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A pigovian tax on beef

- consumption effects and consequence analysis

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Abstract

Meat production accounts for approximately 18 per cent of the total GHG emissions in the world and beef is the kind of meat associated with the highest emissions. This paper derives the beef demand and elasticities in Sweden using regression analysis. Further, it calculates the effects of a hypothetical pigovian consumption tax on beef to reduce beef consumption and the associated emissions. The short (long) run own-price elasticity was estimated to: -0,69 (-1,74) and the short (long) run income elasticity to 1,41 (3,58). When assuming a tax level of 28,1% the short run consumption reduction was 19,25% or 2,44 Kg per person per year. The reduction was illustrated to depend not only on own-price elasticities but also on assumptions made of the costs of environmenal problems in the future affecting the optimal tax level.

In the second part of the paper potential use of the tax revenue was discussed. The conclusion was that a lowering of the tax on green substitutes to meat was likely to be more efficient than a lowering of the tax on labour.

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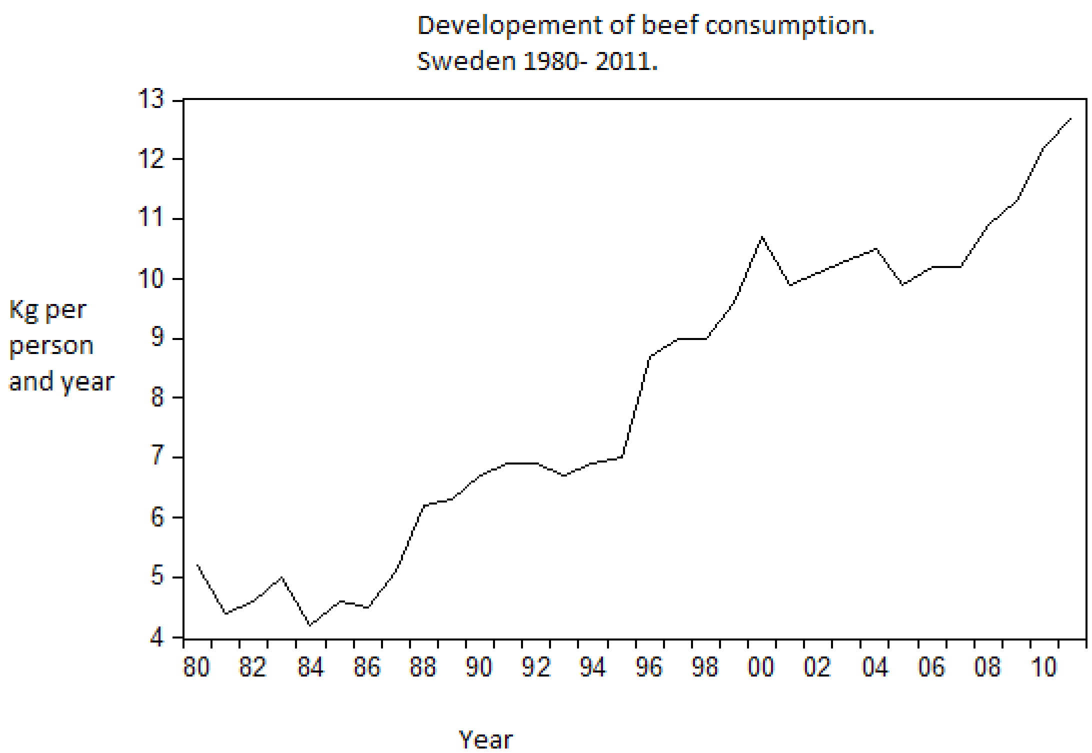
1 Introduction

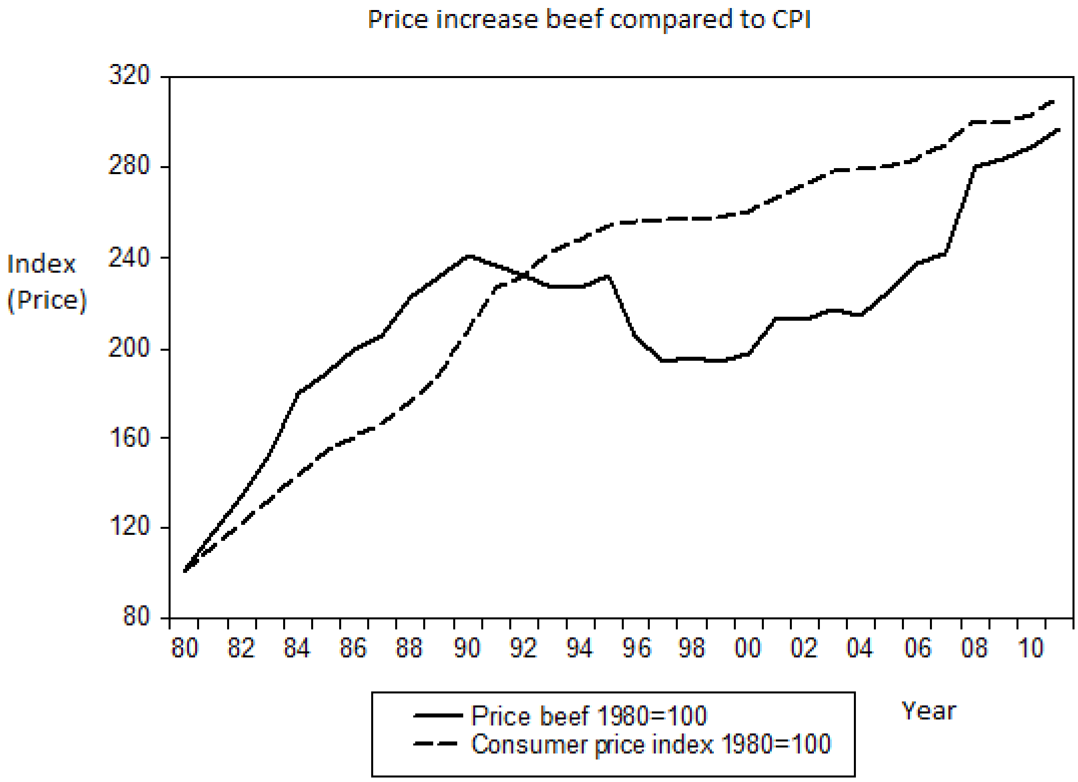
In a report from 2013 the Swedish Board of Agriculture (Jordbruksverket) discussed a CO_2 consumption tax on meat products, as a possible policy method to ensure a sustainable meat consumption. The report was followed by a public debate in which representatives of both the swedish green party (Miljöpartiet) and the left party (Vänsterpartiet) said that they were in general positive to such a pigovian tax on meat. However, as the spokesperson for the swedish social democratic party (Socialdemokraterna) stated, such a tax would be politically difficult to impose.[1]

The main argument for a tax on meat products is the emissions caused by meat production and the increasing consumption of meat in Sweden. One of the explanations is the relatively slow increase of beef prices since 1990 compared to other prices caused by - among other things - cheap imports[2]. In economic terms, production of meat creates an externality: emissions from green house gases (GHG) and other pollutants. If multilateral goals of GHG emission reductions are to be reached it can be argued that all sectors need to carry their own emission costs.



Source: Eviews illustration of the regression data

1 Rosén, Eric (2013) *V och MP vill införa köttskatt – S tvekar.*
2 Lööv, Helena. et al (2013) *Köttkonsumtionen i siffror – Utveckling of orsaker* Jordbruksverket, Rapport 2013:2 p.10



Source: Eviews illustration of the regression data

1.1 Previous research

There is only little literature on the subject of pigovian taxes on meat. However, there seems to be a consensus on some issues. *Säll and Gren (2012)* and *Wirsenius. et al (2010)* argue that the tax should be imposed on the consumption and not directly on the emissions, see 3.2.1 Further, they argue that the tax should be imposed on the consumers, making sure that prices on domestically produced and imported meat are affected equally. Finally they state that a simultaneous taxation on more than one animal product would reduce emissions the most. *Säll and Gren (2012)* argue that if the choice would be between a tax on beef, pork and poultry, a tax on pork would be most efficient. This is because of high emissions of above all nutrients and since it, a bit surprisingly, is found to be a strong complement to the other two causing consumption reductions on all three kinds of meat[3]. *Wirsenius. et al* (2010) argues that a tax on beef would be the most efficient, partly because of the land intensity of the production. The differences in results are most likely a consequence of different

3 Säll and Gren (2012) *Green consumption taxes on meat in Sweden*, Working paper series 2012:10 p.19

focuses. The first article includes nutrient pollutants while the second ads positive effects of alternative land use to the analysis[4].

1.2 Purpose of the paper

The Swedish Board of Agriculture argued that a simultaneous taxation on a range of animal food products weighted with respect to their GHG emissions would be more efficient than a taxation on one single product[5]. This is in line with theory, since substitution to other polluting goods would be discouraged. However, this paper will limit the discussion to a pigovian tax on beef, because of its relatively high GHG emissions and the increase in consumption. [6][7][8] The purpose of this paper is to answer the questions: 1)*How elastic is beef demand and how much will consumption sink when imposing a pigovian tax on beef. 2*)*What would be the best use of the revenues from such a tax?* In the first part of this paper the demand function and elasticities of beef will be estimated. This will be carried out using regression analysis and data on consumption, prices and income in Sweden between 1980 and 2011. The results will be used to discuss the possible impact of a pigovian tax on beef consumption. In the second part the use of the tax revenues will be discussed within the frame of taxation theory of green tax shifting policies, comparing two alternative uses of tax revenues. Distributive effects are not directly estimated, but discussed from a theoretical perspective. This paper will focus on GHG emissions as the main argument for raising a tax on meat and other arguments such as health aspects and other environmental effects are only discussed briefly.

2 Background

Environmental impacts differ to a large extent between different kinds of meet. Emissions from global beef production are estimated to be 22-40 Kilo CO_2-equivalents per kilo beef. This can be compared to 3,2–9,2 Kilo for Pork and 1,5–7,3 Kilo for Poultry. The large variance within the categories is due to differences in production procedure which can differ between producers and countries. As an example, emissions of GHG are estimated to be 30 to 40% higher in primary beef production in Brazil than in Europe. The difference can be explained with a high butchery age, allowing for more methane emissions per animal. Another explanation is that brazilian beef is less

4 Wirsenius. et al *Greenhouse gas taxes on animal food products: rationale, tax scheme and climate mitigation effects* (2010)

5 Lööv, Helena (ed) (3013). p.53

6 In 2010 beef accounted for approximately 30% of total meat consumption in Sweden. *Köttkonsumtionen i siffror* Rapport 2013:2 Jordbruksverket p.5

7 Lööv, Helena (ed) (3013). p.21

8 Total consumption refers to the total usage of different primary products for human consumption. Direct consumption refers to the total deliveries of provisions from producers to private housholds and institutional kitchens aswell as the own usage by the producers.

likely to be the by-product of milk production than in Europe also causing emissions to be higher. Additionally, land use is larger in Brazil. Energy use, however, is considerably lower, about ten per cent of the European level.[9]

From this data two important conclusion can be drawn and they will both be discussed in more detail in later parts of the paper: Firstly, improvements can be made within the meat production procedure, lowering emissions, however as will be discussed in the theory section, these possibilities of reduction are too small to be sufficient. Secondly, a tax imposed on only swedish producers would risk having a negative impact on GHG emissions in a global perspective, since imports would be likely to increase.

2.1 Why a meat tax?

At least in theory, there seems to be a consensus that products associated with high levels of emissions such as fossil fuels and chemicals should be administratively or economically regulated. A report from the UN Food and Agriculture Organization (FAO) from 2006 showed that meat production accounted for approximately 18 per cent of the total GHG emissions in the world[10]. Despite this, voices demanding that meat production should carry its own environmental costs have been few. This can perhaps be explained by the almost political status of meat. Historically meat has been an important source of nutrition and protein. Meat has also been a luxury good associated with wealth and health and this is still the case in some parts of the world. In Sweden, many traditional dishes are meat based and a tax on meat might be considered a controversial issue.

2.2 Health aspects

Historically, and still in some parts of the world, meat has been of scarcity. In Sweden however, as in the rest of Europe, the average person eats more meat than is recommended from a health perspective. Research show that a too high consumption of red meat increases the risk of some types of cancer. The World Cancer Fund recommends not to eat more than 300 grams of red meat per week. In Sweden the average person eats 400 grams, where men eat more than women.[11] An interesting point of further research would be to include health gains from a pigovian tax on meat. This analysis would be close to the related literature on pigovian taxes on fat or sugar to improve public health.

9 Lööv, Helena (ed) (3013). *Hållbar köttkonsumtion – Vad är det? Hur når vi dit?* (Rapport 2013:1) Jönköping: Jordbruksverket p.21
10 Lööv, Helena (ed) (3013). *Hållbar köttkonsumtion – Vad är det? Hur når vi dit?* p.1
11 Lööv, Helena (ed) (3013). p.17-18

2.3 Other externalities from meat production

Emissions from GHG have, rightfully, received a lot of attention in the literature during the last decades. There are however other negative externalities associated with meat production. The swedish meat production accounts for approximately 27 per cent of total phosphorus, 22 per cent of total nitrogen, and 55 per cent of total ammonia emissions[12]. This kind of nutrient pollution causes eutrophication, which among other things is responsible for the excessive algal blooms in the Baltic Sea. When estimating the consumption reduction of the tax later in this paper, the optimal tax level used will be taken from the paper *Säll and Gren 2012* that takes these pollutants into account. Production of beef is not only associated with negative externalities but also with a number of positive externalities. These are discussed in the same report from The Swedish Board of Agriculture that lifted the issue of a meat tax. The sustaining of open landscapes, biodiversity and livelihood in the rural areas where ruminants are held in Sweden, could potentially be threatened by a beef tax. However, the report stresses that these positive externalities are better subsidized by parallel policy tools, directly targeting these.[13] In this paper, therefore, these positive externalities will be left out of the further analysis.

3 Theory

The purpose of the theory section is to present the economic theory used. This is done partly to give the reader tools to follow the process and the results of the paper and partly to show how the paper relate to and use economic theory. The theoretical framework presented below focuses on: econometric theory, pigovian taxes, demand theory, general taxation theory and environmental tax shifting policy. The first three areas provides the theory for part one, the deriving of the beef demand function and effects of a tax. The two last areas are presented to provide a theoretical framework for the discussion in part two of the best use of tax revenues from a consumption tax on beef.

3.1 Econometric theory

When estimating demand functions from time series data there are some potential problems which – if not accounted for – could cause the Ordinary Least Squares (OLS) or Non-linear Least Squares (NLS) estimators to be biased or inefficient. In this section these problems will be presented briefly and potential causes, tests and measures to minimize the problems will be discussed.

12 Säll and Gren (2012) p.5
13 Lööv, Helena (ed) (3013). p.57

3.1.1 Potential problems when estimating demand functions from time-series data

Multicolliniarity occurs when two or more variables are highly positively or negatively correlated, making it difficult for the multiple regression technique to discriminate between the effects. Multicolliniarity is especially common in time-series regressions since economic variables often are depending on a strong time trend. It causes the standard errors to be high, which can lead to insignificant variables, even though they perhaps genuinely belong in the model. The regression coefficients however remain unbiased. Multicolliniarity can be detected by examining correlation statistics and standard errors in regression outputs and if both are high this is a sign of multicolliniarity. Potential cures are: increasing number of observations, decreasing the variance by including a potentially significant omitted variable or combining two ore more correlated variables into an index. [14]

Another problem, common when using time series data, is auto-correlation. It occurs when the disturbance term does not satisfy the condition that $\text{covariance}(u_t, u_{t'}) = 0$ for $t \neq t'$. In words, this means that the disturbance term in each observation is not generated independently from the disturbance term in other observations. Persistence of the effects of excluded variables causes positive auto-correlation, the most common type in economic analysis. Auto-correlation causes regression coefficients to be unbiased but inefficient. The standard errors tend to be biased downwards. There are several test for auto-correlation including the Breusch-Godfrey test, the Durbin-Watson test and Durbin's *h* test. Which test is appropriate depends on the data and the model being tested. In this paper the Durbin-Watson test and the Breusch-Godfrey test will be used.

Finally, when using time series data it is common that the series are non-stationary. If a non-stationary time series is regressed on another non-stationary time series it is likely to obtain a significant relationship even if the variables have nothing to do with each other. This kind of nonsense regression is called a spurious regression. A time series is non-stationary if it does not satisfy one of the following conditions for (weak) stationarity:

1. The mean of the distribution is independent of time
2. The variance of the distribution is independent of time
3. The covariance between its values at any two time points depends only on the distance

14 Dougherty (2011) *Introduction to econometrics* p. 165-166, 169-175

between those points, and not on time.

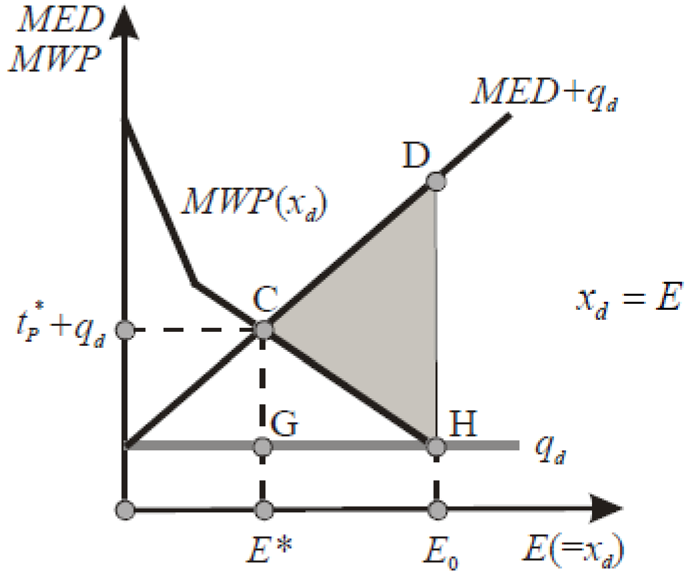
There are a variety of tests for detecting non-stationary, the Augmented Dickey-Fuller test being most common and the test used in this paper. Non-stationary time series can often be made stationary by differencing the series one or two times. They are then said to be difference stationary. If two time-series are non-stationary it is still possible to show that they have a long term relationship if the disturbance term is stationary. They are then said to be cointegrated. This can be tested with an Engel-Granger test. [15]

3.2 Pigovian taxes

The theory behind environmental taxes, so called pigovian taxes, is straight forward. The tax should be set to a level equal to the MED (marginal environmental damage) of the polluting good in the optimal point of consumption. In this way the externality, the extra social cost that arises from the production and/or consumption of the polluting good, is internalized. In the diagram below the Marginal Willingness to Pay MWP(X_d) curve represents consumer demand for beef: (X_d). The MED curve is the marginal environmental damage[16] from production of beef and t_p is the pigovian tax. Further q_d is the pre-tax price of beef. Before the tax the consumers chose a consumption level that results in the emission level (E_0) where the price q_d equals MWP(X_d). After the tax is imposed beef becomes more expensive and consumption and emissions fall to the optimal level (E*). At this level the new consumer price which is the pre-tax price q_d + the tax t_p equals the total cost MED + q_d. This means that MED=t_p[17]

The welfare improvement is the grey triangle CDH reflecting the environmental improvement minus the utility loss of the consumers. The tax can be imposed directly on the emission (E) or indirectly on the production or consumption of the polluting good. Which of these alternatives is the most efficient depends on the nature of the production of the good. Although easy in theory the level of the emissions are often difficult to measure and a pigovian tax directly on the emissions is thereby associated with administrative costs.

15 Dougherty (2011) p.504-506
16 In monetary terms
17 here production is assumed to increase proportional to consumption and the price is assumed to increase proportional to the tax.



$$\Delta W(E_0 \to E^*) = \Delta ED(E_0 \to E^*) - \Delta WP(E_0 \to E^*) = \text{CDH}.$$

Source: Compendium Finanswissenschafliche Steuerlehre chapter 6 p.2

3.2.1 Properties of the Pigovian tax

As mentioned above, a Pigovian tax can be imposed directly on the units of emission or indirectly on the output (or input) of the good as such. The justification of the latter is that this can be assumed to have strong correlation to the emissions. In general, direct taxation of the emissions are preferable since it targets the externality directly. It also gives incentives for technological improvement within the production procedure. However, in some cases an output (input) tax is preferable. *Wirsenius et al. (2010)* present three criteria that motivate when output (input) taxes are preferable to direct taxation of the emissions. This is the case when (1) costs of monitoring emissions are high, (2) there are limited options for reducing emissions apart from output reduction, and (3) the possibilities for output substitution are great.[18]

In addition to that, they show that these conditions are met in the case of a green consumption tax on beef. Firstly,

(1) In general, emissions from GHG are difficult to measure. In the case of the methane

18 Wirsenius. et al (2010) p.3

emissions of ruminants *Wirsenius et al. (2010)* show that the emissions would have to be measured at the farm level, since the emissions vary from animal to animal and by diet. This would result in high administrative costs for monitoring the emissions.[19]

(2) Secondly, *Wirsenius et al*. argue that the possibilities of reducing the GHG emissions within the beef production procedure are low. They refer to studies which show that the global emissions of methane and nitrous oxide from livestock could be reduced only by 10–15% for a price of 100 Euro per ton CO_2-equivalents. The reason is that the GHG emissions in agricultural production can be shown to be related to intrinsic characteristics of the agricultural system. The methane emissions of ruminants are part of their digestive system and not easily manipulated.

(3) Finally, the number of possible substitutes for beef are considered high. [20]

3.2.2 Consumption or production tax?

At present value added taxes on provisions in Sweden are imposed on the producers. In the long run, it generally does not matter whether a tax is imposed on the producers or the consumers: the reduction in consumption, and the distribution of the tax burden will be the same. However, in the case of a tax on meat, as discussed above, most sources argue for imposing the tax on the consumers to avoid comparative disadvantages for Swedish meat producers. [21][22][23] Another argument for this is that swedish beef production is connected to relatively low emissions, in comparison, for example, with brazilian beef production mentioned above. If swedish beef would be substituted with cheaper imported beef the total emissions could increase due to the tax.

3.3 Demand theory – the demand function of beef

The determinants of the demand of beef can be divided into economic factors and non-economic factors. The economic factors are; (1) the price of beef, (2) the prices of substitutes to beef and (3) income. These variables will be included in the regression analysis in the next section. The easier it is to substitute a good, the more elastic the own price demand will tend to be, since the consumers can more easily change their consumption related to price changes. Furthermore, the own price demand will tend to be more elastic the larger the proportion of the total household expenditures the good represents.

There are a large number of non-economic factors determining the beef demand and these are

19 Wirsenius. et al (2010) p.4
20 Wirsenius. et al (2010) p.5
21 Lööv, Helena (ed) (3013)p.52-53
22 Säll and Gren (2012) p.6
23 The reason for this is that the higher prices associated with a consumption tax will affect imported beef in the same extent as nationally produced beef.

difficult to account for with regression analysis. A study from the Swedish Board of Agriculture, estimates the most important non-economic determinants of meat demand to be: Consumer attitudes to health, lifestyle and commercials.[24] Related to health and lifestyle, two trends working in opposite directions can be observed for meat consumption. First, growing interest for vegetarian diets and second the growing popularity of meat intense diets such as the LCHF (Low Carb High Fat) diet. In a report from the Swedish National Food Agency (Livsmedelsverket) three percent of the respondents answered that they are following a vegetarian or vegan diet, six percent of the respondents answered that they where following a specific diet where the LCHF diet was one of them.[25] The lack of sufficient data makes it hard to estimate the extent of the impact on meat demand of these trends. However, since they work in opposite directions, they will be excluded from further analysis assuming that they to some extent neutralize each other.

3.4 Taxation theory

The taxation literature identifies four main objectives of taxation. Different taxes can be motivated by one or more of the four objectives.

1. The fiscal objective, to receive money to the public treasury. This is the most important and common objective of taxation. It will also always be a second objective, even if one of the other objectives are dominating.
2. To influence the behavior of economic actors
3. Redistribution of resources
4. Stabilization of the business cycle, an example is the income tax that works as an automatic stabilizer.[26]

A green consumption tax on meat as a pigovian tax has, by definition, the main aim to change consumer and producer behavior while the fiscal aim can be seen as subordinate. The third and fourth aim are not directly related to pigovian taxes.

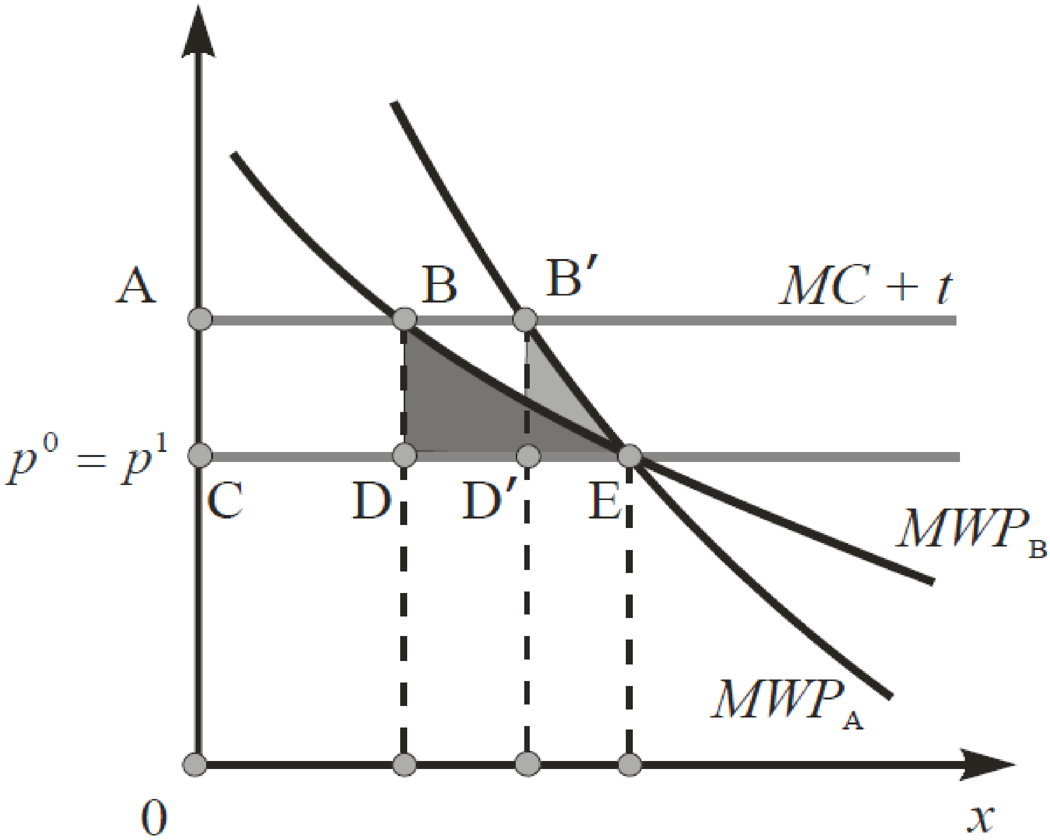
3.4.1 Optimal Taxation theory and the role of the elasticity

The demand elasticity is defined as the percentage change in consumption of one good (the depending variable) relative to the percentage change of either its own price, the price of other goods or the income (the independent variables).

24 Lööv, Helena. et al (2013) p.14
25 Livsmedelsdataenheten (2012) *Riksmaten vuxna 2010-11* p.114
26 *Finanswissenschaftliche Steuerlehre 2 Kapitel. Begriffe und Prinzipien der Steuerlehre* (2013) Freie Universität Berlin

Elasticities are common in economic analysis since they provide neutral information of price and income sensitiveness of consumption. Neutral in this case means that they are unaffected by relative sizes and units of measurement. The own-price elasticity indicates how consumption reacts to a tax on that good. Cross price elasticities give information on substitute and complementary goods. This information can be used to analyse how a tax would affect consumption of other goods. Income elasticity indicates how the consumption depends on the income. It can be used to investigate the distributive effects of a tax.

When the fiscal objective is the dominating objective for imposing a tax, the *inverse elasticity rule* can be used as a guideline when considering tax levels. It states that in the choice of tax levels on different consumer goods, the tax should be set highest on the good with the lowest own price elasticity. The intuitive reason is that the lower price sensitiveness makes the abatement costs or Excess Burden associated with taxation lower for this good. In the diagram below, the consumer demand for good (A) and good (B) are represented by the two MWP functions. The demand for good (B) is more elastic than the demand for good (A), resulting in a higher Excess Burden from the raising of the tax (t) on good (B) than on good (A). In this case a higher tax on good (A) would be the most efficient. This approach is not entirely uncontroversial since basic consumer goods tend to be the least elastic. In practice, *the inverse elasticity rule* is used as one of many guidelines when deciding tax levels. It is more relevant when the fiscal aim is prioritized. In the case of Pigovian taxes, however, the main purpose is to accomplish the change in consumption that is the actual cause of the Excess Burden. If good (A) and good (B) are two goods with equal Marginal Environmental Damage (MED), a tax on good B would be better, since it reduces the damaging consumption the most. Again, the tax should be set equal to the MED in the optimal point of consumption. The conclusion is that the prioritizing of the fiscal aim favors the use of *the inverse elasticity rule* where another aim of taxation, to influence behaviour, favours a focus on the environmental effect. This conclusion will be used in the second part of the paper where the use of the tax revenue will be discussed.



Inverse elasticity rule. Source: Compendium Finanswissenschafliche steuerlehre chapter 5 p.12

3.5 The theory of Environmental tax shifting policies

The basic idea of the theory of tax shifting policies is that the revenues from a Pigovian tax are used to lower distorting taxes. Distortive in this case refers to the Excess Burden of the tax discussed in the previous section. In practice, taxation on labour has been the most common example since they are estimated to be highly distortive. If a double dividend does in fact exist for a specific pair of goods in a specific economy, it is possible to accomplish a welfare improvement by raising the Pigovian tax and lowering the distortive tax, holding total tax revenue constant, even when the environmental effect (represented by the difference of the Marginal Environmental Impact (MEI) of the two tax bases) is not included. The criteria is that the Marginal Cost of Funds (MCF) for the distortive tax base is higher than the MCF for the polluting tax base.

Mathematically the definition of a so called Strong double dividend is:

$$\frac{d\widetilde{W}}{dR_d}\begin{Bmatrix} > \\ = \\ < \end{Bmatrix}0 \Leftrightarrow (MEI_d - MEI_c) + (MCF_c - MCF_d)\begin{Bmatrix} > \\ = \\ < \end{Bmatrix}0 .$$

Source: Finanswissenschaftliche Steuerlehre 6 Kapitel. Besteuerung externer Effekte. (2013) Freie Universität Berlin

$$\frac{d\widetilde{W}}{dR_d}$$

Where,

is the welfare effect.[27]

4 Research, data and method

In this section the data and variables will be presented and the research process and method will be described. Focus will be on providing a clear view of the regression process.

The data was obtained from the Swedish Board of Agriculture and Statistics Sweden (SCB). The price variables are index prices and all independent variables have the base 1980=100. They were deflated by dividing each observation with consumer price index (CPI) of that year, also with base 1980=100. Pork, Egg, Dairy and Potato are all potential complementary or substitute goods based on results from other studies.

4.1 Some notes on the data on beef consumption

Since the methods of calculating beef consumption has changed since the start, the Swedish Board of Agriculture makes notes on these changes for all data. For beef it should be noted that from 1996 the methods of measurement were adjusted and comparisons between years before and after should be done with precaution. From 1988 and onwards frozen beef is included in measurements. This indicates that a small proportion of the increase in beef consumption might be an attribute of these measurement changes.

27 The $MEI_{d,c}$ defines the environmental damage per SEK extra tax revenue, that can be avoided through the rais of $t_{d,c}$. The MCF defines the direct utility loss per SEK extra tax revenue through a marginal rais of a specific tax. In this case the rais of $t_{d,c}$.

4.2 Regression Variables

Table 1. Regression variables / Name of variable	Description	Source
KBEEF	Direct beef consumption in Kilo per person and year	Jordbruksverket
PBEEF	Price index. 1980=100	Jordbruksverket
DI	Disposable income index 1980=100	SCB
PPORK	Price index. 1980=100	Jordbruksverket
PEGG	Price index. 1980=100	Jordbruksverket
PDAIRY	Price index. 1980=100	Jordbruksverket
PPOTATO	Price index. 1980=100	Jordbruksverket
CPI	Consumer price index. 1980=100	SCB

4.3 The model

The consumption of beef was assumed to depend on the price of beef, the income and the price of potential substitute or complement goods. It was hypothesized that the original model had the form (1.) which is commonly assumed for demand functions[28].

$$1.\ KBEEF = \beta_1 DI^{\beta_2} PBEEF^{\beta_3} PRICE_{c,d,e,f}^{\beta_4} v$$

where c=pork d=dairy e=egg f=potato

The model was then linearized by taking logarithms, obtaining:

$$2.\ LGKBEEF = \beta_1' + \beta_2 LGDI + \beta_3 LGPBEEF + \beta_4 LGPRICE_{c,d,e,f} + u$$

Where β_1' is the logarithm of β_1, u is the error term and the natural logarithm of v and β_2 , β_3 and β_4 are income and price elasticities.

Table 2. Descriptive statistics of variables

	LGDI	LGKBEEF	LGPBEEF
Mean	4.779609	2.026321	4.556120
Std. Dev.	0.166421	0.343774	0.180008
Observations	32	32	32

28 Dougherty (2011) p. 395

4.4 Regression process

The regression analysis was performed in the econometrics program Eviews using multiple regression analysis. Regressions were fitted according to model 2 above, including one substitute or complement good at a time. Since the Durbin-Watson statistic in all models was well below two, indicating auto-correlation, a Durbin-Watson test was performed where the null hypotheses of auto-correlation could not be rejected at any level of significance for any of the models. A AR(1) term was included to eliminate the auto-correlation. Eviews then automatically changes the model to a non-linear auto regressive model. The significant AR(1) term indicated that the original models had been subject to auto-correlation. A Breusch-Godfrey test performed both with a t-test of the lagged residual and with the lagrange multiplier statistic nR^2 confirmed that the problem of auto-correlation had been solved.[29]

A time-trend was added to the model to pick up on effects changing over time. It was however not significant and it was concluded that LGKBEEF did not depend significantly on a time trend and it was dropped from the model.

Now non of the price variables for the other goods were significant so they were dropped from the model. The reason for this was suspected to be multicolliniarity caused by high correlation between the price variables, see table 3, resulting in large standard errors (s.e). Various cures for multicolliniarity were considered but since the data was obtained from an external source non of the techniques used in the sampling procedure could be applied. Further an index with the two goods with the best t-statistics was considered, however these were found to be pork and dairy. Since dairy was estimated to be a substitute and pork a complement this approach was also rejected due to their opposite effects on the consumption of beef. It is possible that these variables to some extent influence the beef consumption but this could not be proven by this paper.

All variables in the model were tested for unit roots using the Augmented Dickey-Fuller (ADF) test[30]. The null hypothesis of non-stationarity could not be rejected at 10% level for any of the variables and all variables were assumed to be non-stationary. Since regressing a non-stationary time series on another non-stationary time series is likely to be a spurious regression[31], the model was tested for cointegration using an Engel-Granger test[32]. An ADF test was performed on the

29 See appendix
30 Regression outputs for these tests were not included in Appendix since so many tests were performed
31 Dougherty (2011) p. 475
32 See appendix

residuals of the model and non-stationarity could be rejected at 1% level comparing the t-statistic of -5,199 to the critical values of Davidson and Mackinnon[33]. The cointegration indicated that there in fact exists a long term relationship between the variables[34]. The indirect restrictions of the AR(1) model were tested with the Common Factor test[35] and could not be rejected at any level of significance so the AR(1) model was accepted. The unrestricted model ADL(1,1) was also tested for auto-correlation using the Breusch-Godfrey test[36]. Auto-correlation was rejected at all significance levels.

Table 3. Correlation	LGDI	LGKBEEF	LGPBEEF	LGPDAIRY	LGPEGG	LGPPORK	LGPPOTATO
LGDI	**1.000000**	0.924028	-0.585221	-0.584538	-0.528946	-0.730181	0.372047
LGKBEEF	0.924028	**1.000000**	-0.775151	-0.704156	-0.723317	-0.868456	0.197470
LGPBEEF	-0.585221	-0.775151	**1.000000**	0.931463	0.830786	0.962823	0.101715
LGPDAIRY	-0.584538	-0.704156	0.931463	**1.000000**	0.712450	0.933780	0.019312
LGPEEG	-0.528946	-0.723317	0.830786	0.712450	**1.000000**	0.779627	0.240647
LGPPORK	-0.730181	-0.868456	0.962823	0.933780	0.779627	**1.000000**	-0.079073
LGPPOTATO	0.372047	0.197470	0.101715	0.019312	0.240647	-0.079073	**1.000000**

33 Altered critical values from Davidson and MacKinnon (1993) for performing cointegration tests.
34 Dougherty (2011) p.504-506
35 See appendix
36 See appendix

5 Regression results and analysis

In this section the regression results will be presented and analysed. The results will be compared to results from other studies of swedish beef demand. Table 4 is the regression output from the final fitted model.

Table 4. Regression output final fitted model

Dependent Variable: LGKBEEF
Method: Least Squares
Date: 04/28/14 Time: 16:02
Sample (adjusted): 1981 2011
Included observations: 31 after adjustments
Convergence achieved after 10 iterations

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.586807	1.566030	-1.013267	0.3199
LGDI	1.411984	0.208312	6.778231	0.0000
LGPBEEF	-0.685467	0.185903	-3.687224	0.0010
AR(1)	0.605916	0.159668	3.794844	0.0008

R-squared	0.960003	Mean dependent var	2.038504
Adjusted R-squared	0.955559	S.D. dependent var	0.342363
S.E. of regression	0.072174	Akaike info criterion	-2.299573
Sum squared resid	0.140643	Schwarz criterion	-2.114542
Log likelihood	39.64338	Hannan-Quinn criter.	-2.239257
F-statistic	216.0184	Durbin-Watson stat	1.815999
Prob(F-statistic)	0.000000		

Inverted AR Roots	.61

Since the model contains a lagged variable it is dynamic and the coefficients shall be interpreted as short term elasticities. The short term own-price elasticity was estimated to -0,69 and the short term income elasticity was 1,41. All coefficients are significant on the 0,5% level using one sided t-tests. The exception is the constant which has no economic interpretation in this model. The results are relatively similar to results from other studies on beef demand in Sweden. The estimates from all three studies are presented in table 5. Results of t-tests when estimating autoregressive models should be viewed with precaution since the t-statistic tends to be distorted.[37] However, the estimates yields so highly significant coefficients that the risk of a type 1 error can still be considered to be very small.

37 Dougherty (2011) p. 418,419

Table 5. Results in comparison	Price elasticity	Income Elasticity
This study	-0.69	1.41
Säll and Gren (2012)[38]	-0,39	0,94
Jordbruksverket (2009)[39]	-0,66	ca 1,5

Hence, the demand function of beef was estimated to be:

$$LGKBEEF = -1,59 + 1,41\ LGDI - 0,69\ LGPBEEF + 0,6\ AR(1)$$

Long term elasticities are obtained by dividing the short term elasticities with 1 - the AR(1) coefficient. Hence, the long term own-price elasticity is: -0,685/(1-0,606)= -1,74 and the long term income elasticity is 1,411/(1-0,606)= 3,58. This means that, in the long run, both own-price and income elasticities are highly elastic. Effects tend to be stronger in the long run, when consumens have had time to adjust their behaviour.

The one sided confidence intervals were:

$$1,058 < \beta_2 < 1,764$$

$$-1,000 < \beta_3 < -0,370$$

5.1 Interpretation of regression results

The estimate of the price elasticity indicate that a tax on beef could be efficient from an environmental perspective. The price elasticity is inelastic in the short run but still not as inelastic as many other basic goods. In reality, the tax would be imposed on a range of animal products, with different price elasticities and beef is often estimated to be highly elastic compared to other animal products. The total effect of the reform would depend on the price elasticities of all these products. The short term income elasticity is estimated to be larger than 1 indicating that beef is a luxury good. This means that the tax burden would be larger for richer households if the tax would be imposed only on beef. Once again the effect would in reality depend on the income elasticities on all goods included in the tax reform.

5.2 Consumption reductions when imposing a hypothetical tax

In this section the short run effects on consumption from a hypothetical tax will be calculated. The

38 Säll and Green (2012) p.12

39 Lööv and Widell (2009) *Konsumtionsförändringar vid ändrade matpriser och inkomster* Rapport 2009:8 Jordbruksverket p.24,34

calculations will use tax levels based on tax levels and assumptions from *Säll and Gren 2012* and it will be investigated how the resulting consumption reduction change when changing specific assumptions. The results should be viewed as illustrative since the tax levels assumed are approximate.

Säll and Gren 2012 have calculated the MED of beef production and optimal pigovian tax on beef in Sweden. The emission levels were calculated by using data on pollution from GHG, phosphorus, nitrogen and ammonia. Politically revealed costs of Swedish politicians were used to express the emissions in monetary terms. Revealed costs of emissions were assumed to 1 SEK per kg CO_2/e (CO_2 - equivalents)[40]. In calculating the MED, *Säll and Gren 2012* assumed that all meat production had the same technology as swedish meat production. This was motivated by the fact that 60-78% of the value of meat consumption in Sweden comes from domestic agriculture[41]. The estimated consumer price increase due to the tax was 28,1%. By relaxing the assumption that technology is the same everywhere and assuming stronger environmental preferences for politicians a higher tax level can be motivated. Alternative scenarios will be proposed for comparison with tax levels on 40 and 50%[42]. These tax levels can be motivated with that the swedish green party and the swedish left party have increased their shares in recent polls and are likely to have more influence after the upcoming national elections in September 2014.

If now producer supply is assumed to be perfectly elastic in the long run, 28,1% can be used as the value added tax rate imposed on the consumers. Using the demand function estimated in this paper the decrease in consumption can be calculated under different assumptions on consumption, elasticity and tax levels. The results are presented in table 6. The last two columns show how consumption changes due to the tax. The other columns show rates of elasticities, tax rates and consumption levels used when calculating the consumption reduction. A comparison of the consumption reductions in the different scenarios proposed in the first column illustrates how assumptions made when calculating both optimal tax level and elasticities affect the results. Both a higher assumed elasticity as in the confidence interval minimum scenario and higher tax rates as in the 40 or 50% tax scenarios result in stronger consumption reductions. If long run elasticities would have been used, the resulting consumption reductions would have been even stronger.

40 Obtained from current tax levels on CO_2/e emissions from fossil fuels in Sweden
41 Säll and Gren (2012) p.15
42 It should be noted that these tax levels are not more or less correctly corresponding to the MED than the 28,1 % level. The purpose is to illustrate how hard the MED is to decide and the resulting politication of the tax level.

Table 6. Consumption changes	Price elasticity	Tax rate %	Direct Consumption *[43]	% Consumption reduction	Absolute Consumption reduction*
Original assumptions	-0,685	28,1	12,7**	19,25	2,444
Confidence interval min	-1,000	28,1	12,7	28,1	3,57
Confidence interval max	-0,370	28,1	12,7	10,6	1,35
40% tax scenario	-0,685	40	12,7	27,4	3,48
50% tax scenario	-0,685	50	12,7	34,3	4,35

*KG per Person per Year, **Consumption in latest observation (2011)

5.3 Final discussion part one

Table 6 illustrates how sensitive the resulting consumption change is not only to price elasticity but also to assumptions made when estimating the MED. Hence, if a general pigovian tax on animal products would be implemented the calculations of the MED should be based on data on actual environmental costs. There is however hard to find an objective way of calculating MED since the costs of GHG emissions appear over time. Therefore, MED would be based on the assumed costs of environmental problems in the future and depend on the way of measuring this. This problem not only affects the deciding of the tax level on meat products, but concerns all economic instruments for environmental regulation including all pigovian taxes and emission certificates. As the difficulty to find appropriate price levels for the latter shows, these instruments are in practice not based only on scientific knowledge but are also influenced by economic and political interests.

6 Part two - potential use of tax revenue

In this section, the potential use of the revenues from a pigovian tax on beef or on meat products will be discussed within the framework of taxation theory and theory of environmental tax shifting policy. There are some arguments for introducing the pigovian meat tax within a general policy proposal in which also the use of the revenue is considered. The first argument for this is practical: to increase the level of acceptability of a raising of value added taxes in the public, it is sensible to communicate what the revenues will give in return. The second argument is based on taxation

43 For definition of direct consumption see note 8.

theory. A pigovian tax on meat products will have indirect effects that need to be accounted for. Such effects are: welfare effects, distributive effects and effects on the efficiency of the tax system. The revenues can be used to manage these indirect effects.

Two alternative uses of tax revenues will be discussed and compared. The first alternative is that the revenues will, in the frame of green tax shifting policy, be used to lower the tax on labour. The second alternative is that the revenues will be used to lower taxes on green substitutes to meat.

6.1 Alternative 1 – lowering the tax on labour

The main argument for this approach is the theory of the existence of a second dividend when raising a green tax and using the revenue to lower a distortive tax, often a tax on labour. The economic theory behind this was presented in the theory section. This alternative uses the assumption that green taxes are more efficient than taxes on labour and relates to the fiscal taxation aim indirectly by justifying a green tax by the increased efficiency of the tax system. Further it is based on the aim that the total tax revenues and tax burden should be left unaltered. However, even if the total tax burden of the economy is unchanged the distribution of it is not.

In 1996 *Harrison and Kriström* presented an official report from the Swedish Government (SOU) and a scenario ”C100” : a doubling of the CO_2 pigovian tax on fossil fuels, where the revenue should be used to lower the tax on labour. The analysis was performed within the frame of a general equilibrium model where the effects of the tax reform were investigated, with respect to the pree existence of other taxes. The virtue of this analysis is that it accounts for effects on other tax bases and how changes in relative prices affect the economy as a whole. The main point in the final statement was that there is barely no evidence of the existence of a double dividend in this scenario, or in scenarios where the CO_2 tax was raised with 200 or 300 per cent.[44]

One of the main reasons for the lack of a second dividend proposed by *Brännlund and Kriström (1998)* is the relative small size of the fossil fuel CO_2 tax base compared to the income tax base which is the largest in the Swedish economy. Even with a 300% increase of the CO2/e tax, the income tax could only be lowered by 3.3%. [45]

This would also most likely be the case with a tax on meat. The total revenues from value added

44 Harrison and Kriström (1996). *Effekter av olika skatteväxlingsalternativ enligt en allmän jämviktsmodell* p.208-211
45 Brännlund and Kriström (1998) p.243-244

taxes were 341,6 billions in 2013. That is 35,2% of the total revenues from the taxes on labour (65,1% of direct and 76,8% of indirect taxes on labour)[46]. Even if a broad range of meat and animal products would be included, they still only account for a small proportion of the total value added taxes in Sweden.

A tax shifting reform in Sweden that raises the tax on meat products and lowers the tax on labour is likely to have an unwanted distributive effect favoring richer households. This is due to two effects. First, since taxes on labour are to some extent progressive lowering them would generally favor richer households. Second, a raising of a pigovian tax on meat products is also likely to have a stronger negative effect on low income households because of its regressive characteristic. Especially if the tax is imposed on basic goods that account for a large proportion of expenditures of these households. [47] Beef is in this paper not estimated to be a basic good but a luxury good, but if the tax is in fact raised also on animal products with lower income elasticities such as pork, and dairy products which are both estimated to be normal goods[48] this distributive effect can be assumed to be substantial.

6.2 Alternative 2 – lowering the tax on substitutes

The unwanted distributive effects of the pigovian tax and the first alternative is one of the main arguments to seek a different use of the tax revenues, compensating for and not worsening the distributive effect. This could be achieved by compensating the consumers by using the revenues to lower taxes on other consumption goods. This would increase incentives of substituting the taxed animal products. If the subsidized goods would be chosen based on their substitutability to the meat products and their production emission levels, consumers would be compensated, corresponding to their changed consumption patterns, and the positive environmental effect of the reform would increase. To exemplify: taxes on protein rich vegetarian substitutes such as beans and lentils could be lowered. Consumers that buy less beef and more lentils would pay less tax and the lower demand for beef would reduce production emissions in the long run. This alternative correspond to the second objective of taxation, that is to use taxes to change consumer and producer behavior and to internalize externalities. How are the distortive qualities of taxes affected by this scenario? Since revenues will be used to the lowering of pre-existing taxes the potential increase in inefficiency will be marginal. However, the goods taxed will be chosen, in contrast to the tax on labour, on other criteria than the sole aim of lowering distortive effects. This indicates that distortive effects will be

46 Svenskt näringsliv, *Stadsbudgetens inkomster*
47 Brännlund and Kriström (1998) p.246
48 Lööv and Widell (2009) p.34-36

larger with alternative 2 than with alternative 1.

6.3 Final discussion part two

The discussion above illustrates that the best use of tax revenues depend on which objective of taxation is used to motivate the tax reform. It is also a political question depending on the inequality aversion of the policy makers. In the neo-liberal economic tradition where the theory of the second dividend was developed, the minimizing of the distortive effects of taxes has been an important objective. Hence, the best alternative also depends on the aversion to these distortive effects of the policy makers. If the aversion to inequality is larger (smaller) than the aversion to the distortive effects of taxes, scenario 2 (1) is generally preferable.

However, in the case of Sweden it is questionable if a second dividend for such a tax reform would exist, indicating that the second alternative might be preferable independent of aversion levels. The main argument for the tax reform would then be the environmental effects achieved by the total reform, assuming that the distributive effects could be neutralized by subsidizing substitute goods. How large the total effects would be would depend on: The price elasticity of demand of all goods included in the tax reform, in this paper estimated for beef only, and assumptions made when estimating the MED. Hence, methods used when estimating the emissions from production of different animal products and assumed costs of the emissions. The higher the estimated MED, the higher the optimal pigovian tax would be. This sensitiveness to assumptions was illustrated in table 6.

7 Conclusion

The purpose of this paper has been to answer the questions: *1)How elastic is beef demand and how much will consumption sink when imposing a pigovian tax on beef. 2)What would be the best use of the revenues from such a tax?* First, background information and economic theory were presented to provide a framework to answer these questions. Then, in the first part of the paper a regression analysis of beef demand was carried out and the regression results were presented. The short (long) run own-price elasticity was estimated to: -0,69 (-1,74) and the short (long) run income elasticity to 1,41 (3,58). The coefficients of the other goods were, partly due to multicolliniarity, not significant. It is however likely that they to some extent influence the beef consumption. The consumption reduction of a hypothetical pigovian tax on beef was calculated. The simulation where different assumptions were altered showed how sensitive the results were to assumptions and thereby to political and economic interests. When assuming a tax level of 28,1% the reduction was 19,25%

and 2,44 Kg per person per year. When assuming a higher tax level of 40% the reduction was 27,4% or 3,48 kg per person per year. And finally, with a 50% tax level the reduction was 34,3% or 4,35 kg per person per year.

In the second part of the paper the use of the tax revenue from a potential pigovian tax on beef or a range of animal products were discussed within the framework of taxation theory. The conclusion was that due to the lack of evidence of a second dividend a lowering of the tax on substitute goods was preferable to a lowering of the tax on labour. The discussion also illustrated that political aversion to inefficiency in the taxation system and to inequality mattered.

Generally, a conclusion in this paper is that a pigovian tax on beef or meat products is a highly political issue. Firstly concerning the controversy to regulate consumption of food products in the eyes of the public. Secondly regarding politicians valuation of environmental problems in the future, inefficiency in the tax system and of economic inequality.

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Appendix – Regression outputs and tests

Regression with unrestricted ADL(1,1) model

Dependent Variable: LGKBEEF
Method: Least Squares
Date: 05/26/14 Time: 15:16
Sample (adjusted): 1981 2011
Included observations: 31 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.312408	0.879367	-1.492446	0.1481
LGPBEEF	-0.879272	0.288472	-3.048035	0.0054
LGDI	1.122649	0.656881	1.709059	0.0998
LGKBEEF(-1)	0.594082	0.184937	3.212338	0.0036
LGPBEEF(-1)	0.667544	0.271170	2.461713	0.0211
LGDI(-1)	-0.472095	0.623288	-0.757427	0.4559

R-squared	0.962127	Mean dependent var	2.038504
Adjusted R-squared	0.954552	S.D. dependent var	0.342363
S.E. of regression	0.072987	Akaike info criterion	-2.225092
Sum squared resid	0.133177	Schwarz criterion	-1.947546
Log likelihood	40.48893	Hannan-Quinn criter.	-2.134619
F-statistic	127.0192	Durbin-Watson stat	1.784059
Prob(F-statistic)	0.000000		

The common factor test: n*ln(RSSr/RSSu) = 30*ln(0,140643/0,133177)=1,636. Critical value: chi-squared distribution k-1 degrees of freedom.

Breusch-Godfrey test of restricted model

Dependent Variable: RESID01
Method: Least Squares
Date: 05/26/14 Time: 15:04
Sample (adjusted): 1982 2011
Included observations: 30 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LRESID	0.104716	0.329106	0.318184	0.7530
LGDI	0.041006	0.457283	0.089673	0.9293
LGPBEEF	-0.044166	0.233807	-0.188901	0.8517
LLNKBEEF	-0.052981	0.310796	-0.170467	0.8660
C	0.114929	0.947750	0.121265	0.9045

R-squared	0.010704	Mean dependent var	0.003230
Adjusted R-squared	-0.147583	S.D. dependent var	0.066869
S.E. of regression	0.071634	Akaike info criterion	-2.283490
Sum squared resid	0.128285	Schwarz criterion	-2.049958
Log likelihood	39.25236	Hannan-Quinn criter.	-2.208781
F-statistic	0.067626	Durbin-Watson stat	1.990550
Prob(F-statistic)	0.991093		

Lagrange multiplier test statistic: nR-squared= 0,314148 is tested with chi-square with one degrees of freedom. It is not significant at 5% level. The coefficient of the lagged residual LRESID is also not significant at the 5% level using a t-test.

Breusch-Godfrey test of unrestricted model

Dependent Variable: RESID01
Method: Least Squares
Date: 05/27/14 Time: 13:12
Sample (adjusted): 1982 2011
Included observations: 30 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.040052	0.932530	-0.042950	0.9661
LGPBEEF	0.009528	0.315068	0.030241	0.9761
LGDI	-0.751289	0.747772	-1.004704	0.3255
LGPBEEF(-1)	-0.151616	0.268918	-0.563800	0.5783
LGDI(-1)	0.972313	0.766411	1.268658	0.2173
LGKBEEF(-1)	-0.173787	0.297796	-0.583577	0.5652
LRESID	0.306493	0.339205	0.903564	0.3756

R-squared	0.084817	Mean dependent var	0.003449
Adjusted R-squared	-0.153926	S.D. dependent var	0.064890
S.E. of regression	0.069706	Akaike info criterion	-2.288101
Sum squared resid	0.111755	Schwarz criterion	-1.961155
Log likelihood	41.32151	Hannan-Quinn criter.	-2.183508
F-statistic	0.355265	Durbin-Watson stat	2.034381
Prob(F-statistic)	0.899434		

Lagrange multiplier test statistic: nR-squared= 30*0,084817= 2,54451cis tested with chi-square with one degrees of freedom. It is not significant at 5% level. The coefficient of lagged residual LRESID is also not significant at the 5% level using a t-test.

Engel-Granger test of cointegration

Null Hypothesis: RESIDEG has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=7)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.199443	0.0002
Test critical values:	1% level	-3.670170	
	5% level	-2.963972	
	10% level	-2.621007	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(RESIDEG)
Method: Least Squares
Date: 05/26/14 Time: 15:07
Sample (adjusted): 1982 2011
Included observations: 30 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESIDEG(-1)	-0.949520	0.182620	-5.199443	0.0000
C	0.003463	0.012424	0.278744	0.7825

R-squared	0.491226	Mean dependent var	0.004807
Adjusted R-squared	0.473055	S.D. dependent var	0.093719
S.E. of regression	0.068032	Akaike info criterion	-2.473347
Sum squared resid	0.129593	Schwarz criterion	-2.379934
Log likelihood	39.10020	Hannan-Quinn criter.	-2.443463
F-statistic	27.03421	Durbin-Watson stat	1.965581
Prob(F-statistic)	0.000016		