Is Meat Sustainable? An Estimation of the Environmental Impact of Meat Consumption

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Abstract

This paper adds to the existing literature on the estimation of world consumption patterns for meat products. I first separate meat into beef, chicken and pig products, then divide the world into regions in order to estimate income elasticity using a simultaneous equations model. I find, contrary to other studies, that there is no aggregate income elasticity. With this finding I forecast the world demand for meat products using linear interpolation to the years 2020 and 2040. Using existing research on "best existing case" scenarios of the ecological impact of different foods, I then estimate the total land usage and greenhouse emissions of this meat production. Finally, I discuss the aggregate impact of these consumption patterns on the environment. I argue that, under the most efficient current system of production, this growth of meat consumption is not ecologically sustainable.

JEL Classifications: O13, Q17, Q27, Q53, Q56

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1 Introduction

There is currently a large difference between meat consumption in countries with high incomes and those with low incomes. The average American consumes approximately 124 kg

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of meat each year, the highest in the world. By contrast, the average worldwide consumption is 31 kg a year, with Bangladesh the lowest at 3 kg per person (FAO (2006)). This situation though is changing as meat consumption around the world has more than doubled in the last 15 years, with many developing countries in Asia leading this growth.

While economic development is good news for those who have benefited from greater meat availability, there are some potential problems. Jeffrey Sachs (2006) recently highlighted some of the types of stresses that development could have on the world's environmental system, and thus economic and political systems. For instance, climate changes can increase the chances of droughts or other similar losses to land and food supply, putting pressure on governments and potentially leading to famines and wars. The environment plays a large role in economic development, and so highlighting potential difficulties is important. With a view to the larger issues that Sacks mentions, the main goal of this paper is then to answer the following question: how, if at all, does meat consumption add to environmental stress? To this end I will be looking closely at the environmental sustainability of current consumption patterns, which I define as, in the words of The Worldwatch Institute, "an environmentally sustainable and socially just society, in which the needs of all people are met without threatening the health of the natural environment or the well-being of future generations" (http://www.worldwatch.org/node/24 (2006)). For more on the role of environmental sustainability, see Goodland (1995).

One of the ecological problems with meat is the amount of land required for production. To produce 1 kg of beef in the Netherlands requires 20.9 m^2 of land just for feed and other inputs (Gerbens and Nonhebel (2002)). If every person on the plant were to have the same level of meat consumption as the average person in the US and all land was used at the same technological level as land in the Netherlands, meat production alone would account for 30% of all of the world's potentially arable land, at least 4 times as much as is currently used[1].

[1]These figures were calculated using the average American consumption of beef at 44 kg, 50 kg of chicken

Land availability is not the only problem. Greenhouse emissions and energy requirements also pose potential difficulties. For example, Subak (1999) calculated the environmental effects of methane and CO_2 emissions of cattle in a US style feedlot system. In total, to produce 1 kg of beef requires the equivalent of 14.8 kg of CO_2. As a comparison, 1 gallon of gasoline emits approximately 2.4 kg of CO_2 (EPA (2005)). Producing 1 kg of beef thus has a similar impact on the environment as 6.2 gallons of gasoline, or driving 160 highway miles in the average American mid-size car.

The goal of this paper then is to comprehensively bring together existing data on the ecological impact of consumption patterns along with an estimation of future worldwide consumption in order to quantify what kind of ecological problems may arise. A number of papers have estimated future consumption, including FAO (2003), FAPRI (2003), M. A. Keyzer (2005), OECD (2003), USDA (2001) and York and Gossard (2004). There are though a number of key differences between these works and this paper.

As people achieve higher and higher incomes, their ability to purchase not just more products, but also those of higher quality, increases. Cars are a good example of this phenomenon. As a person's income increases, she will likely purchase a more expensive car. Much of the literature on meat consumption has assumed that this same situation holds for food products. The logic is as follows: as people realize higher incomes, they acquire the ability to purchase more desired foods. For many people this would mean a switch from traditional, low cost foods such as wheat and rice to higher cost meat products such as beef, poultry and pig. Both M. A. Keyzer (2005) and York and Gossard (2004) have estimated income elasticities for meat consumption, finding that income does have a substantial effect. Both of these papers assume though that meat is a unified product and have estimated total meat, defined as the total beef, chicken and pig products a person eats. All meat though

and 30 kg of pig, along with the findings of Gerbens-Leenes and Nonhebel on land usage. Potential arable land is assumed to be 31 million km^2, approximately 21% of total land.

is not the same. For example, while total meat consumption per capita has been growing around the world at a very high rate, this is driven mostly by chicken and pig products as beef consumption per capita has actually been slowly falling. This could be due to differences in preferences across meat products, potentially making aggregation a problem.

In order to get an accurate view of the trends in meat consumption, I estimate a more intricate model than has previously been done. Rather than neglecting the differences between the types of meat and the relationship between food and feed sources, I estimate between elasticities for beef, chicken, pig, maize and rice. Also, instead of assuming food supply is exogenous, I use data on consumption and prices and estimate a simultaneous equations model where both supply and demand is endogenized. Finally, I separate country data out by region in order to take into account the differences in consumption patterns between groups around the world.

This paper makes a number of important original contributions to the literature on consumption patterns. First, no other paper looking at meat consumption has used data on prices. Making use of the Hausman test, I find that a simultaneous equations approach to estimation is in fact far superior to a single equation approach. I add a parameter for lagged consumption in order to observe how much of meat consumption is due to persistence effects. I also differentiate meat products and separate the data by region, which gives a better model specification, and find much lower coefficient values than in other studies. Specifically, for all meat products, I find no income effect. The majority of consumption is due to habit formation and has very little if anything to do with prices or income. This paper also brings together a wide range of environmental data in order to approximate the present and forecast the future ecological impact of meat consumption. Using these results I then discuss how this type of growth in consumption is not sustainable and so is not likely to continue into the future.

Combining this wide array of data and techniques will help to answer more fully how meat adds to environmental stress. The main question can then be broken down into three simpler questions. First, if consumption continues at current levels, what will consumption look like in the years 2020 and 2040? Second, what will be the environmental impact of this level of consumption? Finally, is this consumption level environmentally sustainable?

The rest of the paper proceeds as follows. Section 2 describes the model and data used in the estimations. Section 3 presents estimation results and forecast estimates. Section 4 reviews the existing ecological data and incorporate them into the results. In Section 5 I take all of the findings of the paper and address the main question, that of sustainability. Section 6 then is the conclusion of the paper.

2 Model and Data

2.1 Model

There are a number of benefits of using a simultaneous equations model. As the model is derived from theory, it is a structural specification where prices and quantity are jointly determined. This helps in avoiding the problem of identification. In economic modeling, there is often a problem of observational equivalence. For instance, I may believe that observed values are part of an equilibrium of supply and demand, but cannot distinguish between different functional forms that may be observationally equivalent. Without accounting for both supply and demand, the estimates could be biased. By specifying both a supply and demand function I can avoid this problem [2].

The model I use here thus has the following functional form:

[2] For more information on this, please see Greene (2003), chapter 15.

$$C_i = \alpha_i + \beta P_i + \gamma P_{-i} + \delta I + \theta U + \eta L + \epsilon_i \quad (1)$$

$$P_i = \kappa_i + \lambda C_i + \xi P_{-i} + \pi L + \nu_i \quad (2)$$

Here, C is a vector of per capita consumption of commodity i, in each country, for each year, P_i is a vector of the price of the commodity in that country, P_{-i} is a matrix of prices of other products, I is a vector of income (per capita GDP) per country, U is a vector of level of urbanization and L is a matrix of lags on consumption. I follow York and Gossard (2004) in including urbanization, who found that food preferences change as people move to the cities and thus countries become more urbanized. Equation (1) can thus be thought of as the demand for a given product and equation (2) the supply.

2.2 Data

This is a panel as I use data by country and year. Per capita GDP in constant 2000 US dollars is used for income and urban population as percent of total population is used for urbanization level. Both were found in the World Development Indicators database from WB (2006). Data on per capita consumption and prices of the commodities beef, chicken, pig, maize and rice was found from FAO (2006). Prices are the national average in a given country that producers received for the individual commodity. This value reflects the average price producers received for their products, not necessarily what was paid by the consumer. This value is in 2000 US dollars so all costs are in real terms and comparable across countries. The data, while not ideal for prices, represents the best available. It would be best if I have data on consumer prices for each country; instead I assume that local production prices are a proxy for local end-use prices.

After combining all of these data sets for all commodities I am left with 61 countries covering the years 1991 to 2003. Table 1 summarizes the countries in the sample and what region I include them in.

An important implication of using the years 1991 to 2003 is that the data avoids the structural changes in meat production up until the early 1990s. Before the 1990s, technology in the meat industry was changing radically. Since then though, there has been very little innovation in the production and transportation system (Michael Ollinger and Nelson (2005)). This means that for the 13 years the data of this study covers there have not been any significant supply shocks for much of the world.

3 Estimation Results and Forecast

3.1 Estimation

As the variable of interest is elasticity, I take logs of all the data. Tables 2-4 show the results for the simultaneous equations model for each meat product, estimated using a three-stage least squares approach. For all tables in this paper, * refers to significance at the 90% level, ** at 95% and *** at 99%.

The results show strong evidence that habit formation, or persistence, is the major contributing factor to the demand for meat products. The coefficient for lag consumption is significant for all three products and explains the majority of consumption choices. With a lag included, income elasticity for beef, chicken and pig is not significant. Urbanization level is also not significant for any meat product. As mentioned in the introduction, M. A. Keyzer (2005) and York and Gossard (2004) found large positive effects for income elasticity. I believe that their models though were incorrectly specified as neither used a simultaneous equations specification nor included a lag and so may suffer from an omitted variable bias. Thus, these studies were erroneously associating changes in incomes around the world with changes in meat consumption. As there is a high correlation between income and consumption (0.69, 0.83 and 0.61 between income and consumption of beef, chicken and pig respectively) an incorrectly specified model will likely conclude causal effects between these variables when in fact there is none.

With a lag variable included though, most demand side effects are not significant and so disappear. This result could have very important implications for policy decisions as demand cannot be easily affected through prices. It also means that studies that have assumed an income effect have over estimated future world demand for meat. It is important to note that the data reflects the total quantity consumed of beef, chicken and pig products, not the quality nor choices from within products. The lack of significant demand side effects is thus an aggregate finding and does not necessarily reflect individual preferences.

By running a Hausman test, I can see if a three stage least squares (3SLS) approach for the simultaneous equations model I have specified is a statistically better approach than a first stage least squares (OLS), which specifies only the demand equation. The Hausman test computes the chi-squared statistic $\chi^2 = (B - b)'[V_B - V_b]^{-1}(B - b)$, where B is the estimates of the 3SLS, b is for the OLS and V is the variance/covariance matrix. Under the model specifications I have here, this will test the null hypothesis that the 3SLS and OLS estimates do not differ systematically. The results for the estimates in this paper are $\chi^2 > 200$ for all products and regions, which is above the χ^2 critical point, leading to a rejection of the null and the conclusion that the 3SLS is in fact a much better approach.

There could also be a problem of multicollinearity in the sample data, causing a redundancy in the estimation. One way to test for this is to look at the variance inflation factors (VIF), which shows how much an increase in the variance of one estimate can be attributed to a lack of orthogonality in the data. This is calculated by $VIF = 1/(1 - R_k^2)$ for the k^{th} variable. A high VIF, or as is more commonly computed, a low 1/VIF (below 0.10) will indicate potential problems. The 1/VIF for all regressions run here is greater that 0.20, implying there is not likely a problem.

Because of the relatively large size of the estimates for the lag variable, there is also a potential problem of a unit-root. If the coefficient on the lag variable is 1 the model will be non-stationary and thus explosive. There are two processes necessary to test for this. The first is to test the hypothesis that the coefficient is not 1. Because of the smallness of the standard error in this estimate there is more than a 5 standard deviation from 1 for all meat products in all regions, meaning it is statistically unlikely that this could be 1. This in itself does not solve the problem as we must also test under the null hypothesis that the model is explosive. To see if this is the case it is necessary to use a Dickey-Fuller test statistic[3]. This test though is not usable in panel data, and so I use a statistic, based on the Dickey-Fuller test, by Andrew Levin (2002) for panel data. Running the test I reject the null hypothesis of stationarity at the 99% level for all meat products. This model then is most likely stationary and thus non-explosive.

There is a final potential problem with this specification. The high R^2 value may be indicative of variables that have trends that move together, specifically that of income and lagged consumption. If both trend in a similar way, there is the potential that the lag may be taking more of the explanatory force than it correctly should. To investigate this possibility I have done two additional regressions. The first is a difference approach where I take the difference between years and run a regression on the following model:

$$\Delta C_i = \alpha_i + \beta \Delta P_i + \gamma \Delta P_{-i} + \delta \Delta I + \theta \Delta U + \eta \Delta L + \epsilon_i \tag{3}$$

$$\Delta P_i = \kappa_i + \lambda \Delta C_i + \xi \Delta P_{-i} + \pi \Delta L + \nu_i \tag{4}$$

Here, $\Delta X = X_t - X_{t-1}$ is the difference between time t and t-1. Chavas (1983) uses a similar model specification, arguing it can better account for structural changes in the

[3]For more on this, please see Greene, chapter 20

model. Tables 5-7 show the results of the estimation of this model for beef, chicken and pig products respectively.

Another model specification that can account for similar trending is a residuals estimation. This model has the following form:

$$C_i = \alpha_i + \beta\epsilon_{Pi} + \gamma\epsilon_{P-i} + \delta\epsilon_I + \theta\epsilon_U + \eta\epsilon_L + \epsilon_i \quad (5)$$

$$P_i = \kappa_i + \lambda\epsilon_{Ci} + \xi\epsilon_{P-i} + \pi\epsilon_L + \nu_i \quad (6)$$

In this model, ϵ is the residual from a trend estimation. That is, I first estimate the model $Y = constant + time + time^2 + \epsilon$, where Y is each of the variables from my original regression, C_i, P_i, P_{-i}, I, U and L. I then use the value $\epsilon = Y - constant - time - time^2$ in this new model specification. This has the advantage of de-trending the data, or taking away a common trend source. The results of this estimation are presented in Tables 8-10 for beef, chicken and pig products respectively.

The results of both of these model specifications do not change my results by a significant degree. In none of the specifications is income elasticity significant, thus giving strong support to the results of my original model specification. These estimations can then be thought of as a robustness test for the results in the original regression.

3.2 Forecast

The results of the previous section suggest that there is not much that is important for forecasting demand for beef, chicken and pig products beyond persistence effects. That is, the results suggest that assuming a linear trend to consumption may be an exceptable method. This becomes even more likely to be the case after looking at Figures 1-3, which show worldwide consumption of beef, chicken and pig respectively for the years 1990 to 2004.

For all three products, consumption has been increasing in essentially a linear fashion. If the linear assumption is appropriate and this pattern of consumption growth were to continue, future world meat consumption would look something like Table 11.

As mentioned in the introduction, beef consumption per capita has been slowly decreasing over the years, meaning the aggregate growth in beef consumption is due to population increase. As this paper only focuses on world consumption, the forecast assumes that regional effects are not significant. Whether this assumption biases the results upward or downward is not clear. Countries like China are facing a large growth in meat consumption and population, while India faces population growth, but no real growth in beef consumption and a large growth in chicken. A future study could look at this issue from a country by country standpoint, though there would then be problems with data as there are only 13 data points for most countries.

The results show a striking increase in total consumption for the entire world. Looking at the average forecast value, consumption of beef from 2003 to 2020 will increase by 28% and 60% by 2040. For chicken, the increase is 68% by 2020 and 148% by 2040. Pig products increase 45% by 2020 and 98% by 2040.

My question of interest in this paper is whether current consumption patterns are sustainable, and so I am interested in what consumption could look like in the future. This question will be addressed more fully in section 5 after looking into the ecological implications of this theoretical future consumption in section 4.

4 Ecological Data and Implications

There are numerous studies that have estimated the ecological impact of different food types. In this section I will summarize these findings and discuss the implications of combining them with the results in section 3.

Table 12 summarizes the environmental impact of different meat sources based on the findings of Susan Subak (1999) on the CO_2 implications of beef consumption. Data on chicken and pig CO_2 production is taken from estimates by Pimentel and Pimentel (2003). As methane production is only a problem for beef production, CO_2 emissions are significantly lower for all other foods. Both of these studies assume production systems similar to the US system. The table also includes the findings of Gerbens and Nonhebel (2002) on the land usage of meat in the Netherlands. This is an estimate of the amount of land needed for feed and other inputs and does not include land usage for pasture and production facilities. It will thus represent here a "best existing case" scenario. Compared to other other studies, all of these numbers could be off of the true current value by more than a factor of 2 (White (2000)) for less developed countries. I will discuss this further in the next section.

It is immediately obvious that beef production has the most severe ecological impact by a large degree across all of the categories. This is due in large part to the methane emissions from cows, while chickens and pigs produce relatively less.

Using these values, I estimate the impact of meat consumption for 2003, 2020 and 2040 in Table 13. Beef production accounts for the majority of CO_2 production and is increasing significantly.

This impact can then be compared to soy production, the most efficient source of protein. Reijnders and Soret (2003) summarize estimates of the relative effect of soybeans, given an identical amount of protein. Soybeans require 6-17 less land and 6-20 times less fossil fuel than meat to produce. Greenhouse emissions though are even lower as soybeans are often used as CO_2 absorbers. This means more reliance on soy by 2040 could significantly decrease these CO_2 emissions and land usage to a fraction of this estimate.

Land usage of meat in 2040 is estimated to be almost 16% of potentially arable land, a significant amount, especially considering that this estimate is based on a "best existing case" scenario, meaning the best current technological level is adopted by all producers.

This assumption is obviously not very realistic, so this number will most likely be much higher. Estimating the exact effect of meat, both current and future potential, is extremely difficult as there is little research on the environmental effects in non-western contries. The next section will discuss this issue in detail and offer an interpretation of the environmental sustainability of such a system.

5 Sustainability

As stated in the introduction, the main goal of this paper is to answer the question of how meat consumption adds to the stress that is being placed on the environment. This came in the form of three questions: what will consumption look like in the years 2020 and 2040, what will be the environmental impact of this level of consumption and is this consumption level environmentally sustainable? In the previous sections I have offered answers to the first two questions. In this section I will try to answer the third by discussing what the potential impact of the forecasts from the previous sections may be and if such a system is environmentally sustainable. To answer this I continue the division of the question into two main topics: the impact on land and the production of greenhouse gases.

5.1 Land

The current amount of potentially arable land, i.e. land that can be used for crops, is around 31 million km^2, a little bit more than 1/5 of the earth's total land area. About half of the potentially arable land is composed of land currently being cultivated on, including temporary and permanent crop land (FAO (2006)). That leaves an additional 16 million km^2 that could be expanded upon. It is rather difficult and expensive though to develop arable land, and so the expansion of it so far has been slow. From 1991 to 2002, only 250,000 km^2 were added, a 1.6% increase over 12 years. If this trend continues there will only be a minimal amount of cropland added by 2020 and 2040.

According to the land estimates above, land usage for meat inputs in 2003 were about 17.2% of current cropland. If consumption trends hold, this could increase to 24% in 2020 and 33% by 2040. For various reasons to be discussed below, this estimate is likely to be much lower than the accual amount. Land of course can be developed both intensively and extensively, perhaps lessening some of the land needed. How intensively it can be developed is a difficult question. To answer this it will be helpful to first look at what is behind the assumptions within the ecological data summarized in the previous section.

A major assumption of this paper so far has been that all land is being used at a similar level as the Netherlands, which is in fact two separate assumptions: cattle are raised and crop yields for feed are both at the same efficiency rate as the Netherlands. The Netherlands though produces crops at a much higher rate of efficiency than almost every other country. While there is not a lot of information on the efficiency of feed inputs in developing countries, there is data on crop yields, which can be used to determine crop production efficiency. For example, crop yields in the Netherlands were just over 8100 kg per hectare while in the US it was just over 6500 kg per hectare and in developing countries this number was closer to 2500 and is currently increasing at a very slow rate FAO (2006). Joachim Braun and Bos (2005) forecast cereal yield for developing countries based on three management and policy scenarios until 2050. The difference between the scenarios is rather large, meaning the actual amount of land needed can be radically different depending on what policies are enacted. In all scenarios though, the projected yield for developing countries is still much lower than for developed countries. For this reason, the issue of land could be in fact much more serious than is assumed here. According to Braun and Bos, if developing countries pursue aggressive policy and technology management strategies, average crop yield in 2040 would be just below 4000 kg per hectare, between 60% and 80% of developing countries. If there is policy and technology failure, yields for developing countries could stay very close to the same as in 2000, about 35% to 50% of developed countries.

There is an additional part to the assumption of land usage. For beef production in the US and Europe farming practices normally focus primarily on feedlots rather than pasture for the majority of the cattle's life. In developing countries this is not true as pasture systems are often less capital intensive to operate. This means many farms are in fact very small in the developing world and do not rely on complex feed systems, compared to the large size of farmers in developed countries which use very complicated feed systems. By assuming all producers match the system used in the Netherlands I am also assuming that pasture farming will be minimal. While this may not be a factually correct assumption, it is in fact close to reality for the majority of production because of the low yields from pasture farming. I am thus assuming here that in the future, the majority of production will come from feedlot systems as they are able to better produce the higher quantities that will be needed.

There are essentially four options to achieve the land need projected here. Either cropland area is greatly expanded, a technology is introduced to improve yield or prices of crops increase to shift consumption to inputs for meat, or a combination of the three. Robert Goodland (1997) discusses the first two options in detail, which I will partially summarize here. As for the third option, raising crop prices is possible, though it would mean increasing the strain on an already problematic world food supply, hurting most severely the poorest people on the planet. Introducing a new technology though is unlikely to work alone for two reasons. First, I assume a land efficiency level for production similar to the Netherlands, thus underestimating land need for most developing nations. Second, the technology increase would need to be very large. The system used in the Netherlands is exceptionally efficient for the raising of live animals and any future technology will be highly constrained by this fact. Expanding land area then is the most likely scenario, though it is not clear how easy or difficult this will be, or what the ecological impact will be. It will prove to be difficult though, as some have argued that world wide irrigated cropland can only reasonably be expanded from 2.5 million km^2 to at most 4 million km^2 (Sundquist (2005)). Thus, this option too will prove difficult.

Land usage becomes an even greater problem when looking at topsoil loss, or erosion, as it directly affects land efficiency. Subak (1999) has estimated the topsoil loss of beef production to be between 2000 and 4000 tons per km^2 per kg of beef. This is a very large number when compared with erosion from basic crops at about 400 tons per km^2 (Sundquist (2005)). The complete effects of topsoil loss is not known, but it is clear that it has both short and long-term effects on crop yields.

The sustainability of the growth in meat consumption calculated in this paper is thus unlikely from the perspective of land usage. A number of factors will have to come together in order for the current consumption patterns to continue. Even if these factors do come to pass, the exact environmental effects of this growth are unclear and most likely problematic in the long-run.

5.2 Greenhouse Gases

Estimating the environmental effect of meat consumption becomes a little easier when looking at greenhouse gases. The forecasts that I found for greenhouse gases are quite large, especially when compared to current CO_2 production. Total world production for the latest years available show world wide production to be about 24 billion tonnes of CO_2 equivalent UNFCCC (2005). In this paper, for 2003, the "best existing case" estimate was just over 1 billion tonnes from meat production alone. By 2020 this will be around 1.3 billion tonnes and in 2040, over 1.6 billion tonnes. This represents a large growth in the total production of greenhouse gases. While in 2002 meat contributed to just over 4% of total production, depending on future output of greenhouse gases, this could be as much as 6.7% in 2040. If programs like the Kyoto treaty are going to have any real impact on reducing greenhouse emissions they will need to pay special attention to the effect of animals.

Methane production from the animals, especially cattle, is a big part of this greenhouse production and thus the overall greenhouse effect. J. Shih and Siikamaki (2006) estimate that methane from animals accounts for about 28% of the methane produced in the US. There is though a lot of research currently looking at methane capturing systems, which would capture all or most of the gas for use elseware. These systems are very costly, though they have the added benefit of reducing electricity costs at farms. J. Shih and Siikamaki (2006) look at such a system and find that this energy cost offset though is not enough to cover the cost of running the systems. It becomes economically feasible if credits of about \$12/tonne of CO_2 equivalent are offered, a rather high number considering the estimated externality cost of CO_2 ranges from \$2-\$10 per tonne (Delucchi (2000)) in the developing world and around \$1 in the developed world. With the reduction of electricity costs and enough subsidizing though, this system could become feasible and lead to a great reduction in greenhouse emissions. It would require a major push and funding from the developed world for it to be used in developing countries. As this technology is a long way from being used in the US and Europe, let alone the rest of the world, this is not likely to be a solution in the near future.

6 Conclusion

The original goal of this paper was to answer the question of how meat consumption adds to environmental stress. I believe the answer to this question is: quite a lot. While the forecasts to the year 2040 may not be especially convincing, I have included them to highlight the fact that somewhere between 2020 and 2040 the issue of environmental sustainability will become especially pronounced. Greenhouse gas production and land usage for meat production is not a small issue. Without special attention given to the role animals play in this production it is not possible to significantly reduce CO_2 and CO_2 equivalent gases that programs such as Kyoto were designed to do, or to ensure that there is ample land available for nature and expanding populations of humans.

The main contributions of this paper are threefold: a simultaneous equations estimation of meat consumption patterns, the bringing together of diverse information on the ecological impact associated with this consumption and a discussion of the environmental implications of these trends. The findings are very strong and suggest that the current system is not likely to be environmentally sustainable in the near future.

This paper has so far been focusing on the technology changes that will need to happen to handle the future growth in meat consumption. There is of course another alternative, and that is to look at changing the preferences of people toward meat consumption. By finding ways to decrease a reliance on meat in diets, a positive ecological impact can be made worldwide, as well as creating healthier lives. There is ample evidence that meat consumption is in fact a highly cultural choice, not simply a standard choice for all groups. Gossard and York (2003) look at the social, economic and psychological factors behind meat consumption in the US and find a number of differences across groups. Gender, ethnicity, location, social class, education and even profession all appear to be important factors in determining a persons level of meat consumption.

Vegetarian lifestyles have been shown to be significantly healthier than diets where even small amounts of meat are consumed (Frank Sacks and Kass (1981)). Neal Barnard and Howard (1995) argue that the direct medical costs of beef and poultry consumption for the US in 1992 were between \$28 and \$61 billion. This figure is comparable to the medical costs of smoking (around \$50 billion during roughly the same time period) and does not include the social cost of lost lives.

Subak Subak (1999) estimates the greenhouse externality cost of beef to be between 4%-9% per unit. Using the lower estimate for medical costs associated with beef consumption from Barnard and Howard, the fact that Americans ate over 12 million tonnes of beef in 2002 and an average cost of beef around $3.80 per pound, the medical costs are about 26% per unit in the US. This means a total social cost of between 30% and 35% per unit, a substantial number, especially given that beef production is currently subsidized in the US.

The goal of this paper is to highlight the fact that the impact of meat consumption on the planet is not a small issue, both today and especially in the future. The current pattern of consumption is most likely not sustainable from an environmental perspective, and so will need to be addressed soon if any positive changes are to be made.

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Africa	Asia	Developed	Latin
Algeria	Cambodia	Australia	Argentina
Burkina Faso	China	France	Belize
Burundi	India	Greece	Bolivia
Cameroon	Indonesia	Hungary	Brazil
Congo	Laos	Italy	Chile
Cte d'Ivoire	Malaysia	Japan	Colombia
Egypt	Nepal	Korea	Costa Rica
Gambia	Philippines	Portugal	Dominican Republic
Ghana	Sri Lanka	Spain	El Salvador
Guinea	Thailand	USA	Honduras
Kenya			Jamaica
Madagascar			Mexico
Malawi			Nicaragua
Mali			Panama
Morocco			Paraguay
Mozambique			Peru
Niger			Suriname
Nigeria			Trinidad and Tobago
Rwanda			Uruguay
South Africa			Venezuela
Togo			

Table 1: Countries in sample by region

	Africa		Asia		Developed		Latin	
Obs	286		128		130		259	
R^2	0.923		0.974		0.967		0.978	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Demand								
Price Bovine	0.062	0.041	0.025	0.019	0.076	0.049	-0.034	0.034
Price Chicken	0.04	0.034	-0.04	0.029	-0.116 *	0.07	0.015	0.023
Price Maize	-0.088 **	0.041	-0.041	0.048	0.042	0.06	0.005	0.022
Price Pig	-0.013	0.028	0.024	0.033	-0.033	0.069	-0.025	0.028
Price Rice	0.027	0.029	-0.006	0.048	-0.095 *	0.054	-0.003	0.022
Year	-0.001	0.001	-0.002 *	0.001	-0.001	0.001	-0.002	0.001
GDP	0.001	0.004	-0.003	0.012	0.002	0.009	0	0.002
Urban	-0.001	0.005	-0.002	0.009	0.003	0.021	0	0.002
Bovine Lag	0.953 ***	0.019	0.932 ***	0.018	0.918 ***	0.032	0.941 ***	0.019
Chicken Lag	0.013	0.016	-0.022	0.014	-0.026	0.036	0.01	0.025
Maize Lag	-0.001	0.012	0.003	0.011	-0.004	0.013	-0.002	0.01
Pig Lag	-0.007	0.01	0.018 ***	0.007	-0.101 *	0.054	0.032 **	0.014
Rice Lag	0	0.01	-0.061 *	0.034	-0.015	0.027	-0.032 **	0.013
Constant	2.182	2.776	3.483 *	1.879	2.44	2.596	3.353 *	2.081
Supply								
Price Bovine	0.062	0.041	0.025	0.02	0.075	0.049	-0.034	0.034
Price Chicken	0.04	0.035	-0.041	0.029	-0.117 *	0.071	0.015	0.023
Price Maize	-0.088 **	0.042	-0.04	0.049	0.043	0.061	0.005	0.022
Price Pig	-0.013	0.028	0.025	0.034	-0.033	0.07	-0.025	0.028
Price Rice	0.027	0.029	-0.007	0.049	-0.093 *	0.055	-0.004	0.022
Year	-0.001	0.001	-0.002 *	0.001	-0.001	0.001	-0.002	0.001
Bovine Lag	0.953 ***	0.02	0.932 ***	0.018	0.921 ***	0.032	0.941 ***	0.019
Chicken Lag	0.013	0.016	-0.025 **	0.012	-0.024	0.036	0.011	0.025
Maize Lag	-0.001	0.012	0.003	0.011	-0.004	0.013	-0.002	0.01
Pig Lag	-0.007	0.01	0.018 ***	0.007	-0.101 *	0.055	0.032 **	0.014
Rice Lag	-0.001	0.01	-0.059 *	0.034	-0.015	0.027	-0.032 **	0.013
Constant	2.183	2.8	3.503 *	1.9	2.392	2.638	3.355 *	2.091

Table 2: Simultaneous Equations results for beef.

	Africa		Asia		Developed		Latin	
Obs	286		128		130		259	
R^2	0.979		0.994		0.969		0.953	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Demand								
Price Bovine	0.017	0.028	0.006	0.023	-0.004	0.03	0.075 **	0.033
Price Chicken	0.007	0.023	-0.011	0.034	-0.045	0.044	-0.023	0.023
Price Maize	-0.042	0.028	-0.07	0.058	0.031	0.038	0.013	0.021
Price Pig	0.012	0.019	0.013	0.04	-0.022	0.043	0.039	0.027
Price Rice	0.021	0.02	0.056	0.058	-0.052	0.033	-0.014	0.021
Year	0.001	0.001	-0.002	0.001	-0.002 ***	0.001	-0.001	0.001
GDP	0.002	0.004	0.003	0.012	0.003	0.006	0	0.002
Urban	0.001	0.005	0	0.008	-0.005	0.014	0	0.002
Bovine Lag	-0.005	0.013	-0.056 ***	0.021	-0.029	0.02	0.052 ***	0.018
Chicken Lag	0.995 ***	0.011	0.981 ***	0.016	0.951 ***	0.022	0.902 ***	0.024
Maize Lag	0.003	0.008	-0.01	0.013	0.003	0.008	-0.01	0.009
Pig Lag	-0.001	0.006	0	0.008	-0.011	0.034	-0.017	0.013
Rice Lag	0.005	0.007	-0.053	0.041	0.011	0.017	0.016	0.013
Constant	-1.914	1.896	3.25	2.254	5.358 ***	1.615	2.575	2.024
Supply								
Price Bovine	0.017	0.028	0.006	0.023	-0.003	0.031	0.075 **	0.033
Price Chicken	0.007	0.024	-0.011	0.035	-0.046	0.044	-0.023	0.023
Price Maize	-0.042	0.029	-0.07	0.059	0.031	0.038	0.013	0.021
Price Pig	0.012	0.02	0.013	0.04	-0.021	0.044	0.039	0.027
Price Rice	0.021	0.02	0.056	0.058	-0.051	0.034	-0.014	0.021
Year	0.001	0.001	-0.002	0.001	-0.002 ***	0.001	-0.001	0.001
Bovine Lag	-0.004	0.013	-0.056 ***	0.021	-0.028	0.02	0.052 ***	0.018
Chicken Lag	0.996 ***	0.011	0.983 ***	0.014	0.953 ***	0.022	0.902 ***	0.024
Maize Lag	0.003	0.008	-0.01	0.013	0.003	0.008	-0.01	0.009
Pig Lag	-0.001	0.007	0	0.008	-0.012	0.034	-0.017	0.013
Rice Lag	0.005	0.007	-0.055	0.041	0.01	0.017	0.016	0.013
Constant	-1.93	1.934	3.263	2.271	5.304 ***	1.645	2.573	2.032

Table 3: Simultaneous Equations results for chicken.

	Africa		Asia		Developed		Latin	
Obs	286		128		130		259	
R^2	0.986		0.997		0.979		0.965	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Demand								
Price Bovine	-0.015	0.04	-0.03	0.022	0.069 ***	0.025	0.112 ***	0.041
Price Chicken	-0.018	0.033	-0.026	0.033	-0.051	0.037	-0.037	0.028
Price Maize	0.071 *	0.04	-0.03	0.055	-0.061 **	0.032	-0.007	0.027
Price Pig	-0.027	0.027	0.091 **	0.038	-0.017	0.036	-0.032	0.033
Price Rice	-0.019	0.028	-0.024	0.055	0.02	0.028	0.01	0.026
Year	0.001	0.001	0	0.001	0	0.001	0	0.001
GDP	0	0.001	-0.001	0.008	-0.001	0.004	0	0.001
Urban	0	0.001	0.001	0.006	0.003	0.01	0	0.001
Bovine Lag	0.018	0.019	-0.018	0.02	-0.013	0.017	0.05 **	0.023
Chicken Lag	-0.003	0.015	-0.02	0.014	-0.017	0.019	-0.02	0.03
Maize Lag	0.019	0.012	-0.001	0.012	-0.016 **	0.007	-0.013	0.012
Pig Lag	0.989 ***	0.009	1.01 ***	0.008	0.897 **	0.028	0.968 ***	0.017
Rice Lag	-0.004	0.01	-0.052	0.039	-0.02	0.014	0.017	0.016
Constant	-2.788	2.711	1.106	2.147	-0.403	1.363	0.456	2.521
Supply								
Price Bovine	-0.015	0.04	-0.03	0.022	0.068 ***	0.026	0.112 ***	0.041
Price Chicken	-0.018	0.033	-0.025	0.033	-0.05	0.037	-0.037	0.028
Price Maize	0.071 *	0.04	-0.03	0.056	-0.061 *	0.032	-0.007	0.027
Price Pig	-0.027	0.027	0.091 **	0.038	-0.017	0.037	-0.032	0.033
Price Rice	-0.019	0.028	-0.023	0.055	0.019	0.029	0.01	0.026
Year	0.001	0.001	0	0.001	0	0.001	0	0.001
Bovine Lag	0.018	0.019	-0.018	0.02	-0.013	0.017	0.05 **	0.023
Chicken Lag	-0.003	0.015	-0.021	0.013	-0.018	0.019	-0.02	0.03
Maize Lag	0.019	0.012	-0.001	0.012	-0.016 **	0.007	-0.013	0.012
Pig Lag	0.989 ***	0.009	1.01 ***	0.008	0.897 ***	0.029	0.968 ***	0.017
Rice Lag	-0.004	0.01	-0.052	0.039	-0.02	0.014	0.017	0.016
Constant	-2.788	2.712	1.073	2.157	-0.379	1.38	0.456	2.522

Table 4: Simultaneous Equations results for pig.

	Africa		Asia		Developed		Latin	
Obs	264		118		120		238	
R^2	0.081		0.203		0.22		0.056	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Demand								
Price Bovine	-0.02	0.057	0.03	0.046	0.024	0.086	-0.017	0.059
Price Chicken	0.046	0.064	-0.048	0.045	-0.095	0.081	0.084	0.052
Price Maize	0.003	0.045	0.027	0.052	0.177 **	0.073	0.033	0.032
Price Pig	0.052	0.05	0.027	0.041	0.043	0.068	0.006	0.052
Price Rice	-0.025	0.045	-0.032	0.058	-0.065	0.08	-0.019	0.039
Year	0.002 *	0.001	-0.002 **	0.001	0	0.001	-0.001	0.001
GDP	0	0.009	0.156 *	0.094	0	0.034	0.006	0.026
Urban	0	0.032	0.151	0.22	0.033	0.277	-0.013	0.135
Bovine Lag	-0.085 *	0.049	0.249 ***	0.085	-0.333 ***	0.084	-0.148 **	0.058
Chicken Lag	-0.035	0.079	0.039	0.078	0.115	0.132	-0.063	0.059
Maize Lag	-0.11 ***	0.036	0.052	0.039	-0.054	0.063	-0.017	0.042
Pig Lag	-0.125 **	0.053	-0.063	0.082	0.282 *	0.166	0.057	0.046
Rice Lag	0.009	0.031	-0.01	0.118	0.067	0.085	-0.04	0.036
Constant	-4.43 *	2.481	4.552 **	1.931	0.481	2.627	2.569	1.75
Supply								
Price Bovine	-0.02	0.057	0.034	0.05	0.024	0.086	-0.016	0.06
Price Chicken	0.046	0.064	-0.048	0.048	-0.095	0.082	0.085	0.053
Price Maize	0.003	0.045	0.035	0.056	0.177 **	0.073	0.033	0.032
Price Pig	0.052	0.05	0.032	0.045	0.043	0.068	0.006	0.052
Price Rice	-0.025	0.046	-0.033	0.064	-0.065	0.081	-0.019	0.04
Year	0.002 *	0.001	-0.002	0.001	0	0.001	-0.001	0.001
Bovine Lag	-0.085 *	0.049	0.27	0.091	-0.333 ***	0.084	-0.148 **	0.059
Chicken Lag	-0.035	0.08	0.046	0.084	0.115	0.132	-0.063	0.06
Maize Lag	-0.11 ***	0.036	0.056	0.042	-0.054	0.064	-0.017	0.042
Pig Lag	-0.125 **	0.053	-0.067	0.09	0.282 *	0.167	0.057	0.047
Rice Lag	0.009	0.031	-0.001	0.129	0.067	0.086	-0.04	0.036
Constant	-4.431 *	2.485	4.691	2.099	0.484	2.642	2.576	1.763

Table 5: Difference results for beef.

	Africa		Asia		Developed		Latin	
Obs	264		118		120		238	
R^2	0.069		0.191		0.126		0.119	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Demand								
Price Bovine	0.073	0.048	0.028	0.053	0.033	0.051	0.106	0.058
Price Chicken	0.027	0.054	0.034	0.051	-0.017	0.048	0.013	0.051
Price Maize	-0.084 **	0.038	-0.015	0.059	0.042	0.043	-0.041	0.031
Price Pig	-0.004	0.043	0.068	0.047	0.018	0.04	0.012	0.051
Price Rice	0.042	0.039	0.03	0.066	-0.074	0.047	-0.026	0.039
Year	0.002	0.001	-0.001	0.001	-0.001 *	0.001	-0.003 ***	0.001
GDP	0	0.009	0.007	0.05	0.036	0.051	0.006	0.027
Urban	-0.002	0.03	-0.042	0.117	0.113	0.412	-0.018	0.138
Bovine Lag	0.092 **	0.042	0.108	0.096	0.049	0.049	-0.027	0.057
Chicken Lag	-0.071	0.067	0.277 ***	0.088	0.059	0.078	0.063	0.058
Maize Lag	0.026	0.031	-0.044	0.044	0.079 **	0.037	-0.022	0.041
Pig Lag	-0.033	0.045	-0.108	0.094	-0.168	0.098	0.05	0.046
Rice Lag	-0.009	0.026	0.2	0.135	-0.045	0.05	0.045	0.036
Constant	-3.221	2.107	2.057	2.197	2.893 *	1.55	6.692 ***	1.719
Supply								
Price Bovine	0.073	0.048	0.028	0.054	0.033	0.052	0.106 *	0.059
Price Chicken	0.027	0.054	0.033	0.052	-0.017	0.05	0.013	0.052
Price Maize	-0.084 **	0.038	-0.015	0.06	0.043	0.045	-0.041	0.032
Price Pig	-0.004	0.043	0.069	0.047	0.02	0.042	0.013	0.052
Price Rice	0.042	0.039	0.03	0.068	-0.073	0.049	-0.026	0.039
Year	0.002	0.001	-0.001	0.001	-0.001 *	0.001	-0.003 ***	0.001
Bovine Lag	0.092 **	0.042	0.108	0.097	0.05	0.051	-0.027	0.058
Chicken Lag	-0.071	0.068	0.28 ***	0.089	0.059	0.08	0.063	0.059
Maize Lag	0.026	0.031	-0.044	0.045	0.079 **	0.039	-0.022	0.041
Pig Lag	-0.033	0.045	-0.108	0.095	-0.166	0.101	0.05	0.046
Rice Lag	-0.009	0.027	0.201	0.137	-0.045	0.052	0.045	0.036
Constant	-3.222	2.112	2.051	2.235	2.886 *	1.606	6.698 ***	1.733

Table 6: Difference results for chicken.

	Africa		Asia		Developed		Latin	
Obs	264		118		120		238	
R^2	0.207		0.15		0.206		0.088	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Demand								
Price Bovine	0.007	0.061	-0.086 *	0.05	0.006	0.046	0.148 **	0.067
Price Chicken	0.12 *	0.069	0.004	0.048	-0.065	0.044	0.08	0.059
Price Maize	0.065	0.048	0.013	0.055	0.049	0.039	-0.043	0.036
Price Pig	-0.102 *	0.054	0.131 ***	0.044	-0.088 **	0.037	-0.005	0.058
Price Rice	-0.036	0.049	-0.046	0.063	0.05	0.043	-0.062	0.044
Year	0.001	0.001	0.002	0.001	0	0.001	-0.001	0.001
GDP	-0.001	0.012	0	0.025	0.022	0.047	0.073	0.064
Urban	0	0.041	0.006	0.058	0.234	0.38	-0.018	0.328
Bovine Lag	0.116 **	0.053	0.205 **	0.09	0.082 *	0.045	-0.085	0.065
Chicken Lag	0.006	0.085	0.178 **	0.083	0.033	0.071	0.054	0.066
Maize Lag	0.08 **	0.039	-0.029	0.042	0.008	0.034	-0.015	0.047
Pig Lag	-0.366 ***	0.057	0.06	0.089	-0.107	0.089	-0.011	0.052
Rice Lag	-0.009	0.033	0.035	0.127	-0.176 ***	0.046	-0.034	0.041
Constant	-1.818	2.663	-3.094	2.077	-0.019	1.411	1.35	1.963
Supply								
Price Bovine	0.007	0.061	-0.086 *	0.05	0.006	0.048	0.149 **	0.069
Price Chicken	0.12 *	0.069	0.004	0.048	-0.065	0.045	0.084	0.061
Price Maize	0.065	0.048	0.013	0.056	0.049	0.041	-0.045	0.037
Price Pig	-0.102 *	0.054	0.131 ***	0.044	-0.087 **	0.038	-0.003	0.06
Price Rice	-0.036	0.049	-0.046	0.063	0.05	0.045	-0.061	0.046
Year	0.001	0.001	0.002	0.001	0	0.001	-0.001	0.001
Bovine Lag	0.116 **	0.053	0.206 **	0.091	0.083 *	0.047	-0.086	0.068
Chicken Lag	0.006	0.085	0.178 **	0.083	0.034	0.073	0.054	0.069
Maize Lag	0.08 **	0.039	-0.029	0.042	0.008	0.035	-0.015	0.048
Pig Lag	-0.366 ***	0.057	0.06	0.089	-0.104	0.092	-0.009	0.054
Rice Lag	-0.009	0.034	0.035	0.128	-0.176 ***	0.047	-0.035	0.042
Constant	-1.816	2.669	-3.092	2.087	-0.01	1.464	1.468	2.033

Table 7: Difference results for pig.

	Africa		Asia		Developed		Latin	
Obs	286		128		130		259	
R^2	0.923		0.973	0.973	0.967		0.978	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Demand								
Price Bovine	0.061	0.04	0.024	0.019	0.074	0.05	-0.034	0.034
Price Chicken	0.034	0.034	-0.04	0.029	-0.115	0.07	0.015	0.023
Price Maize	-0.084 **	0.041	-0.035	0.049	0.04	0.062	0.005	0.022
Price Pig	-0.011	0.028	0.022	0.033	-0.032	0.069	-0.025	0.028
Price Rice	0.029	0.028	-0.001	0.045	-0.092	0.057	-0.004	0.022
GDP	0.001	0.004	-0.003	0.012	0.002	0.009	0	0.002
Urban	-0.001	0.005	-0.002	0.009	0.003	0.021	0	0.002
Bovine Lag	0.952 ***	0.019	0.934 ***	0.018	0.919 ***	0.033	0.94 ***	0.019
Chicken Lag	0.012	0.016	-0.022	0.014	-0.025	0.036	0.01	0.025
Maize Lag	-0.001	0.012	0.003	0.011	-0.004	0.013	-0.002	0.01
Pig Lag	-0.007	0.009	0.018 ***	0.007	-0.1 *	0.054	0.032 **	0.014
Rice Lag	0	0.01	-0.059 *	0.034	-0.014	0.027	-0.032 **	0.013
Constant	0	0.005	0	0.003	0	0.004	0	0.003
Supply								
Price Bovine	0.061	0.041	0.024	0.02	0.073	0.051	-0.034	0.034
Price Chicken	0.034	0.035	-0.042	0.029	-0.116	0.071	0.015	0.023
Price Maize	-0.084 **	0.041	-0.034	0.05	0.041	0.063	0.005	0.022
Price Pig	-0.011	0.028	0.023	0.034	-0.032	0.07	-0.025	0.028
Price Rice	0.029	0.029	-0.002	0.045	-0.09	0.058	-0.004	0.022
Bovine Lag	0.953 ***	0.019	0.935 ***	0.018	0.922 ***	0.033	0.941 ***	0.019
Chicken Lag	0.012	0.016	-0.025 **	0.012	-0.023	0.036	0.011	0.025
Maize Lag	-0.001	0.012	0.003	0.011	-0.004	0.013	-0.002	0.01
Pig Lag	-0.007	0.01	0.019 ***	0.007	-0.1 *	0.055	0.032 **	0.014
Rice Lag	0	0.01	-0.056	0.035	-0.014	0.028	-0.032 **	0.013
Constant	0	0.005	0	0.003	0	0.004	0	0.003

Table 8: Residual results for beef.

	Africa		Asia		Developed		Latin	
Obs	286		128		130		259	
R^2	0.979		0.994		0.968		0.945	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Demand								
Price Bovine	0.017	0.028	0	0.023	-0.008	0.031	0.076 **	0.033
Price Chicken	0.006	0.024	-0.015	0.034	-0.043	0.044	-0.023	0.023
Price Maize	-0.042	0.028	-0.03	0.058	0.027	0.038	0.013	0.021
Price Pig	0.012	0.019	0.002	0.039	-0.02	0.043	0.037	0.027
Price Rice	0.021	0.02	0.069	0.053	-0.045	0.036	-0.014	0.021
GDP	0.002	0.004	0.003	0.011	0.003	0.006	0	0.002
Urban	0.001	0.005	0	0.008	-0.005	0.014	0	0.002
Bovine Lag	-0.005	0.013	-0.045 **	0.021	-0.026	0.02	0.051 ***	0.018
Chicken Lag	0.995 ***	0.011	0.983 ***	0.016	0.953 ***	0.022	0.902 ***	0.024
Maize Lag	0.003	0.008	-0.009	0.012	0.003	0.008	-0.01	0.009
Pig Lag	-0.001	0.006	0.002	0.008	-0.009	0.034	-0.017	0.013
Rice Lag	0.005	0.007	-0.041	0.04	0.012	0.017	0.016	0.013
Constant	0	0.003	0	0.003	0	0.003	0	0.003
Supply								
Price Bovine	0.017	0.028	0	0.023	-0.007	0.031	0.076 **	0.033
Price Chicken	0.006	0.024	-0.014	0.034	-0.044	0.044	-0.023	0.023
Price Maize	-0.041	0.029	-0.03	0.059	0.027	0.039	0.013	0.021
Price Pig	0.012	0.02	0.001	0.04	-0.019	0.044	0.037	0.027
Price Rice	0.021	0.02	0.069	0.053	-0.044	0.036	-0.014	0.021
Bovine Lag	-0.004	0.013	-0.045 **	0.022	-0.025	0.02	0.051 ***	0.018
Chicken Lag	0.996 ***	0.011	0.985 ***	0.014	0.955 ***	0.023	0.902 ***	0.024
Maize Lag	0.003	0.008	-0.009	0.013	0.003	0.008	-0.01	0.009
Pig Lag	-0.001	0.007	0.002	0.008	-0.01	0.034	-0.017	0.013
Rice Lag	0.005	0.007	-0.043	0.041	0.012	0.017	0.016	0.013
Constant	0	0.003	0	0.004	0	0.003	0	0.003

Table 9: Residual results for chicken.

	Africa		Asia		Developed		Latin	
Obs	286		128		130		259	
R^2	0.986		0.998		0.978		0.965	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Demand								
Price Bovine	-0.016	0.04	-0.038 *	0.021	0.071 ***	0.026	0.111 ***	0.041
Price Chicken	-0.02	0.034	-0.031	0.032	-0.052	0.037	-0.037	0.028
Price Maize	0.072 *	0.04	0.012	0.055	-0.059 *	0.032	-0.006	0.027
Price Pig	-0.026	0.027	0.077 **	0.037	-0.018	0.036	-0.028	0.034
Price Rice	-0.018	0.028	0.005	0.05	0.016	0.03	0.011	0.026
GDP	0	0.001	-0.002	0.008	-0.001	0.004	0	0.001
Urban	0	0.001	0.001	0.006	0.003	0.01	0	0.001
Bovine Lag	0.018	0.019	-0.004	0.02	-0.014	0.017	0.052 **	0.023
Chicken Lag	-0.003	0.015	-0.018	0.014	-0.018	0.019	-0.019	0.03
Maize Lag	0.019	0.012	0	0.012	-0.016 **	0.007	-0.013	0.012
Pig Lag	0.989 ***	0.009	1.012 ***	0.008	0.896 ***	0.029	0.968 ***	0.017
Rice Lag	-0.004	0.01	-0.037	0.038	-0.021	0.014	0.017	0.016
Constant	0	0.005	0	0.003	0	0.002	0	0.004
Supply								
Price Bovine	-0.016	0.04	-0.037 *	0.022	0.071 ***	0.026	0.111 ***	0.041
Price Chicken	-0.02	0.034	-0.031	0.032	-0.051	0.037	-0.037	0.028
Price Maize	0.072 *	0.04	0.012	0.056	-0.059 *	0.033	-0.006	0.027
Price Pig	-0.026	0.027	0.077 **	0.037	-0.018	0.037	-0.028	0.034
Price Rice	-0.018	0.028	0.005	0.05	0.016	0.03	0.011	0.026
Bovine Lag	0.018	0.019	-0.005	0.02	-0.015	0.017	0.052 **	0.023
Chicken Lag	-0.003	0.015	-0.019	0.013	-0.019	0.019	-0.019	0.03
Maize Lag	0.019	0.012	0	0.012	-0.016 **	0.007	-0.013	0.012
Pig Lag	0.989 ***	0.009	1.012 ***	0.008	0.896 ***	0.029	0.968 ***	0.017
Rice Lag	-0.004	0.01	-0.036	0.038	-0.02	0.014	0.017	0.016
Constant	0	0.005	0	0.003	0	0.002	0	0.004

Table 10: Residual results for pig.

	2003	2020	2040
Beef	61,127	78,118	97,598
Chicken	66,206	111,429	164,429
Pig	98,328	142,287	194,707
Total	225,661	331,834	456,734

Table 11: Meat consumption in 2003, 2020 and 2040 in 1000 metric tonnes

Impact type	Beef	Chicken	Pig
CO_2 equivalent (kg)	14.8	0.2	0.9
Land requirement (m^2)	20.9	8.9	7.3

Table 12: Environmental impact of 1 kg of a given commodity

	Beef	Chicken	Pig	Total
Impact 2003				
CO_2 equivalent (million tonnes)	905	13	88	1,006
Land usage (thousand km^2)	1,276	589	718	2,583
Land usage (% of arable land)	4.1%	2.0%	2.3%	8.3%
Impact 2020				
CO_2 equivalent (million tonnes)	1,156	22	128	1,306
Land usage (thousand km^2)	1,633	992	1,039	3,664
Land usage (% of arable land)	5.3%	3.2%	3.4%	11.8%
Impact 2040				
CO_2 equivalent (million tonnes)	1,444	33	175	1,652
Land usage (thousand km^2)	2,040	1,463	1,421	4,924
Land usage (% of arable land)	6.6%	4.7%	4.6%	15.9%

Table 13: Total impact of commodities for 2003, 2020 and 2040

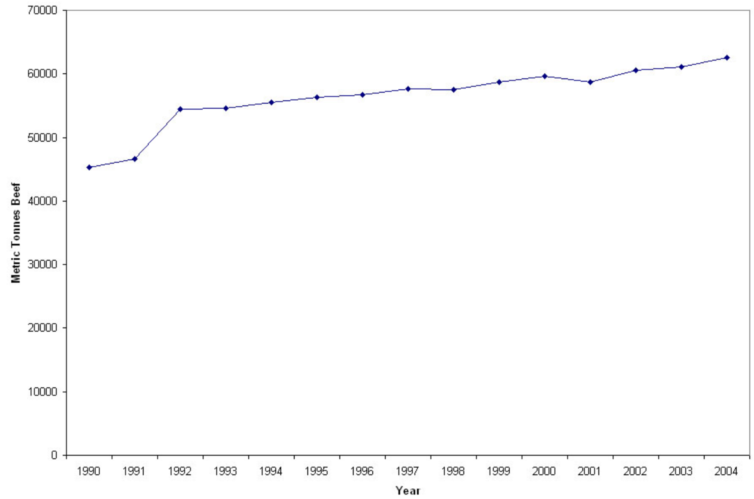

Fig. 1: Worldwide consumption of beef

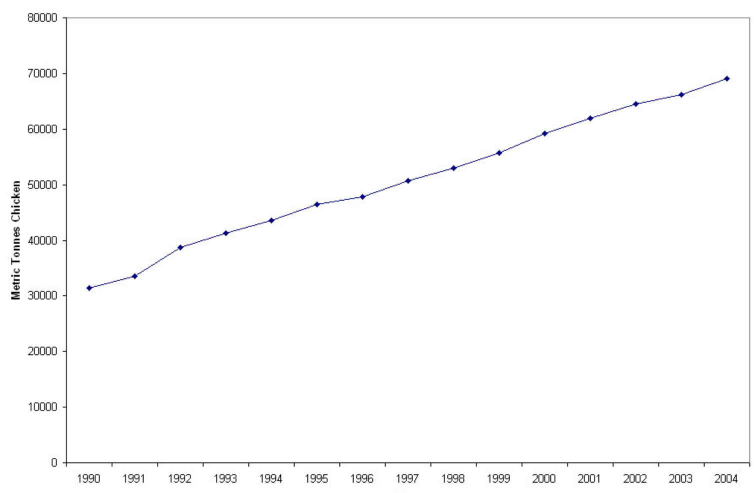

Fig. 2: Worldwide consumption of chicken

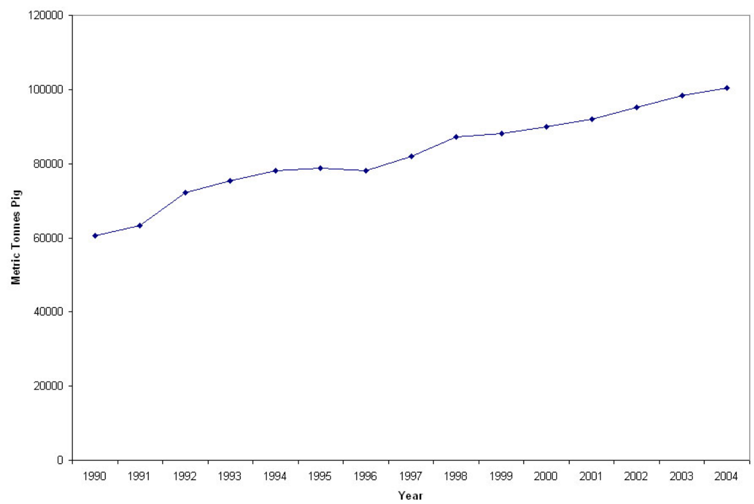

Fig. 3: Worldwide consumption of pig