Economic and Environmental Impact of Meat Consumption

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Abstract

This paper adds to the existing literature on the estimation of future consumption patterns. I first forecast the demand of beef, chicken and pig products for the years 2020 and 2040 using a simultaneous equations model for the world and specific regions. Then, using existing research on "best existing case" scenarios of the ecological impact of different foods, I estimate the land usage and greenhouse emissions of meat production. Finally, I address the impact of these consumption patterns on issues of sustainability. I argue that the current growth of meat consumption is not economically or ecologically sustainable, meaning that a radical shift in consumption patterns will have to happen soon.

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

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1 Introduction

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. This same situation holds for food products. As people realize higher incomes in both the developed and developing world, they acquire the ability to purchase higher quality foods. For many people this means a turning from traditional, low cost food such as wheat and rice to meat products such as beef, poultry and pig.

Currently, there is a large difference between the meat consumption of those with high incomes and those with low incomes. The average American currently consumes approximately 124 kg of meat each year. By contrast, the average worldwide consumption is 31 kg a year, with Bangladesh the lowest at 3 kg per person (FAO). This situation though is changing; meat consumption around the world is growing at an incredible rate.

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 the stress that development could have on the world's economic and environmental systems from a general perspective. A question worth asking is, how, if at all, does meat consumption add to this stress?

One of the problems with meat production 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-Leenes 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]. This estimation is of course a "best existing case" scenario. Some estimates, like

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

those of WRI, have found that about 67% of land is used for pasture. The majority of this land usage comes from Africa and Asia, where agriculture technology lags far behind the rest of the world.

Land availability is not the only problem. Greenhouse emissions and energy requirements also pose potential difficulties. For example, Susan Subak (1999) calculated the environmental effects of methane and CO_2 emissions of cattle. In total, to produce one kg of beef requires the equivalent of 14.8 kg of CO_2. As a comparison, one gallon of gasoline emits approximately 2.4 kg of CO_2(EPA 2005). Consuming one 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 purpose of this paper is to comprehensively bring together existing data on the ecological and economic impact of consumption patterns, along with an estimation of future worldwide consumption. While a number of papers have already estimated future meat consumption (Keyzer, Merbis, Pavel and van Wesenbeeck 2005, York and Gossard 2004, Gill 1999, Rosegrant, Sombilla and Perez 1995 and Durning and Brough 1991), all have neglected the differences and relationships between alternative food sources. In addition, these studies have taken food supply as exogenous. Using data on consumption and prices of beef, poultry, pig, mutton, goat, maize, wheat and rice, I estimate a simultaneous equations model where both supply and demand is endogenized. This distinction between different types of food will become important for countries like India, who is not seeing an increase in per capita beef consumption, but demand for chicken and pig products is increasing dramatically. It will also be important when calculating ecological impact as different foods have different impact.

Combing this wide array of data will allow me to answer more fully a number of questions.

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.

The three main questions that this paper will try to address are the following. First, what will consumption look like in the year 2020? Second, what will be the environmental impact of this level of consumption? Finally, how will this consumption level potentially affect the balance of trade among nations and thus the overall sustainability of preferences?

The rest of the paper will proceed as follows. Section 2 will describe the model and data used in my estimations. Section 3 will present my estimation results and forecast estimates. Section 4 will review the existing ecological data and incorporate them into my results. Section 5 will address the questions of sustainability. Section 6 will address the policy implications of the results, including questions of taxes and tariffs. Section 7 will be the conclusion of the paper.

2 Model and Data

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. We believe that the values we observe are part of an equilibrium of supply and demand, but we cannot distinguish between different functional forms that may be observationally equivalent. By specifying both a supply and demand function we can partially avoid this problem[2]. The difficulty of this kind of specification is that data must be found for the prices of the commodities.

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

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

$$C_{i,n,t} = \beta_{11} P_{i,n,t} + \beta_{12} P_{-i,n,t} + \beta_{13} Income_{n,t} + \beta_{14} U_{n,t} + \epsilon_1 \tag{1}$$

$$P_{i,n,t} = \beta_{21} C_{i,n,t} + \epsilon_2 \tag{2}$$

$$P_{-i,n,t} = \beta_{31} C_{i,n,t} + \epsilon_3 \tag{3}$$

Where C is the amount of per capita consumption of commodity i, in country n, at time t, P is the price of the commodity in that country, Income is per capita GDP and U is level of urbanization. Here, -i refers to the price of all other commodities other than commodity i, meaning we can observe the cross price elasticities. Equation (1) is thus the demand for a given product and equations (2)-(3) are supply.

I follow York and Gossard (2004) in including urbanization as food preferences have been found to change as people become move to the cities and thus countries become more urbanized. I also previously included age and age squared, though it was not significant so I have left it out here.

In addition, there are other model specifications which may be of interest. In the next section I will discuss the results of two single equation models using OLS and Fixed Effects regressions on panel data. These models assume a model form similar to the above, but exclude equation (2).

Per capita GDP in constant 2000 US dollars was used for income and urban population as percent of total population was used for urbanization level. Both were found in the World Development Indicators database from the World Bank. Data on the consumption and prices of the commodities beef, poultry, pig, mutton, goat, maize, wheat and rice was found from FAOSTAT data, 2006. As these variables are not available directly, I derived them in the following way.

Consumption was calculated by taking local production, adding imports and subtracting exports each year. This value was then divided by the population in that year. This is done for each commodity and the final figure is then used as consumption per capita. Local prices are the national average that producers received for the individual commodity. This means that this value reflects what the average farmer received for his product, not necessarily what was paid for by the consumer as there may be significant markup costs. I then took this value and converted it into a worldwide currency using the International Financial Statistics by the IMF so as to be compared across countries.

After combining all of these data sets for all commodities I am left with 42 countries covering the years 1991 to 2002. Table 1 summarizes what countries are in my sample. These countries cover 76% of beef, pig and poultry consumption and include nations from each continent. The advantage of using the years 1991 to 2002 is that it avoids the big technological advances made during the 1980s (Ollinger *et al* 2005).

Algeria	Argentina	Australia
Brazil	Bulgaria	Burkina Faso
Cameroon	Chile	China
Colombia	Costa Rica	Côte d'Ivoire
Dominican Republic	Egypt	El Salvador
France	Greece	Honduras
Hungary	India	Italy
Japan	Kazakhstan	Kenya
Korea	Macedonia	Mexico
Morocco	Nicaragua	Portugal
Romania	Russian Federation	South Africa
Spain	Sri Lanka	Thailand
Togo	Trinidad and Tobago	United States of America
Uruguay	Venezuela	Zimbabwe

Table 1: Countries in sample

An important implication of using the years 1991 to 2002 is that I avoid the problem of the structural changes in meat production up until the early 1990s (Ollinger, Nguyen, Blayney, Chambers and Nelson 2005), as well as data problems with the former Soviet countries.

3 Estimation Results and Forecast

As my variable of interest is elasticity, I take logs of all the data. Because of the detail of the data, I am able to do a number of estimations. Table 2 shows my results for the simultaneous equations model, solved 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%.

	BEEF		CHICKEN		PIG	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Demand						
Income	.2286113***	(.0305974)	.2680301***	(.0284509)	.2678169***	(.0629066)
Percent Urban	.4402783***	(.0829756)	.3200854***	(.0771546)	.0297164	(.170593)
Price of Beef	.5450961***	(.0841767)	.6235478***	(.0767712)	1.412337***	(.2438501)
Price of Chicken	.1282151*	(.0774818)	-.4136172***	(.0706521)	-.1747758	(.2249835)
Price of Maize	-.5262521***	(.0790071)	-.158961**	(.0718983)	-1.787875***	(.2350979)
Price of Mutton	-.367795***	(.0626412)	-.2207788***	(.0570649)	-.7205153***	(.1840539)
Price of Pig	-.0103979	(.0812858)	.051435	(.0740028)	-.5213453**	(.2406792)
Price of Rice	.0046982	(.072529)	-.0417192	(.0660039)	1.242674***	(.2157887)
Constant	-.3202372*	(.1857302)	-.1833205	(.1702523)	.5378077	(.5023393)
R^2	.578		.684		.313	
n	389		389		389	
Supply						
Price of Beef	.9813083***	(.1192215)	1.055612***	(.1115669)	1.726653***	(.2767448)
Price of Chicken	-.2543944**	(.1102587)	-.7975982***	(.1031795)	-.4628842*	(.2559396)
Price of Maize	-.5731166***	(.1179503)	-.2029861*	(.1103772)	-1.81571***	(.2737939)
Price of Mutton	-.287559***	(.0912533)	-.1214559	(.0853944)	-.6135017***	(.2118232)
Price of Pig	-.1063798	(.1201981)	-.059124	(.1124808)	-.6288979**	(.2790117)
Price of Rice	-.0170557	(.1082477)	-.0584394	(.1012976)	1.238962***	(.2512717)
Constant	1.16183***	(.2265163)	1.20499***	(.2119728)	1.408268***	(.5258045)
R^2	.243		.401		.219	
n	389		389		389	

Table 2: Simultaneous Equations Results.

I am also interested in region and some country specific effects, so I have isolated a number of important regions and countries and included the simultaneous equations regression results in Table 3. I have only included the results of relevant meat products.

The coefficient values that are estimated here are almost all significant and quite interesting. Cross price elasticities for supply are almost all negative, as expected, though the price elasticities for demand are not all as expected. The most striking being the large, positive price elasticity of beef. I interpret this to be a result of increasing demand being unhindered by the cost of beef. That is, a rise in cost does stop people from desiring beef products. Also, income elasticity is about the same for each product, at around 0.25. An increase in urbanization is also positive, though is not significant for pig products.

Separating the data by region also has some interesting results. The effect of income and urbanization is still positive for the developed countries in my sample, though the value is lower than for most other regions. This is not true for two surprising cases. First, urbanization in Africa, Asia, China and India seem to have a strong negative effect on consumption. I believe this to be a realistic finding because of the costs associated with urbanization. In the more developed regions in the world urbanization leads to greater access to jobs and products. For developing countries though, this is not always the case. Moving to a large city is often enticing for young people, but they find few opportunities once they get there. Farming communities are the most likely to have access to meat products, though in relatively small amounts. The second surprise comes from the insignificant income effects for Asia. It is not clear to me why this group does not consume more meat as incomes rise, but it does suggest that it is important to look at results by region. Finally, the results for India and China are not very realistic because of the low sample size. Separating out these countries is difficult because of lack of data. Doing so is hazardous at best.

Area	Beef	Chicken	Pig
Developed Countries			
Income	.2492837*** (.0558183)	.2461863*** (.0374594)	.004913 (.0119773)
Urban	1.499001*** (.343266)	.2073223 (.2303642)	-.0411679 (.073657)
R^2	0.8474	0.8256	0.8221
n	83	83	83
South America			
Income	.4056652*** (.0799023)	.0632512 (.0468328)	.5023968*** (.0942972)
Urban	.4613057* (.2303349)	.4335325*** (.1350052)	.0121086 (.2718311)
R^2	0.7680	0.6833	0.5534
n	134	134	134
Africa			
Income	.7844266*** (.0666748)	.5409578*** (.0553108)	-.0040968 (.0314939)
Urban	-.6803215*** (.1363026)	-.2566129** (.1130712)	.0080307 (.0643827)
R^2	0.7082	0.8526	0.6703
n	109	109	109
Asia Developing			
Income	.0951583 (.1642711)	.8598364*** (.2877636)	.4283838 (.4079815)
Urban	-.2730151 (.3876022)	-.8511028 (.6789862)	2.956645*** (.9626437)
R^2	0.9102	0.9630	0.9956
n	31	31	31
China			
Income	4.951755*** (.6829974)	6.601619*** (.4205761)	.0003831 (.4894137)
Urban	-10.77644*** (2.184962)	-16.83344*** (1.345456)	2.165246 (1.565672)
R^2	0.9988	0.9993	0.9955
n	11	11	11
India			
Income	.821341* (.477132)	9.475831*** (.6665951)	.0360589 (.0770489)
Urban	-6.384931*** (2.067308)	-17.13461*** (2.88821)	-3.473962*** (.3338357)
R^2	0.9859	0.9995	0.9998
n	11	11	11

Table 3: Results by selected regions

As stated above, there are a number of model specifications that could be used. I also ran an OLS estimation in order to compare the results with the simultaneous equations specification. The OLS model does not specify prices, though it does make a distinction between meat products. The results were all significant and, while the coefficients for income are only slightly higher, the results for percent urbanized are about twice that of the simultaneous equations estimation. Because of the complexity of the issues behind meat consumption, I do not believe that an OLS estimation is the best way to approach the issue here. I believe a simultaneous equations model is more likely to address this complexity.

I have also run a Hausman test to see if this specification improves efficiency.

In order to construct a forecast, I have compiled data on population estimates (UN), income growth and urban population growth (World Bank) in Table 4. Income and urban growth was calculated as the total effect over the years between 2002 and 2020. Using the results of Tables 2-4, I forecast total meat consumption and compare the results to consumption in 2000 in Table 5. I forecast these models to the year 2020 in order to compare the results to other studies. To estimate an upper and lower bound I construct a 95% prediction interval, which is equal to $\hat{y} = \pm t_{\lambda/2} se(e)$ by the Gauss-Markov theorem[3].

The results that I find here show a striking increase in consumption for the entire world. Looking at the average forecast value, consumption in beef from 2000 to 2020 will increase by 71% and 188% by 2040. For chicken, the increase is 65% by 2020 and 170% by 2040. Pig products increase 42% by 2020 and 101% by 2040. This increase is true for all regions except for Africa. Because of the large, negative coefficient value for urbanization in Africa, my results show a downward trend for consumption. I do not believe this is likely, so I do not report values for this region.

As mentioned before, a number of authors have estimated future consumption. All of the studies above either used an OLS or weighted least squares approach. My coefficient

[3]For more information on this, please see Greene, chapter 6.

Area	Population (Low)	Population (High)	Income per capita growth (percent)	Urban growth (percent)
World	7,280,148,000	7,873,172,000	152.56	156.76
Developed Countries	1,198,800,000	1,289,550,000	142.31	124.27
South America	638,791,000	695,013,000	117.27	152.05
Africa	1,184,495,000	1,270,382,000	124.34	233.12
Asia Developing	4,369,930,000	4,737,350,000	203.56	171.15
China	1,368,138,000	1,479,739,000	450.00	196.13
India	1,277,372,000	1,386,693,000	226.57	161.68

Table 4: Forecast of population, income and urban growth in 2020

estimates here are lower than for OLS. As mentioned above, I believe the reason for this is that here I separate out the different kinds of meat, as well as explicitly take into account the effects of price changes on demand and supply. The difference in results then is most likely evidence that consumption patterns are more complex than they have been previously modeled.

Keyzer *et al* (2005) estimate meat consumption for the world and include dummy variables for China, India, the US and Japan. It is worth noting the difference between their results and ones I have found for India here. The religious heritage of India has a strong anti-beef consumption policy. It is thus important to discern the different types of meat as there is good reason to believe that chicken and pig products may have different popularity than beef products. Assuming that meat is a homogeneous good is thus inappropriate for a country like India, and for the world in general.

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 6 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 estimated from Pimentel and Pimentel (1996). As methane production is only a problem for beef production, CO^2 emissions are significantly lower for all other foods. The table also includes the findings of Gerbens-Leenes and Nonhebel (2002) on the land usage of meat in the Netherlands. This estimates 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, these numbers could be off of the true current value by as much as a factor of 2 (White 1999). It is immediately obvious that beef production has the most severe ecological impact by a large degree across all of the categories.

Beef	2000	2020 (Low)	2020 (High)	2040 (Low)	2040 (High)
World	59,944,940	89,369,495	115,856,316	125,738,588	219,226,723
Developed Countries	29,818,273	37,733,544	54,095,988	44,960,407	88,939,479
South America	13,134,573	16,817,086	27,445,631	18,747,046	52,154,557
Africa	4,627,064	-	4,867,142	-	-
Asia Developing	12,737,064	15,142,307	16,415,460	15,666,236	19,768,086
Chicken	2000	2020 (Low)	2020 (High)	2040 (Low)	2040 (High)
World	69,191,731	99,942,226	128,697,769	136,670,953	237,443,295
Developed Countries	30,733,345	33,130,375	37,701,697	34,392,238	48,089,290
South America	12,170,428	16,174,114	22,053,322	19,080,054	38,234,467
Africa	3,372,616	2,304,370	5,861,312	-5,535,134	9,539,154
Asia Developing	22,452,134	34,869,057	71,603,823	55,925,087	206,783,836
Pig	2000	2020 (Low)	2020 (High)	2040 (Low)	2040 (High)
World	90,094,832	115,967,070	140,520,744	138,567,224	224,318,291
Developed Countries	37,146,352	37,315,873	40,140,711	34,921,843	42,987,525
South America	5,230,247	6,739,489	7,776,414	7,561,739	10,925,172
Africa	732,320	1,067,650	1,145,065	1,383,022	1,693,972
Asia Developing	47,157,287	98,737,501	270,216,314	177,767,115	757,343,135

Table 5: Meat consumption in 2000, 2020 and 2040 in metric tonnes

Using these values, I can estimate the impact of meat consumption for 2002, 2020 and 2040 in Table 7. In 2002, total CO_2 emissions from fossil fuels and cement production was 6,975 million tonnes. Meat production thus accounts for a large portion of this production and has the potential to increase this number significantly. In 2040, meat could account for 2,753 million 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 6: Environmental impact of 1 kg of a given commodity

We can compare these results to soy production, the most efficient source of protein. Reijnders and Soret (2003) summarize estimates of the relative effect of soybeans, given

	Beef	Pork	Poultry
Impact 2002			
CO2 equivalent (1000's mt)	887,185	81,085	13,838
Land usage (km^2)	1,252,849	657,692	615,806
Land usage (% of arable land)	4%	2.12%	2%
Impact 2020			
CO2 equivalent (1000's mt)	1,518,671	115,419	22,863
Land usage (km^2)	2,144,609	936,180	1,017,447
Land usage (% of arable land)	7%	3%	3.3%
Impact 2040			
CO2 equivalent (1000's mt)	2,552,743	163,298	37,411
Land usage (km^2)	3,604,887	1,324,532	1,664,808
Land usage (% of arable land)	11.63%	4.3%	5.37%

Table 7: Total impact of commodities for 2002, 2020 and 2040

an identical amount of protein. Soybeans require 6-17 less land and 6-20 times less fossil fuel than meat. Greenhouse emissions are even lower as soybeans are often used as CO_2 absorbers.

Land usage in 2040 is estimated to be 21% 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. I do not believe this assumption is 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 goal of this discussion is not to give an exact estimation of the effects of meat consumption, but to discuss if this system can be sustained. The next section looks at this issue in more detail.

5 Sustainability

The remainder of this paper will discuss the impact of the forecasts from the previous section and discuss the sustainability of such a system. The three main points that will be addressed are from the standpoint of the impact on the environment and trade.

5.1 Environment

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 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 though rather difficult and expensive to develop arable land, and so the expansion of it has been slow. From 1991 to 2002, only 250,000 km^2 was 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. If we assume that the land estimates above are an addition to current land usage, rather than affected by a technology increase, land demand for meat inputs will increase from 16.4% of current cropland to 26% in 2020 and 41% by 2040.

The assumption of this paper is that all land is being used at a similar level as the Netherlands, which is in fact two separate assumptions. First, cattle are being raised and fed at an efficient rate and second, crop yield for inputs is very efficient. In developing countries, both of these assumptions are unrealistic. While there is not a lot of information on the input efficiency, there is data on crop yields in developed and developing countries. According to the Swedish Board of Agriculture (2005), crop yields are between 5000 and 7000 kg per hectare. In developing countries, this number was closer to 2500 kg per hectare in 2000 and currently increasing at a very slow rate. von Braun *et al* (2005) forecast cereal yield based on three management and policy scenarios until 2050. The difference between the scenarios is rather large, meaning the actual amount of land needed is rather divergent. In any scenario though, the projected yield for developing countries is still much lower than for developed countries. For this reason, the issue of land is in fact much more serious than is assumed here.

As land estimates assume a high yield from crops already, there are three options to achieve the projected land need. Either cropland area is greatly expanded, a technology is introduced to improve yield or prices of crops increase to shift consumption to inputs, or a combination of the three. The last option is possible, though . As for the introduction of new technology, this is unlikely to work alone for two reasons. First, land requirement already assumes a technology level similar to the Netherlands, an assumption which is far from the truth for most developing nations. Second, the technology increase would need to be so great as to be unlikely. Expanding land area is the most likely scenario, though it is not clear how difficult this will be, or what the ecological impact will be. It will prove to be difficult though as some have argued that 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.

Topsoil loss, or erosion, is an important part of the issue of land usage 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, and thus sustainability of production.

The estimates that I found for greenhouse gases are quite large, especially when compared to the current production. In 2003, the largest producers of greenhouse gases, the US, Europe, Australia and Japan emitted just under 12 billion tonnes of CO_2 equivalent

(UNFCCC 2005). In 2002, the "best existing case" scenario was just under 1 billion tonnes from meat production alone. By 2020 this will be around 1.7 billion tonnes and in 2040, 2.8 billion tonnes. This represents a huge contribution to the total production of greenhouse gases, at least 8% in 2002, and, depending on future output, perhaps as much as 23% in 2040.

Methane production from the animals, especially cattle, is a big part of this percentage. Shih *et al* (2006) estimate that animals account for 28% of methane produced in the US. There is though a lot of research currently looking 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. Shih *et al* find that this offset 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, this system could become feasible and lead to a great reduction in greenhouse emissions. An additional problem is the fact that this technology is a long way from being used in the US, let alone the rest of the world.

5.2 Trade

The sustainability of meat consumption growth has an especially large impact on developing countries. Developed countries, like US and Europe, will be affected on a much smaller scale because of the abundant resources and technology they enjoy. Some countries may even benefit from the increased exports of meat products. In this section I will highlight two countries that will be faced with increasing pressure on their local industries, affecting both their balance of trade and food security. I have picked the countries of China and Ghana as they both have a relatively low amount of arable land compared to total land. Arable land for both accounts for between 15% and 16% of total available land (CIA 2006). This will mean it will be difficult to sustain increases in consumption without a heavy reliance on the international market.

Any discussion of China must first mention the problem of reliable data. There is probably good reason to suspect that data on consumption and land area may not be reliable. By best accounts, China currently has approximately 1.4 million km^2 of cultivated land (Heilig 1999), just under 10% of the world's cropland. In 2002 the Chinese accounted for 10% of the world's beef consumption, and in 2040 may account for even more. If we assume a linear trend for consumption in China, in 2040 beef consumption alone will require 470,000 km^2 of land, or about 1/3 of what is currently available to them. Again, this is assuming a "best current case" technology level. China's growing population and expanding urban areas will make it increasingly difficult to create new cropland, let alone sustain current land. Thus, there will need to be an increasing reliance on imports, both of feed and finished meat products, in order to sustain this consumption trend.

While Africa is not realizing the same kind of meat consumption growth of the rest of the world, the example of Ghana does highlight an important implication of a reliance on the international market. Linus Atarah (2005) describes the effect of the reduction of tariffs on chicken products. Eliminating the tariff was part of an IMF poverty reduction plan which has had the effect of increasing the per capita consumption of chicken in Ghana. This benefits the local consumer because they now have greater access to chicken products, but opening the market left a large group of local sellers without a market. The price of imported chicken is half of the price of locally produced chicken. Chicken farming is not an easily substitutable enterprise, so this more than just a short-term impact on Ghanaian industry. In addition, there is growing concern over the inability of the government to monitor health hazards such as salmonella, which could be a serious issue considering the majority of imports are of very low quality.

I mention the Ghanaian poultry industry to highlight some potential problems. Substituting imports for local production will likely become increasingly necessary to sustain increases in preferences in many countries. It will though be highly problematic for local producers, and for a countries balance of trade. It will also lead to a bigger North/South trade divide, as many of the countries that benefit from this increase are northern countries.

Tariffs and taxes would be useful in helping local industries and raising money for countries to fight the externality costs of meat production, but the results of the simultaneous equations model in Section 3 suggests that it is not likely to slow consumption growth. The estimation results show a positive price elasticity for beef. I do not believe this means there is in fact a positive relation between price and consumption of beef, only that the price does not affect people's decisions. Whether the price of beef increases or decreases, through tariffs, taxes or input costs, over the next 20 and 40 years will not be of much impact to consumption.

6 Conclusion

The contribution of this paper is threefold: a simultaneous equations estimation of meat consumption patterns, summarizing the ecological impact associated with this consumption and a discussion of the economic implications of the trends in consumption. The findings are very strong and suggest that the current system is not sustainable over the long-run.

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.

Up until now this paper has been arguing that there will need to be a radical shift in technology 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 our diets we can make a positive ecological and economic impact worldwide, as well creating healthier lives. Vegetarian lifestyles have been shown in to be significantly healthier than diets where even small amounts of meat are consumed (Sacks *et al* 1981). Barnard *et al* (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) and does not include the social cost of lost lives.

Subak (1999) estimates the greenhouse externality cost of beef to be between 4%-9% per unit. Using the lower estimate for the medical costs associated with beef consumption, 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 around 26% per unit. 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 our planet and ourselves is not a small issue, both today and especially in the future. The way the system is currently setup is not sustainable, and so a range of issues must be dealt with by the governments of the world sooner rather than later.