Effects of a consumption tax on livestock food products for reducing greenhouse gasses in the Netherlands

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Preface

You have before you my thesis on the effects of a consumption tax on livestock food products for reducing greenhouse gasses in the Netherlands. This master thesis is the final piece of my study Economics at the Wageningen University. I would like to thank my supervisor dr. ir. C (Koos) Gardebroek for inspiring me and providing me with the opportunity to work on a interesting topic that is very near to my heart. Furthermore, I want to thank my friends and parents for their support during my study.

I hope you will enjoy reading this thesis.

Fabrice van Hoof

Wageningen, 28 February 2019

Abstract

The consumption of livestock food products has increased significantly in the Netherlands since the Second World War. However, this comes not without a cost, since it contributes significantly to climate change and other environmental problems. The government could internalise these social costs in the price of these products, by implementing a consumption tax.

The objective of this research is therefore, to explore the effect of implementing a consumption tax on livestock food products for reducing the emission of greenhouse gasses related to livestock food consumption in the Netherlands. This research calculated the impact of introducing such a tax on the consumption of six different livestock food products (beef, pork, poultry, cheese, milk and eggs). Five different tax scenarios were introduced. The first three scenarios are based on the social costs of carbon, ranging from €0.06 to €0.113, while the last two scenarios imply a 'greening' of the current VAT. The effect of these tax scenarios on the livestock food consumption is calculated in two runs. The own estimated own- and cross-price elasticities are used in the first run, while the second run is based on average own- and cross-price elasticities obtained from the literature.

The results of this study show that the demand of livestock food products is price inelastic and negative. Implementing a consumption tax on livestock food products could cause a decrease in the related greenhouse gas emissions. However, the size of this reduction will depend much on the chosen tax level and on the exact level of the price elasticities. The level of the tax is in the end a political choice, while the exact value of the price elasticities can only be known when a consumption tax will actually be implemented.

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Chapter 1: Introduction

1.1 Problem definition

The western meat consumption culture goes back for more than 2500 years. It is therefore deeply rooted in Western culture and regarded as a social activity. (Swatland 2010; Edjabou and Smed 2013).

The average European consumption of animal food products (like meat and dairy) has increased significantly since the Second World War (Wirsenius et al. 2012). In 2016, the Dutch meat consumption was 76.8 kg per capita and shows a growing trend after a few years of declining meat consumption (Terluin et al. 2017).

However, the livestock sector is one of the most significant contributors to several environmental problems (FAO 2006). Firstly, it contributes significantly to climate change (Povalleto et al. 2012; FAO 2006; Säll and Gren 2015; Wirsenius et al. 2010; Edjabou and Smed 2012). The livestock sector is responsible for 10% of the total greenhouse gas (like carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O)) emissions in the Netherlands (Council for the Environment and Infrastructure 2018). Most scientists agree that there is a causal relationship between the concentration of greenhouse gasses in the atmosphere and climate change (Dincer 2000). Since the industrial revolution, emissions of greenhouse gases have increased significantly due to human activity (FAO 2006, Dincer 2000). If no action would be taken, the global temperature is expected to increase by 1.4 to 5.8 degrees of Celsius in 2100, causing more extreme weather events, deteriorating ecosystems and a rise in the sea level of 30 to 60 cm by the end of the 21th century (FAO 2006; Dincer 2000). Secondly, air quality is degraded due to the emission of pollutants by the livestock sector. The emission of nitrogen oxides and sulphur dioxides causes for example acid rain and snow, which damages crops and forests and makes lakes unsuitable for fish (FAO 2006). Thirdly, the livestock sector uses increasing amounts of freshwater (currently 8% of global human water use), causing a depletion of freshwater. Moreover, it is the largest sectoral source of water pollution (FAO 2006). Fourthly, livestock action is (globally) an important cause of land degradation due to overgrazing, compaction and erosion. Moreover, especially in Latin America, the expansion of livestock production is an important cause of deforestation (FAO 2006). Finally, the FAO report 'Livestock's long shadow' (2006) suggests that the livestock sector is one of the leading players in the loss of biodiversity. This threat arises mainly from the livestock sectors' negative impact on climate and the main resource sectors such as air, water pollution, land degradation and deforestation (FAO 2006). Besides environmental issues, there are also concerns about the effect of meat consumption on human health. Meat consumption will probably increase, for example, the risk of cancer and has a negative effect on becoming obese

(Edjabou and Smed 2012; World Health Organization n.d.; You and Henneberg 2016).

The focus of this study is on the emission of greenhouse gasses, causing climate change which is regarded as one of the greatest challenges of the 21st century. In December 2015, the Netherlands and 194 other countries signed the climate agreement of Paris and agreed on the long-term goal to keep the global temperature rise below two degrees of Celsius (European Commission n.d.). In line with the Paris agreement, the Dutch government committed itself to the goal that the total emissions of greenhouse gasses must be decreased by 95% in 2050 compared to 1990 levels (Council for the Environment and Infrastructure 2018). In other words, the total per capita emissions should be between 0.5 and 2.2t CO2 equivalents per year in 2050 (Wirsenius et al. 2012). However, in western countries like Sweden, the per capita emissions due to consumption of animal food products is currently 1.1t carbon dioxide equivalents (Wirsenius et al. 2012). This means that the agricultural emission of greenhouse gasses have to decrease strongly.

There are several measures at agricultural and post-farm gate stage possible to reduce the emission of greenhouse gasses. Possible measures are for example optimising nutrient use, improving productivity, using cleaner and renewable fuels and increasing resource efficiency (Garnett 2011). However, there could arise a trade-off between the environment and ethics in the case of measures taken at the agricultural stage. Improving the productivity could, for example, lead to animal welfare concerns (Garnett 2011). Moreover, the potential to reduce GHG emissions in agriculture via technology is limited in Europe (Garnett 2011; Wirsenius et al. 2010).

Therefore, several scientists and the Dutch 'Council for the Environment and Infrastructure' propose to implement policies to change the food consumption pattern of people (Council for the Environment and Infrastructure 2018; Säll and Gren 2015; Wirsenius et al. 2010; Edjabou and Smed 2012; Garnett 2011). Also the sectoral platform 'Agriculture and land use' – currently negotiating on a national climate agreement - regards climate friendly food consumption as one of the key factors for a long-term climate policy (Klimaatberaad 2018). Besides environmental benefits, a reduction in the consumption of meat could also be beneficial for human health (Edjabou and Smed 2012; Wellesley et al. 2015)

In general, a policy maker can use several types of policy instruments to regulate food consumption: command and control instruments (for example performance standards), information provision (for example public information campaigns or labelling on product packaging) and price-based instruments (for example taxes or subsidies) (Wirsenius et al. 2010; Edjabou and Smed 2013).

However, command and control instruments are regarded as economically inefficient in relation to food consumption and information campaigns regarding GHG emission of food products would have a limited effect (Edjabou and Smed 2013).

Implementing a consumption tax on animal food products, differentiated with respect to the average GHG emission per kg, could be a cost-effective policy. One of the main determinants of the individual meat and dairy consumption pattern is the price of those food products (Wellesley et al. 2015). The social damage costs of meat and dairy consumption will be internalised in the price via a consumption tax, making meat and dairy food products more expensive (Edjabou and Smed 2013). Normally, a tax placed directly on the emission source would be more cost-effective. However, the monitoring costs are in the case of agricultural emissions high, the technological potential to reduce emissions is low and there are a lot of possibilities for output substitution (between the several meat types, but also vegetable-based meat substitutes) (Wirsenius et al. 2010; Edjabou and Smed 2013). Moreover, implementing an output tax on the production could be problematic due to weakening of the competitiveness of domestic producers. Due to this tax, there would be a cost disadvantage for domestic producers of animal products and the imported animal products will become relatively cheaper. This weakens not only the (local) economy, but it also causes carbon leakage. This means that the CO_2 emissions in a country will increase because of policies in another country to reduce these emissions (Säll and Gren 2015; Wirsenius et al. 2010; Edjabou and Smed 2012).

In the past years, some research is conducted into the effects of implementing a consumption tax on meat and dairy products in Sweden and Denmark (Säll and Gren 2015; Edjabou and Smed 2012). A similar study is done on an emission-based consumption tax on animal food products in the United Kingdom and the European Union (Kehlbacher et al. 2016; Wirsenius et al. 2011). Masselus (2016) studied the effects of a consumption-based meat tax in Belgium, but this study includes only three meat types and dairy food products are not taken into consideration.

This study uses not only data specific for the Netherlands to analyse the effects of a consumption tax in a micro-framework, but it also includes livestock food products (beef, poultry, pork, eggs, cheese and milk) instead of meat food products alone. Moreover, several scenarios for an increase of the consumption tax on livestock food products will be analysed.

1.2 Research objective and research questions

The objective of this research is to explore the effect of implementing a consumption tax on livestock food products for reducing the emission of greenhouse gasses related to food consumption in the Netherlands. The following research questions are discussed:

1. How has Dutch consumption of livestock food products developed since 1900?
2. What is the environmental impact of livestock food consumption?
3. What is the effect of implementing a consumption tax on livestock food products on the consumption level of those products?
4. To what extent do the GHG emissions of food consumption in the Netherlands change, after implementing a consumption tax on livestock food products?[1]

1.3 Methodology

This research will be conducted using a literature review (research question 1, 2 and 3) and data analysis (research question 1, 3 and 4). In particular, an econometric analysis will be done using the AIDS model for answering research question 3. The main analysis consists of three steps. Firstly, the initial consumption of livestock food products in the Netherlands will be calculated. Secondly, a consumption tax will be introduced and subsequently, the new demand for the livestock food products will be derived using price and income elasticities. Thirdly, the emission of environmental pollutants before and after the introduction of a consumption tax will be calculated. This analysis will be done for five scenarios with different tax schemes. The price and income elasticities per capita level will be calculated, by estimating an Almost Ideal Demand System (AIDS) model using the statistical software R.

1.4 Overview

The study is structured as follows. Chapter 2 discusses the historical development of livestock food consumption in the Netherlands and related environmental problems. The methodology and data are discussed in chapter 3. In chapter 4, a Pigouvian tax is introduced and an AIDS Model (including elasticities) for the Dutch livestock food consumption is estimated. This AIDS Model is used to determine the effect of a tax on livestock food products on the private consumption. The effect of the change in livestock food consumption on the GHG emissions is discussed in the last part of this chapter. A discussion and conclusion in chapter 5 forms the last part of this study.

[1] For reasons of simplicity, only the GHG emissions of food consumption related to those of the primary production sector are taken into account. So, other sources of GHG emissions related to food consumption such as, transport and packaging, are not included in this study.

Chapter 2: Historical development of Dutch livestock food consumption and related environmental issues

2.1 Introduction

This chapter provides background information on livestock food consumption in the Netherlands and consists of two parts.
In the first part, the development of Dutch livestock food production is discussed. The start of the 20th century is taken as starting point, meaning that a period of more than 100 years is covered. Such long time period is considered, because climate change is caused by long-term accumulation of greenhouse gasses in the atmosphere. This accumulation is not only due to the current activities, but it is also caused by meat consumption in the past. Moreover, discussing the development of livestock food consumption over such a long time period provides a deeper understanding of the current consumption.
In the second part, a closer look is taken on the environmental issues related to the consumption of livestock food products.

2.2 Development of Dutch livestock food consumption

2.2.1 Current livestock food consumption

The current meat consumption per capita in the Netherlands is shown in Figure 1. This pie chart shows the consumption per capita for each meat type in 2016 and is based on Terluin et al. (2017). In this study seven different meat types are included, however, veal (1.3 kg), mutton and goat meat (1.3 kg) and horse meat (0.1 kg) do not play a significant role in the current meat consumption. The most consumed meat type is pork (36.5 kg), followed by respectively poultry meat (22.2 kg) and beef (15.4 kg). Therefore, the focus in this study will be on pork, poultry and beef.

Private households spent on average 644 euro per year on beef (including veal), pork, poultry, milk, cheese (including cottage cheese) and eggs (CBS 2017). The largest share is spent on cheese and quark (234 euro), followed by respectively beef and poultry. Only a small amount of money is spent on milk (67 euro) and eggs (37 euro) (CBS 2017).

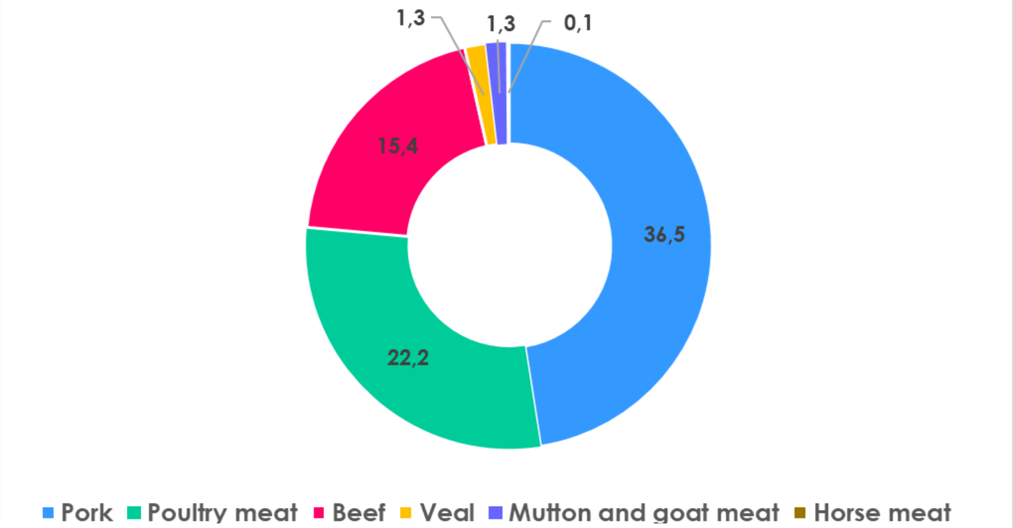

Figure 1: Annual meat consumption per capita (kg) in the Netherlands - 2016 (Terluin et al. 2017)

2.2.2 Development of livestock food consumption in the Netherlands since 1900

At the start of the 20th century the Dutch diet was quite different than it is nowadays. In general, the Dutch population ate mainly potatoes and bread and little meat (Wintle 2004, 63-66). Livestock products were seen as luxury products, since they were (far) more expensive per calorie than nearly all plant foods, like potatoes and wheat. Most people could not afford such expensive food products and bought the cheapest foods (Grigg 1999). However, this diet is changing considerably due to three economic and technological changes. Firstly, agricultural productivity grew rapidly and outpaced population growth, causing a decline in real food prices. Secondly, it became possible to import cheaper food products due to improved transport possibilities and the invention of the fridge. Thirdly, industrialization caused a growth of real incomes (Grigg 1999). According to Engels law, an increase in prosperity will cause food expenditures to increase in absolute terms. However, since total expenditures will increase even more, relatively speaking food expenditures decrease in that case (Zimmerman 1932). During the whole 20th century (and especially during the 1960s), private food expenditures as percentage of total private expenditures decreased from 45% in 1900 to 12% in 1999 (CBS 2001).

Meat consumption is rather scattered before the Second World War, with a dip after the First World War due to food shortages (Wintle 2004, 63-66), a large peak during the twenties and again a dip in the second part of the thirties, due to the Great Depression (CBS 2010B). The consumption of cheese per capita remains relatively stable until the end of the twenties, but shows an upward trend during the 1930s (CBS 2010B)

After the Second World War, the entire Dutch economy was severely disrupted and the country had to be rebuilt (Hulst 1980). It took till the early 1950s until the livestock food production was recovered (Grigg 1999). The consumption of beef, pork and cheese recovered during the fifties and was back at pre-war levels at the end of the 1950s (based on CBS 2010A). The annual egg consumption was around 130 eggs per capita. Eggs had the reputation to be nutritious, healthy and cheap (CBS 2010B).
Meat consumption increased significantly during the sixties and seventies. Especially the strong increase in pork and poultry consumption is remarkable (CBS 2010A).

In the same period, the planned income policy of the Dutch government came gradually to an end and private expenditures rose quickly. The economy was booming and people could afford much (Ellemers 1979; Hulst 1980; CBS 2009).

The consumption of pork and beef consolidated during the last part of the 20th century, although pork consumption still increased a little bit. Remarkably, however, is the strong increase in consumption of poultry. This may perhaps be explained by an increasing awareness about health issues, since poultry is lean low fat meat. Moreover, the time needed to prepare poultry meat is shorter than for other meat types. The consumption of poultry meat increased from 8.9 kg in 1980 to 21.4 kg in 1999 and claimed second place as most consumed meat product. Beef is now the third most consumed meat product (CBS 2010A). Possible explanations for the consolidation of pork and beef consumption are an increasing awareness of health issues and a saturation of the meat market. However, the consumption of beef fluctuated over time, but remains (in contrast with pork) relatively constant (CBS 2010A).

The consumption of cheese fluctuated not as much as meat, but shows a steady increasing trend over the whole second part of the 20th century and during the first years of the 21st century. Annual cheese consumption is in 2018 around 20kg per capita (CBS 2010A; ZuivelNL 2017).
The consumption of eggs increased in the first half of the eighties, but dropped in the second half to 170 eggs in 1991. The egg consumption recovered in the nineties and fluctuated around the same level (182 eggs per capita) in the first decennium of the 21st century (CBS 2010A). There is no data available for the last eight years, but it seems reasonable to assume that the egg consumption will still be around this level. Remarkable is the development of the milk consumption in the second half of the 20th century. The milk consumption not only decreased – which is in contrast with the trend of an increasing livestock food consumption – but full-cream milk is also substituted for semi-skimmed milk (CBS 2010A). A possible explanation is the increasing awareness about health issues related to eating food products with a high percentage of fat. However, milk consumption has been consolidated in the past 15 years and fluctuates now around 50 kg per capita (CBS 2010A; ZuivelNL 2017).

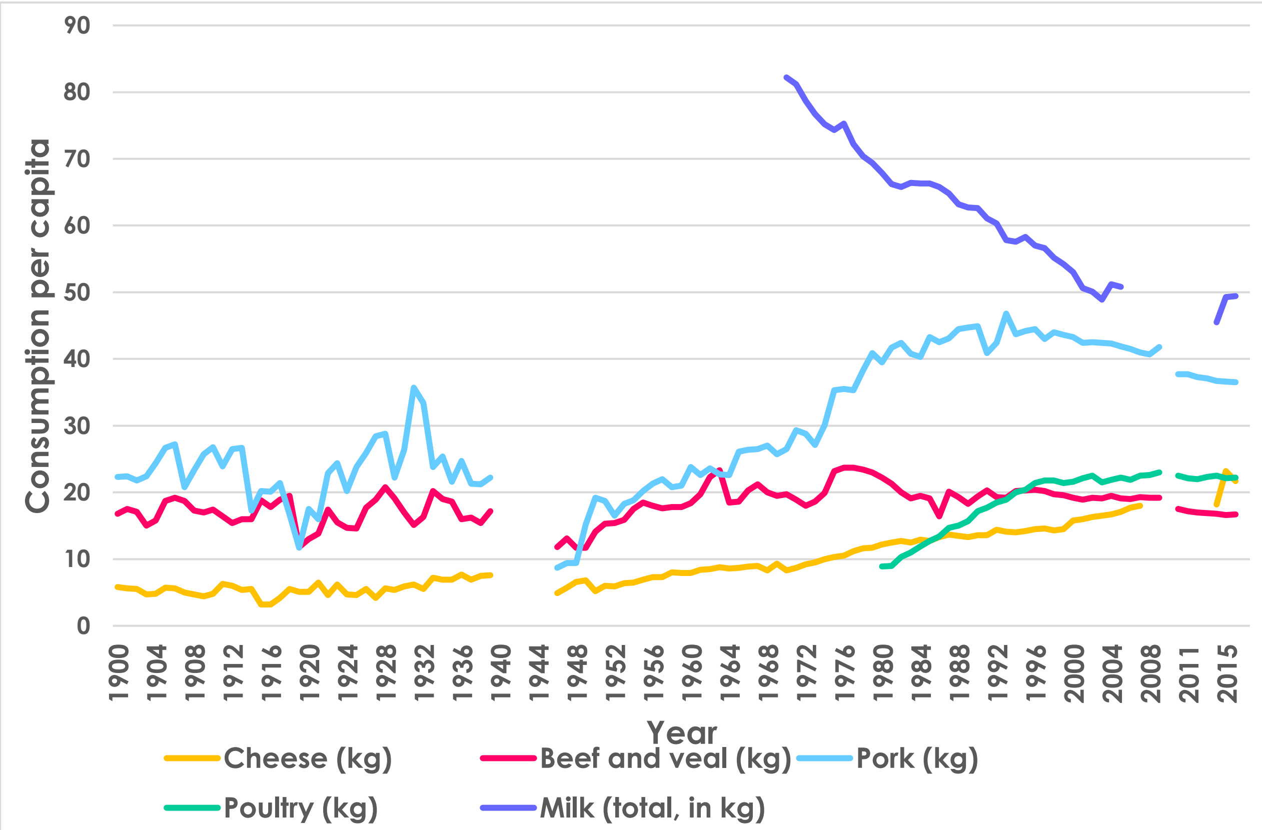

Figure 2: Dutch livestock food consumption per capita (in kg) 1900 – 2016 (CBS 2010A; Terluin et al. 2017; ZuivelNL 2017)

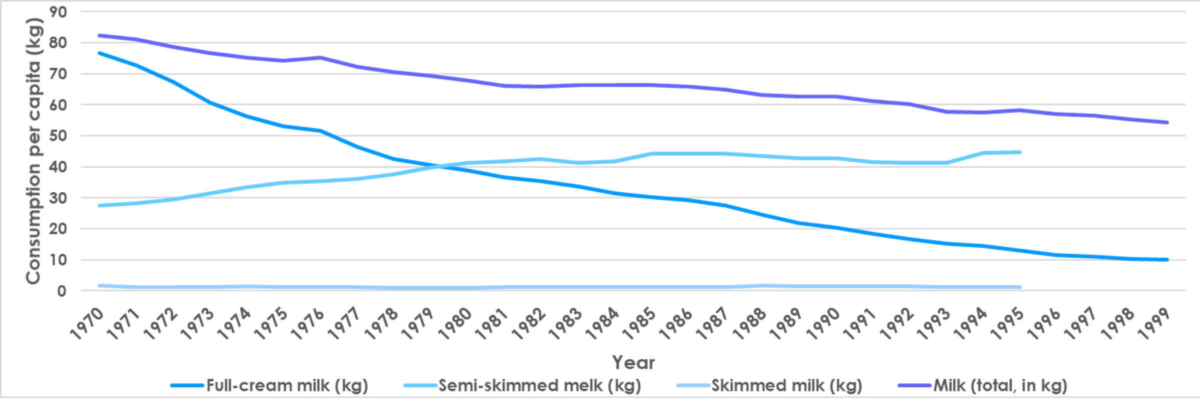

Figure 3: Development of Dutch milk consumption per capita (in kg) 1970 – 1999 (CBS 2010A)

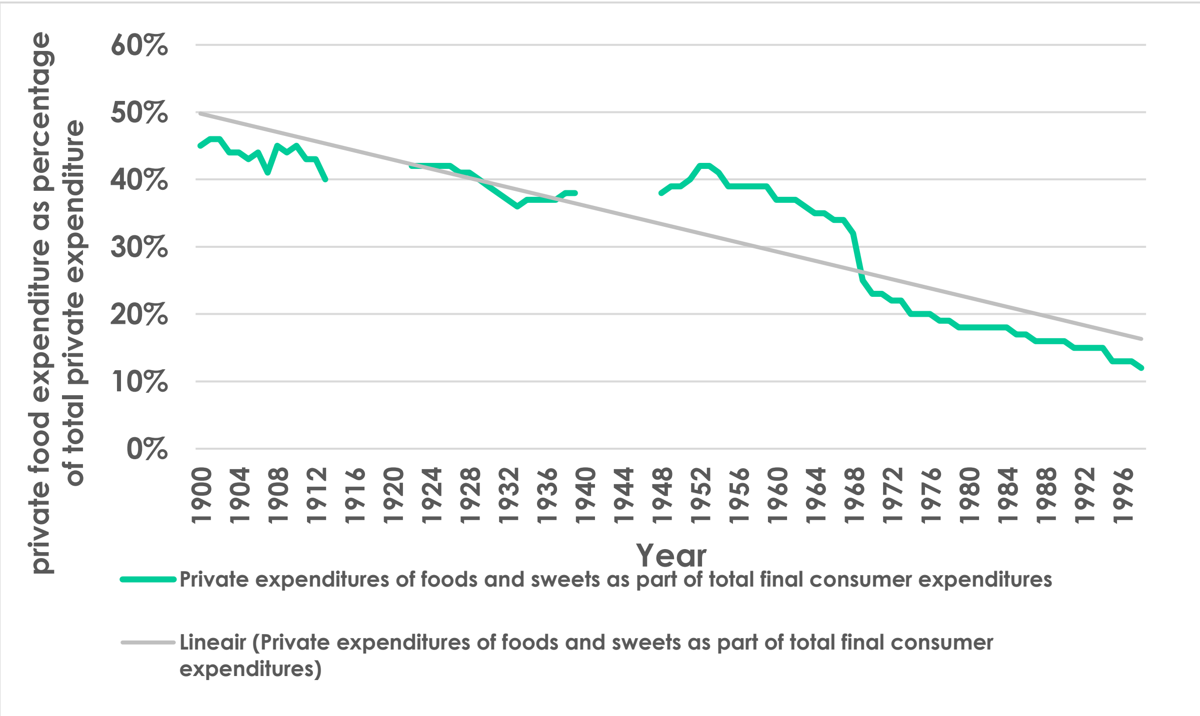

Figure 4: Development of Dutch private food expenditure as percentage of total private expenditure, 1900 – 1999 (CBS 2001)

2.2.3 Development of Dutch meat consumption in the past years and future trend

After a very long period of increasing meat consumption, a decrease was visible between 2009 and 2015 by 3.04%, from 79.0 kg to 76.60 kg (Terluin et al. 2017). These numbers are not completely comparable with the data from before 2009 due to different data sources. The reduction is mainly caused by a lower consumption of pork and (to a lesser extent) beef, while the consumption of poultry meat remained constant (Terluin et al. 2017). The meat consumption recovered a little bit in 2016 (Terluin et al. 2017). However, the question is whether the meat consumption will increase again in the coming years or that the declining trend of the past years will continue.

A first possible explanation for the decreased meat consumption between 2009 and 2015 is the economic crisis, which caused a decrease in consumptive expenditures of households (based on CBS 2018E). The expenditures on meat followed the same trend as GDP and total consumptive expenditures and decreased in 2008, 2009 and 2012 (based on CBS 2018F). The percentage changes of GDP, total consumptive expenditures and expenditures on meat are depicted in figure 5.

The Dutch economy recovered and is growing again since 2014. As a result, people have more to afford and consumptive expenditures increased again (based on CBS 2018E). This could be an explanation for the increase in meat consumption in 2016 (ABN Amro 2018).

However, there is also a second, more deep-rooted, explanation possible. The zeitgeist seems to turn against meat consumption. There are frequently articles in the media in which scientists and professionals express their concerns regarding the health and environmental issues related to the current amount of meat consumption. Many people seem to be responsive to this kind of signals. An increasing number of people eat at least once a week a hot meal without meat. The number of people who eat vegetarian or completely vegan is growing as well (Dagevos et al. 2012). The market for vegetarian products is small at the moment. However, some experts believe that there is a huge potential to grow, with expected growth rates of 6% and 8% for respectively 2018 and 2019 (ABN Amro 2018).

These two possible explanations for the decreasing trend in meat consumption in the past few years are not mutually exclusive. However, time will show how the Dutch meat consumption will develop in the future.

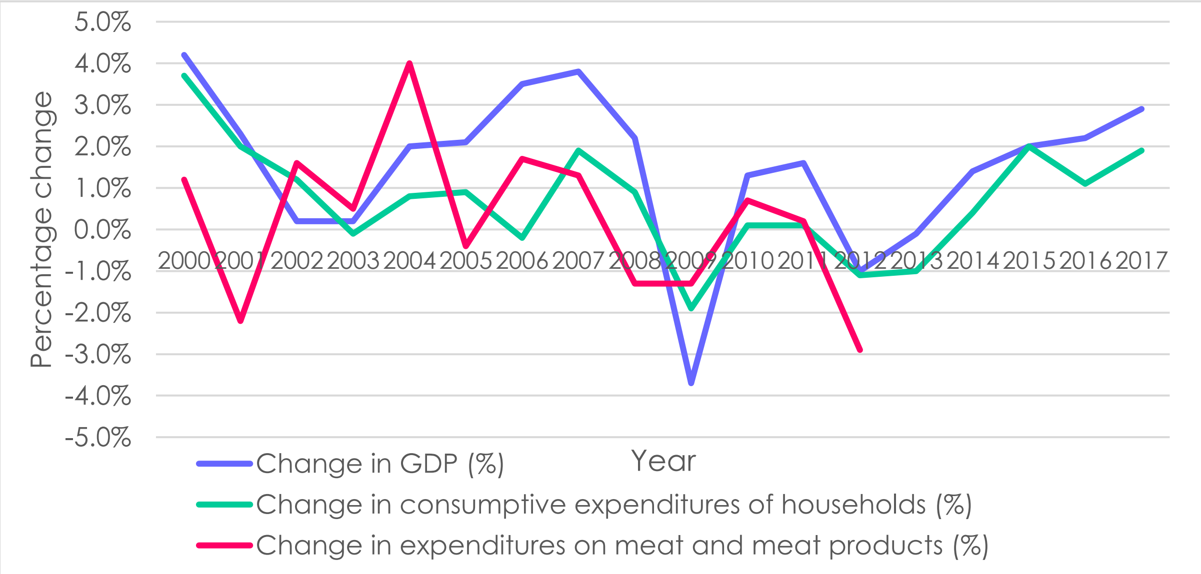

Figure 5: Percentage change in GDP, total consumptive expenditures and expenditures on meat in the Netherlands 2000 – 2017 (CBS 2018E; CBS 2018F).

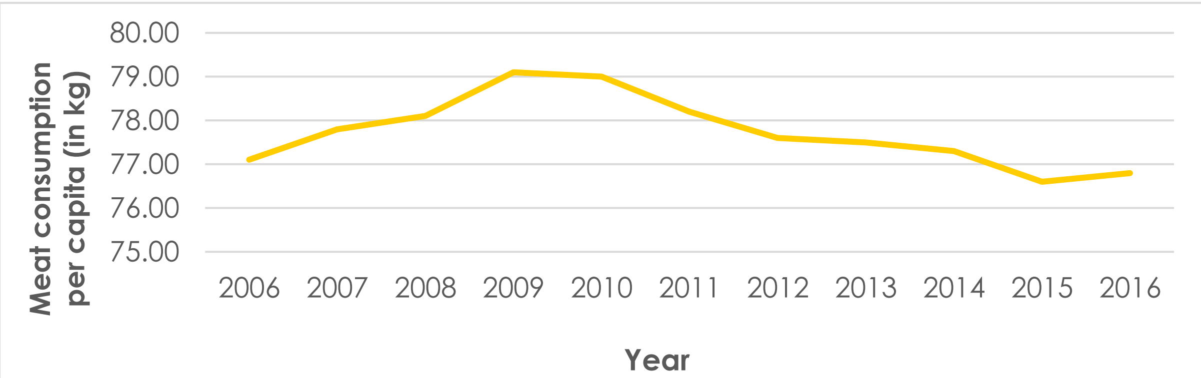

Figure 6: Dutch meat consumption per capita (kg) 2006 – 2016 (Terluin et al. 2017)

2.3 Environmental issues related to livestock food consumption

The increase in livestock food consumption has not come without a cost, since the livestock sector is one of the most significant contributors to several environmental problems (FAO 2006). In 2006, the Food and Agriculture Organization of the United Nations published the alarming report 'Livestock's long shadow', which states that the livestock sector contributes on a massive scale to environmental problems. Urgent action would be needed to decrease livestock's negative environmental impact (FAO 2006). The related environmental problems are diverse and severe, ranging from air pollution and contributions to climate change, to land degradation and water pollution (FAO 2006). However, the focus of this paragraph is on the livestock's emission of harmful pollutants, since this thesis is about the effects of implementing an emission-based consumption tax.

2.3.1 Air pollution

The emission of harmful pollutants (such as carbon monoxide, ammonia, nitrogen oxides, sulphur dioxide, volatile organic compounds and fine dust) due to production and consumption of livestock food products leads to a degradation of air quality. This causes several environmental problems (FAO 2006; Smit and Heederik 2017). Firstly, sulphur dioxide and oxides of nitrogen convert to sulphuric and nitric acids in the presence of atmospheric moisture and oxidants, causing acid rain and snow. Acid precipitation is not only harmful for forests and crops, but it also makes lakes and rivers unsuitable for fish, plants and other animal life (FAO 2006). Secondly, the emission of ammonia (causing a stinging smell around livestock farms) leads to nitrogen deposition in the soil. Potentially, this could cause eutrophication. More than 90 percent of the vulnerable ecosystems in Western Europe receive more than the critical load of nitrogen (FAO 2006). Lastly, high concentrations of fine dust are emitted around livestock farms, causing not only environmental problems, but there are also serious health concerns (Smit and Heederik 2017; Cambra-Lopez et al. 2010). In particular poultry farms contribute significantly to the emission of fine dust in the Netherlands (Wageningen University&Research 2012)

2.3.2 Climate change

Climate change is the second important environmental problem related to the emission of harmful pollutants. It is widely acknowledged that the climate is changing due to human activities (Povalleto et al. 2012; FAO 2006; Säll and Gren 2015; Wirsenius et al. 2010; Dincer 2000; Edjabou and Smed 2012). A changing climate could have devastating effects with more extreme weather events, an increase in sea level (9 – 88 cm by 2100) and deteriorating ecosystems (FAO 2006; FAO 2013; Dincer 2000). Most scientists agreed that there is a causal relationship between climate change and the emission of greenhouse gasses (Dincer 2000). However, the global warming potential, which depends on the capacity to absorb heat and how long the effect lasts, is not the same for each greenhouse gas. Nitrous oxide has the highest global warming potential (296), followed by Methane (23) and Carbon dioxide (1) (FAO 2006).

The Dutch Council for the Environment and Infrastructure estimated that the livestock sector is responsible for 10% of the total greenhouse gas emissions in the Netherlands (Council for the Environment and Infrastructure 2018). The total Dutch food consumption is responsible for an annual emission of 35 megaton in CO_2 equivalents. This is mainly caused by the consumption of meat (34,3%), followed by the dairy consumption (20%) (Valk et al. 2015).

Methane is the most emitted gas by the livestock sector (44%), followed by Nitrous oxide (29%) and Carbon dioxide (29%) (FAO 2013). The largest part of greenhouse gasses is emitted at the agricultural production stage. (FAO 2006; Scarborough 2014). Feed production and processing (in particular Nitrous oxide due to feed fertilization) and enteric fermentation from ruminants (Methane) are the two main emission sources (FAO 2006; FAO 2013). A relatively small part of the greenhouse gasses is emitted during the post-farm production stages and actual consumption. Carbon dioxide is emitted due to the use of fossil fuels for powering farm machinery and to transport, store and prepare food (Scarborough et al. 2014).
A complicating factor in the discussion about the emission of greenhouse gasses by livestock food consumption, is that there are huge differences in the amount of emitted GHG per kg between livestock food products. The country of origin is also important. Beef from Brazil has for example a much higher greenhouse effect than beef from the Netherlands, due to differences in efficiency and lifetime of livestock (FAO 2013; Blonk et al. 2008).

Blonk et al. (2008) calculated the amount of greenhouse gas emission per kg livestock food product in the Netherlands. These calculations are part of a broader report on the environmental effects of Dutch high-protein food consumption. In this report, a lifecycle-assessment is used to determine the environmental effects. Moreover, the whole product chain related to the Dutch consumption is taken into consideration. The greenhouse effect is calculated in CO2 equivalents and three greenhouse gasses are taken into consideration: Carbon dioxide, Methane and Nitrous Oxide. The use of fossil energy and electricity in the production chain for transport, processing, storage and cooling are not included (Blonk et al. 2008).

As figure 7 shows, there is a wide variety in greenhouse effect scores between the several livestock food products. Beef originating from meat cattle has the highest greenhouse effect score. Remarkable is the huge difference in greenhouse effect score between beef from meat cattle (15.9 CO_2 equivalents/kg) and beef from dairy cattle (8.9 CO_2 equivalents/kg). There is such a large difference, because the greenhouse gas emission of dairy cattle is largely attributable to milk (Bonk et al. 2008). However, the greenhouse effect score of pork and poultry is still much lower than for beef. Eggs and milk have the two lowest greenhouse effect scores of the selected livestock food products, while the greenhouse effect score of cheese is as high as beef from dairy cattle (Blonk et al. 2008). This high greenhouse effect score of cheese is probably due to the large amount of milk (10.1 litre) that is needed to produce 1 kg of cheese (Scarborough et al. 2014).

Figure 7: GHG emission in kg CO_2 equivalents per kg of livestock food product (Blonk et al. 2008)

In line with the climate agreement of Paris, the Dutch government committed itself to the goal that the total emissions of greenhouse gasses must be decreased by 95% in 2050 compared to 1990 levels (Council for the Environment and Infrastructure 2018). In other words, the total per capita emissions should be between 0.5 and 2.2t CO_2 equivalents per year in 2050 (Wirsenius et al. 2012). However, the per capita emissions due to consumption of animal food products are currently 1.1t carbon dioxide equivalents in western countries (Wirsenius et al. 2012). This means that the agricultural emission of greenhouse gasses has to decrease strongly. Unfortunately, the scope for reducing GHG emissions via new technologies and changes in farming practices are limited in Europe. A significant reduction could only be achieved by a lower food consumption and a reduction in food waste (Garnett 2011; Scarborough et al. 2014; Wirsenius et al. 2010). The sectoral platform ‘Agriculture and land use’ is currently negotiating on a Dutch national climate agreement and regards climate friendly food consumption as one of the key factors for a long term climate policy (Klimaatberaad 2018).

Chapter 3: Methodology and data description

3.1 Methodology

3.1.1 Almost Ideal Demand System

This study investigates the effect of a livestock food consumption tax on the livestock food consumption and the ensuing reduction greenhouse gas emissions in the Netherlands. Similar studies in Denmark and Sweden analysed the effect of such meat tax on the meat consumption, by estimating price elasticities using an Almost Ideal Demand System (Edjabou and Smed 2013; Säll and Gren 2015).

This study follows a similar approach. The empirical analysis consists of three steps. First, a pre-tax demand function is estimated and the demand elasticities and expenditure shares are derived. Second, post-tax prices are calculated for several scenarios and the new demand for livestock food products is derived, using the calculated price elasticities. Third, the impact of the change in demand for livestock food products on the emission of greenhouse gasses is calculated. This analysis will be done for five different tax scenarios. In the first three scenarios all livestock food products are taxed at a level based on the GHG emissions and the social costs of carbon. The level of the social costs of carbon differs per scenario. In the fourth and fifth tax scenario is the VAT on livestock food products increased to respectively 9 and 21 percent. These two scenarios could be regarded as a practical implementation of a consumption tax on livestock food products.

The demand equations are estimated using an Almost Ideal Demand System (AIDS), developed by Deaton and Muellbauer (1980). This model satisfies the axioms of choice, which give "formal mathematical expression to fundamental aspects of consumer behaviour" (Deaton and Muellbauer 1980; Jehle 2011, 5): completeness, transitivity, continuity, strict monotonicity and (strict) convexity (Jehle 2011, 5-13). It is assumed that the consumer is rational and tries to maximize his utility. The preferences of consumers are represented by an expenditure function, which shows the minimum level of expenditure necessary to get a certain level of utility at given prices (Deaton and Muellbauer 1980).

Engel curves (which show the relationship between income and demand) play an important role in demand system modelling (Dybczak et al. 2014). The standard AIDS model uses a linear-logarithmic form of the Engel curve. However, Banks et al. (1997) argued that the Engel curve is not linear for most products. They added a quadratic income term and developed the Quadratic Almost Ideal Demand System (Dybczak et al. 2014; Banks et al. 1997). The quadratic logarithmic model makes it possible to let goods be luxuries at some income levels and necessities at other levels (Banks et al. 1997). Engel curves are in the case of food products very close to being linear in log income. This means that just the standard AIDS model can be chosen as model to estimate the demand equations for food products (Banks et al. 1997).

In the demand model, there is consumer demand for a set of *k* goods and the consumer has a budget of m units of currency (Poi 2013). In this case, the *k* goods represent different categories of food products and m is the total annual expenditure on food per capita.

The standard AIDS model is denoted as follows (Poi 2013; Deaton and Muellbauer 2013; Curtis and Stanley 2015):

$$w_{it} = a_i + \sum_{j=1}^{k} \gamma_{ij} ln\, p_{jt} + \beta_i ln\left[\frac{m_t}{a(p)}\right], \quad \text{i} = 1,\ldots,\text{k} \tag{1}$$

w_{it} = expenditure share of good i in year t, a_i = constant coefficient of good i, γ_{ij} = coefficient of good j in share of good i, p_{jt} = nominal price of good j in year t, m_t = total expenditure on food per capita in year t, and $a(p)$ is a consumer price index function.

Total expenditure per capita (m) should represent total expenditures on the goods that are included in this demand model. This means that for each observation should hold that $\sum_j p_j q_j = m$. The expenditure share variables have to sum to 1 for each observation (Poi 2013).

From economic theory there are three additional theoretical restrictions that need to be fulfilled by the parameters. First the adding-up restriction, second, the homogeneity restriction, which means that the consumed quantities do not change when there is a proportional change of all prices and income. Third and last, the symmetry restriction, which means that a change in price of good i has the same effect on the budget share of good j as a price change of good j has on the budget share of good i (Poi 2013; Säll and Gren 2015).

The expenditure share equation will be estimated for seven food categories (beef, pork, poultry, cheese, milk, eggs and other food products). The sum of these seven expenditure shares is equal to the total expenditures on food per capita.

The AIDS model price elasticities can be calculated by differentiating the expenditure share equation with respect to lnp_j (Banks et al. 1997).

$$\mu_{ij} \equiv \frac{\partial w_i}{\partial ln\, p_j} = \gamma_{ij} - \mu_i\left(\alpha_j + \textstyle\sum_k \gamma_{ij} ln\, p_k\right) \tag{2}$$

The uncompensated (Marshallian) price elasticities are calculated, using the following formula: $e_{ij}^{u} = \frac{\mu_{ij}}{w_i} - \delta_{ij}$ (Banks et al. 1997). The uncompensated price elasticities are based on the Marshallian demand curve and show the percentage change in quantity demanded of good i, when the price p_j changes by 1 per cent. It is called the own-price elasticity of demand for good

i if $j = i$ and the cross-price elasticity if $j \neq i$. (Jehle 2011, 21, 60). It includes both the substitution effect (due to change in relative prices) and the income effect (due to a change in purchasing power) (Jehle 2011, 51; Paradisi 2016).

The uncompensated own- and cross-price elasticities are used in chapter 4 to calculate the change in demand after the implementation of a consumption tax on livestock food products.

The R micEconAids package (Henningsen 2017), is used to estimate the standard AIDS Model by using the Linear Least-Squares Estimator and to derive the price elasticities.

3.1.2 Tax scenarios

One of the main determinants of the individual meat and dairy consumption pattern is the price of those food products (Wellesley et al. 2015). Implementing a consumption tax on livestock food products, differentiated with respect to the average GHG emission per kg, could be a cost-effective policy. The effect of five different tax scenarios on the consumption of livestock food products will be investigated.

In the first three scenarios, a tax will be implemented that internalises the social damage costs of carbon emissions. Carbon pricing is regarded as a key instrument in climate policy, since it promotes an emission reduction in a cost-effective way. Livestock food consumption contributes significantly to climate change and while consumers receive the full benefit, they bear only a small fraction of the climatic costs. By internalising the social costs of GHG emissions, the consumer price of those products will increase and the consumer has to bear the full social costs of their decisions. So, such a tax could provide an incentive to change the diet in a more environmental friendly direction (Boyce 2018; Säll and Gren 2015).

However, there exists a wide range of estimates for the level of the social costs of GHG emissions in CO_2-equivalents (Boyce 2018; Stern 2006; Edjabou and Smed 2013). Uncertainties that affect the calculation of the social cost of carbon are the climate sensitivity parameter, the expected climate damage at low temperatures, the expected climate damage at high temperatures and the discount rate (Ackerman and Stanton 2012).
Three different levels of the social costs of carbon will be used in the tax scenarios. In tax scenario 1, the social costs of carbon are estimated at 0.06 euro per kg CO_2-equivalent, which is similar to the level used by Wirsenius et al. (2011). In the second scenario is the tax level set at 0.094 euro per kg CO_2-equivalents, which is the estimated Dutch social damage cost of climate change, calculated by CE Delft (2018). Van den Bergh and Botzen (2014) proposed a lower bound to the social costs of carbon of $125 per ton CO_2. This value will be used in the third scenario and is 0.113 euro per kg CO_2-equivalents at the price level of 2017.

The tax is in all three scenarios imposed on all livestock food products and is calculated for each livestock food product separately by multiplying the mentioned social damage costs per CO_2-equivalent by the GHG emissions in CO_2-equivalents per kg. For example, the GHG emissions of beef originating from meat cattle are 15.9 kg in CO_2-equivalents (Blonk et al. 2008), so in scenario 2 the tax would be 1.50 euro (15.9*0.094) per kg beef. Note that only the social damage costs related to climate change are taken into consideration. Moreover, the estimated GHG emissions of each livestock food product are average numbers and could vary between the different sources of origin.

Scenario 4 and 5 can be regarded as a practical implementation of carbon pricing, since the VAT will be 'greened'. Until the end of 2018, the VAT on food products was 6% in the Netherlands. In scenario 4, the VAT on all livestock food products is increased to 9% (which is the current VAT on food products in the Netherlands) (Belastingdienst 2019). This increase will be even larger in scenario 5, since the VAT on all livestock food products is set at 21%. This is the current high VAT-level in the Netherlands (Belastingdienst 2019).

3.1.3 Calculation of change in greenhouse gas emissions

For each tax scenario is first calculated how the consumed quantity of each livestock food product will change. This is done by using the table of own- and cross-price elasticities, following the example of Säll and Gren (2015). The change in consumption for each livestock food product is calculated by multiplying in each row the change in price with the respective own- and cross-price elasticities. The change in demand for beef is for example calculated as follows:

$$\Delta Q_i = p_i \sum_{i,j=1}^{k} e_{ij}^{u},\ \text{j,i} = 1,\ldots,\text{k} \qquad (3)$$

Where p_i denotes the price of livestock food product i and the cross-price elastictiy is denoted by e_{ij}^{u}.

The cross-price elasticities show how much the demand for beef will change, when the price changes of respectively pork, poultry, cheese, milk and eggs.

The new amount of greenhouse gas emissions will be calculated for each livestock food product by multiplying the new consumed quantity per capita by the GHG emissions in CO_2-equivalents per kg.

3.2 Data description

For the estimation of the demand systems, data is needed on prices, consumed quantities and private expenditures. Due to data availability, macro-level data on these variables is used for the period 2000-2016 for estimating the demand system equations.

3.2.1 Data on meat consumption

Data on gross meat consumption is obtained from two different sources. The first dataset is obtained from Statistics Netherlands (CBS) and runs from 2000 to 2009 (CBS 2010A). This data is complemented by more recent data obtained from Terluin et al. (2017), which runs from 2005 to 2016. Although in both datasets the calculations of meat consumption are based on the systematics of annual supply balances (Terluin et al. 2017, CBS 2010A), small differences are observable. There is an overlap in data for the years 2005-2009. The difference in consumption between the two datasets is calculated for each 'overlap year' and each meat type. After that, the data of Terluin et al. is converted to the level of the CBS data, using the average percentage difference for each meat type. Finally, the gross meat consumption quantities are divided by two, to obtain the actual net meat consumption. See Annex 1 for a more elaborate explanation.

3.2.2 Data on milk, cheese and egg consumption

Data on milk, cheese and egg consumption is obtained from three different sources. The first dataset is obtained from Statistics Netherlands (CBS) and runs from 2000 to 2009 (CBS 2010A). However, data are for each of the three livestock food types for a different time period available: cheese (2000 – 2007), milk (2000 – 2005) and eggs (2000 – 2009). The data is about the consumption per capita in kg for milk and cheese and in units for eggs (CBS 2010A). Data on egg consumption in 2010, 2011 and 2012 is found in annual reports of the Dutch product agency Cattle, Meat and Eggs (Productagentschap pluimvee en eieren and Productschap vee en vlees 2013).The third dataset comes from the Dutch dairy marketing organisation, which published data on the consumption of cheese and milk in recent years (ZuivelNL 2017). However, these data are not completely comparable with the first dataset, due to differences in calculations. Moreover, data on milk consumption is missing for the years 2006 and 2007. The data of ZuivelNL on milk and cheese consumption is converted to the level of the CBS data, by calculating the average percentage difference for each overlap year. The missing years for milk (2006, 2007) and eggs (2013, 2014, 2015, 2016) are calculated via linear interpolation in Excel. The Dutch National institute for public

health and the environment reported an increase of 7% in egg consumption between 2012 and 2013 (Pluimveeweb 2018). See Annex 1 for a more elaborate explanation.

3.2.3 Data on prices

The nominal prices of meat, milk, cheese and eggs are obtained from a dataset of Statistics Netherlands (CBS). This dataset runs from 2000 to 2016 and was last updated on 1 March 2018 (CBS 2018G). The prices are retail prices (CBS 2018C). The prices of 1 kg pork steak, 1 kg rib steak and 1 kg chicken fillet represent the price per kg of respectively pork, beef and chicken. The price of milk is represented by the price of 1 litre semi-skimmed milk. The price of cheese is for 1 kg mature Gouda cheese. The price of eggs, finally, is for 1 medium free-range egg (CBS 2018D). These nominal prices are used to calculate the private expenditures on livestock food products.

There is no average nominal price available for the category 'other food products' in the model. Therefore, price indexes are used as price variable for each food product in the AIDS model. The price indexes of beef, pork, poultry, cheese, milk and eggs are calculated using the dataset on nominal prices and by taking 2015 as base year (2015=100). The price index for the other food products is calculated, by excluding the price indices of the mentioned livestock food products from the consumer price index of food. The consumer price index of food comes from a dataset of Statistics Netherlands (CBS 2018J). See Annex 2 for a more elaborate explanation.

3.2.5 Data on private food expenditures

The total private food expenditure per capita is calculated, using data of Statistics Netherlands on the food expenditures of households in the Netherlands. First, the total annual food expenditures of households are divided by the number of households in the Netherlands. After that the private food expenditures per capita are calculated by dividing the total food expenditure per household by the average number of household members. The datasets on households come from Statistics Netherlands as well (CBS 2018F; CBS 2018I).

The private expenditures per capita on each livestock food product are calculated by multiplying the consumed quantity by the price. The private expenditure per capita on other food products is calculated by subtracting the private expenditures on livestock food products from the total private food expenditures per capita.

Chapter 4: The effect of a consumption tax on livestock food consumption

4.1 Uncompensated own- and cross price-elasticities

The estimated uncompensated own- and cross price-elasticities of livestock food products in the Netherlands are shown in table 1. It shows the percentage change in quantity demanded of good i, when the price p_j changes by 1 per cent. An absolute value lower than 1 indicates that it is a price-inelastic good, which means that the change in quantity demanded is less than proportional as the price change. Moreover, substitutes are indicated by a positive cross price-elasticity, while a complementary good is indicated by a negative cross price-elasticity.

The elasticities in table 1 are estimated by using aggregate time series data with relatively few observations. Table 2 provides therefore an overview of price elasticities reported by other scientific studies and table 3 shows the average value of these price elasticities.

Tables 1, 2 and 3 provide several useful insights. First, all absolute values are lower than 1, meaning that both the price- and cross price elasticities are inelastic for all goods in the demand system. Second, the own price-elasticity is negative in the case of beef, pork, poultry, cheese and milk. This is in line with the basic law of demand, since it means that the quantity demanded will drop when the price increases. However, the own-price elasticity of eggs is very small, but positive. This could indicate that eggs are a giffen good, which means that the quantity demanded increases when the price of the good rises. This theory is not supported by the literature, since both Wirsenius at al. (2011) and Edjabou and Smed (2013) found a negative own-price elasticity for eggs. Third, especially the estimated own-price elasticities of beef (-0.078) and pork (-0.006) are very small, where a larger (but still inelastic) value would be expected. Gallet (2011) for example, reported a median own-price elasticity of -0.869 for beef and -0.780 for pork. Also other studies reported a more elastic own-price elasticity for beef and pork (Säll and Gren 2015; Edjabou and Smed 2013). However, the own-price elasticities are negative and inelastic in both cases. The own-price elasticities of poultry, cheese and milk are negative and seem to be in accordance with the results of other studies. Fourth, the results of the estimated cross-price elasticities are rather scattered and differ from study to study. Generally speaking, the cross-price elasticities are (very) small in the case of beef, pork and poultry. This is in accordance with the results found in the literature (Wirsenius et al. 2010; Säll and Gren 2015; Edjabou and Smed 2013). The cross-price elasticity of cheese, milk and eggs seems to be a bit more elastic than initially estimated. However, all cross-price elasticities are inelastic and smaller than the own-price elasticities.

Table 1: Uncompensated own- and cross-price elasticities of livestock food products

	Beef	Pork	Poultry	Cheese	Milk	Eggs
Beef	**-0.078**	0.069	-0.006	0.015	-0.014	-0.028
Pork	0.051	**-0.006**	-0.046	-0.026	0.041	-0.005
Poultry	0.045	-0.015	**-0.821**	-0.497	0.324	-0.014
Cheese	-0.004	-0.085	-0.403	**-0.686**	-0.031	-0.044
Milk	-0.037	0.197	0.912	-0.112	**-0.194**	-0.040
Eggs	-0.104	-0.106	-0.123	-0.215	-0.051	**0.047**

Table 2: Overview own- and cross- price elasticities reported by other scientific studies

	Beef	Pork	Poultry	Cheese	Milk	Eggs
Beef	**-0.661** **-1.184** **-1.30**	-0.368 0.521 0.30	0.024 0.086 0.30	. -0.578 .	. -0.494 .	. -0.144 0.00
Pork	-0.197 0.078 0.30	**-0.562** **-1.178** **-0.80**	-0.175 -0.219 0.30	. -0.578 .	. -0.494 .	. -0.144 0.00
Poultry	0.020 0.473 0.60	-0.770 0.484 0.50	**-0.435** **-1.438** **-1.00**	. -0.578 .	. -0.494 .	. -0.144 0.00
Cheese	. -0.131 .	. -0.232 .	. -0.072 .	**-0.480** **-1.213** .	-0.900 -0.181 .	. -0.328 .
Milk	. -0.131 .	. -0.232 .	. -0.072 .	-0.134 -0.260 .	**-0.709** **-0.477** .	. -0.313 .
Eggs	. -0.131 0.01	. -0.232 0.01	. -0.072 0.00	. 0.220 .	. 0.043 .	. **-1.422** **-0.50**
Legend: black (Wirsenius et al. 2010), red (Säll and Gren 2015) and purple (Edjabou and Smed 2013)						

Table 3: Average values own- and cross price elasticities reported by other studies

	Beef	Pork	Poultry	Cheese	Milk	Eggs
Beef	**-1.05**	0.15	0.14	-0.578	-0.494	-0.144
Pork	0.06	**-0.85**	-0.094	-0.578	-0.494	-0.144
Poultry	0.36	0.07	**-0.96**	-0.578	-0.494	-0.144
Cheese	-0.131	-0.232	-0.072	**-0.85**	-0.54	-0.328
Milk	-0.131	-0.232	-0.072	-0.197	**-0.59**	-0.313
Eggs	-0.061	-0.111	-0.036	0.22	0.043	**-0.96**

4.2 Tax scenarios: change in prices

The effect of five different tax scenarios on the consumption of livestock food products is investigated. The price change differs between the several tax scenarios and is not the same for each livestock food product. Table 4 shows the price changes of each livestock food product for the several tax scenarios. The nominal price of 2017 (including VAT of 6%) is taken as base year (CBS 2018G).

Table 4: Overview price changes – different tax scenarios

	GHG emissions in CO2-equivalents per kg	Price change scenario 1 (SCC = 0.060/kgCO₂)	Price change scenario 2 (SCC = 0.094/kgCO₂)	Price change scenario 3 (SCC = 0.113/kgCO₂)	Price change scenario 4 (VAT 6-9%)	Price change scenario 5 (VAT 6-21%)
Beef	15.9/8.9[a]	6.53%	10.23%	12%	2.83%	14.15%
Pork	4.5	3.55%	5.56%	7%	2.83%	14.15%
Poultry	2.6	1.53%	2.40%	3%	2.83%	14.15%
Cheese	8.9	5.23%	8.19%	10%	2.83%	14.15%
Milk	1.2	8.00%	12.53%	15%	2.83%	14.15%
Eggs	2	5.38%	8.43%	10%	2.83%	14.15%

a) Beef originating from meat cattle is far more polluting (15.9 kg CO2-equivalents per kg), than beef from dairy cattle (8.9 kg CO2-equivalents per kg) (Blonk et al. 2008). It is assumed that 25% of beef consumption comes from meat cattle and 75% from dairy cattle (CE Delft 2018).

The tax based on the social costs of carbon (scenario 1, 2 and 3) is in nominal value the highest for beef, followed by cheese and pork. It reflects the carbon-intensity of those food products, while this is not the case in scenario 4 and 5. The relative price change is equal for each food product (scenario 4 and 5), so the more expensive the product is, the higher the nominal value of the tax will be. This means that food products with the highest carbon intensity will not automatically be taxed at the highest nominal tax value.

4.3 Change in livestock food consumption

The change in livestock food consumption is calculated twice, for five different tax scenarios that were summarised in table 4. The first time are the own estimated price elasticities used, while the second time the calculations are done using price elasticities reported by other scientific studies.

4.3.1. Change in livestock food consumption – own estimated elasticities

Table 5: percentage change in consumption for different tax scenarios – first run

	Tax scenario 1	Tax scenario 2	Tax scenario 3	Tax scenario 4	Tax scenario 5
Beef	-0.46%	-0.72%	-0.86%	-0.12%	-0.59%
Pork	0.41%	0.64%	0.77%	0.03%	0.13%
Poultry	-1.10%	-1.72%	-2.07%	-2.77%	-13.84%
Cheese	-5.02%	-7.86%	-9.44%	-3.55%	-17.73%
Milk	-0.50%	-0.78%	-0.93%	2.05%	10.27%
Eggs	-2.52%	-3.95%	-4.75%	-1.56%	-7.81%

Table 5 shows per livestock food product the percentage change in consumption for the different tax scenarios. As expected, the higher the tax level, the larger the change in consumption would be. Remarkable is the positive change in consumption of pork for all tax scenarios. This comes due to a positive value of the summation of the own- and cross price elasticities of pork. The positive change in consumption of milk for tax scenario 4 and 5 is caused by a relatively high cross-price elasticity with pork and poultry. The consumption of beef changes hardly after implementing a tax, while the consumption of cheese is more sensitive for price changes.

4.3.2. Change in livestock food consumption – average price elasticities obtained from the literature

Table 6: percentage change in consumption for different tax scenarios – second run

	Tax scenario 1	Tax scenario 2	Tax scenario 3	Tax scenario 4	Tax scenario 5
Beef	-13.86%	-21.71%	-26.09%	-5.59%	-27.96%
Pork	-10.52%	-16.48%%	-19.80%	-5.94%%	-29.72%
Poultry	-6.62%	-10.37%	-12.47%	-4.94%	-24.71%
Cheese	-12.32%	-19.30%	-23.19%	-6.09%	-30.46%
Milk	-9.22%	-14.45%	-17.37%	-4.34%	-21.72%
Eggs	-4.52%	-7.08%	-8.51%	-2.56%	-12.81%

Table 6 shows the percentage change in consumption per livestock food product for the different tax scenarios. The higher the tax level, the larger the decrease in consumption is expected to be, since all average price elasticities are negative. Tax scenario 4 (VAT to 9%) has the smallest effect, while scenario 5 (VAT to 21%) has the largest effect on the consumed quantities. The change in consumption is much larger compared to the results of table 5, since more elastic values of the price elasticities of livestock food products are used now. Moreover, the effect of a tax on the consumption of beef, pork and poultry is reinforced by a negative cross-price elasticity of cheese (-0.578), milk (-0.494) and eggs (-0.144).

The tax level in scenario 1,2 and 3 reflect the carbon intensity of the respective products. The food products with the highest carbon intensity (respectively beef and cheese) show the largest decrease in consumed quantity. This is not the case in scenario 4 and 5, where all prices are increased by the same percentage. The consumption of pork, for example, shows the largest decrease, while the carbon intensity (and thus the impact on climate) is higher for beef and cheese.

4.4 Change in GHG emissions related to livestock food consumption

4.4.1 Baseline values

First, it is important to know how high the initial greenhouse gas (GHG) emissions related to livestock food consumption per capita are. Blonk et al. (2008) calculated the amount of GHG emission per kg livestock food product in the Netherlands. These values are multiplied by the consumption of livestock food products per capita, to obtain the baseline GHG emissions related to livestock food consumption per capita. For reasons of simplicity, it is assumed that the GHG emission is equal for all products within a specific livestock food category. Only for beef, a distinction has been made between meat originating from meat cattle and from dairy cattle. The baseline values of the GHG emissions related to the livestock food consumption per capita is shown in figure 8. As expected causes the consumption of beef the highest emission of greenhouse gasses, followed by respectively pork and cheese. Remarkable is the large difference in GHG emissions between the consumption of beef and poultry. The consumed quantity of poultry is slightly higher than the consumption of beef, but the related GHG emissions are more than two third lower than those of beef.

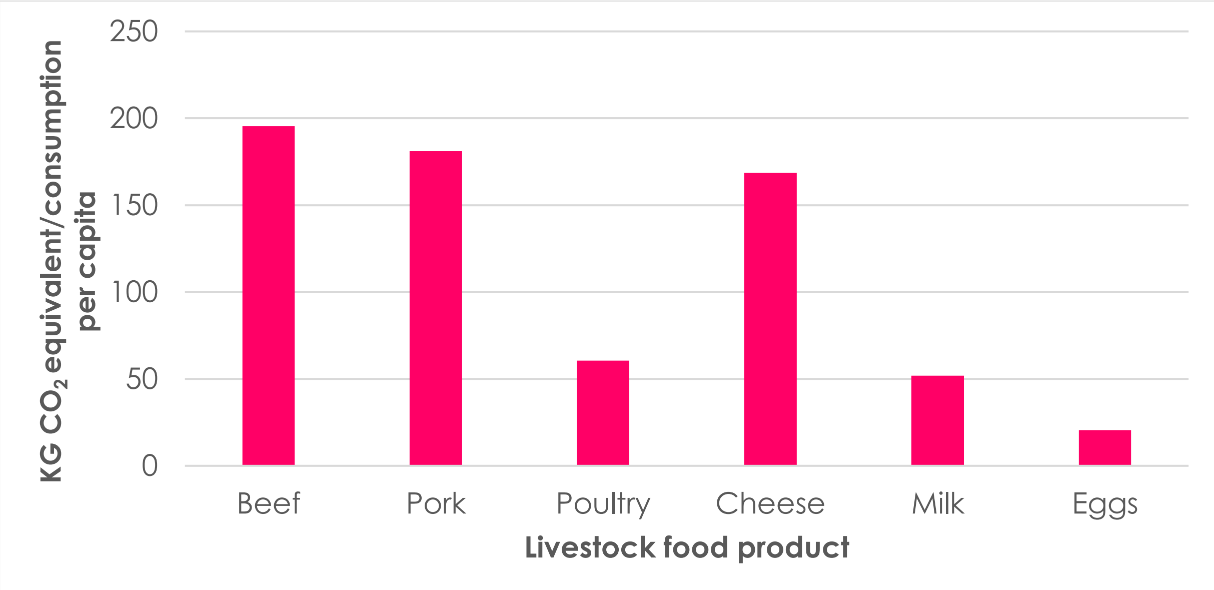

Figure 8: greenhouse gas emissions in CO_2-equivalents related to the livestock food consumption per capita

4.4.2 Change in GHG emissions after implementing a consumption tax

Several tax scenarios are introduced in paragraph 4.3, ranging from a small VAT-increase to a tax based on high social costs of carbon. The effect of these tax scenarios on the GHG emissions related to the livestock food consumption per capita, will be calculated in this part. This is done for each tax scenario by multiplying the new consumption values by the GHG emission per kg livestock food product. The values of these GHG emissions are based on Blonk et al. (2008). Figure 9 shows for each tax scenario the GHG emissions related to the consumption per capita of each livestock food product. The total percentage change in GHG emissions related to livestock food consumption per capita is depicted in figure 10.

The results are no surprise, knowing the new consumption values. In the first run, the consumed values hardly changed as a reaction on the several tax scenarios. As a consequence, the related GHG emissions will not substantially change either. The reduction in GHG emissions ranges from 1.0% to 2.8% in the first four tax scenarios. Only in the fifth tax scenario (VAT increase to 21%) is a significant reduction in the GHG emissions of 5.2% realised.

However, looking at the results of the tax scenarios in the second run provides a different picture. The same tax scenarios are used, but the calculations are now done using other values for the own- and cross-price elasticities. As discussed in paragraph 4.3.2, the consumed values now react much stronger to the several tax scenarios. This is also reflected in the change of the related GHG emissions. The reduction in GHG emissions ranges from 5.6% in the fourth tax scenario (VAT increase to 9%) to 27.8% in the fifth tax scenario (VAT increase to 21%). The reduction in GHG emissions is directly related to the height of the tax. The higher the tax, the stronger the decrease in consumption and the higher the reduction in GHG emissions will be. Moreover, the height of the tax is coupled to the amount of GHG emissions in the first three tax scenarios. Consequently, the food products with the highest amount of GHG emissions show the largest reduction in GHG emissions. The largest reduction (in absolute value) of GHG emissions come from beef, cheese and pork.

4.4.3. Total change

The total GHG emissions related to the consumption of livestock food products (beef, pork, poultry, cheese, milk and eggs) is estimated at 11.6 megaton in CO_2-equivalents in the baseline situation. This is estimated by multiplying the GHG emissions related to the per capita livestock food consumption by the total number of inhabitants in the Netherlands (2017). Valk et al. (2015) stated that the total Dutch food consumption is responsible for an annual emission of 35 megaton in CO_2-equivalents. This is mainly caused by the consumption of meat (34,3%), followed by the dairy consumption (20%) (Valk et al. 2015). The own estimated share is lower (33%), however, only six livestock food products are included in these calculations. The estimated reduction in GHG emissions is the smallest in the case of tax scenario 4 (1.0%) and the largest in the case of tax scenario 5.2 (27.8%). In the latter case, a total reduction in GHG emissions of 3.22 megaton in CO_2-equivalents could be realised. This means that the total annual GHG emission of Dutch food consumption decreases by 9.2%.

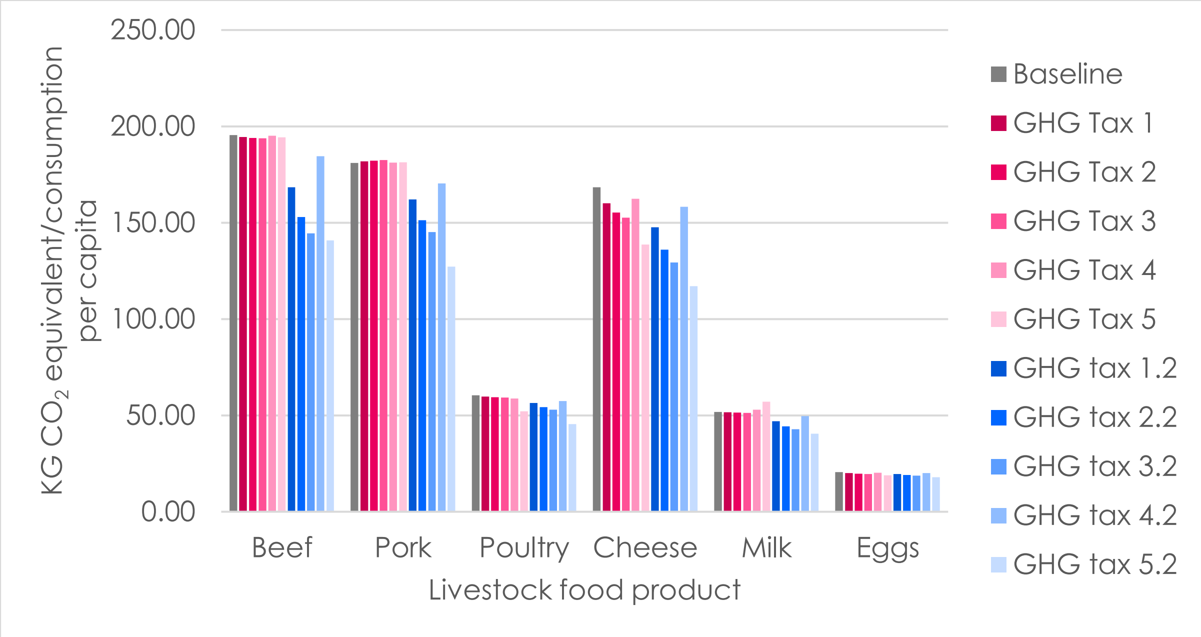

Figure 9: greenhouse gas emissions in CO_2-equivalents related to the livestock food consumption per capita – for each tax scenario

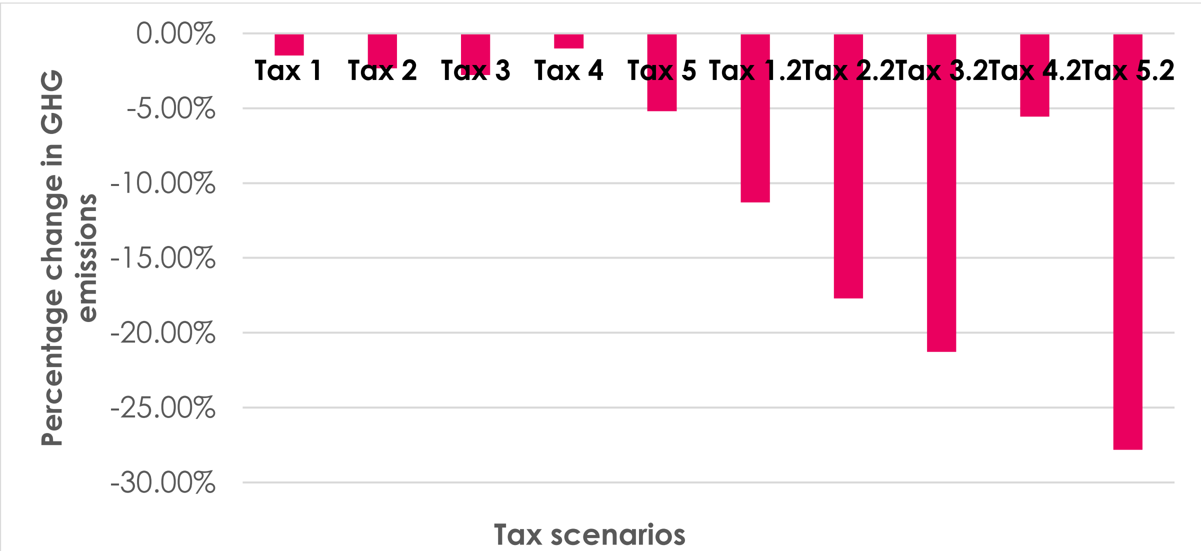

Figure 10: Percentage change in total GHG emissions related to livestock food consumption per capita – for each tax scenario

Chapter 5: Discussion and conclusion

The objective of this research was to explore the effect of implementing a consumption tax on livestock food products for reducing the emission of greenhouse gasses related to livestock food consumption in the Netherlands. This research calculated the impact of introducing such a tax on the consumption of six different livestock food products (beef, pork, poultry, cheese, milk and eggs). Five different tax scenarios were introduced. The first three scenarios are based on the social costs of carbon, ranging from €0.06 to €0.113, while the last two scenarios imply a 'greening' of the current VAT. The effect of these tax scenarios on the livestock food consumption is calculated in two runs. The own estimated own- and cross-price elasticities are used in the first run, while the second run is based on average own- and cross-price elasticities obtained from the literature.

The effects on demand is calculated by estimating an Almost Ideal Demand System for seven food products (beef, pork, poultry, cheese, milk, eggs and other food products) based on aggregate time series data from 2000 to 2017. The own estimated price elasticities are subsequently compared with values found in the literature. All six livestock food products appeared to have an inelastic and negative own-price elasticity. The own estimated own-price elasticity of beef, pork and eggs was much smaller than the values found in the literature.

The effect of the several tax scenarios on the consumed values depends much on the absolute value of the price elasticities. In the first run (using the own estimated, more inelastic, price-elasticities) is the change in consumed quantities low after introducing a consumption tax. Especially the consumption of beef and pork changes hardly, which could be expected given the very low estimated price elasticities of these products. As a consequence, the potential reduction in GHG emissions is also low, ranging from 1% to 5.2%. However, little behaviour change does also mean a high tax revenue for the government, which could be used to promote a more sustainable diet in other ways. Information campaigns could for example change preferences of consumers, which could boost the effect of a consumption tax.

The second run shows a somewhat different picture. The calculations are now done using average values of price elasticities found in the literature. The absolute values of these price elasticities are higher than in the first run, but the livestock food products are still price inelastic. The change in consumption is higher than in the first run and a significant reduction in the consumption is possible. The reduction in the consumption of beef, which is the most polluting food product in the demand model, ranges for example from 5.59% in the lowest tax scenario to 27.96% in the highest tax scenario. A significant reduction in the GHG emissions is possible and ranges between 5.6 and 27.8 percent. The highest percentage emission reduction per 1 percent price change is obtained in scenario 1, 2 and 3, where the tax level depends on the rate of GHG emissions. A differentiated tax level could, therefore, be regarded as more efficient than a uniform tax level on all livestock food products.

Before some concluding remarks will be postulated, it is important to address first some limitations of this study. First, due to data availability the demand system is estimated using macro-level data with only 17 observations. More observations and micro-data instead of macro-level data could possibly lead to more accurate estimation results. Second, a partial equilibrium demand model is used, in which only six livestock food products are included. This model could be extended by including other food products that could also be a good alternative for livestock food products, such as vegetables, nuts and meat substitutes. Third, the GHG emissions per kg livestock food product on which the first three tax scenarios are based, are average values and specific for the Dutch situation. It is possible that for example imported meat products are more polluting. However, this is not taken into account, given the large monitoring costs. Fourth, the first three tax scenarios are based on three different levels of the social costs of carbon that are found in the literature. However, no consensus exists in the literature about the right level. It is possible that a higher social costs of carbon (so a higher tax level) should be used in the calculations. However, the right level is in the end upon the politicians to decide. Fifth, only primary livestock food products are taxed in this study, but there are many food products in which meat or another livestock food product is processed. These food products are not taken into consideration for reasons of simplicity. Moreover, taxing such food products will probably involve high monitoring and administrative costs. Sixth, the effectiveness of a consumption tax based on the level of GHG emissions could be improved by subsidising food products with a low carbon footprint, such as local vegetables and meat substitutes. This will cause an even larger increase in the relative price of livestock food products.

To conclude. The consumption of livestock food products has increased significantly in the Netherlands since the Second World War. However, this comes not without a cost, since it contributes significantly to climate change and other environmental problems. The government could internalise these social costs in the price of these products, by implementing a consumption tax. The results of this study show that the demand of livestock food products is price inelastic and negative. Implementing a consumption tax on livestock food products could cause a decrease in the related greenhouse gas emissions. However, the size of this reduction will depend much on the chosen tax level and on the exact level of the price elasticities. The level of the tax is in the end a political choice, while the exact value of the price elasticities can only be known when a consumption tax will actually be implemented.

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Annexes

Annex 1: Recalculation data on livestock food consumption

There are small differences observable between the consumed quantity of livestock food products in the used datasets. These differences are probably caused by a different calculation method for each dataset. Luckily, there are some overlap years, in which the consumed quantity is available in both datasets. These overlap years are used to calculate the average difference in consumption of each livestock food product between the used datasets. The second datasets (Terluin et al. in the case of meat products and ZuivelNl in the case of milk and cheese) are converted to the level of CBS-data, by using a recalculation factor that is based on this average difference. The missing data for milk and eggs are interpolated.

Converting consumed quantity beef						
Year	**CBS**	**Terluin et al.**	**Difference**	**% difference**	**Recalculation factor**	**Test**
2005	19.1	17.2	1.9	0.110	1.110	19.1
2006	19	17.4	1.6	0.092	1.092	19
2007	19.3	17.4	1.9	0.109	1.109	19.3
2008	19.2	17.5	1.7	0.097	1.097	19.2
2009	19.2	17.7	1.5	0.085	1.085	19.2
					1.099	Average
2010	19.22726106	17.5				
2011	18.89765088	17.2				
2012	18.67791075	17				
2013	18.56804069	16.9				
2014	18.45817062	16.8				
2015	18.2384305	16.6				
2016	18.34830056	16.7				

Converting consumed quantity pork						
Year	**CBS**	**Terluin et al.**	**Difference**	**% difference**	**Recalculation factor**	**Test**
2005	41.9	37.2	4.7	0.126344086	1.126344086	41.90
2006	41.5	37.4	4.1	0.109625668	1.109625668	41.50
2007	41.0	37.6	3.4	0.090425532	1.090425532	41.00
2008	40.7	37.8	2.9	0.076719577	1.076719577	40.70
2009	41.8	37.7	4.1	0.108753316	1.108753316	41.80
					1.102	Average
2010	41.55948607	37.7				
2011	41.55948607	37.7				
2012	41.11853661	37.3				
2013	40.89806189	37.1				
2014	40.45711243	36.7				
2015	40.34687507	36.6				
2016	40.2366377	36.5				

Linear interpolation missing consumption milk		Linear interpolation missing consumption eggs	
Year	**Consumption (kg)**	**Year**	**Consumption (kg)**
2005	50.8	2012	192
2006	49	2013	195
2007	47	2014	199
2008	45.5	2015	202
		2016	205

Converting consumed quantity poultry						
Year	**CBS**	**Terluin et al.**	**Difference**	**% difference**	**Recalculation factor**	**Test**
2005	22.2	20.7	1.5	0.072463768	1.072463768	22.2
2006	21.9	20.8	1.1	0.052884615	1.052884615	21.9
2007	22.5	21.5	1	0.046511628	1.046511628	22.5
2008	22.6	21.6	1	0.046296296	1.046296296	22.6
2009	23	22.5	0.5	0.022222222	1.022222222	23
					1.048075706	Average
2010	23.58170338	22.5				
2011	23.1624731	22.1				
2012	23.05766553	22				
2013	23.37208824	22.3				
2014	23.58170338	22.5				
2015	23.1624731	22.1				
2016	23.26728067	22.2				

Converting consumed quantity cheese						
Year	**CBS**	**ZuivelNL**	**Difference**	**% difference**	**Recalculation factor**	**Test**
2000	15.8	18.6	-2.8	-0.150537634	0.849462366	15.8
2005	17.1	19.1	-2	-0.104712042	0.895287958	17.1
					0.872375162	Average
2008	16.83684	19.3				
2009	16.57513	19				
2010	16.13894	18.5				
2011	16.74960	19.2				
2012	16.57513	19.0				
2013	17.53474	20.1				
2014	15.87723	18.2				
2015	20.23910	23.2				
2016	18.93054	21.7				

Converting consumed quantity milk						
Year	**CBS**	**ZuivelNL**	**Difference**	**% difference**	**Recalculation factor**	**Test**
2000	53	63	-10	-0.158730159	0.841269841	53
2005	50.8	56	-5.2	-0.092857143	0.907142857	50.8
					0.874206349	Average
2006						
2007						
2008	45.45873	52				
2009	44.58452	51				
2010	43.71032	50.0				
2011	42.83611	49.0				
2012	42.83611	49.0				
2013	41.61222	47.6				
2014	39.77639	45.5				
2015	43.09837	49.3				
2016	43.18579	49.4				

Annex 2: Composed consumer price index other food product

A consumer price index of the 'other food product' is used to include the price development of this product group in the demand equations model. Statistics Netherlands calculates each month the consumer price index (CPI). For this calculation is the total consumption subdivided into several categories and each category has its own weight. These weights show the share of each category in the total average consumption. For example, the weight of the category 'food and drink excluding alcohol' is 0.12, so the CPI of this category accounts for 12% of the total expenditures CPI.

The CPI of beef, pork, chicken, cheese, eggs and milk have to be removed from the total food CPI, to get the CPI for the other food products (without the livestock food products). The CPI of the six livestock food products accounts for 24.1% of the total food CPI (CBS 2018H). The CPI of the other food product is calculated by using the following formula:

(weight CPI LFP in total food CPI * CPI LFP) + ((1 – weight CPI LFP) * X) = Total food CPI

X denotes the consumer price index of the other food product. The consumer price index of livestock food products (CPI LFP) is calculated as a weighted average of the CPI of the four separate livestock food product categories. The dataset on the consumer price indexes comes from Statistics Netherlands and 2015 is taken as base year (CBS 2018J).

Jaar	Weight CPI LFP in FCPI	Weight CPI LFP in FCPI * CPI LFP	1 - Weight CPI LFP	CPI Food	CPI other food products
2000	0.273262192	21.48569662	0.726737808	79.25	79.48437903
2001	0.273262192	23.28935973	0.726737808	85.2	85.18978866
2002	0.273262192	23.88999302	0.726737808	88.24	88.54638672
2003	0.273262192	24.24473521	0.726737808	89.41	89.6681913
2004	0.273262192	23.59141817	0.726737808	86.72	86.86569096
2005	0.273262192	23.26388551	0.726737808	85.65	85.84404693
2006	0.260095962	22.03764594	0.739904038	86.91	87.67671305
2007	0.255306307	21.85373504	0.744693693	87.71	88.4340308
2008	0.268369662	25.0757412	0.731630338	92.74	92.48421677
2009	0.255238852	23.96230807	0.744761148	93.78	93.74507801
2010	0.258174056	23.82626467	0.741825944	93.78	94.29939184
2011	0.246896819	23.18630334	0.753103181	95.37	95.84834921
2012	0.245248432	23.63314038	0.754751568	97.17	97.43187396
2013	0.241165234	23.64834862	0.758834766	99.6	100.0898414
2014	0.2397789	24.07651577	0.7602211	99.49	99.19940955
2015	0.241334083	24.13340828	0.758665917	100	100
2016	0.238028432	23.60040404	0.761971568	100.81	101.32871

Annex 3: Calculation of private food expenditures per capita

The total private food expenditures per capita are calculated by using the following formula: $\frac{\frac{\text{total private food expenditure}}{\text{number of households in the Netherlands}}}{\textit{average household size}}$

Year	Total private food expenditure (CBS 2018F)	Number of households (CBS 2018I)	Average household size (CBS 2018I)	Total private food expenditures per capita
2000	18510000000	6801008	2.3	1183.328425
2001	19813000000	6866954	2.3	1254.464181
2002	20659000000	6934263	2.29	1300.988639
2003	20996000000	6995724	2.28	1316.342945
2004	21231000000	7049280	2.28	1320.963574
2005	21029000000	7090965	2.27	1306.433842
2006	22149000000	7146088	2.26	1371.441616
2007	23005000000	7190543	2.25	1421.929393
2008	24353000000	7242202	2.24	1501.183618
2009	24438000000	7312579	2.23	1498.615522
2010	25003000000	7386144	2.22	1524.829818
2011	25505000000	7443801	2.21	1550.380509
2012	26153000000	7512824	2.2	1582.324739
2013	26756000000	7569371	2.19	1614.051101
2014	26985000000	7590228	2.18	1630.839069
2015	27766000000	7665198	2.17	1669.283912
2016	28515682000	7794075	2.16	1693.812881

Annex 4: Dataset AIDS Model

	year	Pbeef	Ppork	Ppoultry	Pcheese	Pmilk	Peggs	Potherfood	Mfood	Wbeef	Wpork	Wpoultry	Wcheese	Wmilk	Weggs	Wotherfood
1	2000	91.05	109.00	87.40	97.50	66.23	71.430	79.48	1183.33	0.0698015	0.1388544	0.0694484	0.0931005	0.0227208	0.0211825	0.5848919
2	2001	97.58	125.86	96.00	102.09	74.03	71.430	85.19	1254.46	0.0699391	0.1491146	0.0763109	0.0937615	0.0230268	0.0202309	0.5676162
3	2002	98.95	116.00	96.19	105.42	79.22	71.423	88.55	1300.99	0.0696673	0.1332124	0.0746063	0.0953864	0.0235938	0.0198873	0.5836467
4	2003	94.84	114.29	97.22	106.68	80.52	96.940	89.67	1316.34	0.0652651	0.1286408	0.0680029	0.0959914	0.0229961	0.0255082	0.5935956
5	2004	90.42	110.71	94.43	102.09	77.92	81.630	86.87	1320.96	0.0632916	0.1238683	0.0634684	0.0926320	0.0232150	0.0218850	0.6116396
6	2005	90.53	107.86	93.37	99.86	77.92	71.430	85.84	1306.43	0.0624933	0.1203547	0.0631766	0.0934227	0.0231925	0.0194945	0.6178657
7	2006	94.74	113.29	91.28	100.70	77.92	71.430	87.68	1371.44	0.0625819	0.1204409	0.0586689	0.0937982	0.0215194	0.0186501	0.6243407
8	2007	94.95	110.43	89.90	98.89	75.32	71.430	88.43	1421.93	0.0609302	0.1109256	0.0572513	0.0895861	0.0190820	0.0178360	0.6443888
9	2008	96.74	112.00	91.45	116.69	90.90	76.530	92.48	1501.18	0.0586319	0.1060297	0.0558726	0.0936739	0.0211669	0.0181430	0.6464821
10	2009	97.79	118.43	91.58	113.35	92.21	76.530	93.75	1498.62	0.0593389	0.1152798	0.0577693	0.0900157	0.0210691	0.0183638	0.6381633
11	2010	83.26	106.29	91.13	122.39	83.12	81.630	94.30	1524.83	0.0496356	0.1011537	0.0537601	0.0926092	0.0182813	0.0193480	0.6652121
12	2011	90.21	116.86	93.29	129.35	87.01	81.630	95.85	1550.38	0.0521810	0.1096267	0.0537387	0.1000689	0.0184764	0.0193811	0.6465271
13	2012	94.11	109.71	95.63	120.03	92.21	86.730	97.43	1582.32	0.0525555	0.0992298	0.0555536	0.0900716	0.0191061	0.0205220	0.6629614
14	2013	90.95	105.86	98.35	123.64	98.70	96.430	100.09	1614.05	0.0498174	0.0939498	0.0604974	0.0964549	0.0196016	0.0228790	0.6567999
15	2014	92.63	98.00	99.46	128.51	103.90	93.880	99.20	1630.84	0.0498329	0.0850434	0.0590195	0.0899416	0.0194924	0.0223599	0.6743104
16	2015	100.00	100.00	100.00	100.00	100.00	100.000	100.00	1669.28	0.0520160	0.0848681	0.0631652	0.0873880	0.0199682	0.0237926	0.6688018
17	2016	99.47	101.43	104.74	96.53	98.70	105.610	101.33	1693.81	0.0511886	0.0843377	0.0648446	0.0775614	0.0193835	0.0251068	0.6775775

Annex 5: Output of AIDS model in R

```
>
> AIDSR <- data.frame(year, Pbeef, Ppork, Ppoultry, Pcheese, Pmilk, Peggs, Potherfood, Mfood, Wbeef, Wpork, Wpoultry, Wcheese, Wmilk, Weggs, Wotherfood)
>
> # AIDS Model opzetten in R:
>
> library(micEconAids) #package laden
Loading required package: lmtest
Loading required package: zoo

Attaching package: ‘zoo’

The following objects are masked from ‘package:base’:

    as.Date, as.Date.numeric

Loading required package: micEcon

If you have questions, suggestions, or comments regarding one of the 'micEcon' packages, please use a forum or 'tracker' at micEcon's R-Forge site:
https://r-forge.r-project.org/projects/micecon/
>
> priceNames <- c("Pbeef", "Ppork", "Ppoultry", "Pcheese", "Pmilk", "Peggs", "Potherfood")
> shareNames <- c("Wbeef","Wpork", "Wpoultry", "Wcheese", "Wmilk", "Weggs", "Wotherfood" )
>
> bestA0 <- aidsBestA0( priceNames, shareNames, "Mfood", data=AIDSR) # meest optimale waarde van alpha0 door het programma laten uitrekenen (in dit geval 3.125)
>
> aidsResult <- aidsEst( priceNames, shareNames, "Mfood", data=AIDSR, method="IL", alpha0=bestA0$alpha0, hom=TRUE, sym=TRUE ) #coëfficiënten schatten, Iterated Linear Least Squares Estimator (ILLE, alpha0=3.125)
>
> print(aidsResult)

Demand analysis with the Almost Ideal Demand System (AIDS)
Estimation Method: 'Iterated Linear Least Squares Estimator' (IL)
(starting with simplified Laspeyres Index, Ls)
Coefficients:
alpha_0
3.125
alpha
     Wbeef      Wpork   Wpoultry    Wcheese      Wmilk      Weggs Wotherfood
0.03025614 0.03244533 0.02132590 0.05554822 0.01148673 0.01867525 0.83026243
beta
      Wbeef       Wpork    Wpoultry     Wcheese       Wmilk       Weggs  Wotherfood
-0.07131458 -0.16391215 -0.12854881 -0.09085036 -0.02658697 -0.01601616  0.49722902
gamma
                   Pbeef         Pporky      Ppoultry      Pcheese        Pmilk        Peggs   Potherfood
Wbeef       0.0519368682  0.0005521098 -0.001243525 -0.003175384 -0.001606739 -0.002678037 -0.043785292
Wpork       0.0005521098  0.1033533608 -0.007215207 -0.012241690  0.002818600 -0.002985244 -0.084281930
Wpoultry   -0.0012435255 -0.0072152072  0.009510447 -0.038212426  0.018748623 -0.002774480  0.021186568
Wcheese    -0.0031753839 -0.0122416898 -0.038212426  0.023757396 -0.003867285 -0.005394811  0.039134199
Wmilk      -0.0016067392  0.0028186000  0.018748623 -0.003867285  0.016582986 -0.001236484 -0.031439701
Weggs      -0.0026780373 -0.0029852438 -0.002774480 -0.005394811 -0.001236484  0.021603642 -0.006534587
Wotherfood -0.0437852921 -0.0842819298  0.021186568  0.039134199 -0.031439701 -0.006534587  0.105720743
> #Elasticiteiten schatten:
>
> pMeans <- colMeans(AIDSR [ , priceNames])
> wMeans <- colMeans(AIDSR [ , shareNames])
> aidsResultElas <- aidsElas( coef(aidsResult), prices=pMeans, shares=wMeans)
> print(aidsResultElas)
```

```
Demand Elasticities (original AIDS formulas)
Expenditure Elasticities
     q_Wbeef      q_Wpork   q_Wpoultry    q_Wcheese      q_Wmilk      q_Weggs q_Wotherfood
 -0.21335765  -0.46278650  -1.07109894   0.01341958  -0.26998794   0.23210034   1.78523308

Marshallian (uncompensated) Price Elasticities
                    Pbeef        Ppork     Ppoultry     Pcheese       Pmilk        Peggs Potherfood
q_Wbeef      -0.078448228  0.068722586 -0.005928253  0.01535500 -0.01429770 -0.027575062  0.2555293
q_Wpork       0.050605711 -0.006127754 -0.046030070 -0.02560324  0.04087393 -0.004953371  0.4540213
q_Wpoultry    0.044639481 -0.014977534 -0.820778451 -0.49722665  0.32432374 -0.013994162  2.0491125
q_Wcheese    -0.003674729 -0.084697111 -0.402581102 -0.68559488 -0.03139389 -0.043957166  1.2384793
q_Wmilk      -0.037091589  0.196734874  0.911511451 -0.11211011 -0.19422711 -0.040234425 -0.4545951
q_Weggs      -0.104420038 -0.105580841 -0.123385088 -0.21474627 -0.05103121  0.047178240  0.3198849
q_Wotherfood -0.093667071 -0.171494674  0.023602470  0.01690071 -0.05808882 -0.021961565 -1.4805241

Hicksian (compensated) Price Elasticities
                    Pbeef       Pporк     Ppoultry      Pcheese       Pmilk       Peggs Potherfood
q_Wbeef      -0.090988233  0.04481485 -0.01917092 -0.004292279 -0.01876431 -0.03202508  0.1204260
q_Wpork       0.023405630 -0.05798517 -0.07475427 -0.068219453  0.03118558 -0.01460576  0.1609734
q_Wpoultry   -0.018313906 -0.13499924 -0.88725934 -0.595859990  0.30190048 -0.03633418  1.3708662
q_Wcheese    -0.002885999 -0.08319338 -0.40174818 -0.684359123 -0.03111295 -0.04367727  1.2469769
q_Wmilk      -0.052960016  0.16648145  0.89475386 -0.136972252 -0.19987926 -0.04586559 -0.6255582
q_Weggs      -0.090778439 -0.07957290 -0.10897910 -0.193373054 -0.04617223  0.05201918  0.4668565
q_Wotherfood  0.011259247  0.02854914  0.13440818  0.181295895 -0.02071530  0.01527322 -0.3500704
> 
```

Annex 6: Data gross Dutch livestock food consumption 1900 – 2016 (CBS 2018A; Terluin et al. 2017; ZuivelNl 2017)

Year	Milk (total, in kg)	Cheese (kg)	Beef and veal (kg)	Pork (kg)	Poultry (kg)	Eggs (units)
1900		5.8	16.8	22.3		
1901		5.6	17.5	22.4		
1902		5.5	17.1	21.8		
1903		4.7	15	22.4		
1904		4.8	15.8	24.4		
1905		5.7	18.7	26.7		
1906		5.6	19.2	27.2		
1907		5	18.7	20.8		
1908		4.7	17.3	23.3		
1909		4.4	17	25.7		
1910		4.8	17.4	26.8		
1911		6.3	16.4	23.9		
1912		6	15.4	26.5		
1913		5.4	16	26.7		
1914		5.5	16	17.3		
1915		3.2	18.8	20.2		
1916		3.2	17.8	20.1		
1917		4.2	18.9	21.4		
1918		5.5	19.5	16.7		
1919		5.1	11.8	11.7		
1920		5.1	13	17.5		
1921		6.5	13.8	16		
1922		4.6	17.4	22.9		
1923		6.2	15.5	24.4		
1924		4.7	14.7	20.2		
1925		4.6	14.6	23.8		
1926		5.5	17.7	25.9		
1927		4.2	18.9	28.4		
1928		5.6	20.8	28.8		
1929		5.4	19.1	22.2		
1930		5.9	17	26.4		
1931		6.2	15.1	35.7		
1932		5.5	16.3	33.4		
1933		7.2	20.2	23.8		
1934		6.9	19	25.4		
1935		6.9	18.6	21.6		
1936		7.7	16	24.7		
1937		6.9	16.2	21.3		
1938		7.5	15.4	21.2		
1939		7.6	17.2	22.2		
1940						

1941						
1942						
1943						
1944						
1945						
1946		4.9	11.8	8.7		
1947		5.7	13.1	9.4		
1948		6.6	11.7	9.4		
1949		6.8	11.7	15.2		
1950		5.2	14.1	19.2		
1951		6	15.3	18.7		
1952		5.9	15.4	16.5		
1953		6.4	15.9	18.3		
1954		6.5	17.5	18.8		
1955		6.9	18.5	20.2		
1956		7.3	18	21.3		
1957		7.3	17.6	22		
1958		8	17.8	20.8		
1959		7.9	17.8	21		
1960		7.9	18.4	23.8		
1961		8.4	19.7	22.6		
1962		8.5	22.3	23.6		
1963		8.8	23.3	22.7		
1964		8.6	18.5	22.6		
1965		8.7	18.6	26.1		
1966		8.9	20.3	26.4		
1967		9	21.2	26.5		
1968		8.3	20	27		
1969		9.3	19.5	25.7		
1970	82.2	8.3	19.7	26.5		
1971	81.2	8.7	18.9	29.3		
1972	78.7	9.2	18	28.8		
1973	76.7	9.5	18.6	27.1		
1974	75.2	10	19.9	30.1		
1975	74.3	10.3	23.2	35.3		
1976	75.3	10.5	23.7	35.5		
1977	72.2	11.2	23.7	35.3		
1978	70.4	11.6	23.4	38.3		
1979	69.4	11.7	23	40.9		
1980	67.9	12.2	22.2	39.5	8.9	190
1981	66.2	12.5	21.3	41.7	9	198
1982	65.8	12.7	20	42.4	10.3	202
1983	66.4	12.5	19.1	40.8	11	197
1984	66.3	12.9	19.5	40.3	11.9	204
1985	66.3	12.7	19.1	43.3	12.7	200
1986	65.8	13.3	16.4	42.5	13.4	193
1987	64.8	13.7	20.1	43.1	14.7	189

1988	63.2	13.5	19.3	44.5	15	190
1989	62.7	13.3	18.3	44.7	15.7	183
1990	62.6	13.6	19.4	44.9	17.2	176
1991	61.1	13.6	20.3	40.9	17.7	170
1992	60.3	14.4	19.3	42.4	18.5	172
1993	57.8	14.1	19.2	46.8	18.9	171
1994	57.6	14	20.2	43.7	20	173
1995	58.3	14.2	20.3	44.2	20.4	175
1996	57	14.5	20.4	44.5	21.4	175
1997	56.6	14.6	20.2	43	21.8	176
1998	55.2	14.3	19.7	44	21.8	178
1999	54.2	14.5	19.6	43.6	21.4	180
2000	53	15.8	19.2	43.3	21.6	180
2001	50.6	16	18.9	42.4	22.1	181
2002	50.1	16.3	19.2	42.5	22.5	184
2003	48.9	16.5	19.1	42.4	21.5	177
2004	51.2	16.7	19.5	42.3	21.9	181
2005	50.8	17.1	19.1	41.9	22.2	183
2006		17.7	19	41.5	21.9	182
2007		18	19.3	41	22.5	182
2008			19.2	40.7	22.6	182
2009			19.2	41.8	23	184
2010	50.5	18.5	17.5	37.7	22.5	
2011			17.2	37.7	22.1	
2012			17	37.3	22	
2013			16.9	37.1	22.3	
2014	45.5	18.2	16.8	36.7	22.5	
2015	49.3	23.2	16.6	36.6	22.1	
2016	49.4	21.7	16.7	36.5	22.2	

Annex 7: Data Dutch nominal prices livestock food products 1900 – 2017 (CBS 2018A)

	Pork steak (euro/kg)	Cheese (euro/kg)	Eggs (euro/1 egg)	Milk (euro/kg)	Beef steak (euro/kg)
Year	**euro**	**euro**	**euro**	**euro**	**euro**
1900	0.25	0.21	0.01	0.03	0.26
1901	0.25	0.2	0.01	0.03	0.27
1902	0.3	0.21	0.01	0.03	0.29
1903	0.29	0.2	0.01	0.03	0.31
1904	0.27	0.22	0.02	0.03	0.29
1905	0.28	0.21	0.02	0.03	0.29
1906	0.31	0.22	0.02	0.03	0.3
1907	0.34	0.21	0.02	0.03	0.31
1908	0.33	0.23	0.02	0.03	0.31
1909	0.35	0.25	0.02	0.03	0.32
1910	0.38	0.26	0.02	0.03	0.34
1911	0.36	0.29	0.02	0.04	0.35
1912	0.35	0.28	0.02	0.04	0.37
1913	0.37	0.28	0.02	0.04	0.37
1914		0.48			
1915		0.52			
1916		0.5			
1917		0.52			
1918		0.7			
1919		0.79			
1920		0.88			
1921	1.11	0.95	0.07	0.1	1.17
1922	1.01	0.78	0.05	0.08	0.99
1923	0.94	0.77	0.04	0.07	0.85
1924	0.94	0.78	0.04	0.07	0.88
1925	0.94	0.72	0.04	0.08	0.87
1926	0.84	0.72	0.04	0.07	0.81
1927	0.77	0.67	0.04	0.07	0.76
1928	0.75	0.72	0.04	0.07	0.77
1929	0.86	0.71	0.04	0.07	0.79
1930	0.84	0.64	0.03	0.06	0.84
1931	0.65	0.55	0.03	0.05	0.72

1932	0.49	0.41	0.02	0.05	0.55
1933	0.53	0.39	0.02	0.05	0.53
1934	0.53	0.35	0.02	0.05	0.62
1935	0.5	0.29	0.02	0.05	0.53
1936	0.49	0.31	0.02	0.05	0.52
1937	0.54	0.32	0.02	0.05	0.6
1938	0.57	0.34	0.02	0.05	0.62
1939	0.56	0.34	0.02	0.05	0.59
1940	0.62	0.44	0.03	0.06	0.66
1941	0.75	0.69	0.04	0.07	0.74
1942	0.82	0.77	0.05	0.08	0.73
1943	0.82	0.77	0.05	0.08	0.73
1944	0.82	0.77	0.05	0.08	0.73
1945	0.82	0.8	0.07	0.08	0.73
1946	1.06	0.87	0.1	0.08	0.91
1947	1.17	0.88	0.08	0.09	0.98
1948	1.35	1.03	0.08	0.1	0.98
1949	1.53	1.47	0.08	0.09	1.03
1950	1.7	1.46	0.08	0.09	1.65
1951	1.96	1.56	0.08	0.1	1.75
1952	2.18	1.55	0.09	0.1	1.74
1953	2.08	1.52	0.09	0.1	1.67
1954	2.19	1.51	0.08	0.11	1.71
1955	2.18	1.55	0.09	0.13	1.68
1956	2.34	1.55	0.09	0.14	1.92
1957	2.45	1.61	0.08	0.15	1.95
1958	2.49	1.47	0.08	0.16	1.78
1959	2.6	1.58	0.08	0.16	1.88
1960	2.54	1.49	0.08	0.18	1.78
1961	2.7	1.52	0.08	0.19	1.84
1962	2.67	1.53	0.07	0.19	1.79
1963	2.94	1.59	0.09	0.2	1.81
1964	3.26	1.84	0.08	0.22	2.58
1965	3.29	1.93	0.09	0.22	2.65
1966	3.42	2.14	0.08	0.23	2.68
1967	3.62	2.32	0.08	0.24	2.7
1968	3.77	2.38	0.09	0.25	2.78
1969	4.27	2.6	0.09	0.25	3.06
1970	4.52	2.68	0.08	0.29	3.12

1971	4.52	3.18	0.09	0.31	3.24
1972	4.86	3.25	0.09	0.34	3.79
1973	5.59	3.35	0.1	0.36	4.25
1974	5.29	3.55	0.1	0.39	4.1
1975	5.55	3.96	0.1	0.43	4.37
1976	6.23	4.16	0.11	0.45	4.89
1977	6.23	4.48	0.11	0.49	5.11
1978	6.31	4.74	0.1	0.5	5.32
1979	6.32	4.73	0.1	0.5	5.51
1980	6.6	5.05	0.11	0.52	5.73
1981	6.93	5.15	0.13	0.56	6.21
1982	7.46	5.44	0.11	0.6	6.78
1983	7.33	5.54	0.12	0.6	6.9
1984	7.12	5.67	0.13	0.58	6.85
1985	7.24	5.8	0.12	0.59	6.9
1986	7.23	5.79	0.11	0.6	6.92
1987	6.87	5.94	0.11	0.59	6.82
1988	6.68	6.22	0.11	0.61	6.82
1989	7.1	6.39	0.11	0.63	7.07
1990	7.51	6.43	0.11	0.62	7.42
1991	7.52	6.46	0.11	0.62	7.5
1992	7.81	6.51	0.11	0.64	7.75
1993	7.51	6.61	0.12	0.66	7.77
1994	7.4	6.6	0.12	0.65	8.94
1995	7.33	6.52	0.11	0.65	8.71
1996	7.47	6.53	0.13	0.66	8.59
1997	7.99	6.59	0.13	0.67	8.57
1998	8.06	6.83	0.11	0.69	8.56
1999	7.82	6.92	0.11	0.69	8.79
2000	7.63	7.01	0.14	0.51	8.65
2001	8.81	7.34	0.14	0.57	9.27
2002	8.12	7.58	0.14	0.61	9.4
2003	8	7.67	0.19	0.62	9.01
2004	7.75	7.34	0.16	0.6	8.59
2005	7.55	7.18	0.14	0.6	8.6
2006	7.93	7.24	0.14	0.6	9
2007	7.73	7.11	0.14	0.58	9.02
2008	7.84	8.39	0.15	0.7	9.19
2009	8.29	8.15	0.15	0.71	9.29

2010	7.44	8.8	0.16	0.64	7.91
2011	8.18	9.3	0.16	0.67	8.57
2012	7.68	8.63	0.17	0.71	8.94
2013	7.41	8.89	0.189	0.76	8.64
2014	6.86	9.24	0.184	0.8	8.8
2015	7	7.19	0.196	0.77	9.5
2016	7.1	6.94	0.207	0.76	9.45
2017	7.61	10.22	0.224	0.9	9.79

Annex 8: Data Dutch real prices livestock food products 1900 – 2017 (euro. CPI=100 in 1900) (CBS 2018A; CBS 2018B))

Year	Real price pork (euro/kg)	Real price beef (euro/kg)	Real price cheese (euro/kg)	Real price milk (euro/kg)	Real price eggs (euro/1 egg)
1900					
1901	0.2356	0.25448	0.1885	0.02828	0.00943
1902	0.2913	0.28155	0.20388	0.02913	0.00971
1903	0.2816	0.30097	0.19417	0.02913	0.00971
1904	0.2545	0.27333	0.20735	0.02828	0.01885
1905	0.2639	0.27333	0.19793	0.02828	0.01885
1906	0.2922	0.28275	0.20735	0.02828	0.01885
1907	0.316	0.2881	0.19517	0.02788	0.01859
1908	0.2984	0.28029	0.20796	0.02712	0.01808
1909	0.3208	0.29331	0.22915	0.0275	0.01833
1910	0.339	0.3033	0.23194	0.02676	0.01784
1911	0.3169	0.3081	0.25528	0.03521	0.01761
1912	0.3038	0.32118	0.24306	0.03472	0.01736
1913	0.3171	0.31705	0.23993	0.03428	0.01714
1914			0.41131		
1915			0.3901		
1916			0.3367		
1917			0.32995		
1918			0.37254		
1919			0.38631		
1920			0.38973		
1921	0.5678	0.59847	0.48593	0.05115	0.03581
1922	0.5798	0.56831	0.44776	0.04592	0.0287
1923	0.5639	0.5099	0.46191	0.04199	0.024
1924	0.5589	0.52319	0.46373	0.04162	0.02378
1925	0.5639	0.5219	0.43191	0.04799	0.024
1926	0.523	0.50436	0.44832	0.04359	0.02491
1927	0.4795	0.47323	0.41719	0.04359	0.02491
1928	0.4627	0.47502	0.44417	0.04318	0.02468
1929	0.5355	0.49191	0.44209	0.04359	0.02491
1930	0.5437	0.54369	0.41424	0.03883	0.01942
1931	0.4467	0.49485	0.37801	0.03436	0.02062
1932	0.3635	0.40801	0.30415	0.03709	0.01484

1933	0.3976	0.3976	0.29257	0.03751	0.015
1934	0.3976	0.46512	0.26257	0.03751	0.015
1935	0.3882	0.41149	0.22516	0.03882	0.01553
1936	0.3895	0.41335	0.24642	0.03975	0.0159
1937	0.4193	0.46584	0.24845	0.03882	0.01553
1938	0.4325	0.47041	0.25797	0.03794	0.01517
1939	0.4201	0.44261	0.25506	0.03751	0.015
1940	0.4055	0.43165	0.28777	0.03924	0.01962
1941	0.4281	0.42237	0.39384	0.03995	0.02283
1942	0.4357	0.38789	0.40914	0.04251	0.02657
1943	0.4209	0.37474	0.39528	0.04107	0.02567
1944	0.41	0.365	0.385	0.04	0.025
1945	0.3564	0.31725	0.34767	0.03477	0.03042
1946	0.4223	0.36255	0.34661	0.03187	0.03984
1947	0.4498	0.37678	0.33833	0.0346	0.03076
1948	0.5013	0.36391	0.38247	0.03713	0.02971
1949	0.5344	0.35976	0.51345	0.03144	0.02794
1950	0.5442	0.52817	0.46735	0.02881	0.02561
1951	0.5723	0.51095	0.45547	0.0292	0.02336
1952	0.6365	0.50803	0.45255	0.0292	0.02628
1953	0.6073	0.48759	0.4438	0.0292	0.02628
1954	0.6148	0.48007	0.42392	0.03088	0.02246
1955	0.6006	0.46281	0.427	0.03581	0.02479
1956	0.6326	0.51906	0.41903	0.03785	0.02433
1957	0.622	0.49505	0.40873	0.03808	0.02031
1958	0.6214	0.44422	0.36686	0.03993	0.01997
1959	0.6434	0.46523	0.39099	0.03959	0.0198
1960	0.6129	0.42954	0.35956	0.04344	0.01931
1961	0.6409	0.43674	0.36079	0.0451	0.01899
1962	0.6218	0.41686	0.35631	0.04425	0.0163
1963	0.6595	0.40601	0.35666	0.04486	0.02019
1964	0.6932	0.54859	0.39124	0.04678	0.01701
1965	0.6648	0.53546	0.38998	0.04445	0.01819
1966	0.6533	0.51194	0.40879	0.04394	0.01528
1967	0.6705	0.50009	0.42971	0.04445	0.01482
1968	0.6735	0.49661	0.42515	0.04466	0.01608
1969	0.7099	0.50873	0.43225	0.04156	0.01496
1970	0.7196	0.49674	0.42668	0.04617	0.01274
1971	0.6691	0.47964	0.47076	0.04589	0.01332

1972	0.6673	0.52039	0.44624	0.04668	0.01236
1973	0.7107	0.54037	0.42594	0.04577	0.01271
1974	0.6135	0.47547	0.41169	0.04523	0.0116
1975	0.5841	0.4599	0.41675	0.04525	0.01052
1976	0.6026	0.47297	0.40236	0.04352	0.01064
1977	0.5648	0.46324	0.40613	0.04442	0.00997
1978	0.5497	0.4635	0.41296	0.04356	0.00871
1979	0.5283	0.46055	0.39535	0.04179	0.00836
1980	0.5179	0.44959	0.39623	0.0408	0.00863
1981	0.5095	0.45655	0.37862	0.04117	0.00956
1982	0.5176	0.47044	0.37746	0.04163	0.00763
1983	0.4946	0.46559	0.37382	0.04049	0.0081
1984	0.4652	0.44757	0.37047	0.0379	0.00849
1985	0.4626	0.44092	0.37063	0.0377	0.00767
1986	0.4612	0.44147	0.36938	0.03828	0.00702
1987	0.4404	0.43724	0.38082	0.03783	0.00705
1988	0.4253	0.43417	0.39598	0.03883	0.007
1989	0.4471	0.44519	0.40237	0.03967	0.00693
1990	0.4615	0.45597	0.39513	0.0381	0.00676
1991	0.4449	0.44376	0.38223	0.03668	0.00651
1992	0.4456	0.44215	0.37141	0.03651	0.00628
1993	0.4198	0.43435	0.3695	0.03689	0.00671
1994	0.4026	0.48635	0.35905	0.03536	0.00653
1995	0.3918	0.46553	0.34848	0.03474	0.00588
1996	0.391	0.44964	0.34181	0.03455	0.0068
1997	0.4094	0.43913	0.33767	0.03433	0.00666
1998	0.4052	0.43035	0.34337	0.03469	0.00553
1999	0.3848	0.43254	0.34052	0.03395	0.00541
2000	0.3663	0.41529	0.33655	0.02449	0.00672
2001	0.4044	0.42552	0.33693	0.02616	0.00643
2002	0.3606	0.41748	0.33665	0.02709	0.00622
2003	0.3479	0.39179	0.33352	0.02696	0.00826
2004	0.3331	0.36916	0.31544	0.02579	0.00688
2005	0.319	0.36338	0.30338	0.02535	0.00592
2006	0.3313	0.37596	0.30244	0.02506	0.00585
2007	0.3178	0.37083	0.2923	0.02384	0.00576
2008	0.3145	0.36863	0.33654	0.02808	0.00602
2009	0.3286	0.36826	0.32307	0.02814	0.00595
2010	0.2912	0.30961	0.34445	0.02505	0.00626

2011	0.3129	0.32777	0.35569	0.02563	0.00612
2012	0.2867	0.33373	0.32216	0.0265	0.00635
2013	0.2698	0.31464	0.32374	0.02768	0.00688
2014	0.2474	0.31737	0.33324	0.02885	0.00664
2015	0.2508	0.3404	0.25763	0.02759	0.00702
2016	0.2536	0.33754	0.24788	0.02715	0.00739
2017	0.2681	0.34494	0.36009	0.03171	0.00789