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Three approaches to reduce Swedish beef consumption

Effects on greenhouse gas emissions and consumer health

This study estimated and compared the effect of three mitigation approaches on greenhouse gas emissions from Swedish beef consumption. In addition, we looked at the effect on the compliance with the recommended intake of red and processed meat. The chosen approaches were a public procurement change, a reduction of subsidies on beef and a consumer tax. The effect of public procurement change was quantified by estimating the amount of beef consumed at preschools, schools and hospitals. The subsidy approach was limited to the cattle support and the effect was quantified with the use of a supply response model, estimated with OLS regression. Finally, the effect of the tax approach was based on price elasticity estimates available in the literature. We found that a tax of 24.29 per cent would result in a 13.07 per cent decrease of greenhouse gas emissions from Swedish beef consumption, compared to 3.37 per cent with a full cattle support removal and 3.55 per cent with a full removal of beef in preschools, schools and hospitals. We concluded that all of these approaches could be valuable political tools to mitigate GHG emissions, while none of the approaches caused a consumption in line with the health recommendation.

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1 Introduction

In later years, climate change mitigation has become a central topic in the political and scientific arena. However, little attention has been payed to one of the key polluting industries, the meat industry. There are several aspects of the environmental impact of meat production. It is the source of a substantial share of the world's greenhouse gas (GHG) emissions (Gerber *et al*., 2013), has a considerable water footprint (Hoekstra & Mekonnen, 2012) and contributes to the release of nitrogen, resulting for example in dead zones in seas all over the world (Chemnitz & Becheva, 2014). We argue that there is a need for addressing this issue.

The purpose of this thesis is to estimate and compare the magnitude of the GHG emission reductions corresponding to three different mitigation approaches focused on Swedish beef consumption (public procurement change, subsidy reduction and taxation). In addition, we wish to relate the changes in beef consumption arising from these approaches to the compliance with the World Cancer Research Fund's (WCRF; last accessed 13 May 2016) recommended intake of a maximum of 300 g/week. We hope that the incorporation of a health perspective will create a multidimensional scientific foundation on which policy makers can form suitable plans of action.

We chose three approaches because we wished to widen the range of policy instruments used to decrease GHG emissions from beef consumption in the literature and compare their relative effectiveness. The approaches were chosen based on what we believed to be the most effective and feasible ones. We focused on beef as it is currently subject to public debate since it is the most emission intensive meat. Indeed, existing evidence indicates that 82 per cent of emissions from livestock production in Sweden originate in milk and beef production (Cederberg *et al*., 2009).

To study the effects of a change in public procurement, we estimated the amount of beef consumed within Swedish preschools, schools and hospitals, and analysed the effects of a mandatory reduction in consumption. For studying the effects of a reduction of subsidies, we estimated the supply response to new market conditions for beef producers and analysed the effect from a decrease in subsidies on the quantity of beef produced. Finally, we estimated the reduction in GHG emissions from introducing a tax on consumption. Taxation of meat products has been addressed in previous literature (e.g. Wirsenius *et al*., 2011; Edjabou & Smed, 2013; Säll & Gren, 2015), but not in a combined study. The supply response for beef producers has been quantified before (e.g. Rezitis & Stavropoulos, 2012; Mbaga, & Coyle, 2003; Marsh, 1994), but not in the context of GHG emission mitigation, with the method we used or applied to Swedish beef production. To our knowledge, the public procurement change approach has not been considered in the literature.

The remainder of this thesis is organised as follows. We present a background to the topic in section 2. We consider public procurement changes in section 3, we consider reducing subsidies in section 4 and we consider imposing a tax in section 5. In section 6, we compare the approaches and in section 7, we perform a sensitivity analysis. Finally, in section 8, we discuss and in section 9, we conclude.

2 Background

Massive amounts of GHG are released by the livestock industry every year. According to Gerber *et al*. (2013), approximately 14.5 per cent of total human-induced GHG emissions originate in livestock production. McMichael *et al.* (2007) estimated an even higher share, where around 17.6 per cent of total human-induced GHG emissions are released due to livestock production. Both estimates imply that emissions from the livestock industry alone are greater than those of the whole transport sector, which amounts to 14 per cent (IPCC, 2014). Beef production is the most emission intensive livestock production, compared with goat, sheep, pig and poultry meat (Revell, 2015).

According to Säll and Gren (2015), GHG emissions per kg Swedish produced, carcase weight (CW)[1] beef is around 24.29 kg CO_2 equivalents (eq.). We will consistently use this estimate in calculations throughout the thesis. This figure is limited to emissions at the farm-gate, i.e. the food industry is excluded. It is based on an estimate by Cederberg *et al*. (2009), but has been adjusted upwards by Säll and Gren to account for IPCC's recently altered global warming potential (GWP) of methane (Myhre *et al*., 2013).[2] The estimate by Cederberg *et al*. (2009) includes 15 per cent of emissions originating in milk production since beef and milk production is closely related in Sweden. In 2013, as much as 55 per cent of produced beef came from pure dairy cattle breeds (Wallman *et al*., 2013). The estimate for beef can be compared to Säll and Gren (2015)'s equivalent estimates for pig and chicken. Based on the given figures, beef production is over six times more emission intensive than pig production and almost 13 times more than chicken production.

Wirsenius *et al*. (2011) estimated that if consumers substitute chicken or pork for beef, GHG emissions per food unit would be reduced by as much as 80 per cent from a global perspective. An even more remarkable reduction would be achieved if consumers would substi-

[1] Carcase weight is the weight of the slaughtered animal including bones (see FAO, 2016 for specifics).
[2] GWP is a measure of how a specific gas affects the Earth's warming in relation to carbon dioxide, in order to make different gases comparable. The larger the GWP, the larger the effect of the gas in question (EPA, 2016).

tute beans for beef, containing an equivalent amount of protein. This substitution would result in a reduction of more than 99 per cent. However, different beans and other legumes contribute differently to the release of GHG in relation to their protein content. The amount of protein in dry beans and peas is between 20 and 25 per cent, and higher for soybeans (34 per cent). These protein levels are comparable to those of meat, which are around 20 per cent (Lagerberg Fogelberg & Carlsson-Kanyama, 2006). On average, 0.7 kg CO_2 eq. are released per kg dried legumes. This figure includes both Swedish produced and imported products, and emissions beyond the primary production level, such as packaging material (Röös, 2014). By assuming an average protein content of 22.5 per cent for legumes, we can estimate that Swedish beef cause at least 39 times higher GHG emissions than legumes per g protein.

Aside from large GHG emissions, livestock production causes a wide range of environmental and health-related issues (see e.g. Chemnitz & Becheva, 2014). For instance, the use of antibiotics increases the risk of bacteria developing resistance to it, thus endangering human lives. There are, however, also positive externalities of livestock production. For example, cattle are important in order to maintain an open landscape and a rich biodiversity (Kumm, 2011). Nevertheless, the need to reduce meat consumption from an environmental perspective has been emphasized by several researchers (e.g. Hedenus *et al*., 2014; McMichael *et al*., 2007; UNEP, 2010). In contrast, the consumption of meat is likely to increase. According to Revell (2015), it is expected that meat consumption will increase by over 60 per cent by 2050 compared to 2010. Specifically, global beef consumption is expected to increase by 45 per cent.

Hedenus *et al*. (2014) have estimated that if current consumption trends continue, GHG emissions produced by the agricultural sector will reach 13 Gt CO_2 eq. per annum by 2070. In order to meet the 2°C target with a probability above 50 per cent, yearly aggregate GHG emissions from all sectors (energy, transport, etc.) have to be kept at 13 Gt CO_2 eq. per annum or less.[3] This implies that the agricultural sector alone will reach the maximum level of GHG emissions per year. Hedenus *et al*. (2014) concluded that dietary change is essential for reaching the 2°C target, but Sweden is far behind the leading edge of this necessary change. Compared to the rest of the world, Swedish consumption of animal products is high and has increased steadily over several decades (Wallman *et al*., 2013).

As reported in the Swedish Board of Agriculture’s statistical database, Swedish total consumption of meat per person amounted to 88.1 kg in 2013. Compared with 1980, meat

[3] The 2°C target is the maximum allowed global temperature increase in order to avoid dangerous changes in climate. It was set as the desirable temperature target in the 2009 Copenhagen Accord (Randalls, 2010).

consumption has increased by around 37.7 per cent.[4] In 2013, pork was the most consumed meat (36.6 kg/capita), followed by beef (26.1 kg/capita) and lastly poultry (20.3 kg/capita). The consumption of pig has been at around the same level since 1980 while the consumption of poultry has increased by over 300 per cent. As can be seen in Fig. 1, consumption of beef has increased with 42.6 per cent during the same time period. According to data provided by OECD (2016), the world's average consumption of CW beef per capita in 2013 was around 9.3 kg. Thus, Swedes consume 180.9 per cent more beef than the rest of the world. Mathijs (2015) categorized Sweden as a high meat consumption country since Swedes' meat consumption is 12.0 per cent of the total energy intake (EI). Among the list of low meat consumption countries are Germany (2.3 per cent of EI), Norway (3.2 per cent of EI) and Belgium (3.5 per cent of EI).

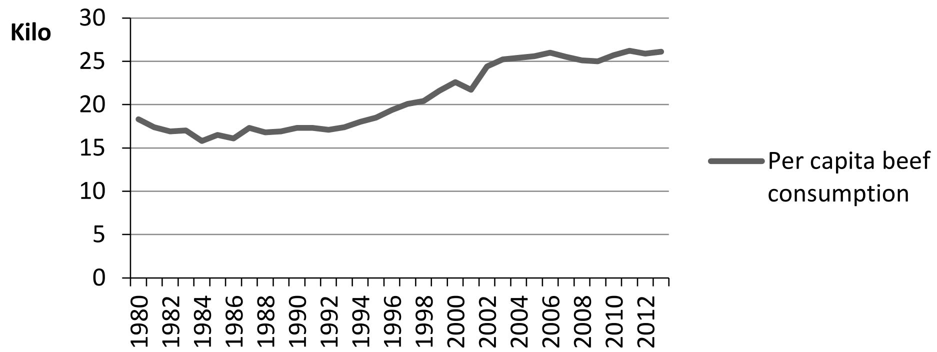

Fig. 1. Per capita beef consumption (kg carcass weight) between 1980 and 2013 in Sweden. *Source*: Swedish Board of Agriculture's statistical database.

Far from all meat consumed by Swedes are produced within the country. Based on given figures in market reports by Lindow and Lannhard Öberg (2015a-b) and Lannhard Öberg (2015), we calculated that beef had the highest import share in 2013 (55.2 per cent compared to 42.6 for poultry and 40.6 for pig meat). As Sweden imports beef primarily from European countries (Lindow and Lannhard Öberg, 2015b), we assumed that imported beef have the same emission intensities as Swedish beef (following Säll & Gren 2015). In total, around 250.4 thousand tonnes of CW beef were consumed in Sweden 2013 according to the Swedish Board of Agriculture's statistical database. We could thus calculate that Swedish beef consumption alone caused the release of ~6.1 Mt CO_2 eq. This estimation is going to be used throughout the thesis to relate the magnitude of the approaches' effects to the current emissions from Swedish beef consumption.

[4] Raw product with bones used for human consumption.

From a health perspective, Swedish meat consumption is worrisome for a number of reasons. For example, clear scientific evidence has been found for a connection between consumption of red and processed meat above 500 g/week and colorectal cancer.[5,6] This cancer type is the third most frequent in Sweden and has a deadly outcome in almost 50 per cent of the cases. Thus, the Swedish National Food Agency has issued an individual based recommendation to not eat more than 500 g/week (Bjerselius *et al*., 2014). In 2010-2011, Sweden's reported average consumption of cooked red meat and sausages was 616 g/week. However, a common problem in food surveys is under-reporting (Amcoff *et al*., 2012a). According to the Swedish National Food Agency, real average meat consumption is around 14.1 per cent higher than reported in the surveys (referenced by the Swedish Board of Agriculture, 2016c). Thus, we estimated that Swedes consume around 703 g red and processed meat per week. According to Bjerselius *et al*. (2014), this figure should be compared with the WCRF's population based recommendation of a maximum of 300 g/week. This implies that Swedes consume more than twice as much as recommended. At the same time, less than a third of the population follow the recommended intake of fish and not even a fifth reach the recommended intake of vegetables, fruit and berries (Amcoff *et al*., 2012b).

3 Public procurement change

In this section, we have analysed the effect on GHG emissions and the compliance with current dietary recommendations from introducing a public procurement change regarding the public sector's beef purchases. Public procurement is a policy instrument that refers to the public authorities' purchase of goods and services. (European Commission, 2016). This instrument is of especially high importance in a country with a large public sector. Based on data available in Eurostat, the Swedish government's consumption expenditure was 27.4 per cent of GDP in 2013. By this measure, Sweden has the third largest public sector in Europe. A public procurement change is not only of key importance as the public sector is a major consumer, but also because public authorities could possibly play a key role in changing habits, both in the short and long term, by offering low-beef dishes.

We have limited our analysis to Swedish preschools, schools and hospitals because we reason that these institutions are some of the major consumers within the public sector's food consumption. Furthermore, only pupils and patients have been included in the analysis. We

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[5] The term "red meat" includes e.g. beef, pork, sheep, game meat, goat, and reindeer (Bjerselius *et al*., 2014).
[6] The term "processed meat" includes e.g. bacon, ham, sausages, black pudding, pâté (Bjerselius *et al*., 2014).

have not taken into account school personnel and children at “fritidshem”,[7] nor have we accounted for hospital personnel and others eating at hospitals. These groups were not included because of lack of data concerning the aggregated number of meals served to these groups. Moreover, only public preschools and schools have been included since a public procurement change would only affect them. However, the same type of distinction between private and public hospitals was not possible because of the limited available data. Therefore, the effect of a public procurement change within hospitals has been estimated as if all hospitals are public. Furthermore, since there currently exists no relevant data available on the amount of beef consumed within Swedish preschools, schools and hospitals, we have contacted municipalities and hospitals personally to collect the data.

3.1 Consumption of beef in preschools and schools

We have divided the Swedish school system into two groups, denoted preschools and schools. Preschool is usually attended by children between the ages 1-5. Schools include the Swedish compulsory school, upper secondary school, schools for the intellectually challenged and special school.[8] In order to estimate the reduction in GHG emissions, we have first estimated the number of lunches served at preschools and schools in Sweden per year. We have then continued by estimating the average amount of beef per lunch, the amount of beef consumed by the children per year and finally the magnitude of the GHG emissions originating in the children’s beef consumption.

In the school year 2015/2016, there were 397,254 children in public preschools and 1,199,219 in public schools according to data collected at the Swedish National Agency for Education’s website (2016). We have estimated an absence adjustment factor of 18 per cent for preschools. This figure was estimated by comparing the number of lunches served to pre-schoolers in Olofström Municipality to the number of enrolled pre-schoolers in the municipality’s communal preschools,[9] reported in the Swedish National Agency for Education’s database. We were unable to use an average of factors estimated in this manner since no other municipality provided the necessary data. However, we conducted a sensitivity analysis for this assumption and found a fairly low sensitivity (see section 7). To estimate an absence factor for schools, we have used an estimate of the number of served meals by Delfi Foodser-

[7] ”Fritidshem” is an institution for children between the ages 6-13 to attend after school and during holidays (Swedish National Agency for Education, 2014b)

[8] Special school is attended by children that cannot attend compulsory school or compulsory school for the intellectually challenged because of their disability (Swedish National Agency for Education, 2013).

[9] Jens Stjernkvist, Dietary Strategist, Olofström Municipality (personal communication, 14 April 2016)

viceguide (2014; referenced by Swedish National Food Agency, 2015). This estimate almost exclusively contains lunch meals since few schools in Sweden offer additional meals, and account has here been taken to pupil absence. By comparing the estimate with the number of pupils enrolled (Swedish National Agency for Education, 2014a), we estimated an absence adjustment factor of approximately 13 per cent.

By Swedish law (SFS 2011:185 and SFS 2010:2039), each school year must consist of at least 178 school days in compulsory school, special school and upper secondary school, and numerous municipalities apply this length (e.g. Werner, 2010; Bredberg, 2015; Törnqvist, 2016; Ragunda Municipality, 2015). Thus, we assumed that a school year consists of 178 days. For preschools, we assumed that lunches are served 226 days per year (an average of the days reported by Nykvarn[10], Ljungby[11], Uppsala[12] and Olofström[13]). We also weighted preschool meals to 50 per cent as pre-schoolers' energy requirements are roughly half of pupils' energy requirements (Nordic Council of Ministers, 2014). Based on these assumptions, we estimated that the number of served lunches to Swedish preschools and schools were 222,520,610 in 2015.

In order to estimate the amount of beef per lunch, we sent out emails to 55 municipalities and received 24 answers, implying a non-response rate of 56 per cent. These municipalities were chosen by randomizing a list of all municipalities in Sweden, available at Statistics Sweden's website (2016b). Depending on the form of the information provided by the municipalities, different corrections were made in order to achieve comparability. If a municipality provided information which was not divided between preschools and schools, we made an approximation. This approximation was based on the number of pre-schoolers enrolled in communal preschools in the municipality of question according to the Swedish National Agency for Education's database, an absence rate of 18 per cent and a year of 226 days. Furthermore, if a municipality provided information regarding beef and pig meat together, we assumed half of the collected amount consisted of beef. Finally, we chose to trim off the highest and the two lowest observations as these observations deviated considerably from the other observations. See Table 1 for summary statistics of the amount of beef per served lunch.

[10] Jeanette Andersson, Dietary Director, Nykvarn Municipality (personal communication, 13 April 2016)
[11] Mariana Axelsson, Dietary Director, Ljungby Municipality (personal communication, 13 April 2016)
[12] Malin Holfve, Production and Purchasing Manager, *Måltidsservice*, Uppsala Municipality (personal communication, 13 April 2016)
[13] Jens Stjernkvist, Dietary Strategist, Olofström Municipality (personal communication, 14 April 2016)

Table 1
Summary statistics regarding the amount of beef per served lunch within our sample of preschools and schools.

	Mean	Std. Dev.	Min.	Max.
Beef per lunch	25.97 g	10.10	8.57 g	46.73 g

The number of lunches served in the sample was 24,199,322 and the amount of beef purchased was 628,440 kg. Thus, our survey showed that each lunch on average consisted of around 25.97 g of beef. By using our previous estimate over the number of served lunches at a national level, we calculated that Swedish pupils consumed ~5,779 tonnes of beef in 2015. We assess that this figure most closely can be assumed to be retail weight as it measures the amount of purchased raw meat. In order to transform this figure into carcase weight, we used an adjustment factor 0.7 (following the European Commission, 2015).

By assuming an emission intensity 24.29 CO_2 eq./kg CW beef (Säll & Gren, 2015), we could calculate that ~200,521 tonnes CO_2 eq. originated in Swedish pre-schoolers' and pupils' consumption of beef. If legumes, containing the same amount of protein as the beef consumed, would have been substituted for beef, the legumes would have only caused ~3,596 tonnes CO_2 eq. Thus, the net reduction is ~196,926 tonnes CO_2 eq. per year. This reduction would imply a 3.24 per cent decrease in yearly emissions from Swedish beef consumption.

As shown in the introduction, there is room for a significant reduction in beef consumption. Based solely on the data provided by the Municipality of Tierp,[14] we have calculated that the pupils consumed around 40.64 g of raw red meat and 23.31 g of processed meat per lunch. However, the data could indicate a too high consumption since account has not been taken to food waste or to purchase errors among the food suppliers. If the children would be served approximately the same amounts at home for dinner and during weekends, the weekly intake would amount to around 733 g of cooked red and processed meat.[15]

In comparison with the WCRF's recommended intake of a maximum of 300 g/week, the pupils consumed 144 per cent too much. In our estimation, meatballs, sausages and other compounded meat products have been accounted for to the full weight (following Bjerselius *et al.*, 2014).[16] Note that, compared to our sample mean (25.97 g), Tierp was a low-beef consumption municipality with only 17.21 g/lunch, which indicates that the use of specifically Tierp Municipality's data would not be cause for an overestimation. Based on the previously

[14] Maria Leopardi, Diet Adviser, Tierp Municipality (personal communication, 22 April 2016)
[15] Following Bjerselius et al. (2014), we assumed that 700 g of raw red meat translates to 500 g of cooked red meat.
[16] The full weight was not induced in the previous calculations. The cause of this discrepancy are the differing purposes. The purpose of the previous calculations was to ultimately estimate the GHG emission reduction from beef alone, while the current purpose is to provide a consumption estimate to relate to a set recommendation.

estimated average consumption of beef within the whole sample, a full removal of beef served at lunches would imply a reduction of around 93 g of cooked red and processed meat. Thus, the pupils would after the proposed procurement change still consume over twice as much as recommended on average.

3.2 Hospitals

We have focused our analysis on the 11 hospitals within *Region Västra Götaland* that uses a common patient menu. *Region Västra Götaland* is a politically controlled organisation (Nyström, 2015) operating on the west coast of Sweden. The concerned hospitals are *Sahlgrenska sjukhuset*, *Mölndals sjukhus*, *Östra sjukhuset*, *Alingsås lasarett*, *SÄS Borås*, *Skene lasarett*, *Kungälvs sjukhus*, *Norra Älvsborgs länssjukhus*, *Uddevalla sjukhus*, *Falköpings sjukhus* and *Lidköpings sjukhus* (Hammarberg, 2016).

Personal communication with *Region Västra Götaland* indicate that 3,329,539 meals (breakfast, lunch, dinner and evening snack) were served to patients at these hospitals in 2015.[17] Moreover, around 1.4 million meals were served to personnel (van Beekum, 2016). Furthermore, based on the data provided by *Region Västra Götaland*, we estimated that the amount of beef purchased by the hospitals in the same year amounted to around 82,998 tonnes. This estimation includes untreated beef to the full weight and shares of compounded products such as sausages and meatballs. The shares were chosen based on the reported beef content of equivalent products on the websites of the food producers Findus Food Services (last accessed 4 May 2016) and Scan (last accessed 4 May 2016). Included in the data of purchased beef were purchases made for breakfast at *Sahlgrenska* and *Mölndal*, but the number of served meals for breakfast at these two hospitals have not been included into the figure of served meals. We estimated that around 386,955 meals were served for breakfast at these hospitals. This estimate is based on the number of beds at these hospitals in 2011 and the region's average share of used beds, amounting to 91 per cent (McKinsey & Company, 2011).

Based on our calculations, each meal consisted of around 16.22 g of beef on average, or 64.88 g per day as four meals are served each day. Around 75,000 meals are served to patients at Swedish hospitals per day (Delfi Foodserviceguide, 2014; referenced by Swedish National Food Agency, 2015). We could therefore calculate that Swedish patients consume around 444,068 kg of raw beef every year, or 634,383 kg carcase weight, which causes the release of ~15,409 tonnes CO_2 eq. When accounting for an increased consumption of legumes of equal

[17] Linda Martinsson, Operating Manager, Hospital Food Service, Region Västra Götaland (personal communication, 28 April 2016)

protein weight, the net reduction amounts to ~15,133 tonnes CO_2 eq. This reduction would be 0.25 percent of total GHG emissions originating in Swedish beef consumption in 2013. However, these estimations are based on the assumption that the hospital food within *Region Västra Götaland* is representative for the hospital food on a national scale.

Furthermore, we calculated that the contacted hospitals purchased 111,439 kg raw red meat and 75,566 kg of processed meat in 2015. Thus, we estimated that Swedish patients on average consume 849 g of red and processed meat. See section 3.1 for specifications regarding equivalent estimations. Observe that account has not been taken to food waste. Compared to the WCRF's population recommendation, Swedish patients consume almost 3 times as much as recommended. If the hospitals would implement a full removal of beef, the weekly consumption of cooked red and processed meat would decrease by around 324 g. Thus, Swedish patients' overconsumption would decrease to around 73 per cent too much.

3.3 Combined net GHG reduction

A public procurement change causing a complete substitution of legumes for beef within Swedish preschools, schools and hospitals would result in a combined reduction in consumption of ~8,890 tonnes CW beef. The net reduction thus amounts to ~212,059 tonnes CO_2 eq. per year. Compared to GHG emissions from the Swedish population's beef consumption in 2013, the full substitution would imply a reduction of 3.49 per cent. The Swedish Environmental Protection Agency's website (2015a), reports that total consumption-based GHG emissions amounted to 104,623 thousand tonnes CO_2 eq. for 2013. We thus calculated a percentage reduction of 0.20 per cent. However, this is an overestimation. Our calculations are continuously based on an emission intensity of beef that has been adjusted upwards due to the most recent GWP of methane, but Sweden has not yet updated the national statistics accordingly (Swedish Environmental Protection Agency, 2015b). The equivalent figures for a 75 per cent, 50 per cent and 25 per cent substitution are given in Table 2.

Table 2
Net reduction in tonnes CO_2 eq., as a percentage of total GHG emissions due to Swedish beef consumption and as a percentage of total consumption-based GHG emissions in 2013 for four scenarios (100 per cent, 75 per cent, 50 per cent and 25 per cent substitution of legumes for beef).

	100%	75%	50%	25%
Net reduction	212,059	159,044	106,029	53,015
% of beef consumption	3.49%	2.61%	1.74%	0.87%
% of total consumption	0.20%	0.15%	0.10%	0.05%

4 Subsidy reduction

The intention of this section was to investigate how a reduction of current subsidies on beef production affects the quantity supplied of beef. Thus, we could estimate the effect on GHG emissions and the consumption of red and processed meat. To achieve this objective, a supply response model has been specified. By changing the expected price in the model, equivalent to a specific reduction in subsidies, we estimated how the amount of beef and GHG emissions would change. However, the effects on the quantity of beef from milk cows were not included in the scope of this thesis. The reason is the possible differences in key explanatory variables between milk and beef production.

Price-based policy instruments like subsidies are commonly used worldwide for various reasons. A sector in Sweden that receives large amounts of subsidies is the agricultural sector. However, the agricultural subsidies system in Sweden is currently undergoing extensive change. This year, 2016, farmers can apply for 13 different subsidies. Seven of these subsidies are part of the Swedish rural development programme. The other six subsidies are single farm payments, greening payments, cattle support, support to young farmers, pig castration compensation and national support (Swedish Board of Agriculture, 2016a). The first four of these supports make up the direct support scheme and are solely financed by the EU. Other supports are typically jointly financed by the EU and the Swedish government (County Administrative Board of Stockholm, last accessed 3 May 2016). Nevertheless, Sweden indirectly finances the support schemes as Sweden is a major net contributor to the EU budget. Based on data available at the European Commission's website (last accessed 13 May 2016), we calculated that Sweden got back less than 40 per cent of the money payed to the EU in 2014.

In this thesis, we have solely focused on the cattle support because it is difficult to disentangle other subsidies. The cattle support is a new production-based subsidy implemented in 2015 (Swedish Board of Agriculture *et al*., 2014). The implementation of this support was based on the EU's decision to grant member states the opportunity to use up to 8-13 per cent of the single farm payments as specific animal or area supports. Sweden chose to reduce the single farm payments by the maximum level of 13 per cent and to use the whole amount solely for financing the cattle support (Ministry for Rural Affairs, 2014). Thus, Sweden has made a decision to support the cattle industry specifically, on the expense of other farmers. The Ministry of Rural Affairs (2014) motivated the introduction of the cattle support with the cattle industry's importance for the open landscape and rich biodiversity. The Ministry also argued that other countries in the EU use animal supports, thus Sweden would need a directed support in order to create equal competition conditions.

The level of the cattle support per year is expected to be 800 SEK per cattle above the age of 1 year (Swedish Board of Agriculture *et al*., 2014). Because calves are not entitled to the cattle support and cows mainly are used in milk production, which is assumed to be unaffected, both calves and cows have been excluded from the analysis. Thus, we have investigated how the produced quantities of bulls, steers and heifers would be affected by the subsidy removal. This is a simplification we have made to keep our estimate as conservative as possible. However, both calve and cow production would probably be affected since suckler cows and breeding cows are used at beef farms.

In order to estimate the equivalent expected price decrease to a removal of the cattle support, we have first used data provided in the Swedish Board of Agriculture's statistical database to estimate the beef farms' sales income. The data concerned the quantity of slaughtered bulls, steers and heifers, the average slaughter weight of these cattle as well as the average output prices in 2015. In constructing the average output prices, we have used the price of young male cattle for both steers and bulls, while the price of cows was used for heifers. Because the prices vary both over time and between different beef qualities, the sales income could be either over- or underestimated.

By our calculations, Swedish beef producers receive around 10,938 SEK for the typical bull, steer and heifer. The cattle support received during the lifetime of the same average cattle is 1,200 SEK.[18] Thus, when evaluating the effect of a removal of the cattle support, we have changed the expected price in our model by 10.97 per cent. Assumptions underlying our analysis were that all Swedish beef producers are price takers and that the removal of the cattle support would be equivalent to a decrease in expected price. However, it could be possible that beef producers in fact assess these two types of income differently. Thus, an equal monetary change in price or subsidy could lead to different responses by the producers, which would reduce the validity of our results.

4.1 Supply response model

We have based the supply response model on the assumption that each producer aims to maximise their own profit. Such assumption is also used in similar studies (see e.g. Marsh, 1994; Rezitis & Stavropoulos, 2010). We have assumed that the j^{th} farmer's profit function consists of sales income, costs of production and subsidies (*S*). Sales income is the product of the current price of beef (*PB*) and the quantity beef supplied (*QB*). In order to identify the key

[18] Based on the median life length for bulls, steers and heifers estimated in section 4.2.

production costs, we have used statistics from the Swedish Board of Agriculture (2016b) regarding costs for Swedish meat producers.[19] The three largest costs in 2014, beside general expenses in agriculture, were (1) animal feeding stuff (*PAF*), (2) cost of fuels and lubricants (*FAL*) and (3) machinery and equipment (*MAE*). In the subsequent analysis, the variable *MAE* have been used as a measurement for the cost of real capital. We have not accounted for the costs of labour for lack of data. However, we do not consider this an issue since the costs for hired labour among meat producers make up a small share of total costs, around 6 per cent (Swedish Board of Agriculture, 2016b). Thus, the following profit function was constructed for the jth beef producer:

$$\Pi_j = PB * QB_j - C_j(PAF, FAL, MAE, QB_j) + S_j \qquad (1)$$

When producers make decisions about the number of cattle to feed, they do so without knowing what the price of beef will be when the animal is slaughtered. Therefore, we include expected price of beef (*EPB*) and the expected prices of the input goods (*EPAF*, *EFAL*, *EMAE*) when deriving the individual short run supply function instead of the current prices:

$$QB_j^s = f(EPB, EPAF, EFAL, EMAE, S_j) \qquad (2)$$

Aggregating the individual supply functions yields the short run supply function for all Swedish beef producers:

$$QB^S = f(EPB, EPAF, EFAL, EMAE, S) \qquad (3)$$

In order to estimate the supply response model, we have used OLS regression. In the regression, we have included the lagged price of milk (*EPM*) as a control variable. Our motivation for including this variable was that when e.g. a milk producer tries to breed more female cattle as a response to a higher expected price of milk they will, by the laws of nature, also breed male ones. Thus, if the expected price of milk changes and the milk producer alters the number of cattle to breed, the supply of young males will be affected. Thereby, the quantity of slaughtered bulls and steers in the future will possibly be affected as well.

[19] Meat producers in Sweden with standardized revenues between 15,000 and 99,999 euro annually are included.

In addition to the previously discussed variables, monthly dummies (*MD*) are included in order to account for seasonality. All the variables except the monthly dummies were transformed by taking the natural logarithm. The reason for this transformation was the improved interpretation and because no strong assumption about a linear relationship between the dependent and independent variables could be assumed (see Thomas, 1997). When testing for non-stationarity with the use of the Augmented Dickey-Fuller unit-root test, results showed that several variables were non-stationary (see Appendix C. Non-stationarity). In order to obtain stationary variables, the first difference was taken, as proposed by several econometric textbooks (Thomas, 1997, page 378; Burke & Hunter, 2005, page 22; Enders, 2003, page 173). No trend variable has been included since the constant will capture if the first differenced, dependent variable follows a trend (Enders, 2003, page 158). Therefore, the econometric specification was:

$$\Delta \log(QB_t) = \alpha + \beta_1 \Delta\log(EPB_t) + \beta_2 \Delta\log(EPAF_t) + \beta_3 \Delta\log(EFAL_t) + \beta_4 \Delta\log(EMAE_t) + \beta_5 \Delta\log(EPM_t) + \sum_{i=2}^{12} \beta_{4+i} \mathrm{MD_i} + \varepsilon_t \qquad (4)$$

We have also tested for autocorrelation by using the Durbin-Watson d-statistic (Durbin & Watson, 1950; 1951; 1971) and the Breusch-Godfrey test for higher-order serial correlation (Godfrey, 1978; Breusch, 1978). Both tests indicated that the error terms were serially correlated (see Appendix D. Serial correlation). To account for this serial correlation, we have used the Newey-West standard errors (Newey & West, 1987) with the maximum lag set to 24. The serial correlation could be due to persistent habits among the producers or to contracts forcing producers to act in a specific way. We assessed that this maximum lag of 24 periods could be a reasonable time frame for these effects to diminish substantially or disappear completely.

4.2 Price expectations

Previous studies have found that price expectations are heterogeneous among meat producers (Chavas, 2000; Marsh, 1994). This makes it difficult to obtain a reliable model of the expected price when using industry accumulated data. Chavas (2000), investigated how price expectations best could be modelled for the US beef market. He found evidence that the proportion of producers who use naive expectations, i.e. expects that the last observed price in the market will be the price in the future, accounted for 46.7 per cent and that 35 per cent of producers use quasi-rational expectations. In this thesis, we have decided to use naive expectations because we assess that this approach is satisfactory for making a rough estimation of the true supply response model.

In order to find at which point in time beef producers make their decision to breed another cattle and thus what price the naive price expectations are based on, we have used the median life length of cattle slaughtered after their first life year at beef farms. Based on data provided by Nyemad (2012) regarding bull and heifer calves born at beef farms in 2008, we have calculated the median life length to 711.5 days.[20] This figure excludes slaughtered calves and cattle deceased from other causes. In addition to the expected life length, the gestation period for a cow is 280 days (Sjaastad *et al*., 2010, page 706). Thus, cattle purposed for slaughter at a grown age at beef farms are bred approximately 991.5 days, or 33 months, prior to the time of their slaughter. However, it is unrealistic to assume that farmers decide to breed at the exact time of breeding. In order to account for the farmers' need for planning, we have assessed it reasonable to assume that farmers decide to breed around three months prior to the actual breeding process, i.e. three years before the time of slaughter. Hence, the expected prices are defined as the prices 36 months prior to time period *t*:

$$EPB_t = PB_{t-36} \tag{5}$$

$$EPAF_t = PAF_{t-36} \tag{6}$$

$$EFAL_t = FAL_{t-36} \tag{7}$$

$$EMAE_t = MAE_{t-36} \tag{8}$$

$$EPM_t = PM_{t-36} \tag{9}$$

4.3 Estimation of the GHG reduction and health effects

In our regression, we used monthly data from the Swedish Board of Agriculture's statistical database for the period January 2000 until December 2014 (see Appendix B. Data). Because lagged values for some variables were used and the regression was first differenced, the number of observations was 143. The results show that, in line with economic theory, the coefficient for the price expectation of beef is statistically significant, positive and equal to 0.886. This result implies that a 1 per cent increase in expected price causes approximately a 0.886 per cent increase in short run produced quantity. None of the other price variables or the constant were significant. See Table 3 for the coefficients and Newey-West standard errors for the explanatory variables, and Table F1 in the appendix for the monthly dummies.

[20] We use the median and not the mean because there existed cattle that was born in 2008 which, in June 2011 when Nyemad (2012) gathered the data, still was alive.

Table 3
Estimated coefficients and Newey-West standard errors for the constant and the following transformed variables: expected price of beef (EPB), expected price of animal feed (EPAF), expected price of fuel and lubricants (EFAL), expected price of machinery and equipment (EMAE) as well as expected price of milk (EPM). Depended variable in the regression is a transformation of the slaughtered quantity of bull, steer and heifer (QB).

Variables	Δ log(QB)
Δ log(EPB)	0.886 ** (0.416)
Δ log(EPAF)	-0.195 (0.916)
Δ log(EFAL)	0.241 (0.500)
Δ log(EMAE)	5.160 (4.164)
Δ log(EPM)	1.099 (0.900)
Constant	-0.075 (0.111)

Note: * Significance at 10% level, ** Significance at 5% level and *** Significance at 1% level.
Newey-West standard errors in bracket. Maximum lags of 24 are used.

The coefficient for the expected price of beef implies that if the cattle support granted to beef producers was removed while everything else was kept constant, the slaughtered quantity of bulls, steers and heifers would decrease by around 9.79 per cent in the short run. By using the quantity of beef in 2015, the removal of the cattle support would cause a reduction in production of ~8,442 tonnes CW beef (see Appendix E. Estimated change in output). For simplicity, we have assumed that the net import would be unaffected by the reduced domestic production, which means that the reduction in production equals the reduction in consumption. This assumption is not realistic but necessary for us in order to perform the comparison between the approaches. Furthermore, we have not taken into account the effect from a potential increase in consumption of other food products when the consumption of beef decreases. Based on these assumptions, we calculated a decrease in GHG emissions of 205,064 tonnes CO_2 eq. As a percentage of our estimate for GHG emissions from Swedish beef consumption in 2013, this reduction would amount to 3.37 per cent. Of total Swedish consumption, the equivalent figure would be 0.20 per cent.[21]

The reduction in consumption of ~8,442 tonnes CW beef could be transformed into cooked weight with the use of the adjustment factor of 0.7 and the relationship between raw and cooked beef of 700 g to 500 g. By relating the reduction in consumption of cooked beef to

[21] The estimate of 0.20 per cent is an overestimation. As previously discussed, our calculations are based on the most recent GWP of methane, while Sweden has not yet adjusted the national statistics.

the size of the Swedish population in 2015 (Statistic Sweden's statistical database) we could estimate that a full removal of the cattle support would decrease the average weekly intake of cooked red and processed meat by around 8 g, to 695 g. In relation to the WRCF's recommendation, the Swedish population would still consume on average as much as 132 per cent too much.

5 Taxation

In this section, we have estimated the reduction in GHG emissions from imposing a tax on beef of the size necessary to fully incorporate the total social costs of beef related to GHG. Furthermore, we have analysed the effect of such a tax on the consumption of red and processed meat, in relation to the WCRF's current recommendation.

From a basic theoretical point of view, the introduction of taxes decreases the efficiency of the market because it creates a gap between buyers and sellers (Pihl, 2014, page 111). Environmental taxes differ in the sense that efficiency increases when imposed on a market suffering from negative externalities (*ibid*, page 117). If producers only take account for their private costs, and not the total social costs, the quantity supplied by the market in equilibrium would not be optimal. This market failure implies a lower than fully maximized welfare level as it creates a deadweight loss (Perloff, 2014, page 622-623). However, regulators can aid the process of reaching the social optimum by imposing a tax (*ibid*, page 629).

A tax aimed at reducing emissions can be designed in primarily two ways: a tax directly on the emissions or a tax on outputs (or inputs) related to the emissions (Wirsenius *et al*., 2011). Based on certain criteria, developed by Schmutzler and Goulder (1997), Wirsenius *et al*. assessed it optimal to impose output taxes in the case of GHG emissions from food production. In economic theory, a constant, specific output tax maximizes welfare when it equals the marginal damage of the emissions at the social optimum quantity. This would result in an internalization of the costs of the emissions at the social optimum (Perloff, 2014, page 629).

Furthermore, there is a choice between levying the tax on the producer or the consumer. Wirsenius *et al*. (2011) as well as Säll and Gren (2015) argued that a consumer tax is preferable to a producer tax, with the motivation that this would lead to a reduced risk for emission leakage. A tax at the producer level would result in a reduced Swedish beef production, but as Sweden is a small open country, Swedish consumers could maintain their high consumption by increasing the import share. Thus, the release of emissions would decrease in Sweden, but increase in other parts of the world. Conclusively, the net effect of a producer tax might even be zero. This aspect was not accounted for in the subsidy section since the assumption that import remains constant was necessary for us in order to make the approaches comparable.

Säll and Gren (2015) have estimated that a consumer tax on beef of 24.29 per cent is necessary in order for the costs of the damages caused by GHG emissions to be incorporated into the price. In Säll and Gren (2015)'s estimate, they have assumed a damage cost of 1 SEK/kg CO_2 eq., which is based on the revealed preference by politicians in Sweden. There is, however, high uncertainties regarding the costs of GHG emissions and there is a wide range of costs in use. For example, Säll and Gren (2015) have calculated that the cost used by Wirsenius *et al*. (2011) translates to 0.55 SEK per kg CO_2 eq., while the maximum cost reported by Stern (2006) translates to 2.8 SEK.

In order to estimate the reduction in GHG emissions from imposing a tax of the specified magnitude, we have used the final uncompensated, Marshallian elasticity of demand for beef, -0.538, estimated by Säll and Gren (2015). This estimation was used since it, to our knowledge, was the most recent price elasticity for the Swedish beef market. It was based on data from the Swedish Board of Agriculture's statistical database from the years 1980 to 2012. The model used to perform the calculations was the non-linear almost ideal demand system (AIDS) model, developed by Deaton and Muellbauer (1980). In the following calculations, we have not taken into account the effect a tax on beef will have on consumption of other food products.

We have calculated that a tax of 24.29 per cent would imply a reduction in demand of ~32,802 tonnes CW beef and a decrease in emissions of ~794,825 tonnes CO_2 eq.[22] Thus, GHG emissions released by Swedish beef consumption would decrease by around 13.07 per cent and emissions from total Swedish consumption would decrease by around 0.76 per cent.[23] The introduction of a tax of the discussed magnitude could also affect the overall health of the population. By using the same methodology as described in section 4.3, we estimated a decrease in the average weekly intake of red and processed meat amounting to around 32 g. The Swedish population's general over consumption would thus be decreased to 124 per cent too much, compared with the WCRF's recommendation.

[22] Calculated by the use of: $\varepsilon \frac{\Delta P}{P} Q = \Delta Q$, where ε is the price elasticity of demand, P is the price of beef and Q is the consumed quantity of beef.
[23] The estimate of 0.76 per cent is an overestimation. As previously discussed, our calculations are based on the most recent GWP of methane, while Sweden has not yet adjusted the national statistics.

6 Comparison

We have in this section compared the three approaches by considering (1) the magnitude of the effect on GHG emissions during full enforcement, (2) the level of enforcement needed to reach set emission reduction targets and (3) the effect on the consumption of red and processed meat. We have used the gross GHG emission reduction for all approaches in order to achieve comparability, since the effect of substitution has only been accounted for in the public procurement change.

Full enforcement implies a 100 per cent reduction in beef consumption within preschools, schools and hospitals, a 100 per cent reduction of the cattle support and a tax of 24.29 per cent. The results show that the largest effect (794,825 tonnes CO_2 eq.) is achieved with taxation. As a percentage of the GHG emissions originating in Swedish beef consumption, the tax causes a reduction of 13.07 per cent. The smallest effect was achieved when removing the cattle support, only a 3.37 per cent reduction was achieved. This implies that taxation is almost four times as effective as the subsidy approach during full enforcement. The public procurement change is only slightly more effective than the removal of cattle support, with a reduction of 3.55 per cent (see Table 4). The presented effects have been measured individually, but since the approaches are intertwined, the magnitude of the GHG emission reductions caused by the individual approaches will be affected in case of a combined implementation.

Table 4
Reduction in GHG emissions in tonnes and as a percentage of GHG emissions due to Swedish beef consumption in 2013 for three mitigation approaches.

	Public procurement	Subsidy removal	Taxation
GHG reduction (tonnes)	215,931	205,064	794,825
% of beef consumption	3.55%	3.37%	13.07%

We have also examined the level of enforcement needed to reach three set target reductions of GHG emissions from Swedish beef consumption (1 per cent, 2 per cent and 3 per cent). These targets were chosen since they are reachable with all approaches. The results show that when a target reduction is set to 1 per cent, the necessary tax amounts to mere 1.86 per cent, while beef consumption within preschools, schools and hospitals need to be reduced by 28.17 per cent and the cattle support needs to be reduced by 29.80 per cent. For the highest set target, almost a full enforcement level is required for the two latter approaches, but only a tax of 5.58 per cent is necessary for the taxation approach. See Table 5 for the required enforcement levels in order to reach all three targets.

Table 5
Necessary enforcement levels for three target reductions of GHG emissions from Swedish beef consumption.

	Public procurement	Subsidy reduction	Taxation
1 per cent	28.17%	29.80%	1.86%
2 per cent	56.33%	59.49%	3.72%
3 per cent	84.50%	89.05%	5.58%

In Table 6, we have presented the initial consumption of red and processed meat. With the use of each approach at full enforcement, the reduction levels presented below are achieved. A full removal of beef at hospitals would result in the largest per cent reduction (38.21 per cent), while a reduction of mere 1.17 per cent is achieved with a full removal of the cattle support. None of the approaches caused a reduction which would imply a consumption in line with the recommended intake of 300 g/week. If the hospitals implement a full removal of beef, the patients' consumption would decrease by 324 g to the closest level of consumption (525 g/week), but this level is still far from satisfactory. A full removal of beef at preschools and schools would cause the second largest reduction (93 g to 640 g/week). Thus, the hospitals' reduction was around 250 per cent larger than the preschools' and schools' reduction.

Table 6
Initial consumption of red and processed meat as well as the level of reduction achieved with the approaches. The procurement approach is divided into two affected groups. In the case of the subsidy and taxation approaches, the affected group is the whole Swedish population. The reduction as a percentage of the initial amount is also displayed.

	Preschools and schools	Hospitals	Subsidy reduction	Taxation
Initial (grams)	733	849	703	703
Reduction (grams)	93	324	8	32
% reduction	12.66%	38.21%	1.17%	4.54%

7 Sensitivity analysis

In the following section, we have conducted two sensitivity analyses to address the uncertainties regarding the estimations in the public procurement and subsidy approaches. A sensitivity analysis was not conducted for the tax section as this approach was largely based on Säll and Gren (2015)'s results and the key uncertainties were addressed in this paper.

7.1 Sensitivity analysis for the public procurement approach

We assumed that preschools serve lunch on an average of 226 days per year, but this assumption is surrounded by high uncertainty. As the longest applied number of days was 230 and the shortest was 220 in the sample, we have used these values in a sensitivity analysis.[24,25] Furthermore, we have done the equivalent calculations for different values of the absence adjustment factors. In the reference case, the factor was set to 13 per cent for schools and to 18 per cent for preschools. We tested for factors five percentage points above and below.

Percentage changes compared with the net GHG reduction, achieved with full enforcement in the reference case, are presented in Fig. 2, and in more detail in Table A1 in the appendix. The analysis shows that our estimations are most sensitive to the absence factor for schools. This is not a surprising result as the two other assumptions regard preschools and fewer pre-schoolers are included in the data, thus pre-schoolers affect the results less. See Table A2 in the appendix for estimations with different preschool days and adjustment factors combined with the figures for patients, in order to view the total effect on the public procurement approach. Most notably, the largest percentage reduction in net GHG emissions from Swedish beef consumption was 3.56 per cent and was achieved with an 8 per cent absence factor for schools.

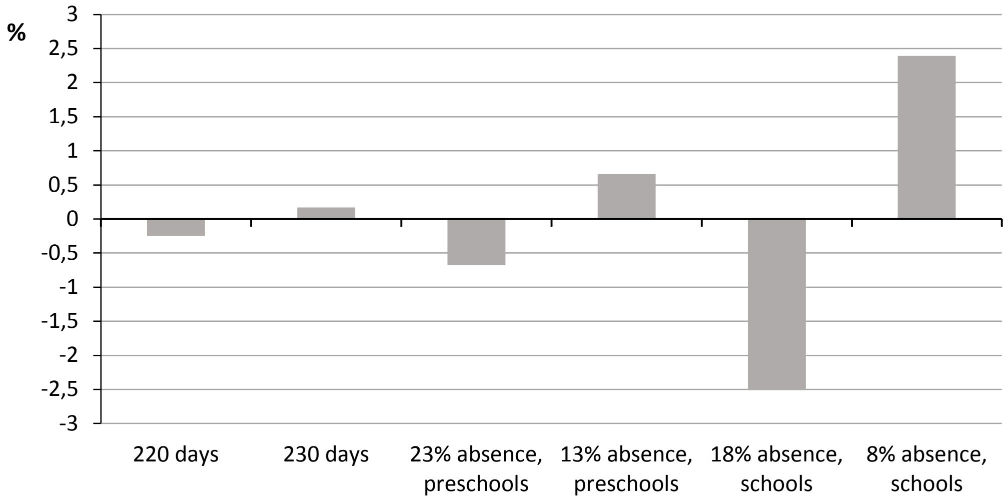

Fig. 2. Percentage change in net GHG reduction for the preschool and school section compared with the reference case when applying 220 preschool days, 230 preschool days, an absence factor of 23% for preschools, an absence factor of 13% for preschools, an absence factor of 18% for schools and an absence factor of 8% for schools, respectively.

7.2 Sensitivity analysis for the subsidy approach

Since the cattle support is a new subsidy and there was no data available regarding the magnitude of the support, we had to make an estimation. In this estimation, account has not been taken to farmers who forget to apply, unapproved applications, etc. This would imply an

[24] Malin Holfve, Production and Purchasing Manager, *Måltidsservice*, Uppsala Municipality (personal communication, 13 April 2016)
[25] Mariana Axelsson, Dietary Director, Ljungby Municipality (personal communication, 13 April 2016)

overestimation of the cattle support and thus the potential effect on GHG emissions. Furthermore, we have used a coefficient for how changes in price affect the produced quantity of beef, but the true coefficient may deviate from our estimated one. In this sensitivity analysis, we therefore tested how the results were affected when (1) the cattle support is 20 per cent less than the reference case, (2) the true coefficient for the transformed expected price of beef, β_1, is equal to the lower bound in the 95 per cent confidence interval (0.063) and (3) the true coefficient is equal to the upper bound in the confidence interval (1.709). Fig. 3 displays the percentage change in GHG reduction compared to the reference case under the three scenarios, while details can be found in Table A3 in the appendix.

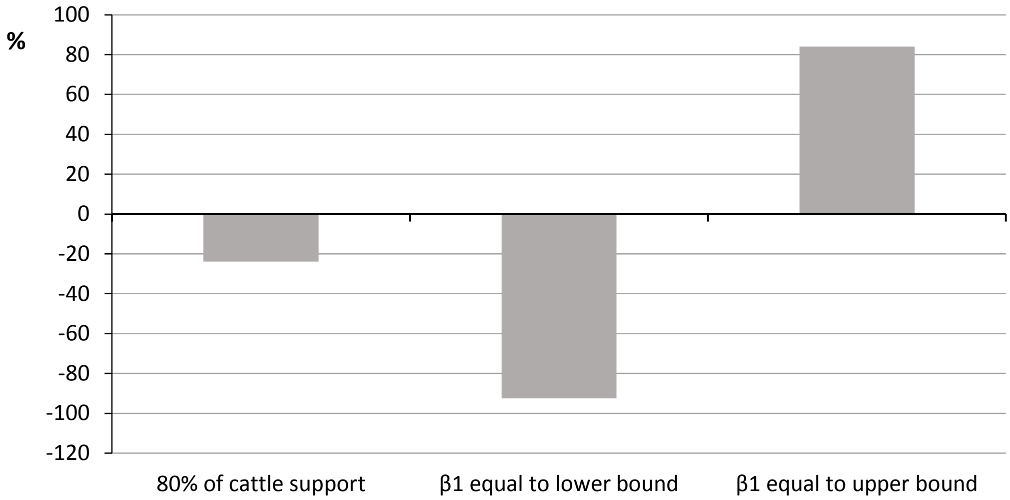

Fig. 3. Percentage change in GHG reduction from the subsidy approach compared with the reference case when applying 80% of the estimated cattle support, coefficient value of β_1 equal to the lower bound in the 95 per cent confidence interval (0.063) and coefficient value of β_1 equal to the upper bound in the confidence interval (1.709), respectively.

The analysis show a very high sensitivity to changes in both the size of the cattle support and the coefficient for the expected price of beef. However, the sensitivity was highest for the latter. When the cattle support was 80 per cent of the reference case, the magnitude of the reduction in GHG emissions decreased by 24 per cent. When the upper bound of the 95 per cent confidence interval was used as the coefficient, the GHG reduction increased by as much as 84 per cent, and when the lower bound was used, the estimation decreased by remarkable 93 per cent.

8 Discussion

The results show that the largest direct effect can be achieved by means of a tax on beef consumption. With a tax level of 24.29 per cent, i.e. the tax level necessary to incorporate the total social costs of the GHG emissions, a reduction of 13.07 per cent was achieved, compared to total GHG emissions originating in Swedish beef consumption. A full elimination of the cattle support granted to beef producers would result in a 3.37 per cent reduction, while a slightly higher reduction, 3.55 per cent, would be achieved with the full elimination of beef within Swedish preschools, schools and hospitals. This is not a surprising result as the taxation approach is a more extensive approach compared to the other two.

Furthermore, our results from the section regarding target reduction levels indicated that for low targets, like 1 per cent, a very small tax level is necessary (1.86 per cent). However, it might not be cost effective to impose such a small tax. For low target reductions, it might be preferable to use one of the two other approaches. In order to achieve the 1 per cent target, a reduction in public beef consumption of 28.17 per cent would be required, or a reduction of the cattle support of 29.80 per cent. Nevertheless, both the latter approaches quickly become insufficient for higher target reduction levels. Almost 100 per cent enforcement levels are required to reach the 3 per cent target. An enforcement level of close to 100 per cent could be in terms of feasibility reasonably difficult to implement. Therefore, a tax could be preferable for high target reductions of GHG emissions. However, high targets could possibly be reached if the procurement and subsidy approaches would have been more extensive, i.e. if additional public institutions and support schemes were included.

Even though the environmental effect is limited, actors within the public sector have other motives to decrease the consumption of beef. Our analysis show that far too much red and processed meat is consumed (144 per cent more than recommended for pupils and 183 per cent more for patients). However, food waste has not been accounted for. Nevertheless, the results indicate that there is room for significant reductions. A high per cent reduction of the consumed amount of red and processed meat is possible with the full removal of beef within hospitals (36.21 per cent) as well as in preschools and schools (12.66 per cent).

The two other approaches caused a much smaller per cent decrease (4.54 per cent for taxation and 1.17 per cent for subsidy). Although the latter effects appear to be small, the subsidy and taxation approaches affect the whole population, in contrast with the public procurement approach. Therefore, it would be unjust to compare effectiveness in this case. The subsidy and taxation approaches could improve the whole population's health prospects, although to a very limited degree, while a public procurement change could possibly significantly improve the prospects of a specific group. This group is the youngest and sickest part of the population, and that could be considered valuable.

Even so, none of the approaches was effective enough to cause such a large decrease in consumption that the average consumption was in line with current recommendations. The lowest consumption level was achieved with the full removal of beef in hospitals (525 g/week) while the second lowest was achieved with the full removal of beef in preschools and schools (640 g/week). The results show that the hospitals' reduction was around 250 per cent larger than the preschools' and schools' reduction. This large difference could possibly be explained by the fact that all the patients' meals are affected by the change, while only five of the pre-schoolers' and pupils' weekly meals are affected.

An aspect of importance for the valuation of the approaches, other than effectiveness, could be the question of fairness. A tax of the discussed design would affect all beef producers, regardless of country of origin, equally and raise the prices faced by all Swedish beef consumers. In contrast, a removal of the cattle support would only affect the Swedish producers and the considered public procurement change would only affect Swedish pupils and patients. In addition, the taxation approach could possibly reduce inefficiency on other markets by using the tax revenue to lower the tax on other areas, like the labour market, creating a double-dividend situation. The double-dividend situation refers to an environmental tax that not only improves the environment, but also reduces the welfare losses of another market (Pihl, 2014, page 117).

Not considered thus far is the cumulative effect of the approaches. A reduction of beef served at preschools and schools could possibly affect the social norms, preferences and knowledge of probably the most important group for future reductions in GHG emissions. The children's dietary habits will have a larger effect on beef consumption and thus GHG emissions than the older generations' habits, simply because they have longer future lifespan. Thus, the cumulative effect of such a procurement change might be significantly larger than indicated by our results (3.24 per cent).

A procurement change within hospitals could also be of importance for climate change mitigation even if our results indicate a small magnitude (0.25 per cent) because of the hospitals' great authority regarding the health effects of beef consumption. A dietary change at hospitals could aid in the process of shifting the Swedish population's believes regarding how a healthy diet should be composited in the direction of what is recommended by the Swedish National Food Agency. Based on current statistics regarding the compliance with these recommendations (Amcoff *et al.*, 2012b), Swedes' dietary habits are far from satisfactory. Not to be forgotten is the hospitals' responsibility for the patients' health during the time they are in the hospitals' care, which reasonably should include a healthy diet.

The effect from fully removing the cattle support (3.37 per cent) was even lower than the effect from the procurement approach. Motives for the implementation of this support, among other things, were cattle's importance for biodiversity and an open landscape (Ministry of Rural Affairs, 2014). However, the cattle support is a production-based subsidy (Swedish Board of Agriculture *et al.*, 2014), while the single farm payments is a land-based subsidy (Statistics Sweden, 2016a). The Swedish government has decreased the latter support scheme by as much as 13 per cent to create the cattle support (Ministry of Rural Affairs, 2014). This means that the Swedish government actually has removed funding from a support which promotes grazing cattle, i.e. cattle aiding in the maintenance of the Swedish landscape and biodiversity, in favour of a support that promotes any type of cattle production. Thus, the cattle support could be viewed as contra-productive, both in terms of promoting a sector with high GHG emissions, but also by cutting the advantage of land-based production.

9 Conclusion

This thesis is the first to compare the effectiveness of different approaches aimed at mitigating GHG emissions from Swedish beef consumption and consider the effect on the compliance of current dietary recommendations for red and processed meat. We have focused on three main approaches: (1) a public procurement change, (2) reducing subsidies on beef production and (3) imposing a consumer tax on beef. The public procurement change concerned children at Swedish preschools and schools in addition to patients at Swedish hospitals, while the subsidy approach was focused on the cattle support granted to beef producers. This topic is of grave importance as beef consumption is a severe environmental issue, but has received little attention by scientists and politicians. The opportunity to use taxation as a means for GHG mitigation has been considered in previous literature (Wirsenius *et al.*, 2011; Edjabou & Smed, 2013; Säll & Gren, 2015), but to our best knowledge, no comparative analysis of possible alternative approaches has been made. In their own, both the analysis of a public procurement change and a subsidy reduction aimed at reducing beef consumption are novel.

Our analysis show that the most effective and feasible approach during full enforcement and for high target reduction levels is taxation. A consumer tax of the equivalent magnitude needed to incorporate the total social costs of GHG emissions from beef, 24.29 per cent, would result in a reduction of GHG emissions from Swedish beef consumption of 13.07 per cent. The impact of a complete removal of beef in preschools, schools and hospitals would result in a reduction of 3.55 per cent, while a removal of the cattle support would only result in a reduction of 3.37 per cent when the import level is assumed to be fixed. Thus, the last two approaches quickly become inadequate in order to reach high target reduction levels.

Our results also showed a worrisome over consumption of red and processed meat, although account has not been taken to food waste. Pupils consume around 144 per cent more than recommended while patients consume as much as 183 per cent more, which is comparable to Sweden's overall consumption of 134 per cent more than recommended. We estimated the effect each approach could have on the possibilities of reaching the WCRF's recommended intake of 300 g/week. The results showed that none of the approaches caused an average consumption in line with the recommendation. The highest per cent reduction was achieved with the full removal of beef within hospitals (38.21 per cent) followed by a removal in pre-schools and schools (12.66 per cent), while the taxation and subsidy approaches only caused a reduction of 4.54 and 1.17 per cent, respectively. Thus, our results indicate that the public procurement approach could be valuable in order to improve the health prospects of the youngest and sickest groups in the population.

By making these three approaches comparable, we have strengthened the scientific foundation on which politicians can form suitable plans of action. Our conclusions are that all three approaches could be suitable courses of action, but that each approach has different strengths and benefits. The public procurement change could be preferable in terms of its effect on health and dietary norms, while a removal of the cattle support might be motivated as it is contra-productive. Finally, the tax approach is possibly preferable as it could be considered fairer and the magnitude of the effect from this approach was largest. However, two or more approaches could of course be implemented simultaneously in order to reach high GHG reduction levels. The effect of such simultaneous actions have not been analyzed in this thesis. Based on beef's immense emission intensity and Sweden's evident over consumption of beef, we deem it necessary to set a high reduction target for GHG emissions.

Our results from the public procurement approach are based on data collected directly from Swedish municipalities. This data in surrounded by high uncertainty as different municipalities have different systems for their food statistics and we have not accessed the data directly. Some municipalities might only have provided us with information regarding untreated beef, while others have approximated a summed figure based on mixed food groups. Furthermore, the estimated effect by the removal of the cattle support on the production of beef should be seen as a rough estimate as it is built on a lot of assumptions. The most problematic being the assumptions regarding homogeneous and naive price expectations as well as that the import of beef would be unaffected when the cattle support is removed. By the use of farm specific data and more dynamic models, the estimate could be made more accurate.

This thesis is limited to GHG emissions, but as beef production also causes the release of other pollutants such as nitrogen, ammonia and phosphorus, which lead to algae blooming and oxygen depletion (Säll & Gren, 2015), there is a need for further research incorporating other aspects. Furthermore, as our procurement approach only included preschools, schools and hospitals, there is a need for a study of larger scope in order to quantify the effects of an extensive public procurement change. Finally, focus has been on beef in this study, but other animal products are major polluters as well. Second to beef, cheese causes the largest production of GHG (Säll & Gren, 2015). One future research area could be to analyse both the environmental and health effects of switching plant based substitutes for dairy products in the public sector.

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Appendix A. Sensitivity analysis

See Table A1-A3.

Table A1

Net GHG reduction in tonnes CO_2 eq. for the preschool and school section when applying 220 preschool days, 230 preschool days, an absence factor of 18% for schools, an absence factor of 8% for schools, an absence factor of 23% for preschools and an absence factor of 13% for preschools, respectively. Moreover, the percentage change in net GHG reduction compared with the 100% reference case is displayed.

	Days		Absence, Schools		Absence, Preschools	
	220	230	18%	8%	23%	13 %
Net GHG reduction	196,437	197,251	191,986	201,637	195,609	198,233
% change	-0.25%	0.17%	-2.51%	2.39%	-0.67%	0.66%

Table A2

Sensitivity analysis regarding (1) number of days preschools are open, (2) absence adjustment factors for schools and (3) absence adjustment factors for preschools. The calculations include preschools, schools and hospitals. The amount of beef consumed, GHG emissions due to beef consumption, GHG emissions due to legume consumption and net GHG reduction are in tonnes. The net GHG emission reduction is also shown as a percentage of emissions due to Swedish beef consumption as a whole and of emissions released due to all Swedish consumption. The figures for the 100%-procurement change are included as a reference.

	Reference	Days		Absence, Schools		Absence, Preschools	
	100% case	220	230	18%	8%	23%	13 %
Beef (CW)	8,890	8,869	8,903	8,683	9,087	8,835	8,944
GHG from beef	215,931	215,432	216,261	210,901	220,728	214,590	217,261
GHG from legumes	3,872	3,863	3,878	3,782	3,958	3,848	3,896
Net GHG reduction	212,059	211,569	212,384	207,119	216,770	210,742	213,365
% of beef consumption	3.49%	3.48%	3.49%	3.41%	3.56%	3.46%	3.51%
% of total consumption	0.20%	0.20%	0.20%	0.20%	0.21%	0.20%	0.20%

Table A3

GHG reduction in tonnes CO_2 eq. and percentage change in reduction from changing estimated granted size of the cattle support and using the upper and lower bound in the 95 % confidence interval for β_1 compared to the reference case.

	Size of cattle support	β_1 equal to the 95 % confidence interval	
	80% of reference case	Lower bound	Upper bound
GHG reduction	156,235	15,390	377,441
% change	-23.81%	-92.50%	84.06%

Appendix B. Data

All of the data was collected from the Swedish Board of Agriculture’s statistical database and concern the period January 2000 until December 2014. The variable for the quantity produced beef (*QB*) is based on data over the quantity of slaughtered bulls, steers and heifers at slaughterhouses in thousand tonnes each month. However, we do not consider it an issue that solely cattle slaughtered at slaughterhouses were included. According to Strid *et al*. (2014), only 17,054 animals were slaughtered at home, for other than medical reasons, in

Sweden 2012. Thus, animals slaughtered at home only account for around 3.9 per cent of the total. The price of beef (*PB*) is based on a monthly price index for cattle where the average price in the year 2000 is set as 100. The index is based on the prices producers receive for different quality of beef and from several slaughterhouses regarding cows and young male cattle. The index is calculated by weighing the different types and qualities together. Approximately, cows constitute for 1/3 and young male cattle for 2/3 of the index.[26] The index does not include any benefits or subsidies that the producer may receive.

The price of animal feeding stuff (*PAF*) is based on an input price index of the price producers pay for animal feed. It is constructed based on several kinds of animal feed, not limited to cattle feed. The second cost variable, the price of fuel and lubricants (*FAL*), is based on weighted prices for electricity, diesel oil and other fuels and lubricants. Electricity and diesel oil account for approximately 2/5 of the index each, while other fuels and lubricants account for 1/5. The last cost variable, the price of machinery and equipment (*MAE*), is based on an index of the price for machinery and other equipment used in agriculture. The price of milk (*PM*) is based on an output price index measuring the price received by milk producers when selling to a dairy.

For all five price indices, adjustments have been made in order to create one continuous index for each variable. The Swedish Board of Agriculture's indices are divided into five year periods, with each index having a different base year and different underlying weights. For each variable, we have joined two indices (one with base year 2000 and one with base year 2005). The two indices overlap during the period January 2005 until December 2008. We have used the ratio between the observations in January 2005 to recalculate so that both indices are in relationship to the average price of 2000. Because different weights have been used, our transformation of the index with 2005 as base year deviate from the index with 2000 as base year during the four overlapping years.[27] However, the deviations were very small and there were no indication that the deviations were getting larger with time. The correlation between the two indices for each and every variable during the overlapping years was close to one. Finally, in order to adjust the combined indices for inflation, data from Statistic Sweden (SCB), collected in the statistical database, was used. A consumer price index for the period January 2000 to December 2014 was used, with January 2000 as the base.

[26] Jimmie Enhäll, Statistician, Swedish Board of Agriculture (personal communication, 17 May 2016).
[27] Part of the deviation is likely to arise from the fact that the figures from the Swedish Board of Agriculture are rounded.

See Table B1 regarding summary statistics over quantity beef produced, expected price of beef, expected price of animal feed, expected price of fuel and lubricants, expected price of machinery and equipment as well as expected price of milk.

Table B1
Summary statistics over the following variables: quantity beef produced, expected price of beef, expected price of animal feed, expected price of fuel and lubricants, expected price of machinery and equipment as well as expected price of milk.

Variable	Observations	Mean	Std. Dev.	Min.	Max.
QB	180	7.24	0.96	4.03	9.93
EPB	144	93.78	7.52	72.91	110.58
EPAF	144	109.56	13.11	94.57	136.80
EFAL	144	123.43	18.31	94.82	156.42
EMAE	144	111.04	9.39	97.99	127.13
EPM	144	91.45	7.26	79.45	106.75

Before using the variables in our regression, they were transformed by taking the natural logarithm. This was done, as described in section 4.1, for the sake of interpretation and because no strong linear relationship between the dependent and independent variables could be assumed.

Appendix C. Non-stationarity

Non-stationary variables can cause what commonly is known as spurious regression (Thomas 1997). We have used the Augmented Dickey-Fuller unit-root test (ADF) to control if our variables were stationary. The null hypothesis is that a unit root is present, which would mean that the variable is non-stationary. Table C1 presents the test statistics from the ADF tests with and without a trend variable.

Table C1
ADF test statistics for two test scenarios: (1) without a trend variable and (2) with a trend variable.

Variables	Without trend	With trend
log(QB)	-9.825 ***	-10.411 *
log(EPB)	-2.327	-2.703
log(EPAF)	-0.930	-1.348
log(EFAL)	-1.022	-2.746
log(EMAE)	-0.380	-2.457
log(EPM)	-1.848	-1.812

Note: MacKinnon approximate p-values were used.
* Significance at 10% level, ** Significance at 5% level and *** Significance at 1% level.

The results show that when no lags were used, the null hypothesis that a unit root is present could only be rejected for the variable *log(QB)*. Thus, we concluded that we could have an issue with non-stationarity. Thomas (1997) suggested first differencing the variables in order to make the variables stationary. The result from the ADF tests after having made the transformation is shown in Table C2.

Table C2
ADF test statistics for the first differenced variables.

Variables	Without trend	With trend
Δ log(QB)	-20.545 ***	-20.491 ***
Δ log(EPB)	-9.230 ***	-9.238 ***
Δ log(EPAF)	-8.453 ***	-8.422 ***
Δ log(EFAL)	-10.716 ***	-10.679 ***
Δ log(EMAE)	-11.526 ***	-11.484 ***
Δ log(EPM)	-8.405 ***	-8.379 ***

Note: MacKinnon approximate p-values were used.
* Significance at 10% level, ** Significance at 5% level and *** Significance at 1% level.

After transformation, the test rejects the null hypothesis that a unit root is present at a 1 per cent significance level for all the variables, both with and without a trend variable included. Thus, we draw the conclusion that all the first differenced variables are stationary.

Appendix D. Serial correlation

When using the OLS method, some assumptions need to hold for the results to be reliable. In the case of time series data, the assumption about independent error terms can often be violated, which commonly is known as serial correlation. If the assumption is not satisfied it causes the OLS estimators to be inefficient, making the regression estimate biased and inconsistent, which then invalidates the hypothesis test for the significance of the coefficients (Asteriou & Hall, 2016, page 160). There are several tests available to investigate if serial correlation is present. We have used the Durbin-Watson d-statistic to control for first order correlation. This method was described by Durbin and Watson (1950; 1951; 1971). To see if the data showed signs of having serial correlation of higher order, we have used the Breusch-Godfrey test for higher-order serial correlation (Godfrey, 1978; Breusch, 1978). The number of lags used in the Breusch-Godfrey test has been set to 24 as we have monthly data and we assessed that two year was an appropriate upper bound for the test. If no serial correlation between the error terms would have been found with 24 lags, we would have concluded that no serial correlation was present.

Table D1
Durbin-Watson d-statistic (17, 143).

Test statistic	2.821929

Note: Critical values at a 5% level for this test: d_L = 1.48595 and d_U = 1.97909

Table D2
Breusch-Godfrey test for higher-order serial correlation.

Lags	Chi-2	Degrees of freedom	Prob. > Chi-2
1	28.712	1	0.0000
2	60.139	2	0.0000
3	60.083	3	0.0000
4	62.829	4	0.0000
5	64.578	5	0.0000
6	70.601	6	0.0000
7	70.490	7	0.0000
8	69.951	8	0.0000
9	76.475	9	0.0000
10	82.380	10	0.0000
11	81.686	11	0.0000
12	82.694	12	0.0000
13	81.993	13	0.0000
14	81.506	14	0.0000
15	86.440	15	0.0000
16	89.836	16	0.0000
17	89.101	17	0.0000
18	93.092	18	0.0000
19	94.400	19	0.0000
20	94.108	20	0.0000
21	99.236	21	0.0000
22	100.582	22	0.0000
23	100.306	23	0.0000
24	102.672	24	0.0000

The Durbin-Watson d-statistic (Table D1) indicated that a negative autocorrelation of the first order was present. The results from the Breusch-Godfrey test (Table D2) strengthens the finding of present autocorrelation. To account for the issue with serial correlation, we have used the Newey-West method (Newey & West, 1987). The maximum number of lags have again been set to 24 based on the same reasoning as previously presented. The cause of the evident serial correlation could have been the presence of habits or contracts, but this effect is likely to diminish over time, when both habits and contracts can be adapted.

Appendix E. Estimated change in output

In the following, the marginal effect of a change in the expected price of beef has been estimated and the effect on the amount of produced beef from a removal of the cattle support.

By keeping everything else constant, the following expression is obtained:

$$\Delta log(QB_t) = \beta_1 \Delta log(EPB_t) \quad (1)$$

Re-writing expression (1), yields:

$$log(QB_t) - log(QB_{t-1}) = \beta_1(log(EPB_t) - log(EPB_{t-1}) \quad (2)$$

Applying the logarithmic laws, making both sides of expression (2) an exponent to e and simplifying, yields:

$$\frac{QB_t}{QB_{t-1}} = \frac{EPB_t}{EPB_{t-1}}^{\beta_1} \quad (3)$$

By plugging in our estimated β_1, the estimated decrease in expected price equal to a removal of the cattle support and the produced quantity in 2015 into expression (3), we obtain the quantity of slaughtered bulls, steers and heifers if the cattle support would not have been in place.

$$QB_t = 0.8903^{0.886} * 86.26 \quad (4)$$

Thus, the produced quantity of beef in Sweden would decrease by around 8,442 tonnes if the cattle support granted to beef producers would be removed completely.

Appendix F. Results

Table F1

Estimated coefficients and standard errors for the following transformed variables: expected price of beef (EPB), expected price of animal feed (EPAF), expected price of fuel and lubricants (EFAL), expected price of machinery and equipment (EMAE) as well as expected price of milk (EPM). In addition, estimated coefficients and standard errors for the monthly dummies and the constant are presented. Depended variable in the regression is a transformation of the slaughtered quantity of bull, steer and heifer (QB).

Variables	Δ log(QB)
Δ log(EPB)	0.886 ** (0.416)
Δ log(EPAF)	-0.195 (0.916)
Δ log(EFAL)	0.241 (0.500)
Δ log(EMAE)	5.160 (4.164)
Δ log(EPM)	1.099 (0.900)
February	0.123 (0.133)
March	0.264 * (0.141)
April	0.038 (0.155)
May	0.185 (0.120)
June	0.026 (0.102)
July	-0.064 (0.067)
August	0.174 (0.117)
September	0.038 (0.131)
October	0.077 (0.107)
November	-0.028 (0.099)
December	-0.062 (0.120)
Constant	-0.075 (0.111)
No. observations	143

Note: * Significance at 10% level, ** Significance at 5% level and *** Significance at 1% level.
Newey-West standard errors in bracket. Maximum lags of 24 are used.