The Influence of an Environmental Tax on Meat Demand in the United States

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Abstract

This paper estimates the demand of beef, pork and chicken in the United States, in order to explore how the introduction of an environmental meat tax might impact meat demand. The agricultural industry, especially the production of meat, is widely attributed to the emission of greenhouse gases, which directly contributes to climate change. This study draws upon monthly data from the United States Department of Agriculture and the Federal Reserve Bank of St. Louis. Through multivariate regression and the log-log model, this paper estimates various elasticities. The results show an inelastic positive income price elasticity of demand for all meats, and an inelastic price elasticity of demand (PED) that is negative for beef and pork, but positive for chicken. However, due to the chicken's positive PED, it is excluded from the modeled 10 % tax on meat. This study posits that the introduction of an environmental tax on beef and pork could reduce national greenhouse gas emissions by one thousandth of 2016 levels.

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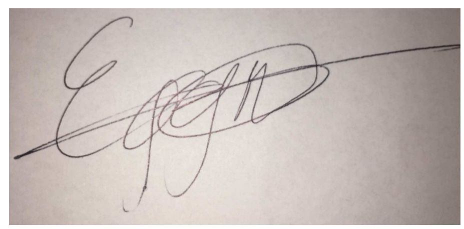

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Introduction

Accurate estimates of demand and supply of agricultural goods are essential in order to understand and predict the product's market, as they supply valuable information to consumers, producers and policy makers alike. This study aims to approximate the price elasticities of beef, chicken and pork in the United States (US). By estimating the own-price elasticity of demand (PED), income elasticity of demand (YED) and cross elasticity of demand (XED) I analyze whether and how the demand of meat changes by increases or decreases in meat price, consumer income and the prices of substitute goods.

The main motivation for this study is the emergent concern regarding the environmental impacts of meat. In recent years, climate change has been a growing concern among the Americans public. According to a Gallup poll, 64% of Americans worry a great deal, or fair amount, about climate change, with 59% of Americans realizing that the effects of climate change are already visible in their surroundings (Gallup 2016). With popular support of American citizens, it is relevant to look at policies the government could implement to reduce greenhouse gases (GHGs), should the political will exist. The Environmental Protection Agency (EPA) found that 9% of U.S. greenhouse gases come from the agriculture industry, of which the meat industry is the largest polluter (EPA 2017). It seems evident that an effective and well-rounded strategy to combat climate change should include a way to reduce emissions in the meat industry.

In this study, I model an environmental tax on meat through the obtained PED, as a potential way of reducing meat demand. Such research has already been conducted in the European Union, and specifically in Sweden and Denmark, where the introduction of an environmental meat tax is found to significantly reduce GHG emissions (Säll and

Gren 2015; Edjabou, Dyhr and Smed 2013; Wirsenius, Hedenus and Mohlin 2010). The log-log model, a widely used and accepted model in the agricultural industry and beyond, is used to approximate meat demand (Hupkova and Bielik 2010; Waheed 2015). After taking the log of both sides of a demand equation, the coefficients of the variables represent elasticities. The coefficient on own-price represents the PED, on GDP per capita it represents the YED and on the prices of other goods it represents the XED.

This paper surprisingly finds a PED with a positive value for chicken, while pork and beef have the expected negative value. The YED for all meats is positive which is in accordance with economic theory, indicating that all meats are normal goods. The XED's of beef and chicken in relation to pork are positive as expected of substitute goods. For chicken, pork and beef acts as a complementary good with negative values contrary to economic theory. For beef, pork acts like a complementary good while chicken had a positive value as a substitute good. All the cases where the sign does not match the expected result, 0 is included in the 95% confidence interval, indicating no relation between the goods, rather than a relation opposite to the economic theory.

This paper begins by giving the reader background information regarding elasticities, the meat industry and its impact on the environment. Then the data and the model are described and analyzed by seeing how the results fit in the wider literature.

Background

Since this paper revolves around the estimation of the demand curve, it is important to first discuss the theory that underlines this concept. Demand is a system that describes how a consumer buys, if willing and able, certain quantities of goods and services at varying prices. This stems from the concept of utility theory that states that a consumer with a limited amount of resources is always trying to maximize their utility. This theory assumes that consumers have full information about the product that they are buying and always make rational economic decisions regarding their utility. While these assumptions are a contested topic in economics (Machine 2004), for the sake of this study I hold them to be true. These assumptions lead to the law of diminishing marginal utility, which states that consumption of consecutive goods provides increasingly less utility than the first. This inverse relationship between quantity and utility is the first step toward understanding the demand curve. A consumer will purchase a good as long as its marginal utility is greater than its price; this goes on until marginal utility equals the price. Consumers will only repeatedly demand goods at an ever decreasing price, hence the downward sloping demand curve. Another way of looking at it is that as the price of a good rises, so does the opportunity cost of purchase. It effectively reduces consumers' real income and they can buy less of said good, also known as the income effect. Additionally the substitution effect posits that consumers might switch to other goods that are relatively cheaper. The purpose of the meat tax in this paper is to bring about a substitution effect, but not reduce the consumer's utility through the income effect. This is achieved by returning the tax revenues to the consumer through, for example, a reduction in income tax.

The demand curve, in practice, is a little more complicated than plotting quantity versus price. This is due to the endogeneity of price and quantity; both are determined within the model. Price, demand and supply fluctuate in a constant interaction. This is a concept known as the identification problem. The correct curve is given by all the interactions between supply and demand at each price-quantity pair. To correct for the identification problem one needs to take a look at other factors influencing supply and demand. These are the exogenous variables of the model; they are determined outside the model. Price causes a movement along the demand curve, but to trace out a correct curve, one needs to take into account the factors causing supply shifts. As supply shifts, there is a new interaction between the supply and demand curves that traces out the correct demand curve at each price-quantity pair. In this paper, this estimation is calculated with use of a log-log model through multivariate regression.

The value of the PED indicates to what extent a change in price will influence change in demand for a certain good. The equation is given by:

$$PED = \frac{\%\,Change\ in\ quantity\ demanded}{\%\,Change\ in\ price}$$

From this equation it follows that a PED value greater than 1 indicates that a product is sensitive to price changes and is therefore *elastic*. A change in price results in a greater change in quantity demanded. A good is *inelastic* when the reverse holds true; the PED value will be between 0 and 1. Most goods have a negative PED; according to basic economic theory the quantity demanded for a good will decrease as the price increases. Extensive literature explores the PED of meats, and findings generally indicate negative inelastic PED's for beef, pork and chicken both in the US and abroad. This is the case for both the log-log model (Masha, Belete, Lefophane and Shoko 2016; Hupkova and Bielik

2010), in other modeling scenarios, (Hassan 2013; Taha and Hahn 2015; Eales and Unnevehr 1993) and in a paper reviews on meat demand (Gallet 2010).

The YED is calculated in a similar way as the PED. Instead of measuring how a change in the price of a product influences demand, it measures how a change in income affects quantity of demand. The equation for the YED is then:

$$PED = \frac{\%\ Change\ in\ quantity\ demanded}{\%\ Change\ in\ income}$$

A normal good is defined as having positive YED; as income increases, so does the quantity demanded for that good. The reverse is defined an inferior good. In general the YED for beef, chicken and pork is shown to be positive and inelastic (Hupkova and Bielik 2010; Masha, Belete, Lefophane and Shoko 2016; Saski 1995; Basarir 2013).

The last elasticity measured in this paper is the XED. This measures how the quantity demanded of a good changes if the price of another good changes. The equation is given by:

$$PED = \frac{\%\ Change\ in\ quantity\ demanded\ of\ good\ A}{\%\ Change\ in\ price\ of\ good\ B}$$

If the sign of the XED is positive, it means the goods are substitute goods. As the price of good B rises, it becomes relatively more expensive compared to other goods, therefore increasing the demand in quantity of good A. If beef suddenly becomes very expensive, one would expect that the quantity demanded for pork and chicken would increase, because consumers are switching to a cheaper substitute. If the XED is negative, it means the goods are complementary goods. If the price of cars increases, the quantity demanded for car tires would decrease because this demand is linked to cars. An XED of 0 indicates that there is no relation between the goods. Generally speaking, past research indicates that different meats are indeed considered substitute goods (Eales and Unnevehr 1993; Masha, Belete, Lefophane and Shoko 2016; Hupkova and Bielik 2010).

The production of meat is one of the biggest contributors to GHGs worldwide. A report in 2013 by the Food and Agricultural Organization of the United Nations found that 14.5% of global GHGs produced by humans is related to the meat industry (FAO 2017). Researchers have found that a significant change in world meat demand is necessary to adhere to the 2 °C limit scientists believe will keep damage of climate change in check (Bailey, Froggett and Wellesley 2014). China is feared to be an enormous strain on this goal due to its rapidly growing middle class, which is often accompanied by increased meat consumption. However, the Chinese government has recently released new dietary guidelines that are believed to cut meat consumption by 50% by 2030, which can reduce GHGs by 1 billion metric tons (Milman and Leavenworth 2016). In 2015, the US Dietary Guidelines Advisory Committee called for Americans to eat less meat for health and environmental reasons (Fulton 2017). Other countries that amended their dietary guidelines for the same reasons include: the Netherlands, Brazil, Germany, Australia, Sweden and the United Kingdom (Fulton 2017)

Reducing total meat consumption is not the only way to reduce meat-related the GHG emissions. A study focused on meat consumption in Australia found that GHG emissions could be reduced by 2.3% by switching meat eating habits from ruminant animals to non-ruminant animals (Ratnasiri and Bandara 2017). Ruminant animals, such as cows and sheep, have multiple stomachs, which allows them to consume plants that other mammals cannot digest. In the process of plant digestion, however, they release additional methane, and expend considerable energy that could have been used for further food production (Gowri and Nierenberg 2008). Methane accounts for 10% of total GHGs in the US, which is largely due to the agricultural industry. This is partially why beef alone is responsible for 65% of GHGs produced by the livestock industry (FAO 2017).

The USDA has released a report in 2016 forecasting the US meat industry. It predicts that beef and pork consumption will rise again, after dropping 15% in the last decade. The USDA contributes this decrease in beef and pork consumption to a steady rise in prices of both meats. However, looking forward, these prices are predicted to decrease due to lower feeding costs and strong demand both in the US and abroad (USDA ERS 2016). Such increased demand, and the associated increased release of GHGs, could stand in the way of the goal to limit climate change by 2 °C. As the world's second largest consumer of meat, it is therefore vital to consider the U.S.'s options regarding decreasing meat production (OECD 2016).

Meat taxes have not yet been implemented in any countries, but in Denmark the Ethics Council, a government think-tank, has called for a tax on red meat (Withnall 2016). Even though the concept of a meat tax is still in its infancy, it is worth investigating how such a tax would influence GHG emissions in the US. A meat tax would be comparable with a carbon tax on fuels, which is a more accepted notion worldwide and has been implemented in various Northern-European countries since the 90's, and more recently in in Canada and California. In Quebec and California a relatively low tax ($3.20 and $0.045 per ton metric ton of CO_2 respectively) is levied to generate revenue that is then used on climate mitigation programs (Sumner, Bird and Smith 2011). Taxes between $15 and $30 per metric ton of CO_2 are collected in Norway, Sweden, Finland, United Kingdom and the Netherlands. These taxes are high enough to actually cause a downward shift in the demand for fuels (ibid.). The revenues are often returned to the public by a reduction in income taxes (ibid.). If implemented similarly on meat, the government could decrease meat consumption with this method while limiting the welfare loss by returning the revenues to the public.

Data

Most data used in this paper comes form the Economic Research Service of the United States Department of Agriculture (USDA ERS 2017). They keep track of monthly prices, production, imports and exports since January 2000. While none of these variables are directly used in the regression, they are manipulated to fit the model. The USDA puts the prices of specific meat in different categories; for example, they have prices for boxed beef, boneless beef and imported boneless beef. To get a general price indication of the beef price for a particular month, the average is taken of these different kinds of meat. However some of these data sets for a particular kind of meat ate not complete, in that case that variable is eliminated in the calculation of the average. The volume of meat is measured in pounds.

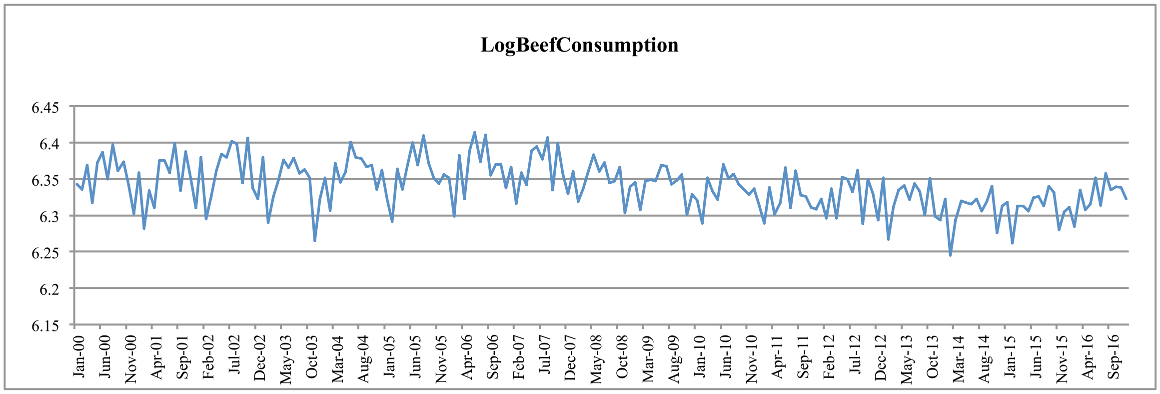
Since the USDA also does not have direct consumption data on meats, an estimate is made using other variables. The amount of produced meat is added to the imported amount while subtracting the export of meat. This is done under the assumption that all the meat that stays in the US is roughly equal to the American demand for meat. The price of meat is measured in US dollars per pound.

The GDP per capita on a monthly interval is also a variable generated from other variables. The Economic Research section of the Federal Bank of St Louis has quarterly GDP data and monthly population data (FRED 2017). To get a rough estimate of the monthly GDP, the quarterly GDP is divided by 3. The monthly GDP per capita is then calculated by dividing the monthly GDP per capita by the monthly population. Income is measured in US dollars.

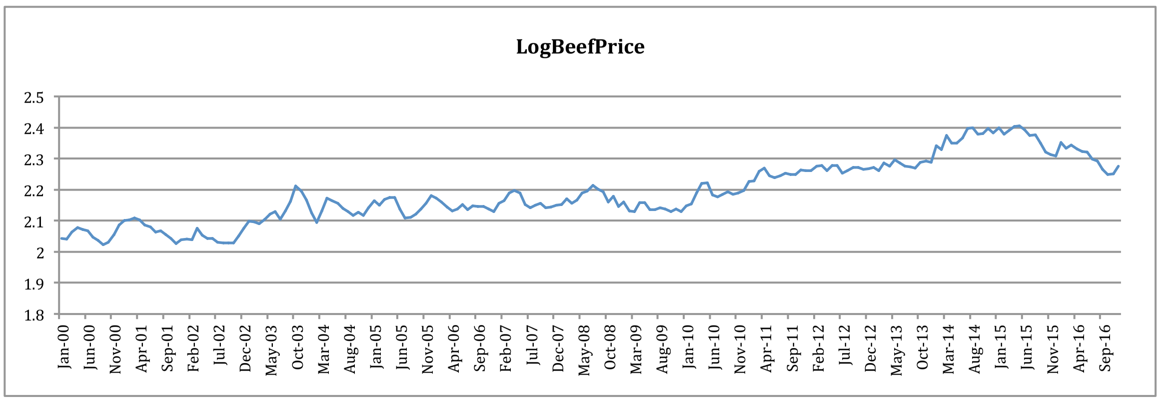
The data for the price of corn originally comes from the National Agricultural Statistics Service from the USDA, but easy access to this data is provided by the farmdoc project of the University of Illinois (Farmdoc 2017). The price is measured in US dollars.

The remaining dummy variables are all the months. When using monthly data, there can be seasonality in the data. People might consume less meat in the month of Lent. To capture these effects, the model contains all the months. To demonstrate this further one can take a look at the graph 1 on the next page. It shows the log of beef consumption over time. One can see enormous swings in consumption within a year, with the peaks all happening in the summer season, while the winter experiences the lows. This can potentially be due to the fact that Americans love barbequing during the summer and therefore consume a lot more meat. Graph 2 contains the log of the beef price over time, where the seasonality is a lot less clear. There are signs of some peaks in March and April, but they also occur in November or October. As this paper uses monthly data it is important to account for this variation.

Graph 1.



Graph 2.



Empirical Methodology

To estimate the demand of meat I used the log-log model. To understand how this model works, one should first look at a regular demand function: $Y_D = \alpha X^{\beta}$. Where Y_D represents the demand, X the price, α a shifting parameter and β a parameter that estimates how Y_D changes when X changes. For a usual downward-sloping demand curve $\beta < 0$. If the natural log is taken of both sides, the result is: $\ln Y_D = \ln \alpha + \beta \ln X + \varepsilon$. Now the equation is in a linear form. Here α and β represent parameters that can be estimated from data of price and quantity using regression analysis. Once analysis is performed, the result is: $\hat{Y} = \ln \hat{\alpha} + \hat{\beta} \ln X$. Now $\hat{\alpha}$ represents the *estimated* intercept and $\hat{\beta}$ *estimates* the slope of the demand curve, how a change in price changes quantity demanded, the *elasticity*. This theory leads to the following mathematical form of the demand equation used in this paper.

$$\ln Q_{D_t} = \ln \alpha + \beta_0 \ln P_{b_t} + \beta_1 \ln P_{ch_t} + \beta_2 \ln P_{p_t} + \beta_3 \ln P_{co_t} + \beta_4 \ln GDP_t + \Omega \ x_t + \varepsilon$$

Where Q_{Dt} represents the demand for beef, chicken or pork depending on which demand is measured. P_{bt} is the price of beef, P_{cht} the price of chicken, P_{pt} the price of pork, P_{cot} the price of corn and GDP_t the GDP per capita. The x_t represents the dummy variables used to account for seasonality in the model. The biggest advantage of this model is that the coefficients now directly represent the elasticities. Once regression analysis is performed, the $\hat{\beta}$ in front of the price correlating to the demand that's being measured represents the estimate of the PED; the $\hat{\beta}$'s in front of the other prices represent the estimate of the XED's while $\hat{\beta}_4$ signifies the estimate of the YED. In accordance with the literature stated in the Background section of this paper, my hypothesis is that all elasticities will be inelastic.

Furthermore I hypothesize that the PED will be negative, the YED positive and the XED of the other meats positive, indicating that they are substitute goods.

Results

Using the log-linear model explained above, the table on the next page shows the regression results of beef, chicken and pork.

Table 1.

Regression results of the log-log model

Variables	OLS (β & SE)		Robust (β & SE)		Newey-West (β & SE)	
Beef						
P_b	-0.292***	0.0346	-0.292***	0.0375	-0.292***	0.0375
P_{ch}	0.0695**	0.0270	0.0695**	0.0272	0.0695**	0.0272
P_p	-0.00219	0.0226	-0.00219	0.0235	-0.00219	0.0235
P_{co}	-0.0421***	0.0115	-0.0421***	0.0113	-0.0421***	0.0113
GDP	0.281***	0.0579	0.281***	0.0644	0.281***	0.0644
Jan	0.0210***	0.00610	0.0210***	0.00622	0.0210***	0.00622
Feb	-0.0320***	0.00615	-0.0320***	0.00610	-0.0320***	0.00610
Mar	0.0209***	0.00621	0.0209***	0.00652	0.0209***	0.00652
Apr	0.00841	0.00625	0.00841	0.00619	0.00841	0.00619
May	0.0314***	0.00650	0.0314***	0.00673	0.0314***	0.00673
Jun	0.0426***	0.00656	0.0426***	0.00621	0.0426***	0.00621
Jul	0.0258***	0.00663	0.0258***	0.00669	0.0258***	0.00669
Aug	0.0383***	0.00656	0.0383***	0.00697	0.0383***	0.00697
Sep	0.0109*	0.00644	0.0109	0.00686	0.0109	0.00686
Oct	0.0315***	0.00620	0.0315***	0.00608	0.0315***	0.00608
Nov	-0.00254	0.00608	-0.00254	0.00676	-0.00254	0.00676
Dec	0	Omitted	0	Omitted	0	Omitted
Constant	5.850***	0.169	5.850***	0.183	5.850***	0.183
Chicken						
P_b	-0.00110	0.0426	-0.00110	0.0394	-0.00110	0.0394
P_{ch}	0.0170	0.0333	0.0170	0.0357	0.0170	0.0357
P_p	-0.0543*	0.0279	-0.0543*	0.0276	-0.0543*	0.0276
P_{co}	-0.0639***	0.0142	-0.0639***	0.0141	-0.0639***	0.0141
GDP	0.680***	0.0714	0.680***	0.0676	0.680***	0.0676
Jan	0.0210***	0.00752	0.0210***	0.00754	0.0210***	0.00754
Feb	-0.0242***	0.00758	-0.0242***	0.00706	-0.0242***	0.00706
Mar	0.0229***	0.00765	0.0229***	0.00806	0.0229***	0.00806
Apr	0.0126	0.00771	0.0126	0.00781	0.0126	0.00781
May	0.0333***	0.00801	0.0333***	0.00797	0.0333***	0.00797
Jun	0.0246***	0.00809	0.0246***	0.00766	0.0246***	0.00766
Jul	0.0184**	0.00817	0.0184**	0.00806	0.0184**	0.00706
Aug	0.0337***	0.00808	0.0337***	0.00712	0.0337***	0.00712
Sep	0.0153*	0.00793	0.0153*	0.00822	0.0153*	0.00822
Oct	0.0302***	0.00764	0.0302***	0.00720	0.0302***	0.00720
Nov	-0.0244***	0.00749	-0.0244***	0.00751	-0.0244***	0.00751
Dec	0	Omitted	0	Omitted	0	Omitted
Constant	4.044***	0.209	4.044***	0.197	4.044***	0.197
Pork						
P_b	0.0571	0.0351	0.0571*	0.0337	0.0571*	0.0337
P_{ch}	0.0684**	0.0274	0.0684**	0.0296	0.0684**	0.0296
P_p	-0.200***	0.0229	-0.200***	0.0224	-0.200***	0.0224
P_{co}	-0.0437***	0.0117	-0.0437***	0.0120	-0.0437***	0.0120
GDP	0.218***	0.0588	0.218***	0.0563	0.218***	0.0563
Jan	-0.00394	0.00619	-0.00394	0.00555	-0.00394	0.00555
Feb	-0.0525***	0.00624	-0.0525***	0.00567	-0.0525***	0.00567
Mar	-0.0127**	0.00629	-0.0127**	0.00629	-0.0127**	0.00629
Apr	-0.0368***	0.00634	-0.0368***	0.00650	-0.0368***	0.00650
May	-0.0501***	0.00659	-0.0501***	0.00660	-0.0501***	0.00660
Jun	-0.0446***	0.00665	-0.0446***	0.00731	-0.0446***	0.00731
Jul	-0.0526***	0.00672	-0.0526***	0.00657	-0.0526***	0.00657
Aug	-0.0172***	0.00665	-0.0172***	0.00651	-0.0172***	0.00651
Sep	-0.0180***	0.00653	-0.0180***	0.00665	-0.0180***	0.00665
Oct	0.0222***	0.00629	0.0222***	0.00567	0.0222***	0.00567
Nov	-0.0756	0.00617	-0.0756	0.00559	-0.0756	0.00559
Dec	0	Omitted	0	Omitted	0	Omitted
Constant	5.591	0.172	5.591	0.165	5.591	0.165

The regression results show that the short-term PED of beef, chicken and pork are -0.292, 0.0170 and -0.200 respectively. While these values for beef and pork are very statistically significant, the one of chicken is not. The PED of chicken also does not have the expected sign. Currently the model seems to implicate that when the price of chicken rises by 2.89%, the quantity demanded for chicken will increase by 1%, contrary to basic economic theory. This is surprising since the model seems to fit very well with both pork and beef and the data used is from the same source. A comprehensive review of papers on meat demand by Gallet has median PED values for beef, chicken and pork as -0.869, -0.650 and -0.780 respectively (Gallet 2010). This indicates that the model used in this paper consistently underestimates the PED when compared to other studies.

The YED's in the regression result are all inelastic and positive as hypothesized. The values for beef, chicken and pork are 0.281, 0.680 and 0.218 respectively and significant at the 99% level. Tonsor and Marsh find YED's of 0.885, 0.309 and 0.662 (Tonsor and Marsh 2007). While they also find positive inelastic YED's, the values do not align. Unlike the case with the PED however there does not seem to be a systematic underestimation, because a beef and pork are understated and chicken is overstated.

For beef the XED's mostly act as hypothesized. The XED of chicken with regard to beef has a positive value of 0.0695 and is significant at the 95% level, as expected for a substitute good. This is not the case with pork, which does not act as a substitute good with a value of -0.00219, but also has no significance. The 95% confidence interval contains 0, so this would indicate pork has no relation with beef. The XED's for chicken are exactly opposite of what is hypothesized. Beef (-0.00110) and pork (-0.0543) both have a negative value. The 95% confidence intervals of both meats do contain 0, which again would indicate zero or very little relation with chicken, with the pork XED having some significance. Pork is the only meat where the XED's act as hypothesized. The XED of beef and chicken in relation to pork are 0.0571 and 0.0684 respectively. Both are positive indicating that they are substitute goods. While the value of chicken is significant, the value of beef is not. The 95% confidence interval of beef also contains 0.

The monthly dummy variables are mostly significant indicating some sort of seasonality that is being corrected for by including them in the model. For beef and chicken the April dummy variable is the only one without significance, while for pork January and November hold no significance. The only month that has a consistent sign among all meats is February, where it seems that all meat demand decreases. The December variable is omitted in all regressions due to collinearity.

To ensure the model works and is appropriately designated multiple regression methods are used. To account for potential heteroskedasticity, an OLS robust regression is used. If a regression contains heteroskedasticity, the variability of the dependent variable is inconsistent across the independent variable. As a result it can underestimate the standard errors and make the model less reliable. The standard error values in the tables above compared to the standard error in the regular OLS regression show that there is little difference and it can be assumed that the model does not suffer from heteroskedasticity.

To check if the model suffers from autocorrelation a Durbin-Watson test is performed. On a scale from 0 to 4, a value of around 2 is generally deemed to indicate that the model doesn't suffer from autocorrelation. This model generated a value of 0, which indicates that there is heavy correlation, meaning that there is high similarity between the independent variable and the lagged version of itself. To correct this a Newey-West regression is applied to the model. This regression showed very similar errors to the general OLS model and therefore autocorrelation does not seem to be a problem in the model. In all three regressions the adjusted R^2 value lies between 70 and 74 %, which indicates, that most of the variation in the dependent variables is accounted for.

Implications

Now that the elasticities are known, calculations can be made regarding an environmental meat tax. In the case of Sweden, Säl and Gren find that a tax on meat between 8.9% and 33.3% is the most effective, while a study in Nature Climate Change calculated that a global tax of 40% on beef and 7% is necessary pork to completely offset their societal cost (Säl and Gren 2015) (Springmann, Mason-D'Croz, Robinson, Wiebe, Godfray, Rayner and Scarborough 2016). This paper is modeling a moderate 10% value- added tax on meat due to the more conservative nature of the US regarding taxes. A kilogram of consumed beef, chicken or pork emits 27, 6.9 and 12.1 kg's of CO_2 respectively (Environmental Working Group 2011). Beef pollutes the most by far due to its ruminant nature.

According to this model chicken has a positive PED value and thus it wouldn't make sense to model a tax on it, since it would actually increase chicken demand. A VAT of 10% on beef and pork however would decrease demand by 2.92% and 2.00% respectively. Based on the data of the quantity demanded of both products in 2016, this decreases CO_2 emissions by 10.5 and 2.6 million metric tons. One does need to take into account the XED however. Since both beef and pork are increased by the same margin, their XED's do not matter in the calculation. The results do show an XED value of 0.0695 for beef in relation to chicken and a value of 0.0684 for pork in relation to chicken. This means that when the price of both goods is increased by 10%, the quantity demanded for chicken will increase by 1.38%, which leads to an increase of CO_2 by 1.71 million metric tons. Hence the net decrease of CO_2 emitted is 11.45 metric tons, or approximately one thousandth of total US GHGs (EPA 2017). This value is most likely an overestimation due to the fact that only the XED's in relation to chicken were calculated in this paper. When the price of beef and pork increases consumers will substitute toward other foods that also have a potentially large carbon footprint such as lamb, eggs or cheese.

For further research an investigation can be done in investigating the long-term effects of a meat tax by estimating the long-term PED, since this paper focused on the short-term effects. One can also look at the welfare impact of this tax and how the revenue can best be returned to the public. If the government decides to return the revenue of the tax through a reduction in income tax, the unemployed cannot get the returns of the revenue while the tax might hurt them the most.

Conclusion

This paper estimates the demand for various amounts of meat in the US using monthly data and the log-log model. The results were broadly speaking in accordance with economic theory and the wider literature, but definitely also showed some unexpected outcomes in PED's and XED's. According to the data, chicken demand increases as price rises and beef, pork and chicken are not strong substitutes, as one would expect. The short-run PED's are also more inelastic than corresponding literature. This means that an environmental tax will not have as much of an effect as hoped for, but according to the calculations a 10% tax would still be able to decrease total GHGs by the US by one thousandth. Studying the long-term effects of might offer a more optimistic view of a meat tax where it could bring about the same results as a carbon tax on fuel.

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