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Impact of Potential Dairy-Beef Production on China's Beef Supply, Demand and International Trade

Dong Wang[a], Kevin A. Parton[b] and Claus Deblitz[c]

a Australian Energy Market Commission, Sydney

b School of Marketing and Management, Charles Sturt University, Orange

c Faculty of Rural Management, University of Sydney, Orange

Abstract

In the past China has been self-sufficient in beef products, but, with a dramatic increase in consumer spending on food, demand for beef, which is seen as a novel and nutritious food, has grown. By employing a partial equilibrium model and sensitivity analysis under different scenarios, this study found that an expanded dairy-beef industry would reduce the beef deficit that arises, from 2008 onwards. The additional dairy-beef production would reduce the price of beef, and reduce, although not fill, the projected gap of 50 000 tonnes per year. Without dairy-beef, China will have a significant beef shortage.

Key words: China, Beef, Dairy–Beef, Price

1. Introduction

With the increase in wealth of Chinese consumers, there has been a dramatic increase in food demand, and beef products are no exception. The question arises as to whether China's domestic supply of beef products can keep up with future consumption: if it can, what are the implications for its international beef trade and for beef export countries like Australia; if it cannot, are there additional resources which could fill this deficit?

Dairy-beef production has yet to be established as a significant component of the Chinese beef industry. In an unpublished survey conducted by the authors, it was found that most of the male calves from Chinese dairy herds were slaughtered shortly after birth for serum production for medicinal purposes: there is almost no dairy-beef production. With the adjustments that are taking place in production systems, dairy

beef production could become more profitable than serum production, and, with many farmers beginning to realise this, there could be a trend towards increased dairy-beef production. This paper contains an assessment of the future self-sufficiency of China in beef products and the impact of future dairy-beef production on Chinese beef supply, demand and international trade. The paper is structured as follows: first, a market equilibrium model of the future beef industry in China is described; this is followed by a review of Chinese beef supply, demand and international trade. Next, the potential impacts of expanded dairy-beef production are discussed in two scenarios. Empirical results from these scenarios are presented, followed by a sensitivity analysis, and the paper concludes with some policy suggestions.

2. The partial equilibrium model

Partial equilibrium modelling is focused on a particular commodity and the trade issues with this commodity or market. Because research resources are concentrated on a particular industry or commodity, it is usually possible to generate a more detailed model using greater care than is the case with general equilibrium models (Toole and Matthews 2002).

In the partial equilibrium model which is the basis for this analysis, the beef market has been divided into two parts: the Chinese domestic market and the international market. The beef price, the only endogenous variable, is derived from the final result. The other variables are treated as exogenous variables. This model is based on the assumptions that the beef traded in China and outside of China is of the same quality and that the elasticities of supply, demand and net export demand are constant. Sensitivity analysis of those elasticities is described in section 8. Income and population growth are assumed constant as well.

The model is structured as follows:

$$S_1 = D_1 + E_1 \quad (1)$$

Where S_1 is the supply of conventional beef in the year 2012, without dairy-beef production,

D_1 is the domestic demand in 2012, and

E_1 is the net export volume of conventional beef in 2012.

$$S_1 = S_0 * [1+(P_1 / P_0 -1)*E_s] \quad (2)$$

Where S_0 is the Chinese beef supply in 2005,

P_1 is the beef retail price in the year 2012 without considering dairy-beef production,

P_0 is the beef retail price in the year 2005, and

E_s is the long run price elasticity of supply.

$$D_1 = D_0*\{1+[(1+In)^7-1]*E_{in}+(P_1/P_0-1)*E_d\}*(1+Pop)^7 \quad (3)$$

Where D_0 is the domestic demand in 2005,

In is the annual income growth of the Chinese consumer,

E_{in} is the income elasticity of beef demand in China,

E_d is the price elasticity of beef demand in China, and

Pop is the annual population growth rate in China.

$$E_1 = E_0*[1+(P_1/P_0-1)*E_e] \quad (4)$$

Where E_0 is the net export volume of beef from China in 2005, and

E_e is the net export elasticity of Chinese beef products.

If we combine equations 2, 3 and 4 into equation 1, with P_1 endogenous, the final partial equilibrium model in the absence of dairy-beef production is as follows:

$$S_0*[1+(P_1/P_0-1)*E_s]= D_0*\{1+[(1+In)^7-1]*E_{in}+(P_1/P_0-1)*E_d\}*(1+Pop)^7$$

$$+ E_0*[1+(P_1/P_0-1)*E_e] \quad (5)$$

To analyse the effect of additional production from a dairy-beef system on the Chinese beef market and exports, the partial equilibrium model is then structured as follows:

$$Q_a + S_0*[1+(P_2/P_0-1)*E_s]= D_0*\{1+[(1+In)^7-1]*E_{in}$$

$$+(P_2/P_0-1)*E_d\}*(1+Pop)^7 + E_0*[1+(P_2/P_0-1)*E_e] \quad (6)$$

Where Q_a is the potential volume of dairy-beef production in the year 2012, and

P_2 is the endogenous beef retail price taking dairy-beef production into account.

The reason that this estimation did not include beef substitutes like lamb, fish and pork is because estimates of cross-elasticities of these products in relation to beef are few and probably unreliable given the poor data (Liu 2007). The omission of cross-elasticities means that some caution must be applied to interpretation of the final results, particularly for estimated equilibrium prices, with supply and demand side impacts of the omission tending to offset each other in the estimation of quantities.

3. Chinese beef supply and supply elasticity

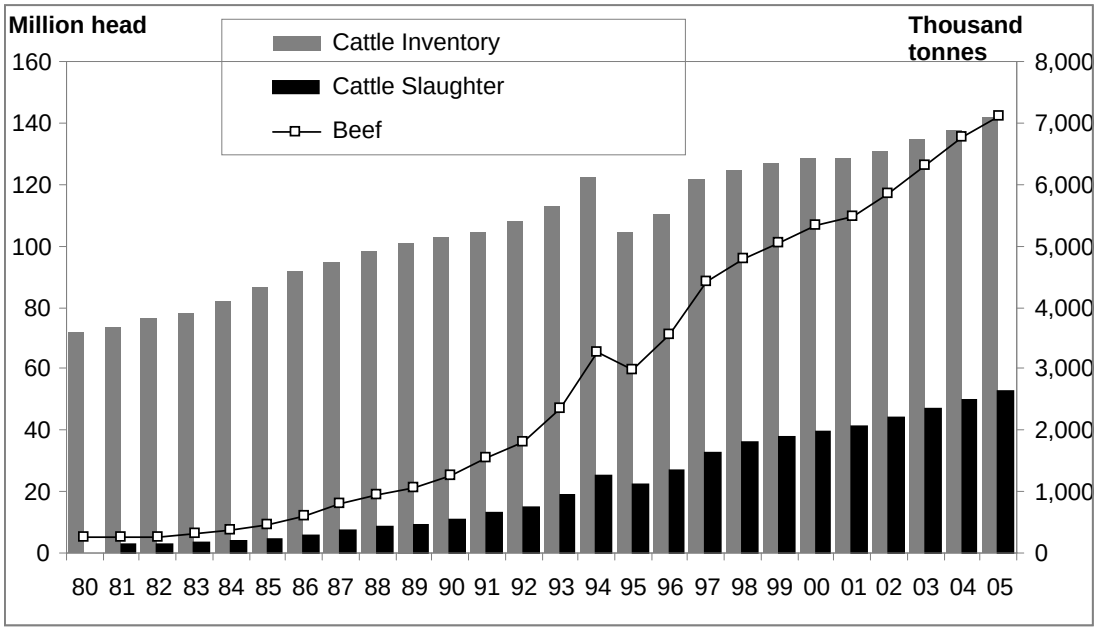
Chinese beef supply has experienced unprecedented increases since the 1990s. Production increased from 934 000 tons in 1990 to over 7 000 000 tons in 2005, and China became the third biggest beef-producing country after the U.S. and Brazil (USDA 2007). This increase has featured an increase of cattle inventories and slaughter percentage, and an improvement of carcass yield per head. However, there is a much slower growth of cattle inventories than of the number of cattle slaughtered

(Figure 1), which might be a negative signal for the sustainable development of the Chinese beef industry. This issue is discussed later in this section.

3.1 Increase in Chinese beef supply

The dramatic increase in supply has enabled a high level of self-sufficiency in terms of beef products. This increase has several aspects, including increases in beef cattle inventory, numbers slaughtered, average yield per cow and scale of beef cattle production.

Figure 1: The development of Chinese beef production



Source: Chinese Bureau of Statistics 1990-2006

3.1.1 Scale of production and average beef yield per head

Traditionally, beef production in China was from small backyard or peasant farmers and cattle were used for draught purposes. With the development of the Chinese economy, strong demand for protein products has required cattle to be used for meat production. Gradually farmers switched to beef production, creating incentives to improve genetics, economics of production and beef production practices. In China, the scale of beef production can be classified as:

(1) small scale, unspecialised household/backyard production with an average of 1 to 3 head,

(2) specialised beef production, or

(3) beef feedlot.

Small backyard cattle production is still the dominant beef production system, although its share has declined. In 1996, cattle from farms which had more than 10 head only accounted for 14 per cent of the total inventory; 8 years later, in 2004, it accounted for more than 30 per cent. The increase in scale has contributed to a faster spread of better production practices. Longworth *et al*. (2001, p. 96) argued that

"large-scale producers (particularly feedlots) are more likely than small-scale producers to feed cattle concentrated feeds, to consistently produce quality slaughter cattle and to develop fixed marketing channels". As a result of the spread of better production practices and the improvement of beef genetics, meat yield per head increased from 101 kg to 134 kg between 1994 and 2004.

An increase in scale also tends to have an effect on supply elasticity. When more capital, labour and other resources are devoted to production, farmers have an expectation of a relatively longer commitment, and are more likely to see themselves as locked-in for longer. The pace of adjustment is slower, because the adjustment cost is higher. Consequently, farmers are relatively less sensitive to price changes in the short run, and the supply elasticity decreases. It would be expected that beef supply elasticity would decrease in the long run.

3.1.2 A higher growth in slaughter numbers than inventory

Between 1994 and 2004, the total number of cattle in China increased by about 11.8 per cent from 123 million to 138 million head; during the same period, the number of cattle slaughtered per year grew even more quickly, the figure more than doubling from 24 million to 50 million.

This increase in slaughter numbers and in average meat yield per head gives a good explanation as to why total beef output has almost doubled since 1994. However, when the growth rate of cattle slaughtered is greater than the inventory increase, it is questionable whether this development is sustainable. This phenomenon needs careful consideration, but is not the focus of this study.

3.2 Chinese beef supply elasticity

Chinese beef supply elasticity has not received much attention in the literature and there is a paucity of estimates. Xin *et al.* (2003) employed a double logarithmic model to measure the supply elasticities of beef and lamb combined for each province of China. The data used are based on the first agricultural survey in China in 1996, with adjustment for some exaggerated figures. The combined beef and lamb elasticities vary from a low of 0.016 for Beijing to the highest, 0.999, for He Nan province. It was noted that where beef and lamb production are less prevalent, the supply elasticity is smaller. Since this estimation has included lamb, it is not precise in terms of describing beef supply, and can only be used as an indication or reference point.

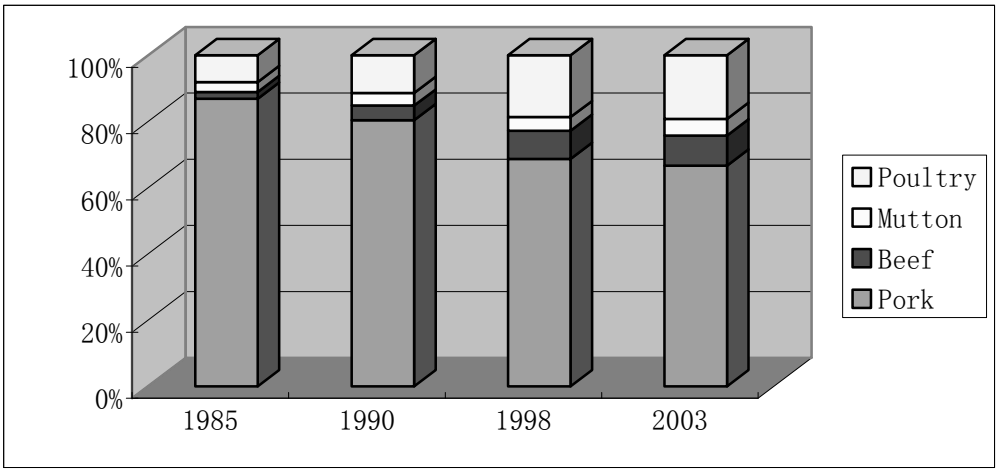
The USDA Economic Research Service (1994), Fuller (1997), and Shaw *et al.* (1997) have estimated Chinese beef supply elasticity. The Country Projections and Policy Analysis Model (CPPA) of the USDA projected a long-run beef supply elasticity of 0.88. Fuller (1997) employed a partial adjustment model and estimated a beef supply elasticity of 0.479 in a 10-year projection, and Shaw *et al.* (1997), employing a structural model developed by Jarvis (1969), derived a supply elasticity of 0.57. It is noted that the estimates of Fuller (1997) and Shaw *et al.* (1997) are very close. Because the theoretical framework developed by Jarvis has been widely used in beef and dairy cattle projection (Rucker *et al.* 1984; Chavas and Klemme 1986; Schmitz 1997), this framework is considered preferable. Therefore, the beef supply elasticity used in this study is 0.57. Sensitivity analysis is used to reflect our uncertainty about this estimate.

4. Chinese beef consumption and demand and income elasticities

4.1 Major factors which influence Chinese beef consumption

Chinese meat consumption per capita has increased dramatically. In 1978, on average, each individual consumed 8.86 kg of meat annually; in 2000, this figure reached 49.10 kg. Within this change, beef consumption increased the most significantly. Jiang *et al.* (2003) reported that, from 1984 to 2000, Chinese beef consumption increased from 0.39 to 4.21 kg per capita, and the percentage of beef consumption in total meat consumption increased from 2.65 per cent to 8.57 per cent (see Figure 2).

Figure 2: Chinese dietary pattern



Source: Chinese statistical Yearbook 1986, 1991, 1999 and 2004

4.1.1 Income and urbanisation

This dramatic increase in beef consumption in China has been mainly driven by increases in income and urbanisation. Many studies have observed a direct relationship between consumer income and beef consumption (Huang and Rozelle 1998; Cai *et al.* 1999; Ma 2000; Fuller *et al.* 2001; Zhou and Tian 2003; and Wang *et al.* 2005). Urbanisation has also contributed to the rapid growth in beef consumption. Urban residents are more exposed to Western lifestyles and Western cooking methods and purchase more beef at all levels of income: the difference is significant. For example, in 1990, urban residents consumed on average about four times the amount of red meat as rural residents, and, in 2000, the annual average home consumption (without including meals eaten away from home) of red meat was 3.33 kg for urban residents and 1.19 kg for rural residents. This is one of the reasons that most studies on Chinese food demand and income elasticities treat urban and rural consumers separately.

However, because of the growth of cities and agricultural labour flow into the cities, the urbanisation process has accelerated greatly and this presented us with a challenge in our exercise to project beef demand. This is the main reason that we used weighted demand elasticities and treated China as a whole in the simulation discussed below.

4.1.2 Own-price elasticity and income elasticity

Most studies of own-price elasticity and income elasticity which combine red meat sources have combined beef and mutton (Huang and Rozelle 1998; Cai *et al.* 1999; Jiang *et al.* 2003; Xin *et al*. 2004; and Wang *et al.* 2005). For income elasticities, the results from those measurements vary greatly, from 0.34 to 1.23. Wang *et al*. (2005) obtained an average of 0.712 from these income elasticities. In this study, we use this value as the assumed income elasticity of demand for beef and apply sensitivity analysis to express the uncertainty of this value.

The own-price elasticity used is from Jiang *et al*. (2003). The authors of the current study believe the result, which is from the adjusted consumption data of China, has fundamental advantages over other results which built their estimation on original official statistical data, which are widely acknowledged to be partially falsified. The elasticity from Jiang *et al*. is -0.78 for rural consumers and -0.69 for urban consumers. We weighted these results, using 64 per cent for rural residents and 36 per cent for urban residents, giving a beef own-price elasticity assumption in this study of -0.75 for the whole of China. Again, sensitivity analysis was applied.

Certainly, the authors would be more confident if there were a widely agreed estimation of the elasticities. However, because of the falsified and inconsistent attributes of the official data in China, we believe the assumptions we have used are closer to the real situation. Because of the funding, scope and the aim of this study, we could not estimate them directly.

5. Chinese International trade in Beef Products

China has never been a major player in the world beef market. Even though it is the third largest beef production country, its imports and exports account for no more than 1 per cent of its total production.

Its exports are mainly destined for Middle East, South East Asian and former Soviet Union countries. As Longworth *et al.* state (2001, p. 326), these countries are all low-value export markets. It might be more profitable to have a higher quality beef market overseas, but because of animal disease and quarantine issues, China cannot get access to the major markets like Japan and the European Union. Until this issue can be solved, it is unlikely that China will have significant beef exports.

The import market in China is basically for two kinds of beef products: premium quality beef and beef offal. The premium quality beef is to supply the upmarket hotels and restaurants, and is usually high in value. On the other hand, China imports low value products like beef offal.

Since China does not currently play an important part in the world beef market, we assume a high net export elasticity of -10**.** In other words, we regard China as a minor player in the world market, a price-taker with an almost perfectly elastic net export curve.

6. Growth of population and income

The growth of population and income in China has certainly resulted in increased consumption of beef.

6.1 Population growth

When projecting food consumption, many researchers (World Bank 1993; Brown 1995; Rosegrant *et al*. 1995; USDA 1996; and Huang *et al*. 1997) have used a 1 per cent population growth or thereabouts between 2000 and 2015. In this study, the assumption for Chinese population growth is 1 per cent per year from 2007 to 2012. Given that there are no separate generalised agreed projections for population growth for rural and urban China, the 1 per cent figure has been applied to both rural and urban projections. This is another reason we used a weighted beef consumption elasticity for the whole of China.

6.2 Income growth

The assumption about China's household income growth plays an important part in the model, and estimates of it vary in the literature. Huang *et al*. (1997) used a rate of growth of 3 per cent to 3.5 per cent of annual per capita GDP, but this has been criticised as pessimistic by Fan and Agcaoili-Sombilla (1997), who suggest that such rates are even slower than those achieved during the period of the Cultural Revolution. Fan and Agcaoili-Sombilla (1997) argued that per capita income growth assumptions in the studies by Rosegrant *et al*. (1995), USDA and the World Bank are also modest, ranging from 6 to 8 per cent per year. OECF (1995) assumed an 8.1 per cent increase per year. This study takes 7 per cent annual per capita income increase, but this assumption may be conservative since, in the last two years, GDP growth in China has been more than 9 per cent per annum.

7. Future dairy-beef production in China

To assess the potential volume of dairy-beef production, it is important to outline how the Chinese dairy herd may evolve in the future. In the past two decades, the Chinese dairy herd has expanded rapidly. The annual average growth rate of the dairy herd from 2000 to 2005 was about 20%, and the size of the dairy herd in 2005 was about 4.5 times that in 1990 (Fuller *et al*. 2006). This rapid increase has raised concerns about the disposal of male calves as a by-product of the dairy industry. An unpublished survey conducted by the authors revealed that almost all male dairy calves are slaughtered before weaning for cheap serum production. As a more profitable alternative to serum production, an expanded dairy-beef industry could develop rapidly in the future.

A study by Wang and Parton (2007) indicated that the Chinese dairy herd will grow rapidly and reach about 24 million head in 2010. This assessment of dairy herd size provides a basis for the estimation of the potential volume of the Chinese dairy-beef production in the year 2010. The projected dairy herd size includes not only cows but also heifers and calves. The recognised ratio of cows in the Chinese dairy herd in the past was 60% (Li 2002). If we assume this continues to be the percentage of cows in the short term then there will be about 14.4 million dairy cows in China in 2010. If 70 per cent of the cows give birth, the sex ratio is 50 per cent and the survival rate of

calves is 95 per cent (Li 2002), then the number of male calves which will be produced and grow out is about 4.8 million. Under a production system in which a male dairy calf can produce 500 kg liveweight in 18 months, with a 10% culling rate and a 42 per cent conversion rate to meat output, just over 900 000 tonnes of beef could potentially be produced per annum.

7.1 Dairy-beef development scenarios

Two scenarios were developed: the maximum possible beef output (Scenario A) and the most likely beef output (Scenario B).

Under Scenario A, a dairy-beef production system is assumed to be accepted by all the farms in the regions where dairy production is most concentrated: these farms account for about 70 per cent of the dairy cattle inventory. The acceptance rate of farms in the remaining regions is assumed to be 30 per cent, because specialist dairy farms are more likely to be interested in dairy-beef production.

Under Scenario B, 60% of farms in the specialised dairy regions and 15% of farms elsewhere are assumed to adopt a dairy-beef production system.

Under Scenario A, just over 700 000 tons of beef would be produced, and, under Scenario B, 400 000 tons.

8. Empirical results

The empirical results are presented in two parts: the first part considers China's future beef supply under current conventional beef production and the second part includes the possibility of dairy-beef production.

8.1 Scenario of conventional beef production only

Assuming beef supply elasticity, own-price elasticity of demand, income elasticity, net export elasticity, per capita income growth and population growth in China are 0.57, -0.75 and 0.71, -10.00, 7 per cent and 1 per cent respectively, and a total beef production in 2005 of 7.115 million tonnes with a net export of 46 000 tonnes and a retail price of 17.87 RMB per kilogram, the conventional beef production scenario, that is, with no dairy-beef production, generated the following results, using Maple software and equation 5.

1. Chinese beef production and consumption will continue to grow, but the pace of consumption will overtake production, and China will start to have a net deficit of beef products from the year 2008. This deficit will continue to grow. In 2012, without dairy-beef production, China will produce 8.6 million tonnes of beef and consumption will be nearly 8.8 million tonnes.
2. The retail price of beef will continue to increase, and, by 2012, it will reach 24.60 RMB per kilogram, an increase of about 38% over the 2005 level.

8.1.1 Sensitivity analysis for the year that beef production moves into deficit

To explore the range for the year when China moves to a deficit of beef products, a sensitivity analysis was conducted by changing one elasticity and keeping the two other elasticities constant. The results are reported in Table 1. The results suggest that China will start to have beef deficits which will emerge no later than 2008.

Table 1. Sensitivity analysis in terms of supply elasticity, income elasticity and own-price elasticity

Supply Elasticity	Year deficit appears	Deficit (thousand tonnes)
0.4	2007	3.40
0.47	2007	0.74
0.57	2008	20.10
0.67	2008	15.7

Income Elasticity	Year deficit appears	Deficit (thousand tonnes)
0.5	2008	4.00
0.512	2008	4.90
0.612	2008	12.50
0.712	2008	20.10
0.812	2007	2.30

Own-price elasticity	Year deficit appears	Deficit (thousand tonnes)
0.70	2008	22.00
0.75	2008	20.10
0.85	2008	15.58
0.95	2008	11.64
1.05	2008	8.17
1.15	2008	5.10
1.20	2008	3.63

8.2 Scenarios of dairy-beef production

As discussed in Section 3, two assumptions might apply to the dairy-beef industry. One (Scenario A) is that all farms in the specialised dairy regions adopt dairy-beef production, as do 30 per cent of farms in the other regions; the second scenario, Scenario B, is that 60 per cent of farms in the specialised dairy regions change to dairy-beef production along with 15 per cent of farms elsewhere. Since agriculture production techniques do not spread rapidly in China, the second assumption (Scenario B) seems more probable, and therefore this paper focuses on the analysis of this second scenario.

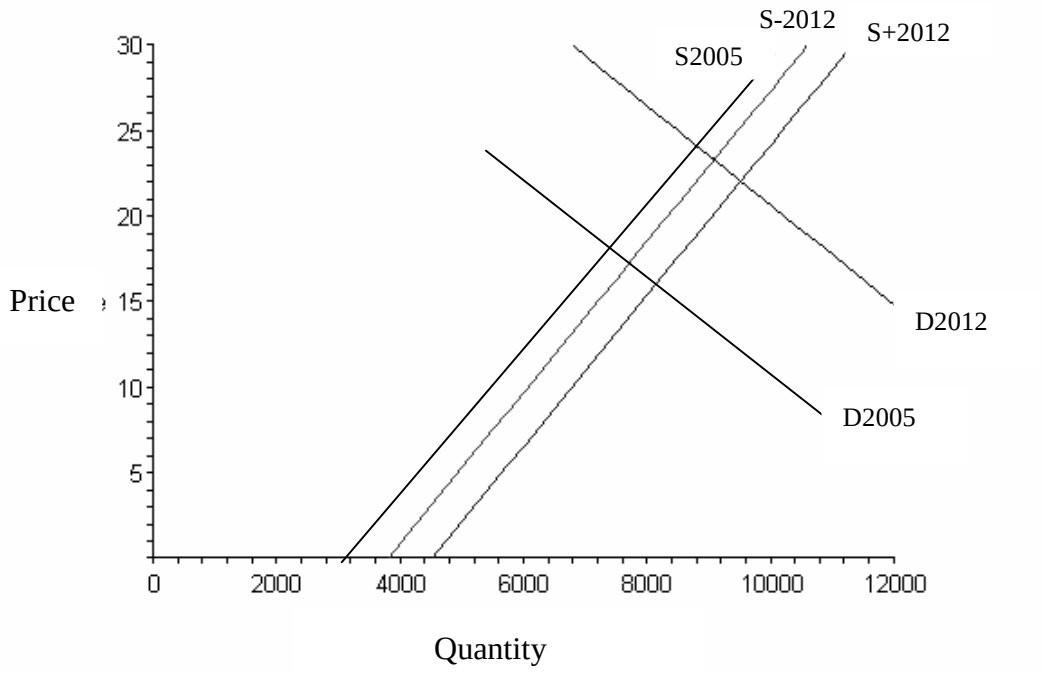
8.2.1 Scenario A

Using the same assumptions as in Section 8.1, where under Scenario A dairy-beef production will generate 716 000 tonnes of beef, then equation 6 generated the following results:

1 Dairy-beef production helps to reduce the degree of beef price increases in China, although the price will continue to increase. The beef retail price in real value will increase by 5.48 RMB instead of 6.73 RMB (Figure 3).

2 Because dairy-beef production keeps the beef price increase down, total consumption increases to 9.2 million tonnes. Moreover, because domestic production increases, the net deficit of beef products is reduced to 95 000 tonnes instead of 200 000 tonnes.

Figure 3. Impact of 716 000 tonnes of dairy-beef production



The S-2012 Supply in 2012 without dairy-beef

S+2012 Supply in 2012 with dairy-beef

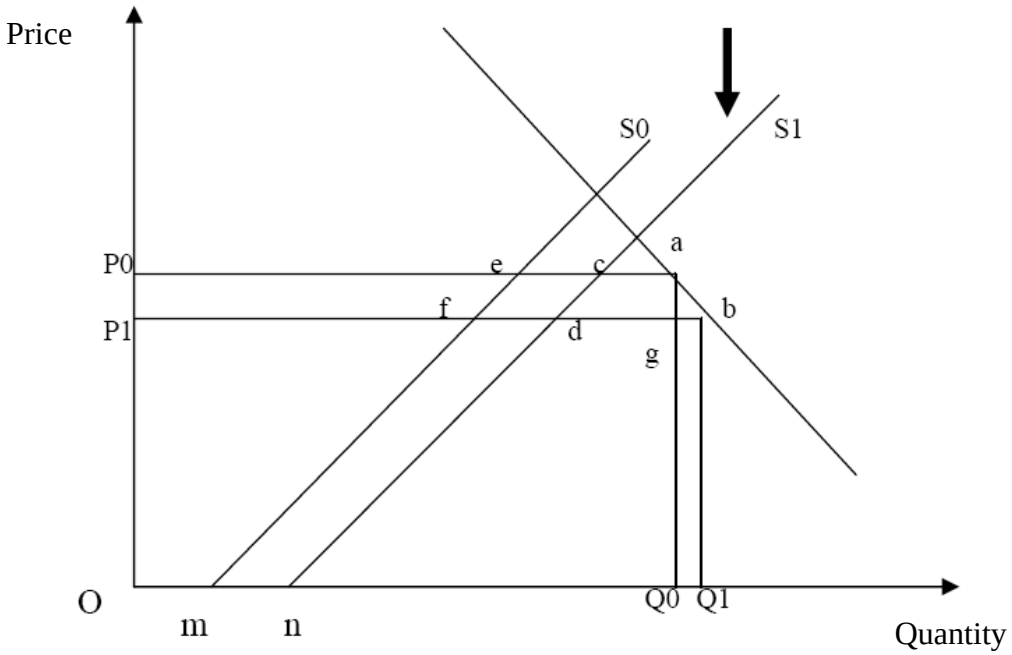
The unit of price is Yuan/Kg and unit of quantity is thousand tonnes.

8.2.2 Scenario B

The following discussion is based on the assumption that 422 000 tonnes of dairy-beef could be produced in 2012. As discussed above, this is considered to be the most likely scenario.

1. The 422 000 tonnes of dairy-beef produced has a negative effect on the beef price increase. This will help to reduce the beef price increase from 6.73 RMB to 6.0 RMB.
2. The gap between beef consumption and supply will be balanced somehow and the Chinese beef product deficit can be reduced to 108 000 tons in year 2012.

Figure 4. Impact of 422,000 tonnes of dairy-beef production



The unit of price is Yuan/kg and unit of quantity is thousand tonnes

In Figure 4, the Chinese beef market is assumed to be in equilibrium at point a (P_0,Q_0). The dairy-beef production will increase the supply and shift the market supply curve from S_0 to S_1. After the adoption of dairy-beef production, a new equilibrium is found at point b (P_1,Q). Line e-a represents 200 000 tonnes of imports without additional beef production and line d-b is 108 000 tonnes of imports with dairy-beef production. Consumers benefit by area P_0ab P_1, which is 64.89 billion RMB. There is a change in producer surplus in beef production (for dairy-beef and conventional beef producers in total) of P_1dnO minus P_0emO equal to mfdn minus P_0efP_1. This is equal to 49.30 billion RMB. Combining consumers and producers together, there is a total gain equal to 114.19 billion RMB.

Assessing the sensitivity of major parameters is the objective of this section. This is achieved by evaluation of (a) supply elasticity, (b) own-price elasticity, and (c) income elasticity. One of the benefits of these evaluations is a better understanding of which parameter contributes most to the equilibrium price of beef and to the deficit of beef products in China. Further, these analyses provide information about the impact on the beef retail price and the deficit of beef products from possibly misspecified parameters. This sensitivity analysis is based on the scenario that an extra 422 000 tonnes dairy-beef can be produced.

Using the range of values for the three elasticities most often suggested by the literature, we generated three figures (Figures 5, 6 and 7) from Maple.

Figure 5. Sensitivity Analysis: Price and income elasticity of demand

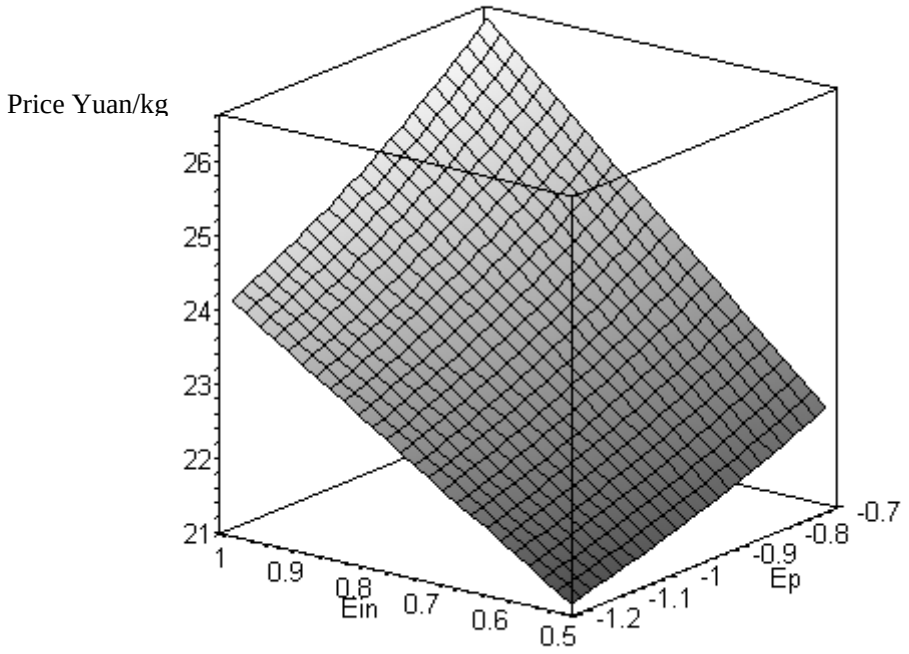


Figure 6. Sensitivity Analysis: Elasticity of demand and elasticity of supply

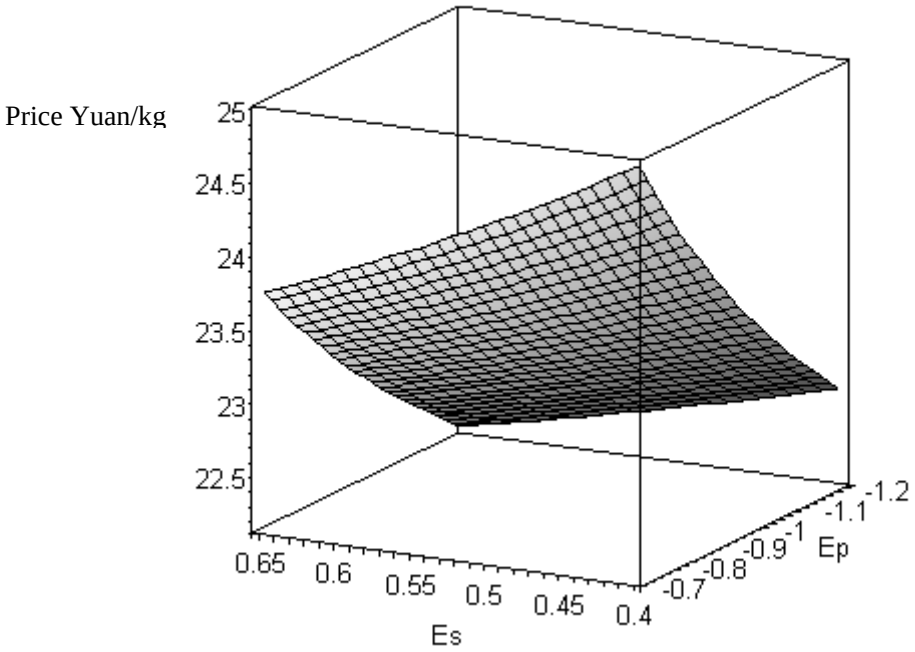
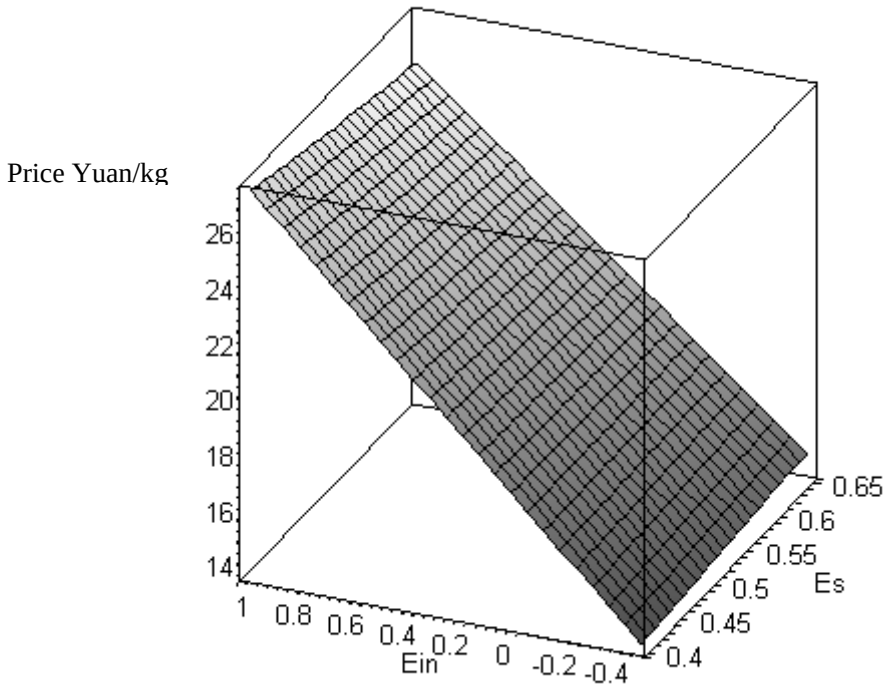


Figure 7. Sensitivity Analysis: Income elasticity of demand and price elasticity of supply



From these three figures, it is clear that price is less sensitive to supply elasticity than it is to own-price elasticity of demand and income elasticity, and it is most sensitive to a change in income elasticity. The results shown in Table 2 confirm these observations.

The possible range of Chinese beef prices is shown in Table 2. Obviously, the lowest price in these scenarios, 21.10 RMB, is much higher than the current beef price. This suggests the beef price in China will continue to grow and the range of this growth is from 3.23 to 9.44 RMB in real terms. However, a price around 23 RMB dominates the scenarios, which is 28.70 per cent above the 2005 level.

Table 2. Sensitivity analysis showing final prices at various levels of income, demand and supply elasticity

		Ein [a]		
		H (1)	M (0.71)	L (0.5)
Ep [b]	H (-1.2)	24.10	22.35	21.10
	M (-0.75)	26.19	23.86	22.15
	L (-0.7)	26.50	24.08	22.31

		Es [c]		
		H (0.65)	M (0.57)	L (0.4)
Ep [b]	H (-1.2)	22.17	22.35	22.79
	M (-0.75)	23.58	23.86	24.67
	L (-0.7)	23.75	24.08	24.95

		Es [c]		
		H (0.65)	M (0.57)	L (0.4)
Ein [a]	H (1)	25.75	26.19	27.31
	M (0.71)	23.55	23.86	24.67
	L (0.5)	21.92	22.15	22.73

Where a = Income elasticity; b = Price elasticity of demand; c = Price elasticity of supply

9. Conclusions

Whether China is able to maintain its relative self-sufficiency in beef is an important question; one which has clear commercial implications for the major beef exporters and the world beef market. The potential contribution of a dairy-beef industry is also an important consideration. Through the selection of the most reliable parameters, and by employing a partial equilibrium model, this paper projects the equilibrium price and quantity of the Chinese beef deficit in the future. In addition, a sensitivity analysis suggests which parameters have the most influence on the results.

In every scenario, China faces a net beef deficit in the future, and this is likely to begin in 2008, with the deficit continuing to grow. Without dairy-beef production, China's beef retail price will increase 6.73 RMB in real value and the beef deficit will be about 200 000 tonnes by 2012. The potential for dairy-beef production means that this is an unlikely scenario.

In the second scenario, it is assumed that by the year 2010, dairy-beef production will be widely accepted by farmers, enabling the production of 716 000 tonnes of dairy-beef in 2012. This quantity of dairy-beef production will balance the gap between beef supply and demand to a certain extent, even if it cannot fully balance the deficit. With this scenario, China's beef deficit will be reduced to 95 000 tonnes and the beef retail price will increase by about 5.48 RMB over its 2005 level. This scenario is

considered to represent the upper end of expectations with regard to dairy-beef production.

The last scenario assumes 60 per cent of the farmers in dairy concentrated regions and 15 per cent in remaining regions will adopt dairy-beef production by 2010. The quantity of dairy-beef produced under this scenario reduces the Chinese beef deficit to 108 000 tonnes in 2012 and reduces the increase of beef price to 6.0 RMB. This is considered the most likely scenario.

The sensitivity analysis found that results are relatively insensitive to supply elasticity, and own-price elasticity of demand and income elasticity have more effect on accuracy. A misspecification of income elasticity has the most impact. Indeed, income elasticity has been the subject of most discussion in the literature with respect to beef production and consumption, and these discussions are certainly not in agreement.

The sensitivity analysis has also effectively indicated the possible range of equilibrium prices, with most being around 23 RMB in real terms for 2012.

10. Discussion and Policy Suggestions

At the outset it was the intention in the research reported in this paper to develop and estimate a supply equation for beef as a component of a spatial equilibrium model. Both of them failed mainly due to lack of data. For their spatial equilibrium model, Xin *et al.* (2004) used the railway as the transportation unit. However, most live cattle and beef in China are transported by truck, and transportation cost based on railway measurements is not a valid reference. It is extremely difficult to obtain data for road transportation. Similarly, it is difficult to develop a supply function for beef products, given the paucity of data. Short time-series data for beef price and quantity do not support the ideal model, an autoregressive distributed lag model. Given these obstacles to constructing a spatial equilibrium model, this study developed a partial equilibrium form based on the available data and literature.

In this study, the timing of a shortage of Chinese beef products is similar to that in FAPRI (2005), although different methods and elasticities are used. FAPRI projected, that in the year 2008, Chinese beef production will be 7.975 million tonnes and consumption will be 7.983 million tonnes and thus a deficit emerges from that year. The projection in the current study comes to almost the same conclusion: that, from the year 2008, China will have a beef deficit. Clearly, because of increases in income, the Chinese consumer will develop more purchasing power and the requirements of food protein will be mostly satisfied. In addition, China's population is still growing and has a preference in the younger generation for an increased consumption of beef and its accompanying health benefits.

The results from the scenarios suggest that the Chinese government needs to address this likely shortage of beef production. Since dairy-beef can partly fill the gap between beef demand and supply, policies which encourage this production system seem advisable. At the 2006 Chinese beef association conference, the shortage of beef cattle calves was declared the prime concern for the major beef production enterprises. Because of the increase in the price of beef, small farmers who currently provide most of the cow-calf production are even selling their cows to the feedlots. This action reflects the short-term expectations of cow-calf production in China.

Obviously, if cows are slaughtered, the beef shortage will worsen, beef prices will rise, the beef cow inventory will be lower, there will be fewer calves, and so the beef price will further increase. This situation seems to have the components of a classic beef cycle. Compared with these Chinese cow-calf farmers, Chinese dairy farmers who produce dairy bull calves have a longer-term expectation. They are more likely to provide male calves in a sustainable manner for the expanding Chinese beef industry, and this could assist to dampen the potential cyclical behaviour of the Chinese beef market.

11. References

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