Identifying the driving forces of global beef consumption

A panel data analysis

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Foreword and Acknowledgement

This thesis has been written for my master *Environmental Sciences*. Supervision was done by two different departments. Thomas Herzfeld of *Agricultural Economics and Rural Policy* (AEP) was my first supervisor and Rolf Groeneveld of *Environmental Economics and Natural Resources* (ENR) was my second supervisor. Jack Peerlings, head of AEP, attended both the presentation of the proposal and of the presentation of the final paper, and he assisted in the final assessment. I want to thank Jack for the good advice he gave me after the presentation of my proposal. I want to thank Rolf for his comments on the draft final paper, which made the final version clearer and nicer. And I especially want to thank Thomas for all his good advice and help. He is not only the most skilled supervisor I have ever met, but also the friendliest. He really made writing this thesis a lot more relaxed.

Eva Fransen

Table of Contents

Abstract

This paper aims to identify the main driving forces of global beef consumption. The analysis is twofold: first, a review of the literature is carried out in order to give a complete overview of the main driving forces. The literature review also serves as a conceptual framework for a global demand function for beef that is estimated subsequently. This demand function is distinctive in the sense that it is global, it allows for a non-constant relationship between income and beef demand, and it takes into account the effect of religion. The demand function is estimated with a panel of 122 countries and 17 years. In this paper a method is applied that separates the effect of religion out via interaction effects with GDP per capita, since religion is more or less constant over time. Our results show that there are strong differences in the size of the income elasticity between religions. In atheistic countries the income elasticity is relatively large, meaning that a substantial increase in beef consumption can be expected there if incomes keep growing. In countries with a large Catholic or Protestant population we see that the income elasticity is relatively small; a sign that saturation occurs. In countries with a large Muslim or Hindu population the elasticities are close to zero and beef consumption is much less responsive to income changes. The results show that the influence of income on beef consumption is moderated by the effect of religion. Our results do not show a global decreasing effect of income as countries get richer; overall the income elasticities are more or less constant over all income levels.

Keywords: beef consumption, religion, income, demand analysis, panel data.

1. Introduction

In pre-industrial societies meat intakes were low and made up only a small part of people's diet. In most developed countries meat is now consumed on a daily basis and it is globally the largest source of animal protein. Rising meat consumption can be seen as an important characteristic of the globally changing diets that have accompanied economic modernization (Smil, 2002). The high level of meat consumption is being recognized as a major contributor to global environmental problems like climate change and biodiversity loss by many international organizations like the Intergovernmental Panel on Climate Change (Black, 2007), the United Nations' Food and Agriculture Organization (FAO) (Steinfeld et al., 2006), The Economics of Ecosystems and Biodiversity project (Netherlands Environmental Assessment Agency et al., 2010) and the Worldwatch Institute (Worldwatch Institute, 2011).

Beef production and consumption especially can be considered as environmentally unfriendly. Enteric fermentation processes of cows, together with large amounts of manure and urine produced, cause high methane and nitrous oxide emissions, which are very potent greenhouse gases. In addition, low feed conversion rates of cows, i.e. the amount of feed needed in order to produce one extra kilo of bodyweight, result in large areas being cleared for either grazing or feed production (mostly soy, grains and maize). In 2006, livestock production was responsible for 70 per cent of all agricultural land use, which equalled 30 per cent of all terrestrial land on this planet (Steinfeld et al., 2006). Native forests and savannahs are being converted into agricultural land and these conversions are causing reductions in biodiversity, water quality and ecosystem services. Land conversions for livestock production are also another major contributor to global CO_2 emissions (NEAA et al., 2010; Steinfeld et al., 2006; McAlpine et al., 2009). It is becoming more and more clear that the current levels of meat consumption in general, and of beef consumption in particular, are putting great pressure on nature and the environment. A further increase in beef consumption will lead to further losses of biodiversity and ecosystem services and will reduce the chances of meeting internationally agreed CO_2 mitigation targets.

It is therefore important to study why global beef consumption is currently this high and still increasing. An often heard argument is economic growth; as people get richer their demand for animal protein increases. Many authors have studied the relationship between beef consumption and income and many of them have found that beef is a meat type that is relatively responsive to income increases and one of the more luxurious meat items (Chern et al., 2003; Taljaard et al., 2004; Masuda & Goldsmith, 2010). This could explain why per capita beef consumption is rising in countries like China and India. However, this theory is not consistent with the current *decline* in per capita beef consumption in Europe. Figure 1 presents the consumption of beef between the years 1961 and 2007. As can be seen, total beef consumption (in million tonnes) has more than doubled in this period, but in Europe it fell by almost fifty per cent. The largest increase has taken place in Asia and the Americas, areas with several countries experiencing high economic growth. Per capita beef consumption in Asia in 2007 was still only 4.1 kg / year, which is the lowest in the world. In Oceania and the Americas beef

consumption was respectively 39.5 kg / year and 30.9 kg / year.[1] One could easily imagine that if Asian beef consumption levels were to rise to American levels it would mean great pressure on the planet's resources.

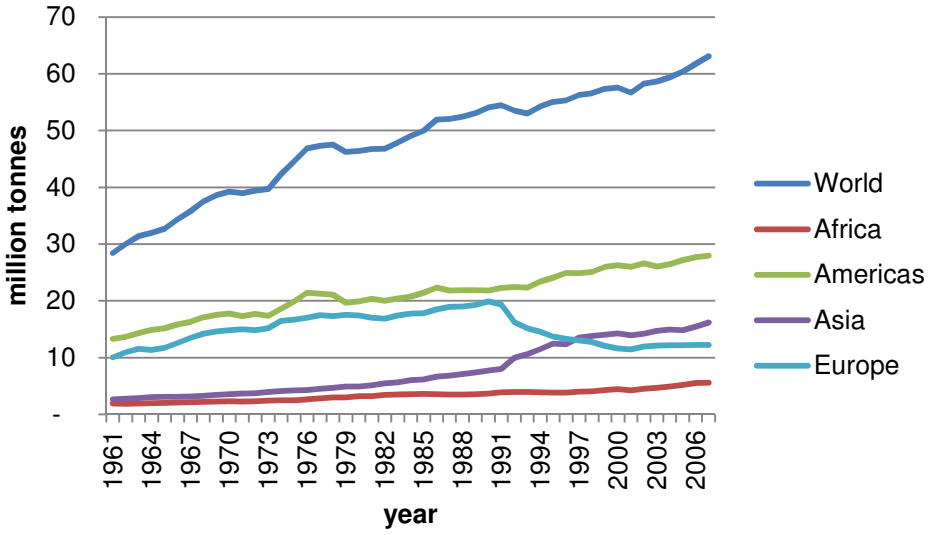

Figure 1: Beef consumption between 1961-2007 by continents and total world
Source: FAOSTAT (2010) Food Supply Database

Besides income, there are also other driving forces of increasing global meat and beef consumption that are mentioned in the literature. A wide range of sociological and psychological studies have provided explanations for why people eat beef and/or meat and why one type of meat is preferred over another. Some examples are: habits, convenience, health and status. According to Hungerman (2011) religion also has a strong effect on people's behaviour. Most religions have clear norms and rules on eating meat; religion is therefore likely to have an influence on the demand for beef.

However, when analysing global beef consumption, the existing literature is incomplete in two ways: first of all most studies focus on one or two driving forces and there is no complete overview of the most important driving forces. Second of all, most studies are country-specific and it is unlikely that results for a single country can be easily translated to the rest of the world. Therefore, this paper aims to fill this gap in the literature by identifying the main driving forces of beef consumption and taking a global perspective.

Analysing global driving forces of beef consumption is done in two ways: first, a review of the literature is carried out in order to answer the question which factors influence the amount of beef that people eat. Second, a global demand function for beef is estimated to study beef consumption behaviour in a more quantitative way. Whereas most quantitative studies focus on a single country, we estimate a panel of 122 countries. The panel is appropriate to analyse global beef demand, since countries from all over the world are included. Another important aspect of our demand analysis is that a flexible

[1] See FAO consumption data for the year 2007. Beef consumption refers to carcass weight.

functional form is estimated, which allows the effect of income to change with income level, i.e. a non-constant relationship between income and demand. Most studies estimate a constant income elasticity, but this is not consistent with reality, as we argued previously (see Figure 1) and discuss in more detail in chapter 2. Our demand function includes the usual economic variables that explain consumption, but new is the fact that we include the effect of religion. In this paper a method is applied that separates the effect of religion out via interaction effects with GDP per capita, since religion is more or less constant over time. The panel serves to identify both the effect of changing incomes as well as the effect of time-invariant religion.

The paper is organized as follows: first, the existing literature is studied and summarized in Chapter 2. Chapter 3 describes the method and data that are used to estimate the demand function. Chapter 4 presents the results and Chapter 5 concludes.

2. Literature Review

In order to identify the driving forces of an increasing global beef demand and a decreasing Western beef demand, we turn to theories about consumer demand. First, in section 2.1 microeconomic theories about consumer demand are applied to the case of beef consumption. Then, in section 2.2 social and other theories about eating beef are examined.

2.1 Microeconomic Foundations

Following standard microeconomic theory, the demand for a good depends on preferences, which determine the shape of the utility function, and on income and prices, which determine the slope and location of the budget constraint. The intuition is straightforward: if a person's income increases he can buy more of the goods he consumes, in this case beef. Also, a price decrease of beef means that he can buy more beef given the same amount of income. How much more a person will spend on beef if his income increases or the price decreases, depends on his preferences. There are many factors that can be headed under preferences: health concerns, culture, religion, routines and convenience.

2.1.1 Income

The main economic factors that are used to explain changes in demand are income and prices. This section focuses on income; section 2.1.2 on prices. Many authors have studied how the demand for beef and other types of meat respond to changes in income by estimating the income elasticity. Most studies focus on a specific country. Table 1 shows an overview of a selection of studies that have estimated income elasticities for beef. Period and place of study is also shown in the table. Most studies find that beef has an income elasticity greater than one, which implies that beef is a luxury food (e.g. Chern et al., 2003; Taljaard et al., 2004; Masuda & Goldsmith, 2010). In these studies beef has a larger income elasticity than pork and chicken (not shown in the table). Pork and chicken are often found to be normal goods. However, as can be seen in Table 1, the two American studies find income elasticities that are smaller than one, which means that beef is a normal good in the U.S., at least it was in the 70s, 80s and 90s (Kinnucan et al., 1997; Eales & Unnevehr, 1993). One possible reason for this could be that in the U.S. a large amount of low quality beef like hamburger is consumed, whereas in countries that have income elasticities larger than one more high quality beef, like steak and beef table cuts, is consumed. Another reason could be that beef consumption in the U.S. was higher than in the other countries and that saturation took place.

Table 1: Selected demand elasticities for beef

Author(s)	Place and period of study	Model	Income elasticity	Own-price elasticity	Cross-price elasticity beef / chicken	Cross-price elasticity beef / pork
Chern et al. (2003)	Japan, 1997	AIDS [a]	1.289	-.197	.081	.141
Taljaard et al. (2004)	South Africa, 1970-2000	LA/AIDS [a]	1.243	-.161	.139	.375
Masuda & Goldsmith (2010)	China, 1961-2008	VECM [a]	1.560	not reported	not reported	not reported
Kinnucan et al. (1997)	United States, 1976-1993	Rotterdam	.721	-.444	.099	.290
Eales & Unnevehr (1993)	United States, 1962-1989	AIDS [a]	.597	-.712 [b]	not reported	not reported

Notes: [a] : AIDS stands for *Almost Ideal Demand System*; LA/AIDS for *Linear Approximated Almost Ideal Demand System*; and VECM stands for *Vector Error Correction Model*.
[b] : calculated average elasticity of two model specifications.

Furthermore, looking at per capita beef consumption data of the FAO, it can be seen that beef consumption has been declining over the past decades in the U.S. and in Europe, despite growing incomes (see Figure 1 in chapter 1). It seems that in developed countries, the income elasticity of beef is declining and reaching numbers lower than one, or is even becoming negative; although this is not confirmed by the results shown in Table 1. Several authors have observed that, especially in Western countries, beef is currently being substituted for chicken on a scale that is not explained by income and relative prices (e.g. Eales & Unnevehr, 1988). Factors such as an increasing demand for convenience and a deteriorating reputation of beef after the BSE crisis are pointed out as possible causes of the decline in beef consumption. Also health concerns are mentioned as an important reason.

Exogenous shifts in preferences are sometimes referred to as *structural change*. Several authors have studied structural change in beef consumption in the past, especially for the U.S. in the 70s, when there was a decline in beef consumption (Moschini & Meilke, 1984). Chavas (1983) found substantial structural change in U.S. beef demand between 1975 and 1979; the income elasticity decreased from .655 to .183. Eales & Unnevehr (1993) also found structural change in the demand for beef in the U.S. mid-70s: the income- and own-price elasticity decreased and chicken became a stronger substitute for beef. However, Moschini & Meilke (1984) state that testing for structural change is prone to misspecification and their detailed analysis shows that the overall evidence for structural change in the U.S. over the 70s is weak. For South Africa, Taljaard et al. (2004) found no structural breaks between 1970 and 2000. A weakness of testing for structural change in a demand system is that one has to choose beforehand when the supposed structural change has taken place. This is not necessarily in

line with reality, because change is often more gradual. A more appropriate way to study changing elasticities is to estimate a flexible functional form that allows for non-constant income elasticities, as it is done in this paper.

2.1.2 Prices

The studies presented in Table 1 also show estimated price elasticities of beef. All reported price elasticities are compensated (Hicksian) elasticities, which means that they represent the pure substitution effect and are net of the income effect. Most studies show an inelastic demand for beef with respect to its own price. Apparently, consumers do not let prices influence their consumption of beef too much. However, the price elasticity of -.7 in the United States given by Eales & Unnevehr (1993) is rather large.

In consumer theory a person allocates his income over several categories of expenditure, like food, and within the food category a further allocation is made. Meat is one of these expenditure categories over which a person allocates a certain amount of money. It is to a large extent *separable* from other food categories like vegetables and cereals in the sense that the demand for vegetables does not significantly influence the demand for meat. However, within the meat category most meat products are likely to be *weakly separable*, which means that there are substitution possibilities between different meat types and that demand for one type of meat influences the demand for another type of meat.

Several authors have studied the assumption of weak separability with respect to meat. Most authors have tested weak separability between meat from different animals (for example Taljaard et al., 2004 for South African meat demand), because separating meat types by animal origin is by far the most common way to model meat demand. However, Eales & Unnevehr (1988) have tested different utility trees, i.e. different ways of allocating expenditure, for the U.S. and found that substitution between low quality meat types (e.g. between whole birds and hamburgers) and substitution between high quality meat types (e.g. between chicken parts and beef table cuts) is also important. According to their analysis, most substitution between beef and chicken that takes place is substitution between the low quality types. In some countries, like Japan, fish is a more common part of the diet than meat. Per capita meat intakes are usually lower in these countries, which suggests that people substitute between fish and meat. However, Eales & Wessells (1999) found that fish and meat are not weakly separable in Japan, and Chern et al. (2003) found that fish and meat are only mild substitutes. Kinnucan et al. (1997) found no effect of the price of fish on the demand for beef.

Table 1 also presents some cross-price elasticities of beef demand with respect to chicken and pork. Both are rather small, but the price of pork seems to have a larger effect than the price of chicken. Assuming that meat products, with the exception of fish, are weakly separable, our beef demand model includes prices of the main substitutes. This is discussed further in section 3.2, which describes the data and modeling strategy.

2.2 Preferences

Controlling for income and prices, there are still large differences in per capita beef consumption between countries. The previous section already mentioned that there are also non-economic factors that can explain consumer's demand for beef. Examples are health concerns, advertising, convenience, culture and habits. Section 2.2.1 describes the social factors that are important, Section 2.2.2 describes consumer's demand for convenience, Section 2.2.3 describes factors that have to do with the reputation of beef (advertising and BSE) and, finally, Section 2.2.4 describes religion as another factor.

2.2.1 Social Structure

Over the past decades, the social sciences have taken an interest in explaining driving forces of meat consumption, mainly because meat became recognized as an environmentally unfriendly good of which consumption should be limited. In the social sciences two important distinctions must be made: social-psychological drivers that have to do with individual preferences and identity and social-structural drivers that have to with cultures, traditions, routines, class, etc. (Gossard & York, 2003). The amount of meat consumed in Western societies is currently two to three times the amount that is considered healthy. Gossard & York (2003: 2) argue that "given that widespread meat-eating behavior in affluent societies cannot be readily explained by biological necessity, other factors must play a major role in determining individual dietary habits." Based on a cross-sectional regression model of U.S. beef demand, Gossard & York show that gender, race and ethnicity have large impacts on total meat and beef consumption in the U.S. Men eat more beef (and total meat) than women; Black consumers eat more beef than white- and Asian consumers; and Hispanics eat more beef than non-Hispanics. Income is not significant in total meat consumption, but it is a significant and positive factor in beef consumption. In line with Gossard & York (2003), Gao et al. (1997) also find that social structural factors like race and sex of the household head significantly influence the demand for beef in the U.S.

2.2.2 Convenience

Several studies have found that beef has been losing market share to poultry and that convenience is the main reason for this. Eales & Unnevehr (1988) found for the U.S. in the 70s that health concerns (e.g. cholesterol) could not fully explain the shift from beef to poultry. The shift from beef to poultry mainly took place among high quality meat (beef table cuts and processed chicken parts) and not between low quality meat (whole birds and hamburgers). Although high quality consumers might be better aware of health risks, Eales & Unnevehr (1988) argue that the shift must also have been caused

by a growing demand for convenience. Anderson & Shugan (1991) also find that convenience has been a more important factor than health concerns. Interestingly, they argue that in the past beef used to be the more convenient meat type, but that poultry has been better able to reposition itself in the market in response to increased consumer demand for convenience.

2.2.3 Health information, advertising and the BSE crisis

Kinnucan et al. (1997) have studied the effects of health information and advertising on U.S. meat demand. They have estimated a Rotterdam model that includes advertising expenditures and a cholesterol information index. They find that poultry demand has benefited from health information, largely at the expense of beef demand. Health information elasticities for poultry and beef were respectively 1.54 and -.583.[2] No significant effect was found for pork and fish. The effect of advertising is insignificant in their sample. Kinnucan et al. (1997) compare their advertising results with other studies and conclude that results among studies are not consistent and that advertising probably plays a minor role in meat consumption behaviour.

BSE outbreaks in the 80s, 90s and 00s in Europe, North America and Japan caused domestic beef demand in these countries to fall between 5 and 20 per cent. Exports from these countries dropped between 50 and 100 per cent, as imports were often banned. As a result prices of beef fell, and demand for other meats like pork and poultry increased (Jin et al., 2004). Whereas these effects occurred in the short run, Burton & Young (1997) have investigated both short-run and long-run effects of BSE on meat consumption in the U.K. With an AIDS estimation the following results were obtained: the short-run effect of BSE on beef expenditure share equalled -5.4 per cent and the long-run effect equalled -4.8 per cent. Burton & Young (1997) conclude that there was a substantial sustained effect on demand. They also find that poultry benefitted most in the short-run and lamb benefitted most in the long-run.

2.2.5 Religion

The relationship between religion and beef consumption has not yet been seriously investigated, but a large amount of studies has made clear that religious participation has a big influence on behaviour (Hungerman, 2011). Hungerman (2011) tests whether different behavioural outcomes of religious people are mainly caused by religious proscriptions or whether it is more an issue of *correlation in preferences*, i.e. that more religious people are also more likely to behave in a certain way. Hungerman (2011) finds that when it comes to heavy drinking and casino spending there is “a large direct role for religious proscription on behavior” (2011:35).

[2] The health elasticity measures the percentage change in consumption as a reaction to the number of articles appearing in medical journals about the link between cholesterol and heart disease.

Turning to food demand, most religions have direct proscriptions for meat consumption. Consumption of beef is disapproved in Buddhist and Hindu societies. According to Hinduism one should be very cautious with eating any kind of animal product, because it is bad karma to kill and eat an innocent animal. In addition, eating a cow is a taboo in Hinduism. Also in Buddhism vegetarianism is very common. According to Judaism and Islam, pork should be avoided, because it is not considered clean. Christianity is the only religion that does not have strict proscriptions with respect to meat consumption. Even though Hinduism and Buddhism discourage eating meat, the data show that also in countries where a large part of the population is Hindu or Buddhist, meat consumption is rising (e.g. in India, Nepal, Thailand and Japan). This paper aims to estimate the effect of a certain religion on beef consumption by including it in the demand system. The next section describes the method and data used for this purpose.

3. Method and Data

One possibility to estimate how the demand for beef changes over time as a result of changing incomes, taking into account the influence of religion, would be to estimate this with a micro-level dataset that contains information on people's beef consumption, income and religious participation. However, micro-level datasets are normally national and the variation in religious participation within one country would still be rather limited. Besides, this method would not be appropriate to analyse *global* beef demand. In addition, pooling these data, whenever actually existing, across countries would be methodologically challenging. A second possibility would be to estimate a macroeconomic panel which includes several countries, years, beef consumption, income and religion. This is the method applied in this paper. The advantages of this method is that both the effect of changing incomes within countries as well as the time-invariant effect of religion can be analysed. Usually, preferences like religion that are stable over time will be merged with other influences in the unobserved error term. This analysis aims at separating the effect of religion out via interaction effects with GDP per capita (since religion is constant over time). Section 3.1 describes the method and the specific econometric model in more detail; whereas section 3.2 describes the data that is used.

3.1 Method

Most empirical studies assume a log-linear relationship between demand and income, which means that the income elasticity is constant over all income levels. However, this is not what we would expect in reality. Moreover, the studies cited in Table 1 suggest that the income elasticity of beef consumption falls as income grows and some saturation point is reached. In addition, it could also be the case that among very low income levels the consumption of beef remains more or less zero until some threshold level of income is reached where demand for beef takes off. The data seem to indicate that this is indeed the case. Therefore, a flexible form demand function, i.e. a nonlinear relationship between income and demand (prices are assumed constant), is the theoretically preferable relationship.

In this paper we follow the estimation method of Gale & Huang (2007). Gale and Huang (2007) estimated food demand curves using a log-log inverse form of the Engel equation. Using a log-log inverse Engel relationship allows the income elasticity to vary with income. Additional parameters of our model are: price of beef, price of chicken, and religious participation (i.e. share of population practicing a certain religion). Not the direct effect of religion on beef consumption is estimated, but its interaction effect with income, because religion is constant. As a result, we obtain different income elasticities for each religion. The final model can be seen in equation 1.

$$\ln y_{it} = \beta_0 + \beta_1 (1 / I_{it}) + \beta_2 \ln I_{it} + \beta_3 \ln P_{it} + \beta_4 \ln I \cdot R_i + u_{it} \qquad (1)$$

Where y_{it} is beef consumption per capita, I_{it} is GDP per capita as a proxy of income, P_{it} is a vector of prices (beef and chicken), β_3 is a vector of coefficients, R_i is a vector of religion types, β_4 is a vector of coefficients, and u_{it} is an error term.

The income elasticity for each country ε is calculated from the estimated coefficients, which is shown in equation 2. ε varies with income if $\beta_1 \neq 0$. ε decreases as income increases if $\beta_1 < 0$ and $\beta_2 > 0$. When $\beta_1 / I = \beta_2$, ε reaches zero and becomes negative if $\beta_1 / I > \beta_2$. If $\beta_1 = 0$, ε is independent of the level of income and equals β_2. If $\beta_2 = 0$ the income elasticity equals $-\beta_1 / I_i$ and varies with income, but never reaches zero or changes sign (Gale & Huang, 2007).

$$\varepsilon = -\beta_1 / I_i + \beta_2 \quad (2)$$

Most studies that estimate a standard demand model, (like those presented in Table 1) compute and report this income elasticity. Based on our model, ε has to be interpreted as a reference elasticity, i.e. the elasticity for those religions not included in the model. If we take the effect of religion into account, the income elasticity is calculated as follows:

$$\varepsilon_R = -\beta_1 / I + \beta_2 + \beta_4 \quad (3)$$

From equations 2 and 3 we already see that the effect of religion will not alter the shape of the curve representing the relationship between income and the income elasticity. Rather, its effect will be an upward or downward shift of the curve, equal to the size of β_4. It is also possible that the actual effect of religion alters the shape of the curve. In order to see whether this is the case, the model is also estimated for groups of countries separated by religion. Only Muslim and Christian countries have enough observations to be estimated separately. Therefore, for these two religions separate models are estimated that allow for different slopes of the curve. So two groups are made: one where the Muslim population is greater than 50 per cent and one where the Christian population is greater than 50 per cent. Equation 4 shows the model that is estimated for these two religions. Equation 2 shows how the income elasticity is calculated.

$$\ln y_{it} = \beta_0 + \beta_1 (1/ I_{it}) + \beta_2 \ln I_{it} + \beta_3 \ln P_{it} + u_{it} \quad (4)$$

A drawback of a macro-panel like this is that there is often correlation between countries situated close to each other (cross-country dependence). Diets and food products of neighbouring countries are likely to influence a country's own diet and food products. Mainly because most migration and tourism takes place between neighbouring countries. Heteroskedasticity and autocorrelation are also present in the panel. Autocorrelation might be caused by habit persistence. Therefore we need an econometric model that takes into account all these causes of biases. A Prais-Winsten Panel Corrected Standard Errors-specification (xtpcse) is chosen. This model calculates panel-corrected standard error estimates for linear cross-sectional time-series models where the parameters are estimated by Prais-Winsten (or Ordinary Least Squares (OLS)). It assumes heteroskedasticity, contemporaneously cross-

sectional correlation, and first-order autocorrelation when computing the standard errors (Hoechle, 2007). Tests for groupwise heteroskedasticity (a modified Wald statistics) and autocorrelation (a user written program, see Drukker (2003)) indicate that both are indeed present.

3.2 Data

A panel dataset is put together with data for 122 countries and 17 years on beef consumption, prices of beef and chicken, and several religions. The price of pork is left out, because including it would result in many missing observations for Islamic countries. In total there are 2010 observations. It is an unbalanced panel; most countries have data for all 17 years, but 23 countries have 16 years or less. For the group of Islamic countries there are 355 observations; and for the group of Christian countries there are 1045 observations (both are also unbalanced panels). The dependent variable is bovine meat (further referred to as beef) supply per capita, which is taken from the food supply dataset of FAOSTAT (2010). The food supply data are an estimate of the per capita amount of food available for human consumption during the reference period. Kilograms per capita represent carcass weight, so actual consumption is lower, approximately one half of the weight. Carcass weight is often used to analyse meat consumption, because it is most readily available. Since actual consumption is a pretty constant fraction of the carcass weight, using carcass weight will not influence the results. Food supply in kilograms is calculated as follows:

food supply = production – exports + imports + change in stocks – used as feed – wasted

Prices of beef and chicken are also taken from FAOSTAT. GDP per capita is taken from the United Nations (UN) statistics. Data on religions are taken from the Religion Adherence Dataset (RAD). Religion is measured as a number between zero and one, representing the fraction of the population adhering a certain religion. This allows for having multiple religions in one country. Data of the following religions are excluded from the analysis and these religions thus serve as a reference category in the estimation: Buddhism, Eastern religions (e.g. Taoism, Shinto, Confucianism) and other religions. Table 2 shows the variables that are included in the dataset, their means, standard deviations, minima, maxima and source. A detailed list with definitions of the variables is presented in Appendix 1.

Table 2: Descriptive statistics of the data

Variable	Obs	Mean	Std. Dev.	Min	Max	Source
Beef consumption (kg)	2010	13.2	10.8	.6	66.3	FAOSTAT
Price beef ($)	2010	2788	2527	109	50619	FAOSTAT
Price chicken ($)	2010	1827	1481	62	30962	FAOSTAT
GDP per capita ($)	2010	8053	12369	112	108017	UN
Catholic (%)	2010	.310	.351	0	.95	RAD
Protestant (%)	2010	.122	.200	0	.90	RAD
Other Christian (%)	2010	.074	.098	0	.51	RAD
Orthodox (%)	2010	.084	.199	0	.92	RAD
Jewish (%)	2010	.008	.071	0	.77	RAD
Muslim (%)	2010	.210	.322	0	.99	RAD
Atheist	2010	.078	.105	0	.50	RAD

The next chapter describes the results of the estimation.

4. Results

A first look is taken at the relationship between income and per capita beef consumption by plotting the averages of the 17-year period of the two variables in one graph (Figure 2). Overall, the relationship is as expected: there is a higher consumption of beef in countries with a higher income and there is a saturation point of around 40 kg per capita per year. Two outliers are visible (circled red in the figure): countries that have a very high beef consumption and a relatively low income. These countries are Uruguay and Argentina, which happen to be large exporters of beef. They have a comparative advantage in beef production, mainly because they have large areas of land available that are suitable for cattle grazing. Beef is therefore relatively cheap in their domestic markets. Average producer prices of beef per tonne in the reference period (1991-2007) in Uruguay and Argentina were respectively $1214 and $1677, against an average of $2788 per tonne for all countries in the dataset. This could be an explanation for the high consumption levels in these countries.

Figure 2: Plot of average income and average beef consumption

4.1 Global Model

The Prais-Winsten regression with panel-corrected standard errors is estimated for all countries. The results are presented in Table 3. The specification shows a very good fit; R^2 is equal to .891. The coefficients of price of beef and chicken have the expected signs, but the price of chicken is statistically insignificant. All the religions have a positive sign and are statistically significantly different from zero, except for Hindu. These significant religion coefficients indicate that religion does influence global beef demand. All the religions that are included in the model have a larger interaction effect with

income than the reference religion, i.e. the elasticity for all those religions not included in the model (e.g. Eastern, Buddhism and other).

Table 3: Estimated parameters of global beef demand

	Coefficient	Std. Err.	t-value	P-value
Inverse of income	9.495	13.767	.69	.490
Ln (income)	.130**	.027	4.85	.000
Ln (price of beef)	-.084**	.024	-3.56	.000
Ln (price of chicken)	.027	.024	1.11	.265
Ln (income * Catholic)	.135**	.016	8.30	.000
Ln (income * Protestant)	.094**	.016	5.76	.000
Ln (income * other Christian)	.190**	.043	4.39	.000
Ln (income * Orthodox)	.125**	.018	7.01	.000
Ln (income * Jewish)	.158**	.021	7.67	.000
Ln (income * Muslim)	.053*	.023	2.34	.019
Ln (income * Hindu)	.015	.062	.24	.811
Ln (income * Atheist)	.389**	.039	10.07	.000
Constant	.743**	.223	3.33	.001

Notes: * = significant at the 5-per cent level, ** = significant at the 1-per cent level.

With the estimates presented in Table 3 we are able to calculate income elasticities. The coefficient of the inverse of income is not significantly different from zero, which means that statistically speaking the income elasticity is constant over all income levels, and equal to the coefficient of *ln* income (.130). However, economically speaking we have to include the coefficient in the calculation of the income elasticity. Because β_1 is greater than zero, ε increases with income and becomes negative for small income levels. For the reference religion the income elasticity becomes negative for incomes smaller than $73. Since this is lower than the minimum income in our sample it is save to conclude that in all countries and for all religions included in this sample the income elasticity is positive. Figure 3 shows the income elasticities of all religions plotted against income. It is clear that the elasticity is constant over the largest width of income.

Subsequently, income elasticities are calculated for each religion with averages of income. The results are presented in Table 4. In Table 4 we see that the reference income elasticity is equal to .128. This is rather small, especially when we compare it to the elasticities presented in Table 1. Looking at the religion-specific income elasticities, we see that the highest income elasticity of .516 is computed for countries with a large Atheist population, e.g. China and North Korea. Also in countries with a large population of 'other Christian' denomination the income elasticity is relatively large, namely .319 (this religion is widespread in the USA, South Africa, Jamaica and many African countries). Catholic countries have a slightly higher income elasticity than Protestant countries, but the difference is small. The lowest income elasticity is found for countries with large Hindu or Muslim populations. For all religions, the demand for beef increases as income increases. But all the elasticities are smaller than unity; therefore, we cannot conclude that beef is a luxury good, as did several of the studies mentioned in Table 1.

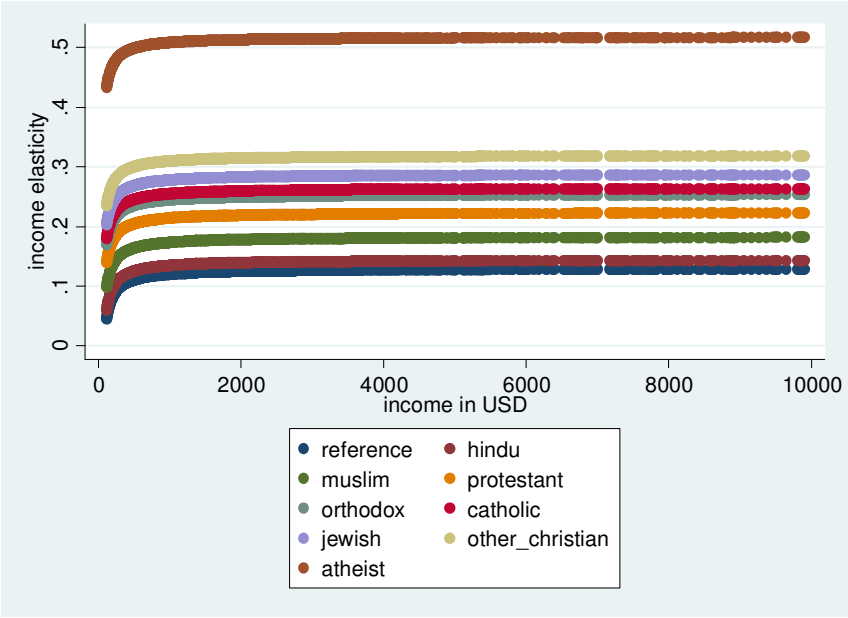

Figure 3: Plot of estimated income elasticities and income

Gale & Huang (2007) have estimated Engel curves of the same functional form for Chinese households and their consumption of several food- and beverage items. They have computed income elasticities for different income levels and found that the elasticities fall as incomes grow. Elasticities are close to zero for very high income levels, implying that a saturation point is reached. This is also in line with theory presented in Chapter 2. However, our results do not confirm this relationship. Table 4 shows that some of the lowest income elasticities are among the poorest countries and in general there is no such trend visible. This indicates that the relation between income and the beef income elasticity is not as straightforward as expected. Religion, and probably also other cultural determinants, strongly influence this relationship.

Table 4: Average incomes and income elasticities by religion

	$\overline{income}$	ε
Atheist[a]	4859	.516
Other Christian[a]	9902	.319
Jewish	18414	.287
Catholic	8982	.264
Orthodox	3346	.252
Protestant	28474	.224
Muslim	1594	.177
Hindu[a]	2279	.140
Reference	8052	.128

Note: - incomes and elasticities for each religion are calculated for countries in which the majority (> 50 per cent) of the population practises that religion.
- [a] incomes and elasticities are calculated for countries in which more than 30 per cent of the population practices that religion, because in all three cases there is only one country in which a majority of the population practices that religion. Elasticities did not change much when taking countries with > 30 per cent religion; but average income did differ considerably.

4.2 Separate Models for Christianity and Islam

In order to test not only differences in intercepts but also in slopes, two separate models are estimated and their results presented in Tables 5 and 6. The results for Islamic countries are shown in Table 5. Although the model explains a large share of the dependent variable's variation, none of the explanatory variables is statistically different from zero. R^2 is high (.83), but all the variables, including income, are statistically insignificant at the 5-per cent level. Apparently, income in Islamic countries does not influence beef consumption in a significant way. Statistically speaking the income elasticity is zero.

Mean income in these countries is $1594. Plugging this number in Equation 2 gives an average income elasticity of .019. This is smaller than the income elasticity shown in Table 4, but the fact that it is small is in line with the results of the model for all countries. Both price elasticities have opposite signs than expected but they are both not statistically different from zero.

Table 5: Output of the Prais-Winsten model for Islamic countries

	Coefficient	Std. Err.	t-value	P-value
Inverse of income	59.975	32.711	1.83	.067
Ln (income)	.057	.072	.79	.429
Ln (price of beef)	.016	.047	.35	.727
Ln (price of chicken)	-.004	.046	-.08	.934
Constant	1.093*	.616	1.77	.076

Note: * = significant at the 5-per cent level, ** = significant at the 1-per cent level.

Figure 4 shows the relationship between income and the income elasticity in Islamic countries. As can be seen, the income elasticity *increases* with income. This result is opposite to the theory which predicts a negative relationship between the income elasticity and income. In fact, Figure 4 shows that for very small income levels the income elasticity is negative. For incomes around $1500 the elasticity becomes positive. The smallest income elasticity is found in the poorest country Tajikistan, where average income equals $139, and is equal to -.373. The highest income elasticity is found in the richest country Saudi Arabia, where average income equals $15597, and is equal to .053. These negative elasticities could be explained by the fact that the model has a poor fit. Another explanation for these results - the fact that coefficients are insignificant; that the income elasticity is very small; and that the relationship between the income elasticity and income is contradictory with the theory - could be the relative poverty and way of life in Islamic countries. Many people, especially those living in rural areas, might not demand beef at all as their food consumption comes for a large part from subsistence farming. Mutton and poultry might be better capable to fit local climatic conditions. Alternatively, small animals require less inputs (water, feed). As people move out of subsistence farming, they start to buy more food in the market where they encounter, mainly imported, beef products. This could explain a positive and increasing income elasticity of beef demand from a certain income level.

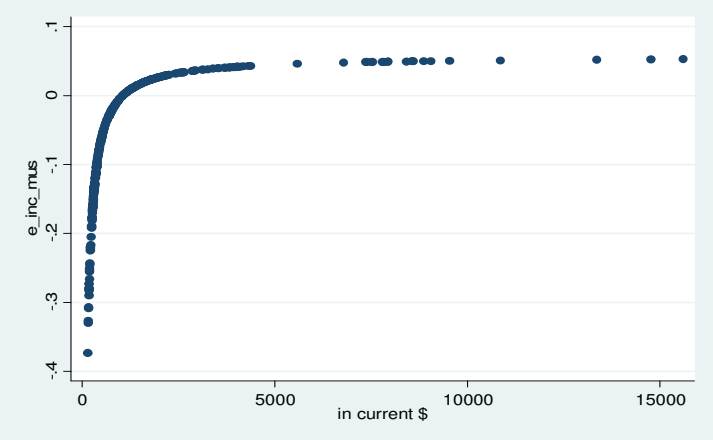

Figure 4: Plot of income elasticity and income level in Islamic countries

Results of the model estimated based on the subsample of by majority Christian countries are presented in Table 6. It explains a large variation of the beef consumption per capita (R^2 is equal to .95) and all explanatory variables are statistically significant. This is again in line with the results of the aggregate model, where all Christian religions had a significant interaction effect with income. Average income in Christian countries is $12744, which gives an income elasticity of .388. The income elasticity varies with income and the relationship can be seen graphically in Figure 5. It is clear that the elasticity falls as income grows, which is in line with the economic theory. The smallest income elasticity is found in the richest country Luxembourg, where average income equals $108017, and is equal to .377. The highest income elasticity is found in the poorest country Burundi, where average income equals $115, and is equal to 1.785. The cross-price elasticity and the own-price elasticity both have the expected signs and are significantly different from zero. Beef's own-price elasticity is rather large, implying that in Christian countries the price of beef is a relatively important factor influencing demand.

Table 6: Output of the Prais-Winston regression for Christian countries

	Coefficient	Std. Err.	t-value	P-value
Inverse of income	-162.429**	34.701	-4.68	.000
Ln (income)	.375**	.027	13.95	.000
Ln (price of beef)	-.372**	.044	-8.43	.000
Ln (price of chicken)	.089*	.036	2.45	.014
Constant	1.687**	.376	4.49	.000

Note: * = significant at the 5-per cent level, ** = significant at the 1-per cent level.

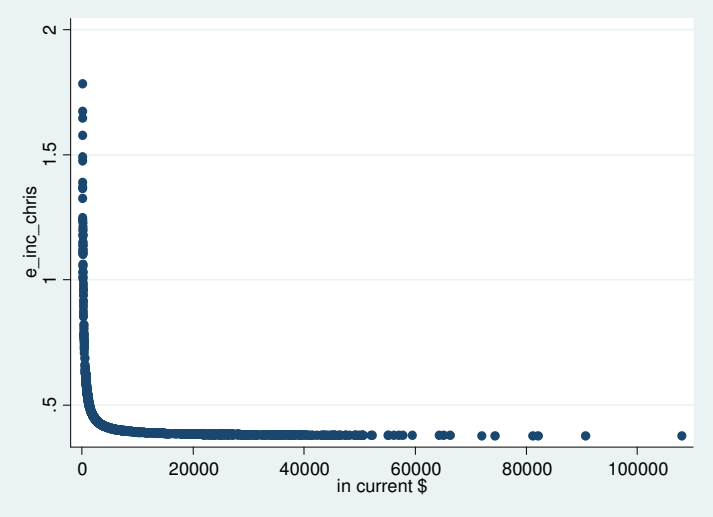

Figure 5: Plot of income elasticity and income level in Christian countries

5. Conclusion

Globally, beef consumption has been rising at the same time that incomes have been rising too. This observation is confirmed by the results of our first model, which show that in all countries and for all religions the income elasticity is greater than zero. Previous studies have estimated income elasticities of beef greater than one, which means a luxury good. Our results show otherwise: all elasticities are between zero and one, which means a normal good. Beef can be a luxury good in generally poorer countries (the range of elasticities in the Christian subsample indicate that this is indeed the case), but on average it is not.

There are strong differences in the size of the income elasticity between religions. In Atheistic countries the income elasticity is relatively large, meaning that a substantial increase in beef consumption can be expected there if incomes keep growing. In countries with a large Protestant population, which are mainly in Europe, we see that the income elasticity is relatively small; a sign that saturation occurs. In countries with a large Catholic population, which are mainly in Latin America, the income elasticity is also rather small and saturation is taking place there too, however at a much higher consumption level. In countries with a large Muslim or Hindu population the elasticities are close to zero and beef consumption is much less responsive to income changes. This result was to be expected for Hindu countries, because of the taboo on beef consumption; however, the result for Islamic countries is remarkable. Overall, we see that the effect of income is moderated by religion. A model without religion will always assume equal influence of income, while this is not the case. The method applied here is the simplest way to make effect of religion visible

Our results do not show a global decreasing effect of income as countries get richer; overall the income elasticity is more or less constant over all income levels, except for the Christian subsample. The results of the two subsamples show that the relationship between income and the income elasticity can differ between religions. These globally differing relationships make clear that standard economic demand models, assuming a constant income-demand relationship, are not always realistic. The results also show that the findings of studies focussing on countries with a predominant Christian population cannot simply be translated to the rest of the world. It is also not likely that saturation levels are globally comparable. Country-specific effects like religion, but probably also other factors like tradition, habits and health perceptions, are underlying this incomparability.

What does this say about analysing global development of beef consumption with respect to sustainability? Income elasticities for all religions are greater than zero, so global beef consumption will keep rising if people get richer. The high income elasticity in Atheistic countries confirms the concerns about increasing beef consumption in Asia. In this paper a first indication has been given of the importance of religious proscriptions with respect to beef consumption. Environmental organisations and politicians attempting to discourage beef consumption usually overlook the

importance of religion on consumption behaviour. Perhaps the discussions on reducing beef consumption and sustainability should be conducted more within the religious environment.

The analysis of the effect of religion on the income elasticity of beef consumption would improve if more years of data on religious participation were available. In that way we could also see what the effect of shifts in religious participation would be. It would also be interesting to extend the analysis in a more qualitative way to see what is behind the differences between religions.

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Appendix I: List of Variables

Variable	Description
Atheist	Fraction of the population that adheres no religion in the year 2000. Prevalent in communist countries like China, Democratic People's Republic of Korea (North Korea), Kazakhstan, Mongolia and Cuba.
Beef	The culinary name for meat from bovines
Bovine	Biological subfamily that includes cattle (cows), buffalo's, bison's and yaks.
Bovine meat consumption (y)	Data refer to the total amount of the commodity available as human food during the reference period. Data include the commodity in question, as well as any commodity derived therefrom as a result of further processing. Units are in annual kilograms per capita.
Catholic	Fraction of the population adhering the Catholic religion in the year 2000. Highest fractions are found in Latin America.
GDP per capita (I)	Gross Domestic Product per capita in US Dollars. Taken from the United Nations Statistical Division. Used as a proxy for income.
Hindu	Fraction of the population adhering the Hindu religion in the year 2000. Prevalent in India and Nepal. Smaller fractions in Sri Lanka, Bangladesh and several islands in the Caribbean sea and Pacific ocean.
Jewish	Fraction of the population adhering the Jewish religion in the year 2000. Prevalent in Israel. Small fractions are found in the Americas.
Muslim	Fraction of the population adhering the Islamic religion in the year 2000. Prevalent in the Middle East and North Africa.
Other Christian	Fraction of the population adhering a Christian religion other than Catholic or Protestant in the year 2000. Examples of other Christian religions are: Evangelical, Black Church, Mormon, Jehovah's Witness, and Seventh Day Adventists.
Orthodox	Fraction of the population adhering an Eastern Orthodox religion in the year 2000. This religion is prevalent in the Slavic countries and Greece, Romania, Moldova, Cyprus and Georgia.
Price of beef	Prices in US Dollars. Equal to producer prices in local currency times the exchange rate of the selected year. The main exchange rates source used is the IMF. Where official and commercial exchange rates differ significantly, the commercial exchange rate may be applied.
Price of chicken	Prices in US Dollars. Equal to producer prices in local currency times the exchange rate of the selected year. The main exchange rates source used is the IMF. Where official and commercial exchange rates differ significantly, the commercial exchange rate may be applied.
Protestant	Fraction of the population adhering the Protestant religion in the year 2000. Highest fractions are found in the Scandinavian countries and Iceland.

Appendix II: Alternative Specifications

Besides the Prais-Winston model, also some other panel data methods have been estimated: the fixed and random effects models (xtreg) and two regressions – pooled OLS and fixed effects – with Driscoll and Kraay standard errors (xtscc). Both alternative methods are discussed below.

2.1 Fixed and Random Effects

First, a fixed and a random effects model are estimated (equation 1). A Hausman test shows that fixed effects are preferred. The results of the fixed effects model is shown in Table A1. The model has a rho equal to .98, i.e. : a strong influence of fixed effects on the variation of the dependent variable. The within-R^2 is equal to .049. Tests for heteroskedasticity and autocorrelation confirm that both are present. When estimating the fixed effects model with robust standard errors, only the following variables are significant at the 5 per cent-level: ln price of beef (coefficient = -.12, t-value = -2.45) and ln income * Jewish (coefficient = 1.07, t-value = 3.99). All in all, the model explains little of the variation in the panel (only 2 per cent); the majority is explained by the fixed effects. A disadvantage of a fixed effects model in comparison with the Prais-Winsten model is that it is not possible to correct for cross-country dependence.

Table A1: Output of the fixed effects model

```
Fixed-effects (within) regression               Number of obs      =      2012
Group variable: country                         Number of groups   =       122

R-sq:  within  = 0.0488                         Obs per group: min =        10
       between = 0.0921                                        avg =      16.5
       overall = 0.0855                                        max =        17

                                                F(12,1878)         =      8.03
corr(u_i, Xb)  = -0.8840                        Prob > F           =    0.0000
```

ln_con	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
inv_inc	-4.507753	16.87308	-0.27	0.789	-37.59971	28.58421
ln_inc	.2396683	.1029574	2.33	0.020	.0377453	.4415912
ln_p_beef	-.12627	.0232075	-5.44	0.000	-.1717851	-.0807549
ln_p_chick	.0932373	.0219837	4.24	0.000	.0501223	.1363524
ln_inc_cath	-.3169689	.1062666	-2.98	0.003	-.5253819	-.1085559
ln_inc_prot	-.2411262	.1397552	-1.73	0.085	-.515218	.0329656
ln_inc_oth~t	-.2000677	.2207323	-0.91	0.365	-.6329741	.2328387
ln_inc_orth	-.2851605	.1069395	-2.67	0.008	-.4948933	-.0754277
ln_inc_jews	1.072784	.5159198	2.08	0.038	.0609481	2.084621
ln_inc_mus~m	.063652	.1063768	0.60	0.550	-.1449772	.2722812
ln_inc_hindu	-.4208679	.2744753	-1.53	0.125	-.9591765	.1174408
ln_inc_non~l	-.4589174	.175809	-2.61	0.009	-.8037189	-.1141159
_cons	2.201655	.205804	10.70	0.000	1.798027	2.605284
sigma_u	1.7445557					
sigma_e	.22581395					
rho	.98352157	(fraction of variance due to u_i)				

F test that all u_i=0: F(121, 1878) = 105.74 Prob > F = 0.0000

2.2 Regression with Driscoll and Kraay Standard Errors

The regression with Driscoll and Kraay standard errors (xtscc) does correct for cross-country dependence, in addition to heteroskedasticity and autocorrelation. It can be done with pooled OLS or with fixed effects. Pooled OLS does not take into account the country-specific fixed effects, which is an important added value of the dataset. Therefore, only the model with fixed effects is estimated. In Table A2 the results are presented. The within R^2 is equal to .04, so the model has a very poor fit.

Tabel A3: Output of the Driscoll and Kraay fixed effects model

```
Regression with Driscoll-Kraay standard errors   Number of obs     =      2012
Method: Fixed-effects regression                 Number of groups  =       122
Group variable (i): country                      F( 12,   121)     =   1333.69
maximum lag: 2                                   Prob > F          =    0.0000
                                                 within R-squared  =    0.0488
```

ln_con	Coef.	Drisc/Kraay Std. Err.	t	P>|t|	[95% Conf.	Interval]
inv_inc	-4.507753	19.07792	-0.24	0.814	-42.27753	33.26202
ln_inc	.2396683	.077642	3.09	0.003	.0859554	.3933811
ln_p_beef	-.12627	.0273428	-4.62	0.000	-.1804023	-.0721377
ln_p_chick	.0932373	.0405059	2.30	0.023	.0130451	.1734295
ln_inc_cath	-.3169689	.0864016	-3.67	0.000	-.4880236	-.1459142
ln_inc_prot	-.2411262	.1741757	-1.38	0.169	-.585953	.1037006
ln_inc_oth~t	-.2000677	.22289	-0.90	0.371	-.6413373	.2412018
ln_inc_orth	-.2851605	.1180023	-2.42	0.017	-.5187773	-.0515437
ln_inc_jews	1.072784	.2025434	5.30	0.000	.6717963	1.473773
ln_inc_mus~m	.063652	.0835181	0.76	0.447	-.1016941	.2289982
ln_inc_hindu	-.4208679	.1464383	-2.87	0.005	-.7107812	-.1309546
ln_inc_non~l	-.4589174	.189167	-2.43	0.017	-.8334233	-.0844115
_cons	2.201655	.3243482	6.79	0.000	1.559523	2.843788