Meeting the Demand: An Estimation of Potential Future Greenhouse Gas Emissions from Meat Production

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Abstract

Current production processes for meat products have been shown to have a significant impact on the environment, accounting for between 15% and 24% of current greenhouse gas emissions. Meat consumption has been increasing at a fantastic rate and is likely to continue to do so into the future. If this demand is to be met, technology used in production in the form of Confined Animal Feeding Operations (CAFOs) will need to be expanded. This paper estimates future meat consumption and discusses the potential aggregate environmental impact of this production if the use of CAFOs is expanded. I first separate meat into beef, chicken and pig products and estimate the elasticities associated with each product in order to forecast the world demand for meat. Using research on the environmental impact of food production in the US, which uses one of the most efficient CAFO processes in the world, I then calculate the total potential greenhouse emissions of this meat production and discuss the impact of these consumption patterns. I find that, under an expanded CAFO system, meat production in the future will still be a large producer of greenhouse gases, accounting for up to 6.3% of current greenhouse gas emissions in 2030.

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

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1 Introduction

In a recent report on the environmental impact of livestock production, Steinfeld and deHaan (2006) found that the production of meat is currently contributing between 4.6 and 7.1 billion tonnes of greenhouse gases each year to the atmosphere, which represents between 15% and 24% of total current greenhouse gas production. Much of this effect is due to deforestation for grazing and processes that many countries are still using to produce meat which require the animals to live longer than in other more economically efficient processes[1].

Many countries that have inefficient production facilities are either looking to foreign countries to find cheaper alternatives for meat products[2], or are beginning to adopt the more economically efficient processes of developed countries in the form of Confined Animal Feeding Operations (CAFOs). Nierenberg (2006) finds that CAFOs are the fastest growing form of meat production in developing nations, either supported by local governments to improve the competitiveness of local production or fueled by large corporations moving to countries with fewer regulations. This leads to the question of what would be the effect on the estimates of greenhouse gas production if the number of CAFOs increases in countries with low tech processes?

The CAFO system, while reducing economic costs, puts the environment at risk. Subak (1999) calculates the environmental effects of methane and CO_2 emissions of cattle in a US style feedlot system, one of the most efficient meat production processes in use today. In total, to produce 1 kg of beef in a US feedlot requires the equivalent of 14.8 kg of CO_2. As a

[1]Economically efficient here refers to processes that produce meat faster and at lower costs, which for beef means a feedlot system similar to the US. This does not always mean more efficient from an environmental or social perspective. As will be discussed later, the feedlot system itself introduces a number of special problems.

[2]For example, in 2002 Ghana eliminated tariffs on chicken imports, which has lead to extremely low cost chicken products from the US and Europe to flood their market. As it costs local producers much more to produce chicken than foreign competitors, local production has essentially ended. While this is bad for local producers, consumers are now eating much more chicken than they could have afforded before (Atarah (2005)).

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 miles in the average American mid-size car.

The impact of future consumption growth is also an important part of this question. 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 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, especially those in Asia, leading this growth.

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. Keyzer and van Wesenbeeck (2005) and York and Gossard (2004) have find that income does have a substantial effect, though both of these papers assume 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 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 difference in preferences across meat products makes aggregation a problem for the prediction of future consumption.

This paper brings together existing data on greenhouse gas production for different meat products, along with a projection of future worldwide consumption, to determine the potential impact of greater adoption of CAFOs. While a number of papers have estimated meat consumption patterns[3], this paper makes the following contributions to the literature on consumption patterns and the environment. First, I include data on prices to capture price elasticity effects. Second, I add a parameter for lagged consumption in order to observe how much of meat consumption is due to either partial adjustment or persistence effects. Third, I differentiate meat into beef, chicken and pig products and estimate separate equations. Fourth, I forecast meat consumption using these estimates to the years 2010, 2020 and 2030. I bring together data on greenhouse gas production for the US and Europe in order to approximate the present and forecast the future potential environmental impact of meat consumption under a CAFO system. Finally, using these results, I discuss the implications of this impact and what additional technology is available to alleviate it.

The main findings of the paper are as follows. First, if current consumption patterns continue, the amount of total meat consumed in the year 2030 will be 72% higher than the amount consumed in 2000, lead mostly by large increases in chicken and pig consumption. Second, the production of this meat in 2030, under CAFO systems, will produce almost 1.9 billion tonnes of greenhouse gases. Finally, while there are some solutions to limit this effect, they will be very difficult to impliment. Thus, if nations are serious about cutting their production of greenhouse gases, meeting future meat demand will need to be a serious area of discussion for policy makers.

The rest of the paper proceeds as follows. Section 2 describes the data used in the estimations. Section 3 presents the model, estimation results and forecast estimates. Section 4 reviews the existing environmental data on CAFOs and incorporates them into the results from section 3. In section 5 I discuss some solutions that have been put forward to reduce

[3]See FAO (2003), FAPRI (2003), M. Keyzer and van Wesenbeeck (2005), OECD (2007), USDA (2001) and York and Gossard (2004).

this production. Section 6 is then the conclusion of the paper.

2 Data

The data I use is a panel as it is 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[4]. Both are from the World Development Indicators database from WorldBank (2006). Data on per capita consumption and prices of the commodities beef, chicken, pig, maize and rice is 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. I assume that local production prices are a proxy for local end-use prices. This value is in 2000 US dollars so all costs are in real terms and comparable across countries. As the variable of interest is elasticity, I take logs of all the data.

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 table 2 presents the summary statistics.

Previous to the 1990s there were a number of technological advancements in meat production methods. Since that time there has been very little innovation in the production and transportation system[5]. This means that for the 13 years the data of this study covers there have not been any significant technology supply shocks for much of the world. There have though been a number of shocks related to disease, including foot-and-mouth and BSE, both of which could have had substantial affects in the stock of cattle.

[4]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.

[5]For more information, see Michael Ollinger and Nelson (2005).

3 Estimation Results and Forecast

The model I use to estimate the elasticities for consumption has the following functional form:

$$C_{i,n,t} = \alpha_{i,n,t} + \beta P_{i,n,t} + \gamma P_{-i,n,t} + \delta I_{n,t} + \theta U_{n,t} + \eta C_{i,n,t-1} + A_n + \epsilon_i \tag{1}$$

Here, C is a vector of per capita consumption of commodity i, in each country n, for year t. P_i is a vector of the price of commodity i in that country, P_{-i} is a matrix of prices of other products, I is a vector of income (per capita GDP), U is a vector of level of urbanization and C_i is a matrix of lags on consumption for commodity i. The term A is the unobserved characteristics of each country, meaning equation 1 is a fixed effects a model.

A fixed effects model allows for a group specific constant term, meaning unaccounted for differences across countries are taken into consideration. For example, the fixed effects model takes into account the differences in cultural factors, religion, geography, etc. between countries. I will discuss different possible specifications in section 3.1.

3.1 Estimation

Table 3 shows the estimation results for equation 1. I include the results for a model with and without lags. With a lag included the R^2 values increase and income elasticity for beef, chicken and pig decreases substantially. There is thus strong evidence that either habit formation (persistence effects) or partial adjustment is a major contributing factor to the demand for meat products[6].

[6]Habit formation and persistence effects refer to when people's consumption of a product in period t is due in part to how much they are used to the product from periods 0 to t-1, and so is not related to economic variables. Another equally valid interpretation of the lag is that the lag is due to partial adjustment, which is where there is a optimal point of consumption, but people adjust slowly to that point. The coefficient of the lag variable then is the speed at which people adjust.

In addition to a fixed effects model, I also estimate a random effects model and a simple OLS. The random effects model puts A_n in the error term, assuming that A_n is orthogonal to other explanatory variables. If this assumption is incorrect though, the estimation will be biased as the fixed effects model in equation 1 allows A_n to be correlated with other variables. To determine the best model to use, a Hausman test can be run to determine which is the better specification[7]. I do not report the results of the OLS and random effect models as the Hausman test results give a 99.99% probability of rejection for the random effects and OLS models, meaning the fixed effects model is both consistent and efficient.

Further model specifications that could be used here is a difference model and a residual model. In the difference model, all of the variables are differenced across the years, and so the variable of interest becomes the growth rate. In a residual model, the variables of interest are the residuals remaining from an OLS specification for each country. The results do not substantially change in either of these specifications, and so I do not include them here.

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, 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[8]. 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

[7]For more information on these issues, see Greene (2003) chapter 13.
[8]For more on this, please see Greene, chapter 20

stationarity at the 99% level for all meat products. This model then is most likely stationary and thus non-explosive.

3.2 Forecast

I use two different methods to construct a forecast of future production patterns for each meat product. In the first method I use the estimated values from the previous section and combine them with mean value forecast levels of population, GDP and urbanization levels from the UN (2006) for the years 2010, 2020 and 2030. World GDP is assumed to grow at 3.5% per year and urbanization percentage to grow at 12% every 5 years. Population increases from 2000 by 13% in 2010, 25% in 2020 and 34% in 2030. This can then be thought of as a forecast of the demand for meat products in the future.

The second method consists of a forecast from an autoregressive model with 3 lags. This method consists of estimating a model where each period of production is determined by the previous 3 periods. The coefficient results from this estimate are then used to construct the future forecasts. The advantage of such a model is that it is entirely a-theoretical and determined entirely by past patterns of production only. This then eliminates the need to rely on forecasted values of population, GDP and urbanization. This forecast is thus similar to the potential supply of meat as the only variables used are important for supply determination.

Figures 1-3 show worldwide production of beef, chicken and pig respectively for the years 1990 to 2004, along with the results of both forecast techniques. The difference in results is very small. For the purposes of calculations in the next sections of the paper, I use the lowest of these values for each period. The forecast levels to be used are presented in Table 4.

The results show a striking increase in total consumption for the entire world. Looking at the lowest forecast values, consumption of beef from 2000 to 2010 will increase by 12%, 22% in 2020 and 32% in 2030. For chicken, the increase is 42% in 2010, 80% in 2020 and 110% in 2030. Pig products increase 27% in 2010, 51% in 2020 and 73% in 2030. These results can be compared to OECD (2007), who use a least squares approach to forcast and find that beef will increase over the 10 year time span from 2007 to 2016 by 16%, chicken by 21% and pig products by 18%. The difference in results is due to the different time frames, as well as different methods of estimation. I will use the results found here, rather than the OECD study, because of the more informative method that I use, as well as that my results are "double-checked" through an autoregressive model.

4 Greenhouse Gas Production Data

In this section I will summarize the findings from research on the production of greenhouse gases for some of the most economically efficient producers of meat products and discuss the implications of combining them with the results in section 3. For each of the studies discussed, the data is for the production process only and does not include energy for transportation or cooking.

For beef production, Subak (1999) compares greenhouse gas emissions between standard US feedlot and African pasture systems. She finds that, while the African pasture system produces more methane than the feedlot system - due to the much longer life of the animals - when incorporating indirect greenhouse gas production from fossil fuels used in production the feedlot produces nearly twice the greenhouse gases at 14.8 kg CO_2 equivalent per kg of beef, compared to 8.1 kg CO_2 equivalent per kg of beef in the African pasture system. Production processes actually in use today range between these, and could produce much more greenhouse gases.

Chicken and pig greenhouse gas production has not been directly studied and so I combine estimates from Eshel and Martin (2006), Pimentel (1997) and Subak (1999). Pimentel calculates the average US ratio of energy input to protein output for different animal products, including beef chicken and pig products. I use the difference between meat types to approximate the fossil fuel requirement of producing chicken and pig products. Eshel and Martin calculate average non-CO_2 greenhouse gas emissions in the US for different meat types. Again, I use the difference between products to approximate the non-CO_2 greenhouse gas emissions. Both of these methods use the assumption that the difference in protein kcal per kg of meat product is at 80% between chicken and beef, and negligibale between pig and beef. Both fossil fuel and non-CO_2 greenhouse gases are then added together to give the total greenhouse gas impact of 1.1 kg CO_2 equivalent per kg of chicken and 3.8 kg CO_2 equivalent per kg of pig products.

Table 5 summarizes the greenhouse gases expelled in the production of each meat product as CO_2 equivalent. Beef production has the most severe environmental impact, with pigs being second and chicken having the least impact. This is due in part to the methane emissions from cows, while pigs produce relatively less and chickens almost none. The amount of inputs needed are also much different across products, with pig products using 1/3 as much fossil fuel as beef, and chicken using about 1/8 of beef.

Using these values, I then calculate the potential impact of meat consumption for 2000, 2010, 2020 and 2030 in Table 6. Beef production accounts for the majority of CO_2 production and is increasing, though pig products also has a large aggregate impact due to its high use. The total potential greenhouse gas emissions, if all meat were produced in the same method as the US CAFO system and there was no deforestation, would have been 1,3 billion tonnes of CO_2 equivalent in 2000. This number increases by 17% to 1.5 in 2010, 33% to 1.7 in 2020 and 47% to 1.9 billion tonnes in 2030. In 2007 the total CO_2 output was approximately 30 billion tonnes of CO_2 equivalent (WorldBank (2006)). If future CO_2 production is to stay at the current amount, meat production accounts for 5.0% of total production in 2010, 5.7% in 2020 and 6.3% in 2030.

5 Possible Solutions

While these numbers are a decrease from the actual current production that Steinfeld and deHaan (2006) estimates, which is around 4.6 to 7.1 billion tonnes, it is still a large amount, especially considering this is in many ways a "best case scenario" as these estimates assume no deforestation and a minimum lifespan for the animals. If programs like the Kyoto treaty are going to have any real impact on reducing greenhouse emissions, they will thus need to pay attention to the effect of animals. There exist a number of solutions to environmental problems; this section will discuss some solutions to this production that have been put forward.

Methane from the animals is a significant part of the greenhouse gas production. J. Shih and Siikamaki (2006) estimate that methane from animals accounts for about 28% of the methane produced in the US. Methane capturing systems, which capture all or most of the gas produced for use elseware, are a solution. Currently these systems are very costly, though they have the added benefit of reducing electricity costs at farms. Shih and Siikamaki look at such a system and find that this energy cost 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 in the developing world and around \$1 in the developed world (Delucchi (2000)). 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, and 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.

Nierenberg (2006) argues that there needs to be changes to production methods through increasing regulation, improving occupational and welfare standards for workers and animals, and educating consumers to decrease this production. An effect of these better production conditions could be a decline in meat production, thus likely making meat more expensive. A difficulty with this solution is that it is politically challenging from both producers and consumers. Producers may oppose it as it will decrease profits. Far from being highly regulated, meat production in the US and many other countries is subsidized. Consumers may object because of lower access to meat. In addition, educating consumers is not likely to have a great impact as most consumers are already aware of conditions but are not willing to demand change.

Perhaps a more feasible argument, from Harry Aiking and Vereijken (2006), is that if people are convinced to substitute towards more vegetable proteins instead of animal proteins, there would be multiple benefits, such as reducing energy demands, water usage, biodiversity, human health and animal welfare. He argues that, while people do not have to adopt a vegetarian diet, a change in production and mentality is necessary.

For example, the impact of meat can 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 6-20 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 2030 could significantly decrease these CO_2 emissions to a fraction of the estimate in this paper.

By changing the preferences of people away from meat consumption to more efficient foods like soy, a positive environmental impact can be made worldwide, as well as creating healthier lives and decreasing the impact of health problems on a society. 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.

6 Conclusion

This paper looks at how increased demand, leading to more economically efficient meat production systems, could potentially affect greenhouse gas production. The findings of this paper suggest that this effect will still be large. Greenhouse gas production from meat production is an important 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 help bring about.

The US feedlot system, or CAFO, while one of the most efficient current processes at producing meat, comes with a number of problems that are well known. In addition to issues of human and animal welfare, an additional potential problem is that adopting it around the world means a cultural and lifestyle change for many people, in part due to the different attitude to the raising of animals. Feedlots do not allow for co-existence between people and animals. They are also counter to a natural life-cycle for animals. In order to get a large amount of meat from feedlot cattle, which live around a fourth as long as some pastoral cattle, hormones are used to speed up growth. This often leads to the animals becoming very sick, meaning they must be isolated from people and other animals. In the majority of countries, animals live very close to the people. In order to deliver on increased demand though, there will have to be less reliance on this type of co-existence. There thus may be additional difficulties for a feedlot system in the form of political and cultural opposition.

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 mostly to population growth. As this paper focuses on world consumption, the forecast assumes that regional effects are not significant, thus potentially biasing the results. Countries like China are facing a large growth in meat consumption and population, while India faces population growth, but no significant growth in beef consumption and a large growth in milk and chicken consumption (Steinfeld and deHaan (2006)). Estimating country specific growth rates is difficult because of the small amount of data, and so cannot be included here. Future studies could look at this issue in greater detail.

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Table 1: Countries in the sample.

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

Table 2: Summary statistics.

Variable	Mean	SD	Min	Max
Price of Beef	3.2991	0.2796	2.3290	4.3201
Price of Chicken	3.2020	0.1991	2.2265	4.1665
Price of Maize	2.2383	0.2315	1.5420	3.1633
Price of Pig	3.1696	0.2184	2.3484	4.0996
Price of Rice	2.3879	0.2576	1.3051	3.5264
Beef consumption/capita	1.3027	0.4198	0.4183	2.2590
Chicken consumption/capita	1.2400	0.5309	-0.3010	2.0755
Maize consumption/capita	1.7564	0.4661	0.3139	2.5986
Pig consumption/capita	0.8993	0.8640	-2.0000	2.2650
Rice consumption/capita	1.8585	0.5651	0.2122	2.8940
GDP/capita	3.1634	0.6441	2.0257	4.5758
Urbanization %	-0.3757	0.2654	-1.2233	-0.0340

[1]All data are in logs. Prices are in constant 2000 US dollars.

Table 3: Results for fixed effects model with and without lags for each meat product. Standard errors are in parentheses. * refers to significance at the 90% level, ** at 95% and *** at 99%.

	Beef		*Chicken*		*Pig*	
GDP	0.2245 ***	0.3889 ***	0.2561 ***	0.9049 ***	0.1889 ***	0.4553 ***
	(0.0616)	(0.0732)	(0.0501)	(0.0650)	(0.0587)	(0.0642)
Urbanization	-0.1492 *	-0.3209 ***	0.0257	0.3802 ***	-0.0757	-0.2189 **
	(0.0773)	(0.1030)	(0.0629)	(0.0914)	(0.0737)	(0.0903)
Price of Beef	0.0793 ***	0.0776 **	0.0388 *	0.0388	0.0125	-0.0185
	(0.0254)	(0.0350)	(0.0207)	(0.0310)	(0.0242)	(0.0307)
Price of Chicken	-0.0239	-0.0925 *	0.0308	-0.0174	0.0603 **	0.1648 ***
	(0.0280)	(0.0377)	(0.0228)	(0.0335)	(0.0267)	(0.0331)
Price of Maize	-0.0358	0.0091	-0.0386 *	0.0577 *	0.0021	-0.0189
	(0.0262)	(0.0356)	(0.0214)	(0.0316)	(0.0250)	(0.0312)
Price of Pig	-0.0047	0.0132	0.0060	0.0076	-0.0481 *	-0.0922 ***
	(0.0274)	(0.0377)	(0.0223)	(0.0334)	(0.0261)	(0.0330)
Price of Rice	0.0538 **	0.1030 ***	0.0263	-0.0202	0.0138	0.0394
	(0.0237)	(0.0321)	(0.0193)	(0.0285)	(0.0226)	(0.0282)
Beef Lag	0.6383 ***	.	-0.0274	.	0.0781 ***	.
	(0.0256)		(0.0209)		(0.0244)	
Chicken Lag	-0.0271	.	0.7084 ***	.	-0.0183	.
	(0.0288)		(0.0235)		(0.0275)	
Maize Lag	-0.0581 ***	.	-0.0034	.	0.0279	.
	(0.0186)		(0.0151)		(0.0177)	
Pig Lag	-0.0487 *	.	-0.0454 *	.	0.5790 ***	.
	(0.0299)		(0.0243)		(0.0285)	
Rice Lag	-0.0484 **	.	0.0230	.	0.0413 *	.
	(0.0234)		(0.0190)		(0.0223)	
Constant	-0.2463	-0.3160	-0.6109 ***	-1.6570 ***	-0.5704 ***	-0.8490 ***
	(0.2085)	(0.2695)	(0.1696)	(0.2393)	(0.1987)	(0.2363)
R^2	0.8881	0.3568	0.9605	0.7179	0.9712	0.3633

Table 4: Actual consumption by meat product in 2000 and forecasts for 2010, 2020 and 2030 in 1000 metric tonnes.

Product	2000	2010	2020	2030
Beef	59,606	66,485	72,751	78,506
Chicken	59,240	84,241	106,635	124,566
Pig	89,961	113,860	135,563	155,995
Total	208,807	264,586	314,949	359,067

Table 5: Greenhouse gas impact of 1 kg of a given commodity.

	Beef	Chicken	Pig
CO_2 equivalent (kg)	14.8	1.1	3.8

[1]Data is from Subak (1999), Eshel and Martin (2006) and Pimentel (1997)

Table 6: Estimate of total greenhouse gases in million tonnes of CO_2 equivalent for each commodity.

Product	2000	2010	2020	2030
Beef	882	984	1077	1164
Chicken	67	96	121	142
Pig	338	427	509	586
Total	1287	1507	1707	1891

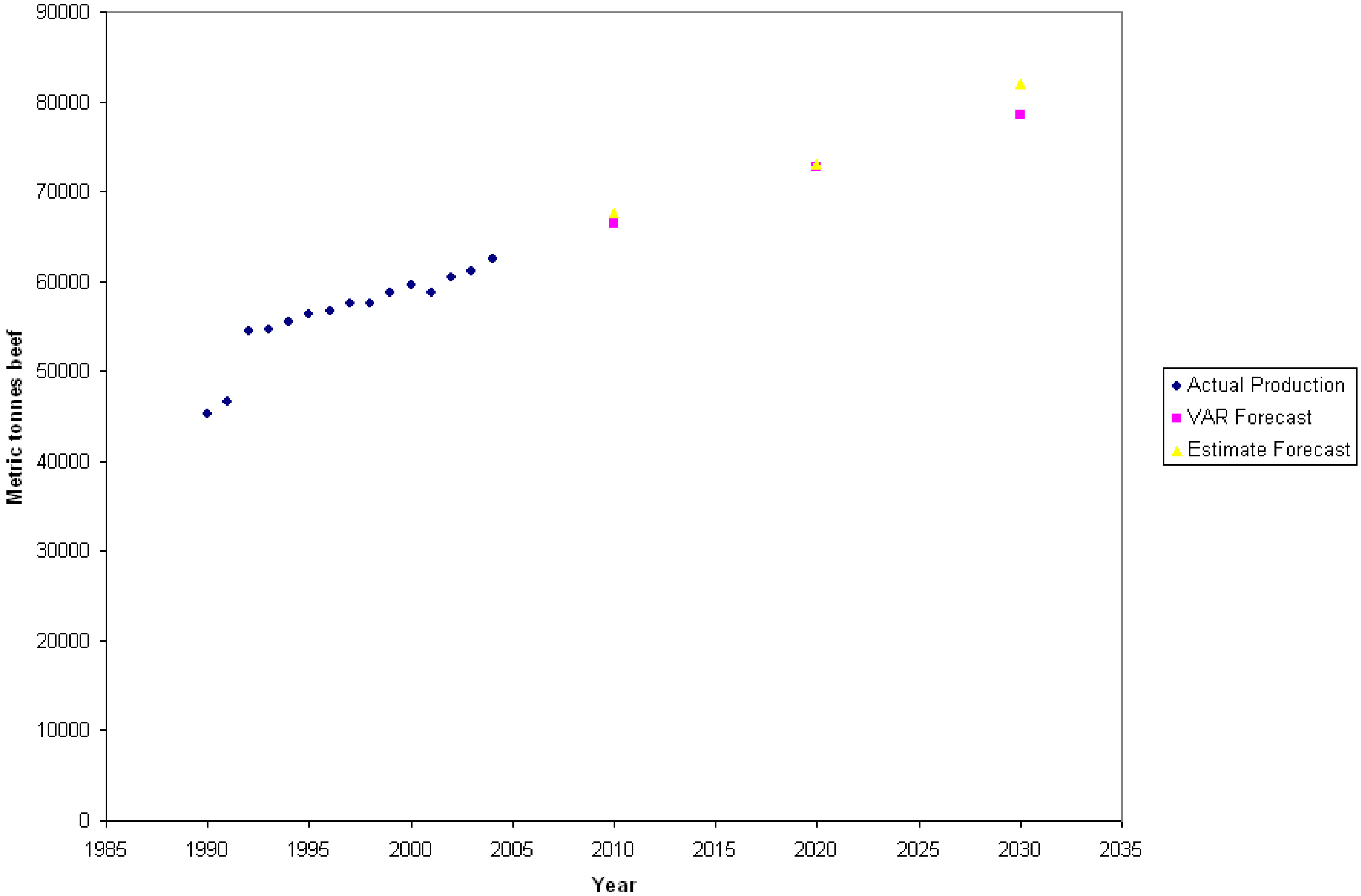

Fig. 1: Worldwide consumption of beef with forecasts.

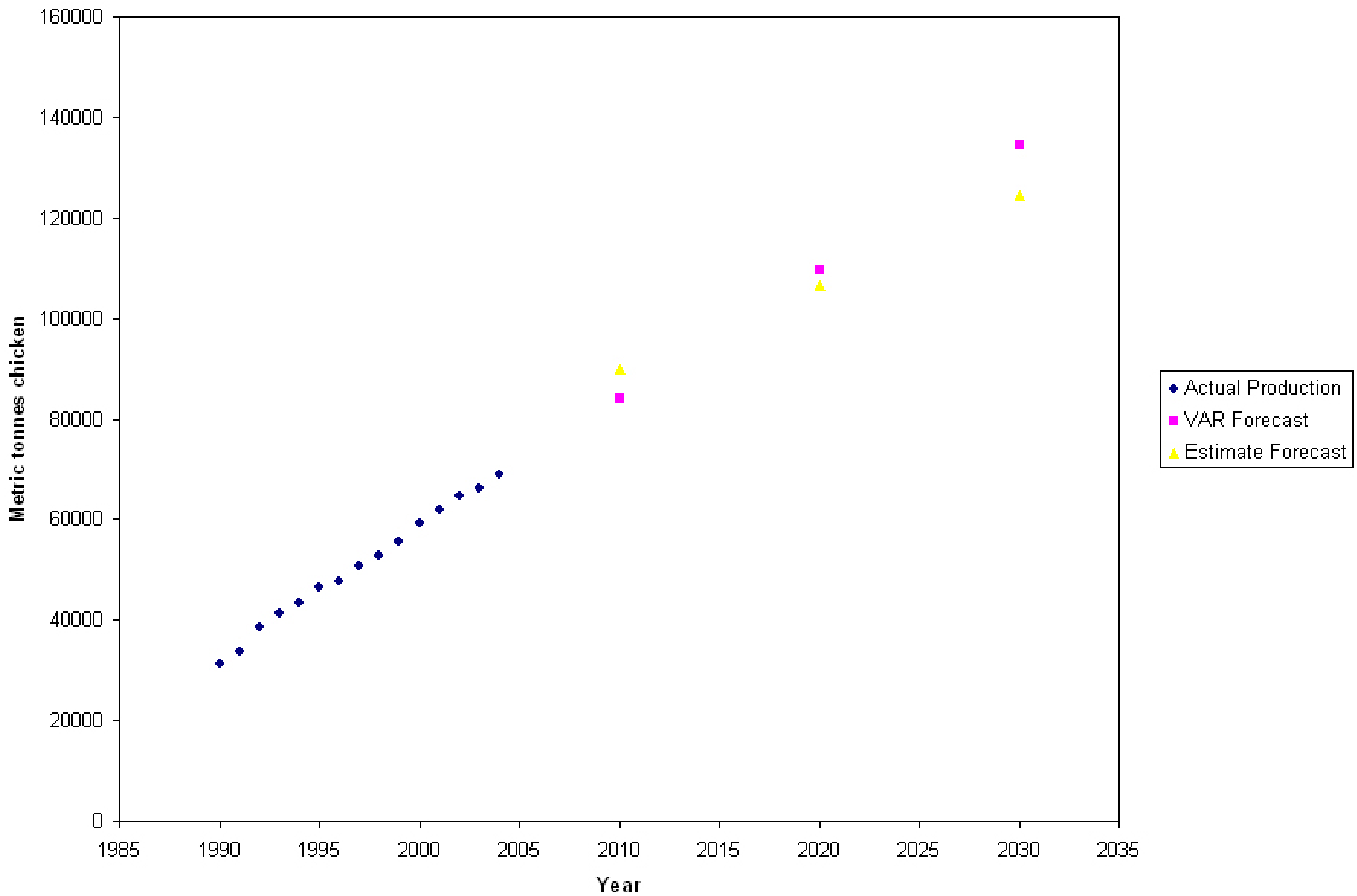

Fig. 2: Worldwide consumption of chicken with forecasts.

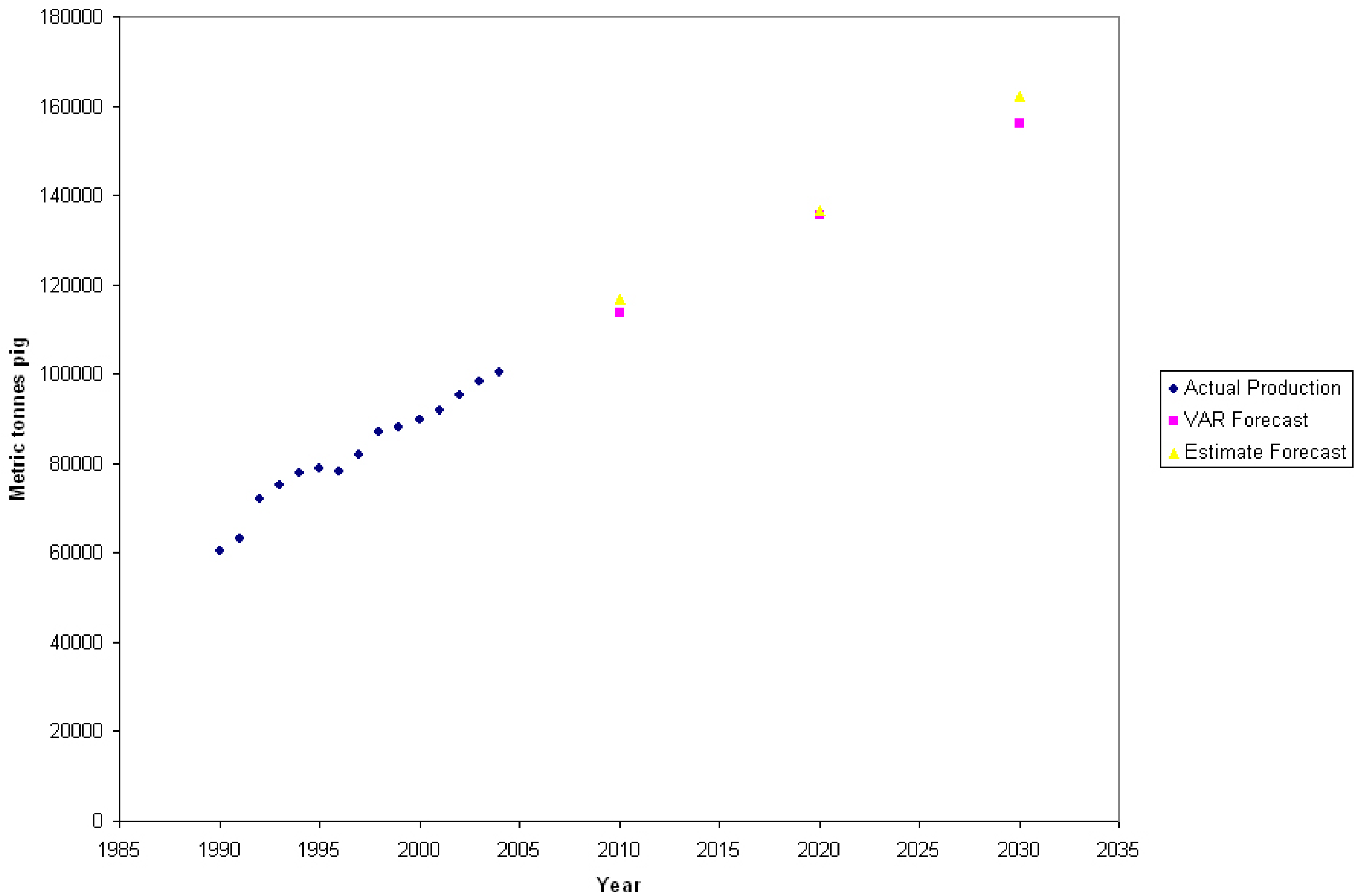

Fig. 3: Worldwide consumption of pig with forecasts.