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Green consumption taxes on meat in Sweden

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Abstract

This paper designs and evaluates the environmental impacts of a tax on meat consumption in Sweden which reflects environmental damage at the margin. Three meat products are included, cattle, chicken and pork, and three pollutants generating environmental damages; green house gases, nitrogen, and phosphorus. The calculated unit taxes on meat products correspond to 28%, 26%, and 40% of the price per kg of beef, pork, and poultry in 2009. Consumer responses to the taxes are calculated by means of econometric estimates of a linear demand system of the meat products. The results indicate relatively high own price and income elasticities of the meat products and complementarity in consumption. A simultaneous introduction of taxes on all three meat products can decrease emission of GHG, nitrogen, phosphorus and ammonia by at least 27%. If only one meat product can be taxed, a tax on pork meat gives the largest reductions in emission of all pollutants, which to a large extent is explained by the high complementarity in consumption.

Key words: environmental meat tax, environmental impacts, Sweden, meat demand elasticities

JEL: H23, Q18, Q52, Q58

1. Introduction

Globally, meat production has increased by 245% during 1961 and 2001 and is likely to continue to increase in the near future driven by growing incomes in many countries (Steinfeld and Gerber, 2010). Several studies have pointed at detrimental environmental effects of meat and food production, such as climate change from green house gas emissions and impaired water quality from nutrient leaching (e.g. FAO, 2006; Galloway et al., 2008). FAO (2006) finds that livestock is responsible for 18% of total greenhouse gas (GHG) emissions worldwide, which is the largest share of all sectors. Galloway et al (2008) point at the important role of the agricultural sector in the increasing threat of reactive nitrogen at the global scale. These negative externalities of meat production could, in principle, be mitigated by means of a so-called Pigovian tax which implies an increase in the consumer price of meat corresponding to the marginal environmental damage. Such a tax would give incentives to reduce environmentally damaging practices in meat production.

Although simple in theory, the implementation of a Pigovian meat tax in practice is challenging because of the difficulties of measuring environmental damages in monetary terms. This can be one reason for the lack of economic studies of the design of environmental charges on meat. In fact, we find only one published paper on environmental tax on meat (Wirsenius et al., 2011). Instead, there is large body of literature on the regulation of specific pollutants such as pesticides and nutrients at the farm level (e.g. Batie and Horan, 2004). As argued by Schmutzler (1997) motivations for introducing consumption taxes instead of taxes on direct emissions from production arise when i) monitoring costs of emissions are high ii) technological improvements for emission reduction is difficult, and iii) substitution possibilities between production outputs are good. Wirsenius et al (2011) argue that all three conditions are fulfilled within the livestock sector. The purpose of this study is to design a Pigovian tax on meat consumption in Sweden and evaluate associated environmental impacts. The included pollutant emissions are green house gases and nutrient releases. Consumers' adjustments to the introduced environmental taxes are assessed by econometric analyses using the Almost Ideal Demand System (LA/AIDS) on the three included meat products; beef, chicken, and pork.

In Sweden, the total level of GHG emissions from Swedish meat consumption exceeded 6 million tons in 2009, which is close to 8% of total emissions from Swedish consumption (including net imports- Swedish EPA 2008) and 32% of total emissions from food consumption. Total consumption increased from 460 thousand tons to 725[1] thousand tons between 1990 and 2009, which is an increase of 58% (Statistics Sweden,2010). Environmental problems caused by nutrient emissions have received less attention at the global scale than GHG emissions and global warming. In Sweden and many countries surrounding the Baltic Sea, there has been a concern since early 1970s of the eutrophication damages caused by nitrogen (N) and phosphorus (P) which cause algae blooming in lakes and oceans as well as excessive nutrition loads in forests. Nitrogen compounds such as ammonia (NH3) also cause acidification. The Swedish meat production accounts for approximately 22% of total nitrogen, 27% of total phosphorus, and 55% of total ammonia releases in Sweden.

Starting in 1920s there is a large body of literature on the economic analyses of economic instruments for combating environmental damages, which has been applied to, among others, water pollution, climate change, and biodiversity conservation (see e.g. Helfand et al., 2003 for a review). In spite of this extensive literature there is, to the best of our knowledge, only one empirical study of the design and implications of an environmental meat tax (Wirseniues et al., 2011). The design of meat tax as such is also close to the larger literature on taxing or subsidizing food for other purposes, mainly to improve health conditions (e.g. Schroeter et al.,

[1] Taking population increase into account. In 1990 the total population was 8 590 630 and in the year 2009 it was 9 340 682 (Statistics Sweden 2010)

2008; Nnoaham et al., 2009; Nordström and Thunström, 2009; Nordström and Thunström, 2011). Following these two strands of literature we impose the tax on consumption instead of meat production in Sweden, where one main argument is to avoid comparative disadvantages for Swedish meat producers. Another related argument is that a tax on consumption is more likely to reduce overall environmental damages (or improve health conditions) because of the neutrality among producers. In our view, the main contribution of this study is the inclusion of nitrogen and phosphorus emissions in addition to GHG, and associated assessment of environmental impacts by econometric analyses of the demand for three types of meat in Sweden; beef, pork, and chicken. The econometric approach follows the literature by constructing an AIDS (Almost Ideal Demand System) model for estimating demand and income elasticities of the meat products.

This paper is organized as follows. First, the theoretical model is presented and the linear version of the Almost Ideal Demand System (LA/AIDS) is used to estimate demand and income elasticities. In the second section, data for the Swedish meat consumption between 1980 and 2009 is presented. The third section presents calculations of marginal emission levels and marginal damage costs for each kilo of meat. In the fourth section results are presented, which is followed by a summary and discussion.

2. Model specification of meat demand, meat tax, and emission reductions

The modeling framework and the subsequent empirical analyses consists of three main steps; i) the derivation of demand for the meat products before the tax, ii) calculation and introduction of the tax and derivation of the new demand for meat products, and iii) estimation of emissions of environmental pollutants before and after the introduction of taxes. Starting with the first step, we use the AIDS model, which is one of the most frequently used models for estimating demand systems (Deaton A, Muellbauer J, 1980). The linear version LA/AIDS using the stone index is common for annual time series and panel data. In the following, we calculate elasticities on per capita level to calibrate individual demand functions which are then aggregated to give demand functions for the Swedish population.

The model framework is as follows: shares of total consumption of a meat product in each period of time, $s_{j,t}$, where $j=,1..,m$ meat products, are expressed as functions of a constant, α_j, logged prices of all commodities and total expenditures X_t. A time trend t, is introduced to capture trends in consumption not explained by the included independent variables. The LA/AIDS is then:

$$s_{j,t} = \alpha_{j,t} + \theta_i t + \sum_k^m \gamma_{j,k} \ln p_{k.t} + \beta_j (\ln X_t - \ln P_t) \quad (1)$$

where $k=1,..m$ meat products, $s_{j,t} = p_j q_t / X_t$ where X_t is the total expenditures for each year, $X_t = \sum_j^m p_j q_j$, and $\ln P_t = \sum_j^m s_{j,t} \ln p_{j,t}$ is the Stone price index.

Parameters should fulfill adding up restrictions as well as homogeneity and symmetry conditions. This means that $\alpha_{j,}$ which is the logarithm of consumption shares, should add to one., and β_j, which shows the change in budget shares when real expenditure change, add to zero. Further, $\gamma_{j,k}$ indicates the change in budget shares when prices of beef, pork and poultry change and the homogeneity restriction requires that $\sum_j^m \gamma_{j,k} = 0$. Symmetry conditions imply that a change in price of good j has the same marginal effect on the budget share of good k as a price change of good k has on the marginal change of budget shares of good j, i.e. that $\gamma_{j,k} = \gamma_{,k,j}$. The coefficients θ_j show the change in trends over time and they sum to zero.

Price and income elasticities are carried out by using definitions in Green Alston (1990). In the following, the index *M* denotes Marshallian elasticities, *H* Hicksian elasticities, and *I* income elasticities, which are defined as

$$\varepsilon_j^I = 1 + \beta_j / s_j \tag{2}$$

$$\varepsilon_{j,k}^M = \left[(\gamma_{j,k} - \beta_j s_k) / s_j\right] - \delta_{j,k} \tag{3}$$

$$\varepsilon_{j,k}^H = (\gamma_{j,k} / s_j) + s_k - \delta_{j,k} \tag{4}$$

where the Kronecker delta, $\delta_{j,k}=1$ if $j=k$ and 0 otherwise. Imposed restrictions on the elasticities are; 1) $\varepsilon_{j,k}^M = \varepsilon_{j,k}^H - \varepsilon_j^I s_k$, 2) $\varepsilon_j^I + \sum_k^m \varepsilon_{j,k}^M = 0$ and 3) $\sum_j^m \varepsilon_{j,k}^H = 0$.

Linear demand functions, q_j, for the products are obtained from the estimated system described by eqs. (1)-(4), which are written as

$$q_j = \mu_j + \nu_j p_j + \sum_{k \neq j}^m \nu_{j,k} p_k + \nu_{j,X} X \tag{5}$$

where the coefficients υ_j are calculated from the Marshallian demand function (in the case of one stage demand estimations this is equal to the compensated demand elasticities) and income elasticities in eqs. (2)-(3), per capita consumption and prices, μ_j is the per capita consumption of the reference year.

The second main step constitutes the imposition of meat taxes on consumption. These are calculated from average emissions per kilo meat and marginal damage costs of pollutants (see next section 3), according to

$$tax_j = \sum_i^n e_{i,j} MD_i \qquad (6)$$

where e_{ij} is average emission per kilo meat of pollutant i, where $i=1,..,n$ pollutants. After introduction of the environmental taxes, meat demand is determined by

$$q'_j = \mu_j + \nu_j p_j + \sum_{k \neq j}^m \nu_{j,k} (p_k + tax_j) + \nu_{j,X} X \qquad (7)$$

Impacts of the environmental taxes on pollutant emissions are calculated in the third step. Equations 5 and 7 are then aggregated to total demand in Sweden $Q_j = hq_j$ and $Q_j' = hq_j'$, where h is the population size, which are used to estimate emission reductions as the change from the initial level to the level after the introduction of the taxes, $E_i^{'}$ for included pollutants in Sweden according to

$$\Delta E_i = \sum_j^m e_{ij} (Q_j - Q_j') \qquad (8)$$

As shown in (8) it is assumed that e_{ij} are constant and unaffected by the introduction of the taxes. This assumption is likely to hold in the short term perspective with insufficient time for producers to adjust to the tax.

3. Derivation of meat demand

As demonstrated in the modeling section, the first step of our calculations of the environmental impacts of green meat taxes consists of the econometric estimate of demand for different meat products in Sweden. Data for the AIDS model are collected from the Swedish board of Agriculture and show per capita consumption of beef, pork, and poultry, including bone, from

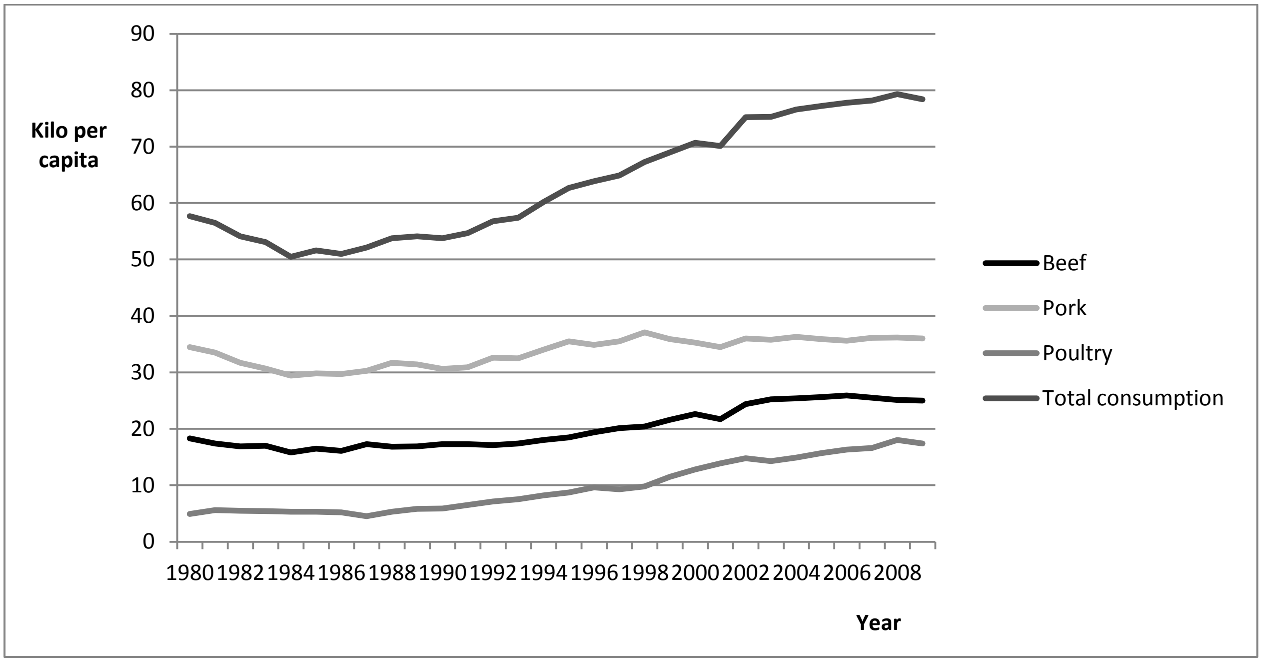
1980 to 2009 in Sweden. These three meat products account for 78 kilo/person out of total 83 in 2009. Motivation to use data from 1980 are provided by studies done by Rickertsen (1995) for Norwegian meat consumption and by Lööf and Widell (2009) who estimate demand systems for Swedish food consumption. Both papers show a structural change in meat consumption around 1980.

It would have been preferable to include food groups that are substitutes for meat in a second stage of the demand system to be able to observe the changes from meat to other commodities and include the income effect of meat taxes. Fish and legumes would be good substitutes to include in the second stage, but consumption data on both commodities is insufficient.

Since 1980, per capita consumption of beef pork and poultry has increased with almost 36% or more than 20 kilo per person and year. The main increase comes from poultry consumption which has more than tripled, followed by consumption of beef that increased with almost 37%. Consumption of pork has been rather constant. During this time period, prices have increased as well. Price index of beef for 2009 was 2.5 (1980 = 1), for pork 2,7 and for poultry only 1.4. The prices of beef and pork are highest in 2009, but only little higher than 1990 (2.4 and 2.6 respectively). The decrease in relative prices could be one explanation for the large increase in poultry consumption.

Per capita consumption of beef, pork and poultry between the years 1980 to 2009 is shown in graph 1. Data of consumption and prices are also presented in Appendix table A.1 to A.3.

Figure 1: Per capita consumption of beef, pork and poultry in Sweden 1980-2009.



Source: Swedish board of Agriculture, statistical database.

In Table 1, descriptive statistics of per capita consumption is presented, showing min, max and mean values of prices, consumption and shares of total consumption.

Table 1: Descriptive statistics, 1980-2009. n=30

Data	Min	Max	Mean
q Beef, kg	15,8	25,9	20,1
q Pork, kg	29,4	37,1	33,7
q Poultry, kg	4,5	18	9,7
P index Beef	1	2,5	1,96
P index Pork	1	2,7	2,14
P index Poultry	1	1,9	1,43
Share Beef	0,2866	0,3428	0,3169
Share Pork	0,4700	0,5843	0,5392
Share Poultry	0,0974	0,1889	0,1440

The demand system presented in the modeling section 2 and with the data shown in Table 1 is estimated using SURE (seemingly unrelated regression equations). Log likelihood tests are carried out for the restrictions, which give no indication that restrictions are not to be imposed on elasticity estimations, which are shown in Table A2 in Supplementary material. Further, Durbin Watson tests indicated no problem with autocorrelation. Regression results with restricted values of Marshallian (compensated) and income elasticities from eqs. (2)-(3) are presented in Table 2.

Table 2: SURE estimates of Marshallian and income elasticities, time trends and DW for the demand system of meat in Sweden

	Beef	Pork	Poultry	Income
Beef	**-0,394***** **(0,124)**	-0,429** (0,187)	-0,117 (0,091)	0,939*** (0,244)
Pork	-0,235*** (0,072)	**-0,561***** **(0,128)**	-0,089 (0,059)	0,886*** (0,153)
Poultry	-0,454*** (0,174)	-0,699*** (0,204)	**-0,409**** **(0,209)**	1,562*** (0,485)
Time trend	0,0176 (0,027)	-0,065** (0,028)	0,0473** (0,025)	
Durbin Watson	2,186	1,528		

Standard deviations are presented within parenthesizes, and notations ***', ** , and *, show significance at the levels of 1%, 5% and 10%. Supplementary information is found in appendix, table A.4. Underlying budget equations are concave, with the Slutsky matrix being negative definite (negative eigenvalues).

All estimated own price elasticities are significant and negative, which is in accordance with theory. The levels of these elasticities are in the same order of magnitude for all three meat products. However, levels are likely to be somewhat underestimated since only the "within group" elasticities are found. Changes towards other food groups are not taken into account.

Another expected result is the positive signs of the income elasticities. The income elasticity of poultry is considerably higher than for the other meat products. Similar levels of income elasticity for poultry are also obtained by Lööv and Widell (2009) and Rickersten (1995). A less expected result is that all cross price elasticities are negative, showing that beef, pork and poultry are complements. This might be explained with consumers not eating the same kind of meat every day. Results by Lööv and Widell (2009) also show complements, except the effect poultry has on beef and pork. However their results do not fulfill restrictions on elasticities and values differ. Rickertsten (1995) estimates elasticities for i.e. Norway and Scotland. In Norway, elasticities have similar effects with the exception of the effects of poultry and beef on each other. Results for Scotland are all negative as well.

The estimates of time trends are significant and positive for beef and poultry and negative for pork. This can be discerned also from Figure 1 where the development of consumption of the different meat products is plotted. The relatively high increase in poultry consumption follows a global pattern (see e.g. Fabiosa, 2011).

4. Calculation of green meat taxes

The calculation of the green meat taxes constitutes the second step in our calculations. The taxes are derived from the environmental damages of GHG emissions, nitrogen, phosphorus and ammonia emissions. The taxes are calculated for emissions at the production stage of the meat products. The choice of these pollutants is based on data availability and possibility of calculating environmental damage in monetary terms.

Starting in mid 1960's there is a large body of literature on the measurement of environmental damages in monetary terms (see Turner et al., 2003 for a review). A common approach in the literature has been to assess estimates of environmental problems of concern such as degraded water quality, climate change, and biodiversity loss. Very seldom has the causes of these damages, such as pollutant emissions and land use changes, been identified and quantified. This creates difficulties with respect to the calculation of environmental damages in monetary terms of specific pollutants. In this paper we will use revealed preference by Swedish politicians for assessing damage costs of GHG and nutrients. These preferences are expressed as a tax on carbon dioxide and by participation in international agreement on nutrient reductions. The abatement costs at the margin of obtaining the nutrient reduction targets are used as the revealed damage cost. This approach is used for assessing damage costs of nitrogen, phosphorus and ammonia.

Since dairy products are excluded in this paper and beef and dairy are complements in production, emissions from beef are calculated to exclude emissions from dairy. According to Cederberg (2009) the economic allocation of cattle for dairy and beef production is 65% and 35% respectively. The dairy production, in turn, generates 90% dairy products and 10% beef products. Emission from beef production is then the sum of the emission from the 35% of the cattle that are only producing beef, and 10% of the emissions from dairy production. In average, one kilo of meat from beef cattle, emits 3,3 times as much nitrogen and 2,2 times as much phosphorus, than one kilo of meat from dairy cattle. Since ammonia is a nitrogen compound and due to lack of better data, the weight 3,3 times more from beef cattle meat then dairy cattle meat will be used to find an average emission levels of ammonia per kilo beef.

Emissions of GHG create environmental damages regardless of location of the emission sources, and can therefore be directly related to emissions from meat. Emissions per kg for the different meat products as measured in carbon dioxide equivalents are obtained from Cederberg (2009), see Table 3. In contrast to GHG, environmental damages from nitrogen and phosphorus depend on location. A crucial assumption then concerns the origins of production of the meat consumed in Sweden. A simplification is made by assumption that the production technology for all consumed meat is the same as for the Swedish agriculture. One justification for this assumption is that 60-78% of the value of meat consumption originates from the Swedish agriculture. Damages from nitrogen and phosphorus occur mainly for water quality, and data are available on impacts of emissions on the Baltic Sea from emissions at different locations in Sweden (Elofsson, 2003). In this paper we calculate the average leakage per kilo meat where emission levels in the different regions are recalculated to given total loads to the Baltic Sea, where the shares of emissions that reach the Baltic Sea constitute weights. Calculations of nutrients that reach the Baltic Sea constitute the basis for estimation of environmental damage for different meat products, see Table 3.

Table 3: Average emission levels for meat produced in Sweden after non leakages are removed.

Kilo/Kilo	$CO2/e$ [1]	Nitrogen[2]	Phoshorus[2]	Ammonia[2]
Beef	21,0	0,0063	0,00005	0,0483
Pork	3,4	0,0258	0,00065	0,0426
Poultry	1,9	0,0330	0,00046	0,0730

1. Carbon dioxide equivalents, Cederberg et al 2009 ; 2. See appendix table A.5 and A.6

Beef is the main emitter of only GHG per kilo (since most emissions are directed towards dairy). Pork has the highest values for phosphorus emissions while poultry generates highest average emission of nitrogen and ammonia. There is thus no obvious meat product with the highest average damage, which is also determined by the monetary estimates of the emissions presented in Table 3.

Due to lacking values of damage costs of emissions, abatement costs and current tax level in Sweden are used for assessing damage costs. Stern (2006) refers to studies that find costs of GHG emissions to range between $0 and $400 per ton, which corresponds to 0 and 2.8 SEK per kilo CO2/e. With such uncertainties, the politically revealed cost of GHG emissions in Sweden will be used instead. Within the transportation sector, the taxes on CO2/e emissions is 1 SEK per kilo, which is used in this paper. Gren et al (2008) find that abatement of one kilo of nitrogen in the Baltic Sea costs 252 SEK at a 50% reduction level and phosphorus 3279 SEK per kilo at a

60% reduction level. Again, since no damage functions are available, this already revealed cost will be used as a proxy for damage costs of nutrients. Average damage costs, and final tax levels from equation 6 are presented in Table 4.

Table 4: Average environmental damages and tax in SEK/kg meat, and consumer price increase.

	CO2/e	Nitrogen	Phosphorus	Ammonia		
Beef	21,00	1,58	0,17	1,93	24,69	28,1%
Pork	3,40	6,50	2,14	1,70	13,74	26,4%
Poultry	1,90	8,32	1,51	2,92	14,65	39,6%

According to the results presented in Table 4 one kilo of beef has the highest damage costs and pork the lowest, while poultry has the highest relative cost, almost 40% of the initial price. Nitrogen is the largest part of the damage costs for pork and poultry while CO2/e is the largest share of damage costs for beef.

5. Impact of meat taxes on pollutant emissions

As reported in Section 2, the impact on emissions from the meat taxes in Table 6 are calculated by taking the difference in emissions before and after the introduction of the taxes. Aggregated emissions from meat consumed in Sweden before the introduction of the taxes are shown in Table 5.

Table 5: Aggregated pollutant emissions from Swedish meat consumption, domestic production and imports, in 2009, kton carcass weight.

	CO2/e		Nitrogen		Phosphorus		Ammonia	
	Dom. prod.	Imports	Dom. prod.	Imports	Dom. prod.	Imports	Dom Prod	imports
Beef	2936	1987	1.47	0.98	0.02	0.01	6.75	4.52
Pork	886	257	10.9	3.17	0.42	0.12	11.1	3.22
Poultry	216	92	6.35	2.71	0.13	0.05	0.56	3.55
Sum	4039	2317	18.8	6.86	0.56	0.19	26.2	11.3
% of total emissions in Sweden	6.73		21.8		27.0		54.5	

Total loads for Sweden are 60000 ton CO2/e (Swedish EPA 2009), 85.8 kton nitrogen and 2.1 kton phosphorus 86 of human activity (Brandt et al 2008), 48 kton ammonia 48 (Staaf Bergström 2011) . Import levels are presented in appendix, table A.7.

Meat consumption in Sweden accounts for approximately 7% of total emissions of GHG from production in Sweden, and for considerably higher shares of nutrients and ammonia. It can also be seen from Table 5 that at least 2/3 of the emissions from consumptions are created in Sweden. Another noteworthy result is that consumption of beef has the highest emissions of GHG and that of pork on the other three pollutants.

In the following, impacts on emissions in Table 5 are calculated under two scenarios of tax implementation; 1) simultaneous introduction of all taxes on all meat products and 2) on one of the meat products. Starting with evaluating the effects on meat demand under these two tax simulations, it is interesting to note the considerable differences in meat demand, in particular for poultry, see Table 6.

Table 6: Effects on meat demand from introduction of environmental taxes on all meat products or only one meat product, % decrease from reference demand in Table 1

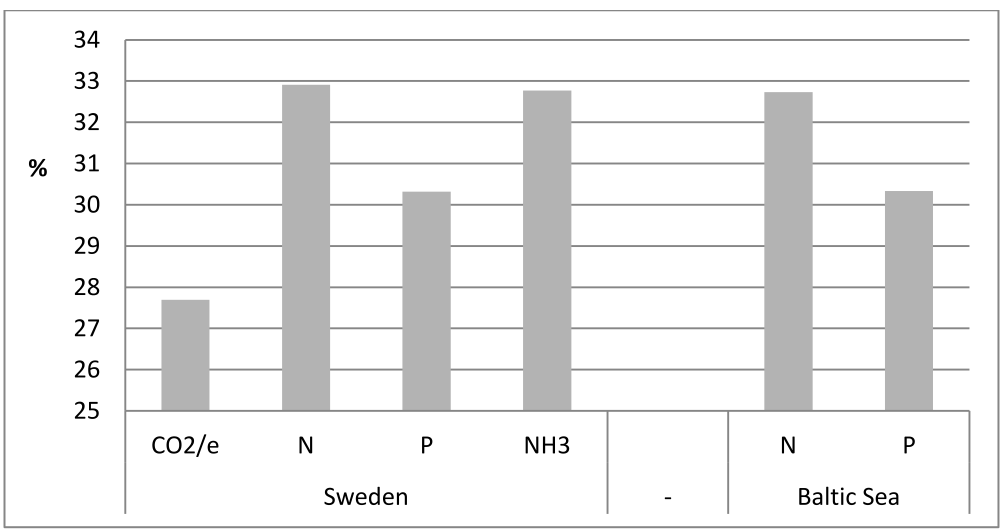
	Tax on all meat products	Tax on beef	Tax on pork	Tax on poultry
Beef	27.0	11.1	11.3	3.3
Pork	25.0	6.6	14.8	2.5
Poultry	47.4	12.7	18.5	16.2

The results presented in Table 6 show that the introduction of taxes on all meat products reduces the demand at least two times more than introduction of single meat tax. This is explained by the relatively high level of cross price elasticities (in absolute terms). It is interesting to note that a tax on pork has higher impact on poultry demand than a poultry tax.

5.1 Emission impacts in the reference case

When calculating impacts on emission from the changes in demand presented in Table 6, it is assumed that demand for domestic and imported products are reduced proportionally to imports and locally produced according t the allocation in 2009. Emission reductions (equation 8 in Section 2) with all demand impacts presented in Table 6 are shown in Figure 2.

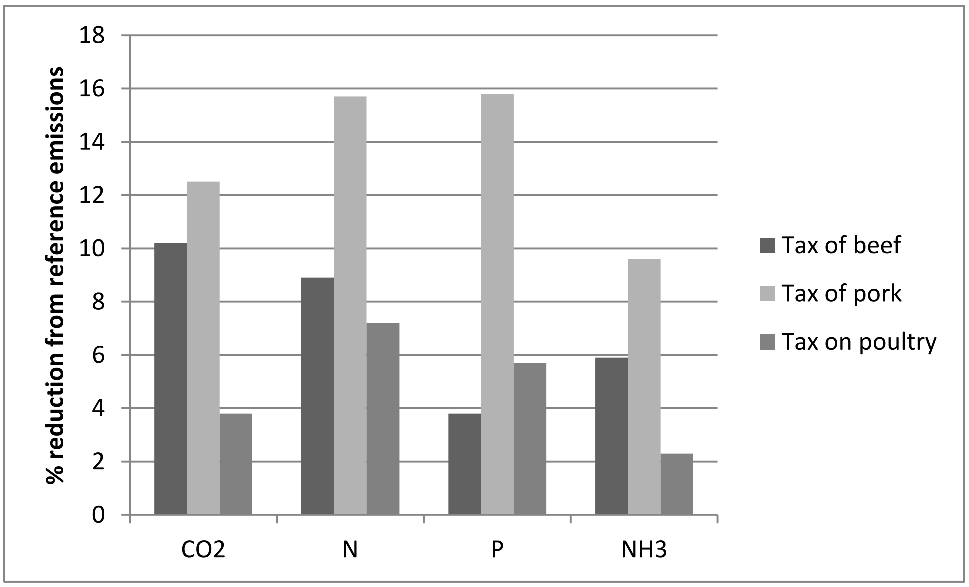
Figure 2: Emission reductions from introduction of all meat taxes, % from initial emission in Table 5.



The introduction of environmental taxes could reduce pollutant emissions from the Swedish meat production with approximately 28 - 34%. The largest reductions occur for nitrogen and ammonia and the smallest for GHG emissions. When compared with total emissions in Sweden, GHG emissions could be reduced by approximately 2%, nitrogen by 7%, phosphorus by 8% and ammonia emissions by 18%.

When introducing an environmental tax on only one of the meat products the largest impact on all emissions are obtained from introducing a tax on pork, see Figure 3

Figure 3: Emission reductions from introduction of an environmental tax on one meat product, in % decrease from reference emission in Table 5.



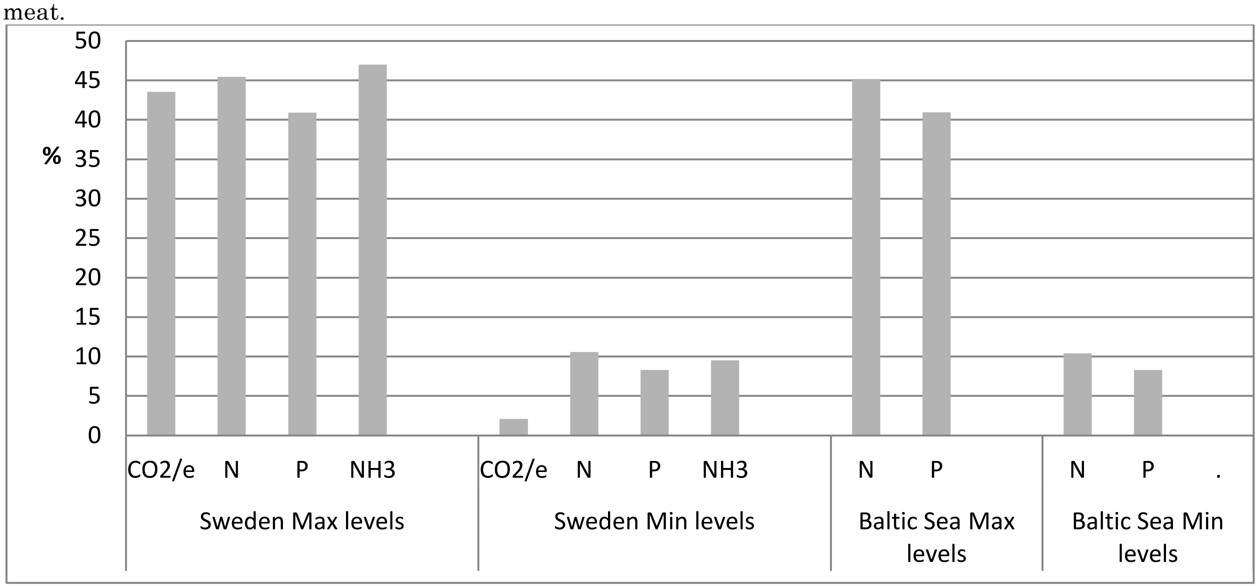
The high impacts on nitrogen and phosphorus of a tax on pork are due to the relatively high emission per unit pork meat and the magnitude of cross price elasticities. A tax on beef generates the largest relative reduction in CO_2 emission, and a tax of poultry on nitrogen.

5.2 Sensitivity analyses

Sensitivity analyses are conducted by changing assumptions with respect to the allocation of reductions between domestic and imported meat products and on the environmental tax levels since there are uncertainties about the damage costs of emissions. The analyses are carried out for the scenario where all environmental meat taxes are introduced.

Due to uncertainties about where demand reductions take place, if demand of locally produced meat would decrease most, or if demand of imported meat would decrease, a sensitivity analysis of where reductions take place is conducted. Max levels in Figure 4 show a scenario where all demand reductions are on meat produced in Sweden, and the Min levels show a scenario when as much as possible of the reductions are done on imported meat.

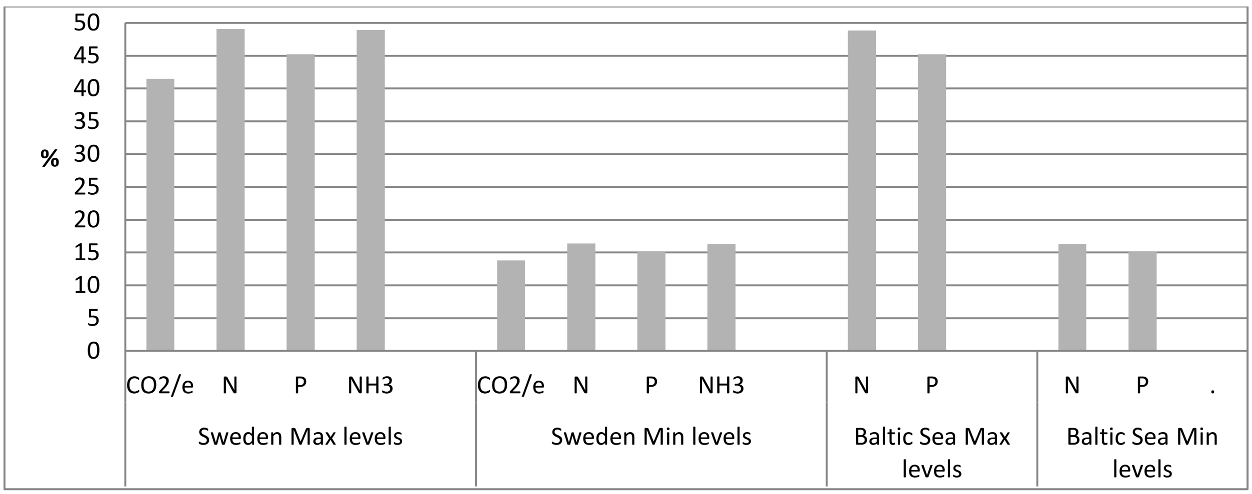
Figure 4: Emission reductions for different scenarios regarding where demand reductions take place. Max levels are for all demand reduction from Swedish produced meat, Min levels are when most is reduced from imported meat.



If as much as possible is reduced of Swedish produced meat, obviously emission reduction in Sweden would be the largest. From the meat sector, emission reductions could be up to 47% (ammonia). If as much as possible of the demand reduction is done on imported meat, emission levels in Sweden would not reduce much. GHG emissions from the Swedish meat production would decrease only with 2%.

Sensitivity analyses are also carried out for changes in the environmental tax levels since there are uncertainties about actual damage costs. Taxes are then are assumed to increase or decrease with 50%. In Figure 5 minimum and maximum levels of pollutant reductions are presented where the allocation of reduction in domestic and imported products are proportional.

Figure 5: Emission reductions for different scenarios regarding damage costs from meat. Max levels are for increase in costs with 50% and Min levels for decrease in costs with 50%.



Higher damage costs, resulting in associated increases in environmental tax on meat, reduce emissions by at least 42% as compared to 28% in the reference case. A cut in the tax rates by 50% generates lower emission reductions which then are approximately 15% for all pollutants.

6. Summary and discussion

One way of dealing with environmental problems arising from meat production is to introduce Pigovian taxes which cover marginal damage costs. The purpose of this paper was to calculate impacts of such taxes for selected pollutants, GHG, nitrogen, phosphorus, and ammonia, on three different meat products; beef, pork, and poultry. It was found that marginal emission costs from Swedish meat from these pollutants are 24,69 SEK per kilo beef, 13,74 SEK for each kilo of pork and 14,75 SEK per kilo poultry. These tax levels correspond to 28%, 26%, and 40% of the price per kg of beef, pork, and poultry. All environmental damage are not included in the costs, i.e. local effects from nutrient emission are excluded due to lack of cost functions and only emissions to the Baltic Sea are included. On the other hand, positive external impacts from agricultural landscape are not included.

A linear demand system was estimated for beef, pork and poultry based on time series data from 1980. The results revealed relatively high (in absolute terms) own price and income elasticities, and negative cross price elasticities which point at complementarity in demand of the meat products. Impacts on emissions were calculated for simultaneous introduction of taxes on all meat products, and on only one of them. Taxing beef, pork and poultry simultaneously could result in reductions up to 4.4% of GHG emissions, 14.7-16.4% reductions of nutrients and 38% reduction of ammonia emissions from total emissions in Sweden. It was found that pork taxes have the largest environmental gain.

If reductions in demand affect mainly imported meat, the environmental gain in Sweden might be zero, while if demand affects Swedish produced meat, the gain could be important for the Swedish environment. If the latter is the outcome, Swedish emission reductions could be even larger when change in land use can take place (as found in Wirsenius et al 2011). Which is the most realistic scenario on where reductions take place is not covered in this paper, however, similar taxes on all meat, Swedish or imported, will most likely shift relative prices in favor of Swedish meat, decreasing imported meats the most. There is also an ongoing discussion in Sweden about eating locally produced meat which might make the Swedish population more hesitant to buy imported when price increase.

However, the results in this paper only reveal partial effects of a green tax on meat. One reason is the exclusion of dairy products, which account for a large share of total emissions from livestock. A second reason is the exclusion of land use and feed production. A third aspect is that damage costs are not included. Local costs of eutrophication are missing, as well as costs of reduced biodiversity. Last, but not least, the total effects are most likely underestimated since a second stage of the demand system has been excluded.

Admittedly, policy makers have shown resistant to impose regulations on food products, regardless of recommendations to reduce meat consumption for mitigating GHG emissions and improving food security (e.g. UNEP 2009; Röös 2001). However, unit taxes to compensate for externalities from food commodities are used in for example Denmark where a "fat tax" has been introduced to improve Danish health.

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Appendix : Tables

Table A.1: Consumption per capita and year. Kilo weight with bone.

Year	Beef	Pork	Poultry
1980	18,3	34,5	4,9
1981	17,4	33,5	5,6
1982	16,9	31,7	5,5
1983	17	30,7	5,4
1984	15,8	29,4	5,3
1985	16,5	29,8	5,3
1986	16,1	29,7	5,2
1987	17,3	30,3	4,5
1988	16,8	31,7	5,3
1989	16,9	31,4	5,8
1990	17,3	30,6	5,9
1991	17,3	30,9	6,5
1992	17,1	32,6	7,1
1993	17,4	32,5	7,5
1994	18	34	8,2
1995	18,5	35,5	8,7
1996	19,4	34,9	9,6
1997	20,1	35,5	9,3
1998	20,4	37,1	9,8
1999	21,6	35,9	11,5
2000	22,6	35,3	12,8
2001	21,7	34,5	13,9
2002	24,4	36	14,8
2003	25,2	35,8	14,3
2004	25,4	36,3	14,9
2005	25,6	35,9	15,7
2006	25,9	35,6	16,3
2007	25,5	36,1	16,6
2008	25,1	36,2	18
2009	25	36	17,4

Table A.2: Price per kilo and year. 1980=1

Year	Beef	Pork	Poultry
1980	1,0	1,0	1,0
1981	1,2	1,3	1,1
1982	1,3	1,5	1,2
1983	1,5	1,7	1,2
1984	1,8	1,9	1,4
1985	1,9	2,0	1,5
1986	2,0	2,1	1,7
1987	2,1	2,2	1,7
1988	2,2	2,3	1,8
1989	2,3	2,4	1,9
1990	2,4	2,6	1,9
1991	2,4	2,5	1,9
1992	2,3	2,4	1,7
1993	2,3	2,4	1,5
1994	2,3	2,4	1,5
1995	2,1	2,3	1,4
1996	1,9	2,1	1,3
1997	1,7	2,1	1,3
1998	1,8	2,0	1,3
1999	1,7	1,9	1,3
2000	1,8	2,0	1,3
2001	1,9	2,2	1,3
2002	1,9	2,3	1,4
2003	2,0	2,2	1,3
2004	1,9	2,2	1,3
2005	2,0	2,3	1,3
2006	2,1	2,3	1,3
2007	2,2	2,4	1,3
2008	2,5	2,6	1,4
2009	2,5	2,7	1,4

Table A.3 Prices, reference year 2009.

Prices 2009 SEK per kilo	
Beef	88
Pork	52
Poultry	37

Table A.4 Tests for restricted model.

	Log likelihood	Likelihood ratio (restricted)	DF	Critical value	Schwarz b i c
Unrestricted model- no homogeneity or symmetry	203,177	0,2459	6	12,59	-176,784
Unrestricted model- no symmetry	203,126	0,298	3	7,82	-180,793
Restricted model	203,054				-182,752

Table A.5 Results of parameter estimations for the restricted model.

	Beef	Pork	Poultry
	0,185962***	-0,14624***	-0,03973
	-0,14624	0,20325***	-0,05701
	-0,03973	-0,05701	0,096738*
	0,29692***	0,605079***	0,098001***
	-0,19195	-0,61682	0,80877
	0,017661	-0,06496**	0,0473*
	0,692441***		

Table A.6 Emissions per animal, total emissions and kilo meat per animal.

	Kilo N per animal[1]	Kilo P per animal[1]	Total emissions of NH3 2009 Kilo[2]	Nr of animals 2009[2]	Kilo meat per animal
Beef cattle	38	4	24240000	539000	326
Dairy cattle	115	18	(all cattle)	10010000	326
Pig	21	8	5380000	1530000	82,5
Chickens	0,63[3]	0,15[3]	2540000	17400000	2

Source: 1) Schou et all 2006 2) Staaf Bergström 2011 3) Elofsson 2000

Table A.7: Livestock holding, leaching and retention of nitrogen and phosphorus

	Holding shares			Leakage share		Retention shares	
Region	Beef	Pork	Poltry	Nitrogen	Phosphorus	Nitrogen	Phosphorus
1	0,042	0,047	0,044	0,051	0,019	0,23	0,4
2	0,163	0,176	0,048	0,085	0,025	0,27	0,4
3	0,229	0,259	0,228	0,164	0,013	0,6	0,47
4	0,238	0,161	0,296	0,164	0,013	0,6	0,47
5	0,063	0,067	0,077	0,276	0,016	0,3	0
6	0,267	0,290	0,307	0,207	0,016	0,2	0,4

Source: Gren et all 2008

A.8: Import shares 2009

2009	Import %
Beef (1)	40,13
Pork (2)	22,47
Poultry (3)	29,92

Source: 1) Lukkarinen et al 2011a 2) Lukkarinen et al 2011b 3) Lukkarinen et al 2011c

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