\sum_{i=1}^{n} \beta_i = 0$ This means that the parameter for the square term also is summed to 0 according to $\sum_{i=1}^{n} \mu_i = 0$.

The model is also constrained by symmetry and homogeneity. Symmetry implies that a change in the price of goods *i* has the same marginal effect on the budget share of goods *j* as a change in the price of goods *j* has on a marginal change in budget shares of goods *i*. This means that $\gamma_{ij} = \gamma_{ij}$. Homogeneity implies that γ_{ij} is summarized to $\sum \gamma_{ij} = 0$ and thus indicating the response to price changes in the budget shares. By fulfilling these conditions, the total expenditure becomes 1 within the system of demand functions ($\sum si = 1$). If real expenditure (x/P) and relative prices are kept unchanged, the expenditure shares are constant. An appropriate starting point is then created for measuring changes in demand in response to price and income changes (Deaton & Muellbauer, 1980).

5.3 Elasticities

Income and expenditure elasticities needs to be estimated to assess relative changes in consumption in the event of a price change. First, the elasticities of the first stage must be estimated. The index for the whole consumption is a and b where a = 1… c and b = 1… c. For the first stage, the indices r and u are used where r = 1… k and u = 1… k. The second stage has the indices i and j where i = 1…k and j = 1 … k. The compensated elasticities are calculated for each stage and then used to determine the final uncompensated elasticity. The full demand system is included with the uncompensated elasticities and can therefore include all preconceptions between goods as well as redistributions between aggregated groups. The research by Edgerton (1997) is used to model these elasticities. The Marshallian elasticity is mainly relevant as its calculations consider both income effects and substitute effects. This means that the benefit is maximized under a budget constraint and the demand can be studied in terms of income, price, and substitution. The equations are the following:

$$\varepsilon_i^I = 1 + \beta_i / s_i \quad (4)$$

$$\varepsilon_{i,j}^M = [(\gamma_{i,j} - \beta_i s_j) / s_i] - \delta_{i,j} \quad (5)$$

Where I stand for income elasticities and M stands for Marshallian elasticities. If $i = j$ and $r = u$, then $\delta = 1$, otherwise it is 0. For a homogeneity of degree zero, it is required that the restrictions on the elasticity are $\varepsilon_i^I + \sum_{i=1}^{n} \varepsilon_{i,j}^M = 0$. Then the elasticities for each stage are combined into uncompensated elasticities which consider all levels of the demand system so that $\varepsilon_i^{I*} = \varepsilon_i^I \varepsilon_r^I$ for the uncompensated income elasticity. This should hold according to (Edgerton, 1997) for each good i and $\varepsilon_{i,j}^M$ for the uncompensated own price and cross-price elasticities.

$$\varepsilon_{i,j}^{M*} = \delta_{r,u} \varepsilon_{i,j}^M + \delta_{r,u} s_j \varepsilon_i^I + s_j \varepsilon_i^I \varepsilon_{r,u}^M \quad (6)$$

The terms r and u are used for stage one while i and j represent goods within the group *Meat and other protein products*. Since the compensated Hicksian elasticities are $\varepsilon_{ij}^{H} = \varepsilon_{ij}^{M} + s_j\, \varepsilon_i^I$, the equation can be rewritten as:

$$\varepsilon_{i,j}^{M*} = \delta_{r,u}\ \varepsilon_{ij}^{H} + \varepsilon_i^I\ s_j\ \varepsilon_{r,u}^M \tag{7}$$

where the compensated Hicksian elasticities capture the price/substitution effect of price changes but not the income effect as the uncompensated Marchallian elasticities dose. This final elasticity is used together with averages and changes in prices and quantities to build up demand curves. The demand curves can then be used to calculate the effect of a change in price.

5.4 Policy Scenario and change in demand

The demand function is required to calculate the change in quantity when the price increase due to the tax. The changes in quantities are used, which is the difference between the initial consumption and the consumption level when a tax is introduced. The initial level has the exponent 0 while the quantity when the tax is introduced has the exponent 1 according to $\Delta q = q_i^1 - q_i^0$. If demand is assumed to be a linear function of the own price and cross prices, then $q_i = \frac{\Delta q_i}{\Delta p_i} p_i + m_i + \Delta h_i$ where $\frac{\Delta q_i}{\Delta p_i}$ is the negative slope that exists in the elasticities. The initial intercept is m_i. This means that the uncompensated Marshallian elasticity also can be expressed as:

$$\varepsilon_{i,j}^{M*} = \frac{\Delta q_i}{\Delta p_i} \frac{p_j^0}{q_j^0} \tag{8}$$

Which holds when $i = j$. For scenario 1 and 2, a tax of 14.1 SEK per kilo is added for the group *Meat and charcuterie*, a tax of 7.32 SEK is added for *Seafood* and a tax of 2.7 SEK is added for *Other*. The initial intercept of the demand curve will shift with the price increase from p_j^0 to p_j^1 in the following way:

$$m_i^1 = m_i^0 + \sum_{i=1}^{n} \left(\frac{\Delta q_i}{\Delta p_i} + \text{tax}\right) \tag{9}$$

where m_i^0 is the initial intercept and the new intercept is m_i^1. The choice of the added tax is described in Chapter 4. This model can be applied for scenario 3 as well. The difference is though that the tax and subsidy is in percentage form. It must thus be processed so that it can be added to the slope. As scenario 3 is a VAT-tax of 25% added to *Meat and charcuterie*, *Seafood*, *Other*, and to the subsidy it needs to be recalculated thus:

$$Tax = (p_j^0 \text{ x } 1.25) \text{ or Subsidy} = (p_j^0 \text{ x } 1.06) \tag{10}$$

Since the price has already been increased to the VAT rate of 12% for previous calculations, the prices must first be divided by 1.12 and then multiplied with 1.25 or 1.06. Furthermore, the demand curve is the negative slope from the elasticities $\frac{\Delta q_i}{\Delta p_i} = \frac{\varepsilon_{i,j}^M q_i^0}{p_j^0}$, which can also be defined as h_i. The sum of shifts in the demand curve is therefore referred to as Δh_i, which is zero before the tax is introduced. It changes through a changed price Δp_j and a change in the intercept which is applied for each scenario. The shift in demand is finally calculated in the following way:

$$\Delta h_i = \sum \Delta p_j \frac{\varepsilon_{i,j}^{M*} q_i^0}{p_j^0} + \sum \Delta p_r \frac{\varepsilon_{r,u}^{M*} q_u^0}{p_r^0} s_u \quad (11)$$

This model captures shifts that are due to price changes in different stages. Price changes within stage two and the sum of group elasticities in the first stage create these shifts. The model assumes constant budget shares within each group of goods and each commodity and that expenditure flows are distributed accordingly. This then includes not only the change for the goods that are taxed but also for other goods for which consumption is substituted. If the assumed sustainability cost for the external effects is applied to the decreasing quantity, sustainable gains from taxation can be calculated.

6. Results and analysis

6.1 Results from the model

The results from the second stage demand system on all categories within the group of M*eat and other protein goods* are presented in this chapter. The elasticities from the first stage demand system were not processed in this study but were taken from Röös et al. (2021). The own price elasticity that the author's research resulted in was, not unexpectedly, relatively inelastic like many other food-provisions, estimated to -0.606. The income elasticities were estimated to 1.150, which, unlike the own price, indicates that the group of *Meat and other protein goods* is a luxury consumption. The QAIDS model was applied to calculate the budget shares in the second stage of the demand system. Three models were estimated as the basis for the approximation of the fourth model. In the model, lags were also applied to various variables, which capture the consumer's previous purchases and the average consumption. The lags may be an advantage as the consumption patterns can differ for different days of the week. Two lags were applied to the logarithmic price for both *Meat and charcuterie* and *Other*. Total logarithmic expenditure, the aggregate quantity and the logarithmic price for *Seafood* have one lag. Three lags were applied to the aggregated logarithmic price and logarithmic price for *Plant-based.* This combination of lags gave the lowest autocorrelation and match result from earlier studies. The results for the various budget shares are presented in the appendix Table A1. The most important test for this model is the examination for the risk of autocorrelation since the research include aggregate data from several time periods. However, in this study, the Lagrange Multiplier test showed no autocorrelation. Table A2 shows all the 15 estimated parameters where eleven are significant at a 10 % level at least and seven of them are significant at a 1 % level.

Table 3 presents the estimated compensated Marshallian elasticities and income elasticities of the category *Meat and other protein products*. It thus sums the elasticities from the second stage in the utility tree, which is calculated in TSP according to equations four and five. Standard error and significance level are also presented in this model. The table shows that all own price elasticities are negative, which is in line with the theory of non-inferior goods according to Snyder and Nicholson (2012) as consumption decreases with a price increase. However, there is a variation for the different categories where both the *Meat and charcuterie* and *Plant-based* have an own price elasticity above -1. This indicates that its consumption is sensitive to a price change. The results indicate that the demand for *Seafood* and *Other* is insensitive to a price change. The insensitivity to price changes may be due to that both groups include many different types of goods. The cross-price elasticity shows low results. Not unexpectedly, the group *Other* seems to be a complement to many other groups as it is not uncommon to serve cheese and eggs together with other proteins. However, the category *Plant-based* seem to have a substitutable relationship with *Meat and charcuterie*, which indicates that the consumption of this group may increase when a tax is introduced. The results of the income elasticities indicate that only *Meat and charcuterie* and possibly *Seafood* can be considered luxury goods. 15 of 20 estimates have at least a significance level of 10% and 13 estimates have a significance level of 1%. In Table A3, the homogeneity of grade 0 has also been tested. The sum of the Marshallian elasticities is there added to the income elasticities which should be equal to 0, as shown in the table.

Table 3: Compensated elasticities and their standard errors for four categories of Meat and other protein goods
Source: Calculations through TSP, based on ICA data.

Compensated elasticities within the categories					
	Meat and charcuterie	Seafood	Plant-based	Other	Income
Meat and charcuterie	**-1.35233***** (0.052369)	-0.005477 (0.029571)	0. 175999*** (0.028344)	-0.005987 (0.028160)	1.18780*** (0.023971)
Seafood	0.029737 (0. 131603)	**-0. 859294** *** (0. 137596)	-0. 220794 ** (0. 103205)	-0. 243217 (0. 092518)	1.05278*** (0.082762)
Plant-based	0. 537214*** (0. 090226)	-0. 106857* (0. 062787)	**-1.12490***** (0. 078297)	-0. 183447*** (0. 055294)	0.877990*** (0.045394)
Other	0. 132376*** (0. 037839)	0. 019679 (0. 028174)	-0. 079770*** (0. 027391)	**-0. 905413***** (0.032089)	0.833128*** (0.020694)

** Shows significance level at 10 %*, 5%**, 1%****

Equation 7 has been calculated in Excel to obtain the uncompensated Marshallian elasticities and the uncompensated income elasticities. These elasticities are presented in Table 4. The result is slightly different from the compensated ones as they are somewhat lower or higher and thereby captures the higher stage of demand systems. Less goods have a complementary cross price elasticity and the own price elasticities are lower, which indicates that they are necessary goods, but the income elasticities are higher, which in turn indicates luxury consumption. The cross-price elasticities are higher, which suggests that the changeability between the goods is higher, but the margin is quite small. As the income elasticities are so high in relation to the Cross-price elasticities it indicates that there is a greater income effect than a substitution effect. This is in line with the changing consumption patterns according to Statista (2022) that shows that the consumption of meat has increased substantially in the last decades when the income of the population has increased. As the income effect is greater than the substitution effect, a tax has a lower impact according to Hart (2019).

Table 4: Final uncompensated elasticity estimations
Source: Calculations through Excel, based on ICA data.

Uncompensated elasticities within the categories					
	Meat and charcuterie	Seafood	Plant-based	Other	Income
Meat and charcuterie	**-1.168787028892**	0. 04539338	0.284882435	0.232516257	1.354092
Seafood	0.160331971	**-0.82091662**	-0.134329565	-0.18891926	1.2001692
Plant-based	0.60700392	-0.07773924	**-1.076067029**	-0.0591913	1.0009086
Other	0.18457092	0.044645766	-0.038386029	**-0.79682530**	0.94976592

The results are expected and in accordance with previous research. Several other studies, however, assess a third step in the utility tree by estimating elasticities within the categories used for this study. For this reason, the cross-price elasticities are not comparable. However, Säll et al. (2020) estimated elasticities for meat, other proteins, and dairy products and they estimated elasticities for eggs, seafood, and cheese. They also estimated the first step in the utility tree, which corresponds to the price elasticity used in this study. Their results differ as it shows that seafood has a lower own price elasticity than eggs and especially than cheese; 0.491, −0.628, and −0.947 respectively. Their results even show that other proteins had higher elasticities than meat. Bonnet et al. (2018) estimated own price elasticities and their result shows that meat and fish are higher and the elasticity for meat reambles the result of this study. They also highlight that the demand for animal products is less elastic at the aggregate level. On the other hand, Forero-Cantor et al. (2020)'s estimate lower elasticities for meat and even lower for fish. The result of Revoredo-Giha et al. (2018) also follow the same line. Their results show that cereals and legumes have a relatively high own price elasticity, especially in relation to pork but lower than cheese, poultry, and eggs of 0.9. Seafood also has a low elasticity in this study but so does cheese and eggs. The average for the compensated own price elasticities of the different types of meat in the research by Roosen et al. (2022) is around 0.77 and 0.97. The uncompensated elasticities are also slightly below this result. There seem to be some differences from some research but in general the results are reasonable.

6.2 Policy Scenario Analysis

This chapter presents the result when the tax scenarios are applied and what that indicates. Table A4 in the appendix includes the final calculations of the model. The change in intercept and in quantity as a response to the price change is presented. The change in quantity is also calculated as a percentage of consumption. The table includes the different scenarios of tax systems which are also presented as three diagrams in Figure 3. For scenario 1, the increase of 14.1 SEK per kilo for *Meat and charcuterie* will be about a 10 % increase in price. This results in a 11.7 % decrease in quantity. Here the other categories consumption increases were *Plant-based* increases the most, by about 6 %. In scenario 2 where a tax is also applied to *Seafood* and *Other* the effect of a decrease meat consumption and increase plant-based consumption is fairly similar to scenario 1. However, consumption of *Seafood* and O*ther* doesn't increase but decreases with about 0.8 %. For scenario 3, the price of *meat and charcuterie* increases even more by 11.6 %, which is due to the increase from 12 to 25 %. Its results in a reduction in consumption of 11.87 %. Even though there is a very high price increase for *Seafood,* the low own price elasticity and the substitute effects for meat do not decrease the consumption for *Seafood* very much (around 5 %). There is a larger effect on the group *Other* with a decreased consumption by 6.38 %. The subsidy seems to influence *Plant-based* as it increases with 11.22 %. It seems that additional taxes of more goods lead to less transition to plant-based consumption, but the difference is quite small. In general, the results are reasonable as they do not lead to extreme effects, but the effects are prominent. Possibly the relatively strong substitute effects between the *Meat and charcuterie* category and *Plant-based* category can be questioned. However, this effect results in the change from meat consumption to more plant-based consumption. In addition to taxation's own effects on meat consumption and substitute effects on plant-based consumption, the subsidy also has a major impact. Without the subsidy, *Plant-based* will increase by about 5.5 %, which is similar to the other scenarios. If a subsidy is added, in the two first tax scenarios, consumption will increase by more than 11 %, which is slightly higher than for scenario 3. The demand shifts to less meat consumption, but overall consumption drops by between 2 to 10% in total for the entire group of *Meat and other protein goods*, where the highest decrease is in scenario 3.

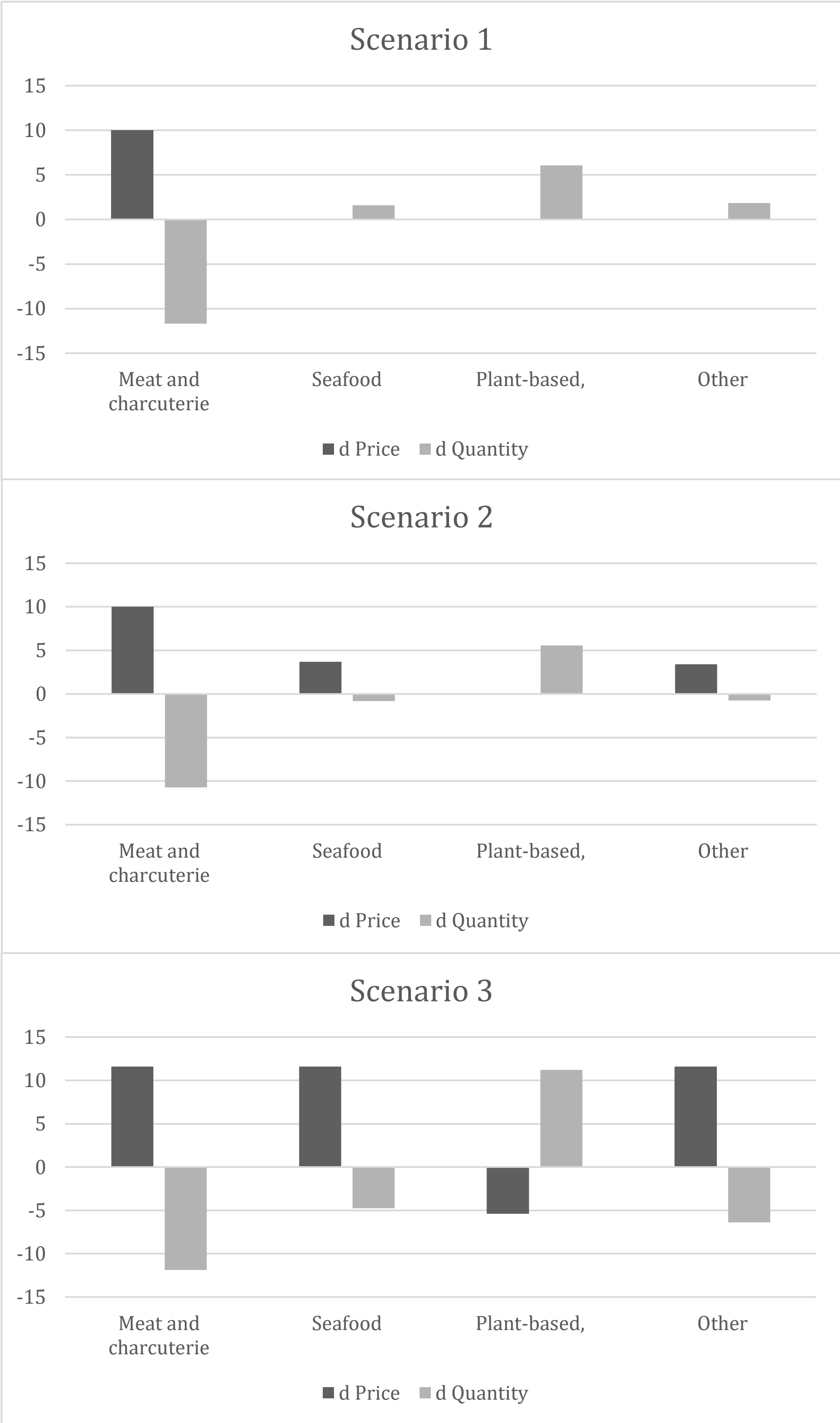


Figure 3. Tax scenario estimations, the price changes impact on quantity consumed for all categories within the group Meat and other protein goods. Source: Illustration made in Excel, based on ICA data.

The effect of these taxes on GHG-emissions is described in Figure 4. Although the focus of this study is not only GHG-emissions but also other sustainability factors, the perspective is still important. The figure shows the reduction of CO_2-eq in kilograms calculated by GWP_{100}. This is also presented in more detail in Table A5 in the appendix. With the first tax scenario, emissions will fall by 2.62 tonnes per day, which is largely due to the 11.7% reduction in meat consumption. Scenario 2 results in a reduction of 2.55 tonnes of CO_2, which is mainly because of the reduction in meat consumption of 10.7%, and the reduction in emissions from the decreased consumption of *Seafood* and *Other*. Even though the difference is small, the decrease in scenario 1 is larger. The third scenario results in a reduction in GHG-emissions of approximately 3.08 tonnes of CO2. The total reduction in GHG-emissions for scenario 1 is 8.605%, 2 8.367% for scenario 2 and 10.029% for scenario 3.

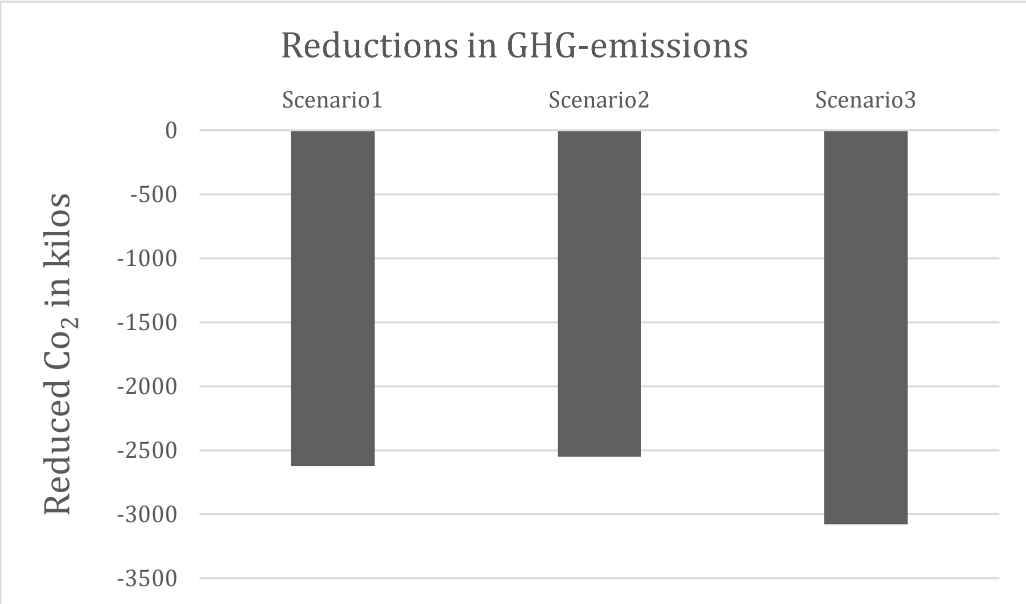
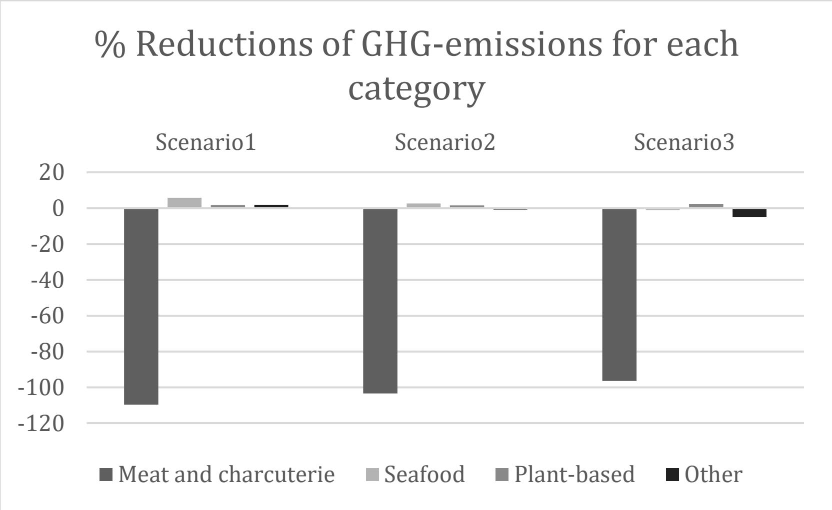


Figure 4. Reduction of GHG-emissions for the different tax scenarios including all goods. Source: Illustration made in excel, based on ICA data and GHG-estimations from Potter et al. (2020).

The category that reduces emissions the most is presented in Figure 5 and in Table A5. For scenario 1, *Meat and charcuterie* decreases with approximately 105% of the total reductions in the entire scenario, corresponding to about 2.8 tonnes. For scenario 2 the decrease is about 99% while for scenario 3 about 91%. Even if the percentage change is less than for the first scenario, the reduction of GHG-emissions is similar as the reduction is about 2.5 and 2.8 tonnes respectively. For all scenarios, the taxation of *Meat and charcuterie* is the most important factor when it comes to reducing emissions. This indicates that taxing seafood, egg and cheese only would have a minor effect. However, it can be noted that for cheese, this is partly explained by the low consumption. If the proportion of cheese in the group *Other* would be larger the effect might be enhanced. Although *Meat and charcuterie* has the lowest percentage reduction in scenario 3, this scenario has the largest reduction in weight. The change in the other groups also makes this scenario the most effective for the GHG emission reduction, despite the increase in *Plant-based*. This is the case as the plant-based consumption leads to much lower emissions. However, it can be highlighted that this scenario also has the highest price increase, which can affect welfare. Even though there is a price reduction on *Plant-based*, it is still low in relation to the price increase in other categories. At most the price increase is about 10 times as high as the price reduction, so welfare would be affected.

In addition to these results, it is important to note that the changes in consumption within the categories are not included but will be discussed based on previous studies in the next chapter.



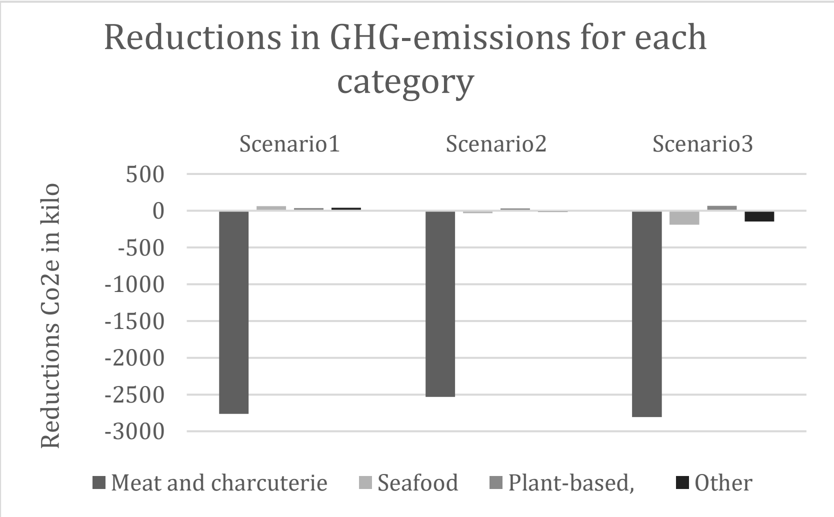


Figure 5. Reduction or increase of GHG-emissions in kilo and it shears for each category within the group Meat and other protein goods.
Source: Illustration made in excel, based on ICA data and GHG-estimations from Potter et al. (2020).

The results imply that changes in consumption can be achieved with economic instruments. The results can be compared with previous studies, but it should be noted that taxation for only the whole group *Meat and charcuterie* is research in this paper. This research gets a reduction of between 8.3 to 10 %, depending on scenarios, in accordance with several other studies. Bonnet et al. (2018) show how emissions are reduced by approximately 6%, with a taxation of either 56 or 200 Euros per ton of 2020 CO_2-eq. The results by Säll et al. (2015) showed a reduction of approximately 12%, and Springmann et al. (2017) showed a reduction of 9%. However, there is a varied price increase as, for example, Roosen (2022) increases VAT by 19%, which results in an 11% reduction in consumption. The above indicate that, in general, the results of this study are reasonable.

The reduction is also affected by the market share consumption of the different animal species. These distributions have weighted GHG-emissions as well as the tax applied and the calculation of the reduced GHG-emissions. For example, Bonnet et al. (2018) found that the consumption of beef accounted for only 14.5% of the total meat consumption while pork accounted for 57% and poultry for 14.5%. It is then remarkable that their results still showed such a large reduction in emissions as beef is the most effective meet to tax in their model. In this research, beef consumption accounts for approximately 33% of total meat consumption, while pork accounts for 34% and poultry for 27%. Other meat such as venison and duck accounted for only 6%. As the distribution has been calculated directly from ICA's data, where the shares have been divided by the total consumption, it captures specifically the distribution consumers have in the data used. It is an even distribution and resembles the distribution in the research of Säll et al. (2020). The high proportion of beef means that the reduction in GHG-emissions is greater. The fact that the distribution differs might be because different consumers are examined. In this case, it seems that the Swedish consumer, that lives in Stockholm and are generally richer, prefers beef as much as other meat. This distribution seems to represent the area rather than the whole nation, as beef is more of a luxury consumption with the highest own price elasticity according to Säll et al. (2015). This preference also seems to be stronger than in French were Bonnet et al. (2018) did their research. However, it can also be due to that French consumers generally consume more meat than the Swedish consumers, even if it is the same amount of beef.

6.3 Sensitivity Analysis

The sensitivity analysis is made to assess one of the uncertainties in the results, which in this case concern the cross-price elasticities. Although these elasticities are not extreme, there is still a risk that the policy instruments do not lead to the expected response. To perform these analyses the cross-price elasticities are changed between *Meat and charcuterie*, *Seafood*, *Plant-based* and *Other* are changed to zero. The new calculated effect on consumption is presented in the appendix in Table A6, where price changes and quantity changes are presented both in absolute numbers and as a percentage. The percentage changes are presented in Figure 6. Without the cross-effects, the result differs somewhat, where the most obvious change is that consumption does not change for a category if it is not taxed. In scenario 1, consumption does not change for any category more than for *Meat and charcuterie*, where it falls by the same amount as when cross-price elasticities are included. However, it is worth noting that if the cross-price elasticities for the *Plant-based* category are lower, consumption will not shift to a plant-based consumption. For scenario 2, the change will be greater, where consumption for all categories that are taxed will fall sharper in consumption than otherwise is subdued by the cross-effects, especially for *Seafood*. *Meat and charcuterie* fall by 11.7% instead of 10.7% as in the case of cross-price elasticities. *Seafood* falls by 3.07% instead of 0.82% and other falls by 2.7% instead of 0.74%. Scenario 3 is the only scenario that has an increased consumption of *Plant-based* which is to the subsidy. This scenario also has the largest effects but also the highest price changes where consumption of meat and charcuterie falls by 13.57% instead of 11.87%. *Seafood* falls by 9.5%, which can be compared with 4.76% with the cross-price elasticities. *Other* decreases by 9.25% instead of 6.38%, but *Plant-based* increases only by 5.76% instead of 11.22%. This change correspond with the theory as the change in consumption reflects the price increase quite well when all own price elasticities are around 1. It is thus an expected change in consumption, but this analysis is important as it shows that there is only a reduction in consumption due to the price increase and consumption will not shift. This means that if cross-price elasticity is overestimated, taxation would only mean reduced consumption, which can be criticized from a welfare perspective. In principle, this means that the consumer becomes poorer. Although this is also the case with e.g., alcohol taxation, as the consumer must pay for its negative external effect, declining food consumption is more problematic.

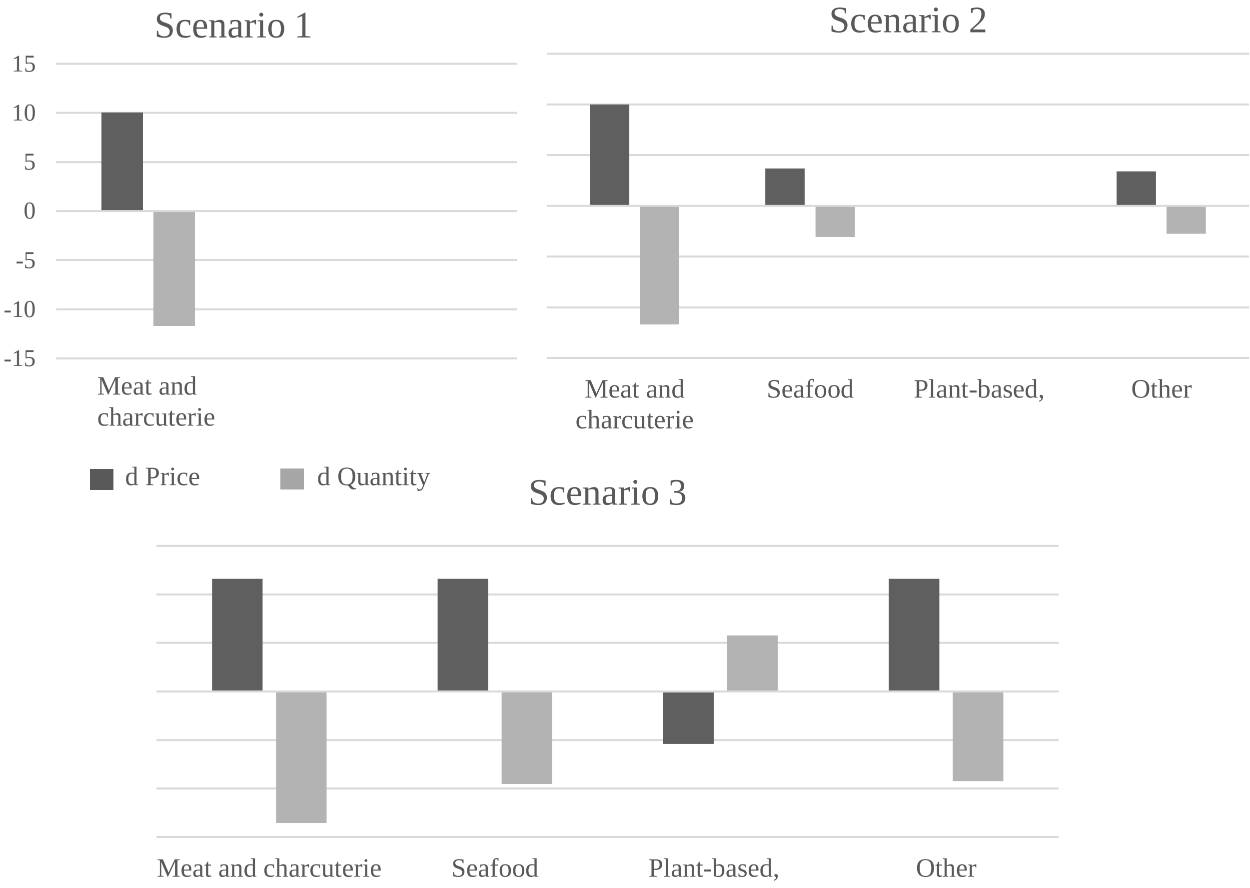


Figure 6. Sensitivity Analysis for the tax Scenario estimations, the price changes effect on quantity consumed.
Source: Illustration made in excel, based on ICA data.

Table A7 in the appendix also presents the scenario's effect on GHG-emissions when the cross-price elasticities are 0. In scenario 1, 100% of the reduced emission comes from the reduction of *Meat and charcuterie*, which gives a reduction of 2.7 tonnes of CO_2 instead of 2.6. This makes the reduced emissions to 9.1% instead of 8.6%. In scenario 2, the share of the emission reduction is lower than with the cross-price elasticities, as it is only 93%. This is the case as *Meat and charcuterie* account for 2.8 of the total reduction of 2.9 tonnes CO_2. *Seafood* accounts for 0.12 tonnes and *Other* 0.062 tonnes. This can be compared to the result with the cross-price elasticities, were *Seafood* account for 0.0032 tonnes and *Other* 0.0016 tonnes. The total emission reduction is 9.7%. For scenario 3, the share of emission reduction is lower without the cross-price elasticities at 85%, which can be compared with 91% when includning the cross-price elasticities. The number of reduced CO_2 for this group is up to 3.2 tonnes instead of 2.8 tonnes. Then *Seafood* is also reduced by 0.37 tonnes and *Other* by 0.21 tonnes instead of 0.18 and 0.15 tonnes. The total emission reduction is 3.7 tonnes of CO_2 and 12.35%. The total emission reduction for all scenarios is presented in Figure 7. The emission reductions are larger without the cross-price elasticities as it can be compared to the similar result in Figure 4. It is also remarkable that scenario 2 falls more than 1, This is not the case when including cross-price elasticities. However, it is relevant to point out that it obviously drops more as consumption decreases but there are no shifts to a more sustainable alternative.

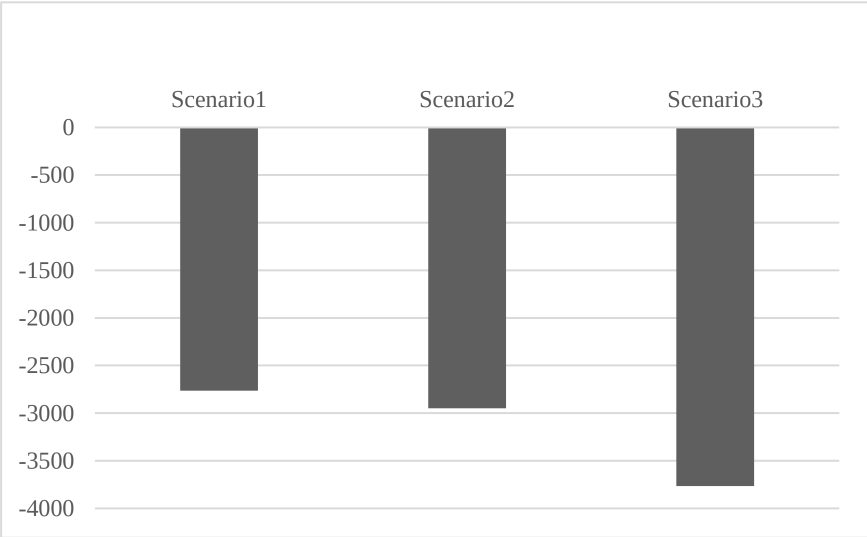


Figure 7. Sensitivity Analysis for the Reduction of GHG-emissions
Source: Illustration made in excel, based on ICA data and GHG-estimations from Potter et al. (2020).

7. Conclusions and Discussion

The purpose of this study is to investigate the effect of economic policies, in particular price changes, on animal goods, especially on meat. This is done to decrease meat consumption for the several negative effects meat production has. Specifically, the study aims to include several sustainable perspectives for a more nuanced view of the possibilities of economic instruments. These perspectives include GHG-emissions, biodiversity, health, animal welfare, food security, national interests, and limited resources. As the production of different animal species affects these factors to varying degrees, the economic instruments have been applied to all meat consumption. This is the case because it is difficult to weigh which production that is most sustainable when including all mentioned perspectives. Price changes are therefore applied to the entire category of meat to assess the magnitude of the shift in consumption. Based on this, three tax scenarios were applied. The first two scenarios are GHG emission taxes where the emission per consumed product is multiplied by the emission tax in Sweden. The first scenario is applied on meat consumption but the second is also applied to other animal goods. The third scenario is instead an increased VAT on animal goods and a reduced VAT for plant-based goods. These scenarios lead to a shift from meat consumption to a more plant-based consumption. The reduction in meat consumption amounts to approximately 10–12% for an equally high price increase. Without a subsidy for plant-based consumption, the increase is around 5-6 %. When the subsidy is included, there is a direct shift to plant-based food with a 10-12% increase in consumption. This increase can be compared to the same decrease in meat consumption. However, it is worth noting that plant-based consumption is consumed to a much lower extent than meat, which means that consumption generally still falls or shifts to a consumption outside the group of meat and other protein goods.

The categories *Seafood* and *Other* were less affected by the tax as these have a lower own price elasticity. There is also a positive cross-price effect between these categories and meat, which means that certain consumption shifts from meat to these categories. This indicates that taxation on seafood, eggs and cheese has a low effect. Since meat consumption has the largest effect on GHG-emissions the scenario that has the highest reduction of its consumption reduces emissions the most. Again, this indicates that taxation of seafood, eggs, and cheese hardly has any effect on reduced emissions but possibly on other sustainability factors. The third scenario decreases meat consumption the most as it has the largest price increase, and the second scenario decreases meat consumption the least. This scenario has the lowest reduction in meat as the price increase of *Seafood* and *Other* indicates that consumption switches to meat. The different scenarios reduce GHG emissions by 2.5 to 3 tonnes of CO_2 per day. The sensitivity analysis underlines the importance of the cross-price elasticities as the results without these only show a reduction in consumption and not a shift.

7.1 Limitation

The most important limitations for this thesis are that there is no prices for all the different sustainability perspectives. Using the GHG-emission tax is the solution for the absence of the possibility of taxing all meat based on its unique impact on various sustainability aspects. There is also a limitation in examining meat as a whole group. Different animal species have different influence on different factors, and so has meat that is organic, conventional, locally produced, imported etcetera. Instead of including these factors, the solution for this study has been to price everything equally within its category, which is the same strategy as when using VAT, but not for the use of a percentage increase. However, this is the most reasonable solution for such a limited study without using materials devoted to other research projects. It is also the most reasonable solution to achieve the ambition to raise several sustainability perspectives, which is important to highlight.

The second limitation is that the market data cannot fully represent Sweden. The typical consumer in Nacka may differ from the average consumer in Sweden. For example, the data show that consumption of beef is almost a third of meat consumption. As beef is more of a luxury consumption, it is possible that the consumers in Nacka with higher income have other consumption habits. The relatively high cross-price elasticity between meat and plant-based may be because consumers in Nacka are already more environmentally conscious than other consumers in the country. These are of course only speculations, but there are possible distortions.

7.2 Effect on sustainable aspects

GHG-emissions are just one way to measure the effect on the sustainability of reduced meat consumption. Other sustainability factors such as biodiversity, health, animal welfare, food security, national interests and limited natural resources are more difficult to value. Meat production can increase biodiversity, be an important livelihood, and fulfils other national interests. Since the study does not include any analysis of which meat consumption decreases the most, it is difficult to determine the effect on these factors. However, there are indications from previous studies and intuitive conclusions. The tax scenarios with an added cost for emissions for the whole group of meat are an additional tax per consumed kilogram for all animal species. This results in that the cheapest meat receives the largest percentage increase and will probably decrease the most. Poultry is most affected by this type of taxation but imported meat will also be more affected as it is cheaper. The increased VAT tax therefore has the opposite effect as the percentage increase on more expensive goods leads to a higher price increase in absolute values. Beef and Swedish meat will probably be more negatively affected by this taxation. The consequences for sustainability vary in the choice of type of taxation. Swedish production and biodiversity, animal welfare and the national interest in self-sufficiency will be more negatively affected by tax scenario 3. Health, global biodiversity, and global livelihoods will be more negatively affected by tax scenario 1. Global biodiversity can increase by imports from certain countries with more natural pastures, but the reduction of beef can reduce deforestation.

From a health perspective, reduced meat consumption has both positive and negative consequences. The negative consequences are reduced intakes of vitamin D, folate, and iron, but Moberg et al. (2021) write that these are most reduced by a decreased consumption of fish and dairy products. Consumption of these goods was most affected by tax scenario 3 where the price of these goods increases the most, but it also has the highest reduction of red meat which is unhealthy. From other perspectives, such environmental issues as eutrophication and limited natural resources, the high proportion of crops that go to the various productions has a great impact. The production of poultry requires a lower proportion of resources, but in cases where the production of pork and beef uses biomass that has low potential, this production requires lower resources. An overconsumption of both pork and beef limits the possibilities for a circular system where an overconsumption of meat is problematic in any case. Only an approximately 11% decrease of meat consumption will not decrease all overconsumption, but it will be mitigated. The problem arises when consumption only decreases and do not shift to another consumption as consumers' welfare then declines. The result therefore indicates that a subsidy for plant-based food as a complement to the tax is beneficial.

7.3 Further research

The general meat tax has advantages from several sustainability perspectives, but the distribution of the tax burden can be problematic. This study can only speculate about the distribution so further research is therefore needed. Studies where all sustainability perspectives are included, and all categories of meat are studied individually will provide a deeper insight into the consequences for taxing meat. Such reports exist like Röös (2021), where the effect of a climate tax has been examined from several sustainable perspectives. However, that research was made before access to the actual market data from Sweden used in this study. It is also relevant to explore the possibilities of applying a sustainability tax instead of just an emissions tax and to highlight the circular system. In addition to this, other mechanisms for shifting consumption can be further researched. Only about 11% can seem like a small effect where policy instruments are just a way to shift consumption. Technical development for better substitute for meat and changes in norms are may also be examined for a broader perspective. An example of further research could be nudging in stores and its consequence for a changed consumption towards a more plant-based diet.

This study gives a general but clear indication of how consumption changes with different economic instruments. The scenarios are also relatively easy to administrate when it comes to such large groups. A common argument for applying a VAT tax is that it is easy to apply (Röös et al. 2021). From the theoretical background the indication is that a taxation of goods with low elasticity gives a high tax revenue rather than a high effect. The elasticities are not very low, but the high consumption of meat still indicates that it can result in high tax revenues as about 89% of consumption remains with the new price increase. The remaining question is what the tax revenue should be used for. When there is an indication of a certain welfare loss, the income can go directly back to the consumer. Röös et al. (2021) also investigate whether the tax revenue can be returned to farmers. They point out that Swedish farming may be negatively affected by a tax increase, which may lead to opposition to the policy. The return can then be applied to hectares of land which then may, for example, stimulate an increase in biodiversity. In the case of the VAT-tax, where Swedish cattle are most affected, the negative consequences for this taxation can be compensated. The tax revenue could also go to the technical development of plant-based alternatives to meat. With better alternatives that can be produced cheaper, plant-based consumption may replace meat consumption to a greater extent without taxation. As the increased meat consumption seems to be due to the population becoming richer globally, taxation of the meat can only effect to a certain extent and then the development would be a more long-term solution. The choice of what the tax revenue can be used for can be further researched. With research on all sustainability perspectives, all different types of meat consumption and the use of tax income, could make these policies applicable.

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Appendix

Table A1. Test results for the budget shares dependent variables in the second stage of the utility tree. Source: Calculations through TSP, based on ICA data.

Budget share equations	**EQAIDS1**	**EQAIDS2**	**EQAIDS3**
Mean of dep. var.	0.391821	0.092531	0.166413
Std. dev. of dep. var.	0.041408	0.027208	0.031672
Sum of squared residuals	0.278358	0.174740	0.205181
Variance of residuals	0.115982E-02	0.728084E-03	0.854920E-03
Std. error of regression	0.034056	0.026983	0.029239
R-squared	0.322468	0.013843	0.148194
LM het. Test	2.40665[0.121]	1.92309 [0.166]	1.03233 [0.310]
Drubin-Watson	0.802942	1.22473	0.882710

Table A2. Estimated parameters for multivariate regression of the second stage. Source: Calculations through TSP, based on ICA data

Number of observations = 240		**Log likelihood = 1704.42**		**Schwarz B.I.C. = -1655.08**
Parameter	**Estimate**	**Error**	**t-statistic**	**P-value**
C11	-0.109297	0.019123	-5.71539	[0.000]
C12	0.466665E-02	0.011223	0.415814	[0.678]
C13	-0.081256	0.013550	5.99684	[0.000]
C22	0.013470	0.012325	1.09291	[0.274]
C23	-0.019617	0.010037	-1.95457	[0.051]
C33	0.024103	0.013519	-1.78286	[0.075]
B1	0.073654	0.940129E-02	7.83442	[0.000]
B2	-0.488361E-02	0.784251E-02	0.622710	[0.533]
B3	-0.020259	0.823508E-02	-2.46008	[0.014]
A1	0.387214	0.266181E-02	145.470	[0.000]
A2	0.091413	0.210942E-02	43.3357	[0.000]
A3	0.168841	0.228665E-02	73.8376	[0.000]
D1	0.082986	0.019512	4.25314	[0.000]
D2	0.019563	0.015455	1.26581	[0.206]
D3	-0.038941	0.016768	-2.32239	[0.020]

Table A3. Homogeneity of degree 0 test
Source: Calculations through Excel, based on ICA Data.

	Income elasticity	**Sum of The Marshallian elasticity**
Meat and charcuterie	1.1878	-1.1878
Seafood	1.05278	-1.05278
Plant-based	0.87799	-0.87799
Other	0.833128	-0.833128

Table A4. Tax Scenario estimations.
Source: Calculations through Excel, based on ICA data.

Scenario 1								
	dp	$\% \, dp$	m_i^0	m_i^1	q_0	q_1	dq	$\% \, dq$
Meat and charcuterie	14.1	10.0	4369.021	4369.021	2014.5	1779.215	-235.285	-11.7
Seafood	0	0	1184.324	1194.745	650.4	660.821	10.421	1.6022
Plant-based	0	0	659.982	679.2647	317.9	337.183	19.283	6.0657
Other	0	0	1756.39	1774.426	977.5	995.529	18.029	1.8444
Scenario 2								
	dp	$\% \, dp$	m_i^0	m_i^1	q_0	q_1	dq	$\% \, dq$
Meat and charcuterie	14.1	10.0	4369.021	4388.592	2014.5	1798.785	-215.715	-10.7
Seafood	7.32	3.7	1184.324	1198.982	650.4	645.097	-5.303	-0.82
Plant-based	0	0	659.982	677.6919	317.9	335.610	17.710	5.57
Other	2.7	3.4	1756.397	1776.057	977.5	970.302	-7.198	-0.74
Scenario 3								
	dp	$\% \, dp$	m_i^0	m_i^1	q_0	q_1	dq	$\% \, dq$
Meat and charcuterie	16.38	11.6	4369.021	4403.260	2014.5	1775.445	-239.055	-11.87
Seafood	22.73	11.6	1184.32	1215.371	650.4	619.473	-30.927	-4.76
Plant-based	-2.9	-5.4	659.982	677.327	317.9	353.571	35.671	11.22
Other	9.088	11.6	1756.40	1784.414	977.5	915.109	-62.391	-6.38

Table A5. Reduction or increase of GHG-emissions
Source: Calculations through Excel, based on ICA data and GHG-estimations from Potter et al. (2020).

Scenario 1				
	$\text{GHG} - \text{emissions}$ for q_0	$\text{GHG} - \text{emissions}$ for q_1	d $\text{GHG} - \text{emissions}$	$\%\, d$ $\text{GHG} - \text{emissions}$
Meat and charcuterie	23670.38	20905.8	-2764.6	-105.361
Seafood	3967.44	4031.01	63.567	2.423
Plant-based	578.578	613.673	35.095	1.338
Other	2277.575	2319.58	42.008	1.601
Total			**-2623.9**	**-8.605**
Scenario 2				
	$\text{GHG} - \text{emissions}$ for q_0	$\text{GHG} - \text{emissions}$ for q_1	d $\text{GHG} - \text{emissions}$	$\%\, d$ $\text{GHG} - \text{emissions}$
Meat and charcuterie	23670.38	21135.7	-2534.6	-99.338
Seafood	3967.44	3935.09	-32.35	1.268
Plant-based	578.578	610.811	32.233	1.263
Other	2277.575	2260.8	-16.771	-0.657
Total			**-2551.5**	**-8.367**
Scenario 3				
	$\text{GHG} - \text{emissions}$ for q_0	$\text{GHG} - \text{emissions}$ for q_1	d $\text{GHG} - \text{emissions}$	$\%\, d$ $\text{GHG} - \text{emissions}$
Meat and charcuterie	23670.38	20861.5	- 2808.9	-91.26
Seafood	3967.44	3778.79	- 188.65	-6.13
Plant-based	578.578	643.399	64.9214	2.109
Other	2277.575	2132.2	- 145.37	-4.72
Total			**-3078**	**-10.029**

Table A6. Sensitivity Analysis for the tax Scenario estimations.
Source: Calculations through Excel, based on ICA data.

Scenario 1	dp	$\% \, dp$	q_0	q_1	dq	$\% \, dq$
Meat and charcuterie	14.1	10	2014.5	1779.2	-235.285	-11.7
Seafood	0	0	650.4	650.4	0	0
Plant-based	0	0	317.9	317.9	0	0
Other	0	0	977.5	977.5	0	0
Scenario 2	dp	$\% \, dp$	q_0	q_1	dq	$\% \, dq$
Meat and charcuterie	14.1	10	2014.5	1779.215	-235.285	-11.7
Seafood	7.32	3.7	650.4	630.439	-19.961	-3.07
Plant-based	0	0	317.9	317.9	0	0
Other	2.7	3.4	977.5	950.641	-26.859	-2.7
Scenario 3	dp	$\% \, dp$	q_0	q_1	dq	$\% \, dq$
Meat and charcuterie	16.38	11.6	2014.5	1741.207	-273.293	-13.566
Seafood	22.73	11.6	650.4	588.427	-61.973	-9.529
Plant-based	-2.9	-5.4	317.9	336.226	18.326	5.765
Other	9.088	11.6	977.5	887.092	-90.408	-9.2489

Table A7. Sensitivity Analysis for the reduction or increase of GHG-emissions
Source: Calculations through Excel, based on ICA data and GHG-estimations from Potter et al. (2020).

Scenario 1				
	$\text{GHG} - \text{emissions for } q_0$	$\text{GHG} - \text{emissions for } q_1$	d $\text{GHG} - \text{emissions}$	$\% \, d$ $\text{GHG} - \text{emissions}$
Meat and charcuterie	23670.38	20905.8	-2764.6	-100.00
Seafood	3967.44	3967.44	0	0
Plant-based	578.578	578.578	0	0
Other	2277.575	2277.575	0	0
Total			**-2764.6**	**-9.066**
Scenario 2				
	$\text{GHG} - \text{emissions for } q_0$	$\text{GHG} - \text{emissions for } q_1$	d $\text{GHG} - \text{emissions}$	$\% \, d$ $\text{GHG} - \text{emissions}$
Meat and charcuterie	23670.38	20905.773	-2764.602	-93.7489
Seafood	3967.44	3845.679	-121.761	-4.129
Plant-based	578.578	578.578	0	0
Other	2277.575	2214.995	-62.5803238	-2.122
Total			**-2948.943**	**-9.671**
Scenario 3				
	$\text{GHG} - \text{emissions for } q_0$	$\text{GHG} - \text{emissions for } q_1$	d $\text{GHG} - \text{emissions}$	$\% \, d$ $\text{GHG} - \text{emissions}$
Meat and charcuterie	23670.38	23670.375	-3211.189	-85.256
Seafood	3967.44	3967.44	-378.037	-10.037
Plant-based	578.578	578.578	33.3529	0.886
Other	2277.575	2277.575	-210.65	-5.593
Total			**-3766.523**	**-12.352**

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